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Semantic, lexical, and phonological influences on the production of verb inflections in agrammatic aphasia

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Abstract

Verb inflection errors, often seen in agrammatic aphasic speech, have been attributed to either impaired encoding of diacritical features that specify tense and aspect, or to impaired affixation during phonological encoding. In this study we examined the effect of semantic markedness, word form frequency and affix frequency, as well as accuracy and error patterns, in an attempt to evaluate whether diacritical or affixation operations are impaired. Verb inflections (*V + ing*, *V + ed*, *V + s*, and *V stem* in present progressive, past, present 3rd person singular, and future tense contexts, respectively) were elicited in eight mild-moderate agrammatic aphasic individuals in a sentence context using a picture description task. Results revealed that the majority of verbs produced were affixed (75%) although accuracy was low (36%). Word form frequency was found to be a significant predictor of the accuracy with which verb inflections were produced; while affix frequency and semantic markedness were not found to influence accuracy. These results suggest that a diacritical deficit is more likely to undermine the production of verb inflections than a affixation deficit, and indicate that when diacritical processes are compromised, word form frequency is likely to influence production of verb inflections in agrammatic aphasia.

Keywords

Agrammatism; Aphasia; Inflection; Verb production; Frequency

1. Introduction

An impairment in the production of inflectional morphology is one of the characteristic features of agrammatic Broca's aphasia and this has been the focus of much research in the past two decades. In English speaking individuals with agrammatic aphasia, a deficit in producing inflectional morphology is manifested as verb inflection errors, frequently in the form of omissions of inflectional affixes and overuse of the *ing* form of the verb (*V + ing* as in *kicking* and *smiling*) (De Villiers, 1974; Goodglass, 1976). Across most languages studied, difficulty with verb inflections is largely restricted to features of tense and aspect with relative sparing of subject verb agreement (Benedet, Christiansen, & Goodglass, 1998; Friedmann & Grodzinsky, 1997; Goodglass, Christiansen, & Gallagher, 1993). However, the underlying source of tense/aspect errors is unclear.

The mental operations involved in the production of inflected verbs are generally believed to include two crucial processes: selection of diacritical features and concatenation of verb stems with affixes (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999). The term *diacritics* was

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used by Levelt (1989) to refer to segments of the speaker's message that are typically conveyed by inflectional affixes (e.g., tense, aspect, mood, person, and number). For the production of inflected verbs in English, conceptual and semantic information is used to specify diacritical features that indicate tense and aspect, such as +PAST or +PROGRESSIVE. According to Levelt, selection of diacritical features determines which verbal affix is retrieved from the mental lexicon (*ed* for +PAST and *ing* for +PROGRESSIVE and so on).[1] Thus, production of regular verbs is believed to proceed by locating the lexical entries of the verb stem and the appropriate inflectional affix. This is followed by concatenation of the verb stem and the inflectional affix(es), which then receive a phonological form (Janssen, Roelofs, & Levelt, 2002; Levelt et al., 1999). As per Levelt and colleagues, selection of diacritical features and relevant verbal affixes is considered a pre-phonological process, while affixation occurs during phonological encoding.

The process of selecting the exact tense/aspect diacritic necessitates a degree of precision that may be problematic for individuals with agrammatic aphasia. Retrieval of the exact inflectional affix on the basis of the selected diacritical feature(s) also demands specificity and is a potential locus of breakdown for individuals with verb inflection errors. Indeed, a number of investigations of verb inflections have implicated such prephonological morphosyntactic operations (Badecker, 1997; Bastiaanse, 1995; Luzzatti & Blesser, 1996; Miceli & Caramazza, 1988). Support for difficulty in relating tense/aspect features to specific verb forms comes from more constrained tasks such as reading, where aphasic individuals have been reported to produce verb stems for both regular (e.g., *talk-talked*) and irregular (e.g., *take-took*) inflections (Badecker, 1997). Conversely, the phonological process of affixation of a verb stem with an inflectional affix(es) could be a source of difficulty. Past research has implicated such a morphophonological deficit (Badecker & Caramazza, 1991; Kean, 1977; Nadeau & Rothi, 1992; Ullman et al., 1997). The frequent occurrence of verb stems in agrammatic narrative speech (De Villiers, 1974; Goodglass, 1976) has been taken as evidence for a failure of affixation. In other words, verb inflection errors observed in agrammatic aphasia could potentially arise from a deficit of either diacritical (i.e., pre-phonological), or affixation (i.e., phonological) operations. This study attempts to elucidate whether verb inflection errors denoting tense in English speaking agrammatic aphasic individuals are due to a diacritical deficit or due to a difficulty with affixation.

Different predictions can be made about error patterns resulting from diacritical and affixation deficits. In the case of a diacritical deficit, there is a failure to select semantically and syntactically appropriate diacritic features, and/or failure to utilize diacritical feature information to retrieve the exact affixes. Hence verb inflection errors are most likely to result in inflectional substitutions. Production of verb inflections may be determined by ease of lexical access, rather than semantic and syntactic appropriateness since the process of specifying diacritical features is either ineffective or erroneous. Two factors that could influence 'ease of lexical access' are semantic markedness (Lapointe, 1985; LaPointe & Dell, 1989; Wunderlich, 1995), and frequency of occurrence.

Lapointe (1985) suggested that the mental lexicon may be organized along a semantic dimension and proposed a hierarchy of verb groups. The hierarchy was based on the complexity of semantic notions expressed by verb forms (attitude, voice, aspect, tense, and agreement) and the complexity of derivational properties of verb forms. Thus, for example, passive voice is more marked (i.e., complex) than active voice, and past tense is more

[1]According to some authors, the mental lexicon consists of both inflected verbs as well as verb stems (Joanisse & Seidenberg, 1999; Stemberger, 1985). Production of inflected verbs therefore involves retrieval of a single lexical unit. In this view, a single lexical entry representing the whole inflected word is retrieved. Pinker and Ullman (2002) point out that regular verbs might be stored since human memory can store verbal material such as idioms. However, even if inflected verbs are represented in the mental lexicon, there needs to be a stage during production where diacritical features are used to select and retrieve the appropriate inflected verb.

marked than present tense. Lapointe proposed that accessing more marked inflections placed greater processing demands on mental mechanisms than accessing less marked inflections. According to this hierarchy, verb stems are the least marked and hence engage in a minimal processing load, followed by present progressive tense (expressed by the affix *ing*), present third person singular tense (expressed by the affix *s*), and past tense (the affix *ed*) in that order. Lapointe assigned numerical values to represent the amount of processing resources required to access each verb form (see Table 1). The central claim of this proposal is that verb inflection errors in agrammatic aphasia result from a reduction in available processing resources which limit the ability to perform an extensive search through the mental lexicon. This results in verb form substitutions that abide by the proposed semantic markedness hierarchy. Therefore less marked verb forms are produced in the place of more marked verb forms since the former require fewer processing resources. Hence verb stems are produced more often than inflected verbs.

Lapointe's (1985) semantic markedness hierarchy predicts that verb stems, *V + ing*, and *V + s* verb forms will be substituted for a past tense (*V + ed*) target, but *V + ed* forms will not be substituted for verb stem, *V + ing*, and *V + s* targets since *V + ed* is the most marked verb form. Similarly, verb stems and *V + ing* will be substituted for *V + s* targets and only verb stems will be substituted for *V + ing* targets. Lapointe (1985) analyzed the narrative speech of two Italian agrammatic aphasic individuals and found that all verb inflection errors were in accordance to the semantic markedness hierarchy in Italian. However, the limitation of Lapointe's analysis is that in narrative speech, the target proposition is often unknown, leading to guesswork in analyzing verb form substitutions. For instance, utterances such as *"Tom go hospital Tuesday"* are common in agrammatic speech. In this utterance the target verb form could be *go* as in *Tom will go to the hospital on Tuesday*, or, it could be *goes* as in *Tom goes to the hospital on Tuesdays*. Indeed, in a constrained speech elicitation task designed to examine subject–verb agreement (SVA), Janssen and Penke (2000) reported that errors did not always favor Lapointe's semantic markedness hierarchy. Although Janssen and Penke's findings failed to support Lapointe's hierarchy, one cannot rule out the possibility that the processes that guide SVA are different from the processes that guide tense/aspect inflection because SVA is relatively preserved in agrammatic aphasia, yielding only a 7% error rate in the Janssen and Penke study. Given these contradictions, the role of semantic markedness in agrammatic speech warrants further investigation.

As mentioned earlier, frequency is another possible factor that could influence lexical accessibility in the production of inflected verbs. Frequency has been demonstrated to be an influential factor that determines access in the mental lexicon, with high frequency words being relatively easier to access than low frequency words (Griffin & Bock, 1998; Jescheniak & Levelt, 1994; Oldfield & Wingfield, 1965). Aphasic individuals also show greater difficulties in naming pictures with low frequency names compared to pictures with high frequency names (Caramazza & Hillis, 1990; Nickels, 1994). Since various inflected forms of a verb have the same lemma (stem) frequency but different word form (lexeme) frequencies, the latter frequency measure could potentially influence the production of inflected verbs in agrammatic aphasia. Hence verb inflections with higher word form frequencies are predicted to be produced with a higher accuracy compared to lower frequency variants of the same verb. Word form frequency could account not only for accuracy of production, but also for substitution patterns in verb inflection errors. For example, the occurrence of verb stems instead of inflected verbs in agrammatic speech could be because verb stems typically have relatively high frequencies when compared to their inflected forms (especially in English). Similarly, substitutions of an inflected verb such as *cooking* for the target *cooked* might occur because *cooking* (with a written word form frequency of 26/million, Francis & Kucera, 1982) is more frequent than *cooked* (written word form frequency 2/million). Thus we may hypothesize that instances of inflectional

errors in agrammatic aphasia are also instances of substitution of less frequent forms of a verb by more frequent forms of the same verb.

In the event of impaired diacritics, affix selection could also be influenced by the frequency of affixes. In English, the past tense affix, *-ed* is the most frequent,[2] followed by the progressive affix (*-ing*). The third person singular affix (*-s*) is the least frequent (Francis & Kucera, 1982). The affix frequencies are given in Table 1. Assuming that affix retrieval follows the same general principles of lexical access of whole words, we could predict that *-ed* affixes will be retrieved and produced more often by agrammatic individuals in comparison to other verbal affixes *(-ing* and *-s*). Thus verb inflection errors would consist of substitutions of *V + ed* verb forms for *V + ing* and *V + s* targets. In contrast, *V + s* verb forms would not be produced for *V + ed* and *V + ing* targets. In support of this hypothesis, affix frequency was found to influence accuracy of production in Spanish and German agrammatic Broca's aphasia (Centeno, Obler, Cairns, Garro, & Merrifield, 1996;Penke, 2003). Present and past tenses, the most frequently used tense-aspect forms in Spanish discourse, were more accurately produced than other tense-aspect forms by aphasic patients. To our knowledge, the effect of inflectional affix frequency has not been investigated in English-speaking agrammatic aphasic individuals.

To summarize, a pre-phonological diacritical impairment is likely to cause substitution errors. Substitutions may be by other inflectional affixes or by verb stems. Given the above discussion, it is predicted that the pattern of substitutions may not be random, and could be influenced by either semantic markedness, word form frequency and/or affix frequency. These predictions are tested in the study reported here.

As mentioned earlier, agrammatic aphasia has also been characterized as an impairment of the procedural rules required to combine verb stems with affixes during encoding of phonological form (Tyler et al., 2002; Ullman et al., 1997). Two findings support this hypothesis: greater accuracy with irregular past tense verbs (e.g., *sing-sang, go-went*) compared to regular past tense verbs (e.g., *call-called, kiss-kissed*) (Ullman et al., 1997), and a predominance of verb stems in agrammatic narrative speech (De Villiers, 1974; Goodglass, 1976). The lower accuracy of regular inflections compared to irregular inflections in English agrammatism can only be explained by a difficulty in affixation during phonological encoding since only regular inflections undergo affixation in English. Nonetheless there are a few caveats. First, several studies reporting differences between regular and irregular verbs have actually done so in receptive tasks such as reading, past tense judgement, lexical priming, and word monitoring (Tyler et al., 2002; Tyler, Randall, & Marslen-Wilson, 2002). Second, production of irregular words is also impaired to some extent. For instance, Ullman et al. (1997) reported an accuracy rate of 52% for irregular verbs and 20% for regular verbs for sentence completion and reading in a group of 5 Broca's aphasic patients. Third, some studies comparing production of regular and irregular inflections are confounded by the large discrepancy in the frequencies of the stimuli (e.g., Ullman et al.). Further, the reverse pattern of worse performance with irregular inflections has been reported for other languages in which both regular and irregular verbs are affixed (e.g., Penke, Janssen, & Krause, 1999 for German; Tsapkini, Jarema, & Kehayia, 2002 for Greek). Finally, an impairment in affixation should affect the production of other regular verb inflections such as *V + ing*, a prediction that is incompatible with previous reports that *V + ing* forms predominate in agrammatic speech (De Villiers, 1974; Goodglass, 1976). For

[2]In English, the affix *-ed* is used in past tense contexts as well as in some participle contexts (e.g., *had delivered*). However, if one were to assume that substitution errors arose due to a deficit with diacritics, then this overlap in phonological form of two different affixes should not matter.

the above reasons, drawing conclusions about impaired affixation in agrammatic aphasia on the basis of regular and irregular verbs is not straightforward.

The predominance of verb stems in agrammatic narratives also does not resolve the question of the source of verb inflection errors since both diacritical feature and affixation deficits could result in the production of verb stems. Hence it is undetermined if affixation is in fact impaired, and if this produces verb inflection errors in agrammatism.

To summarize, there are broadly two potential loci of verb inflection errors in English agrammatism: a prephonological deficit arising from failure of selection and/or implementation of tense marking diacritical features, and impaired affixation during phonological encoding. The purpose of this study is to determine which of the above two sources influence the production of verb inflection errors in agrammatism. It is predicted that impaired diacritics will result in an effect of semantic markedness, and/or word form frequency and/or affix frequency on the production of verb inflections. On the other hand, impaired affixation is predicted to result in greater accuracy of verb stems and a predominance of stem substitution errors.

2. Method

2.1. Participants

Eight mild-moderate native English speaking individuals with agrammatic Broca's aphasia (six men and two women, age range = 44–69 years, Mean age = 58.2 years, *SD* = 8.2) participated in the study. All had suffered a single left hemisphere cerebrovascular accident and were all at least 1-year post onset, had no prior neurological history, developmental speech and language disorders, psychiatric disorders, or history of substance abuse. One of the participants had two seizures after his stroke (JP). All participants had normal or corrected vision/hearing. Participant details are given in Table 2. The diagnosis of Broca's aphasia was made based on their performance on the Western Aphasia Battery (Kertesz, 1982). For all participants, auditory comprehension was only mildly impaired and was superior to expressive abilities. The fluency score was 4 for 7 participants and 5 for one participant. Narrative speech was also elicited by asking participants to describe the Cinderella fairy tale. The speech samples thus collected were analyzed following the coding procedure of Thompson et al. (1995), and were examined for features of agrammatism. Results of the narrative analysis are given in Table 3. All participants were considered agrammatic because they had reduced phrase length as demonstrated by a reduced mean length of utterance (MLU), produced at least a few ungrammatical sentences, and omitted function words as revealed by high ratio of open class to closed class words. Further, all patients made errors of verb morphology as shown by the proportion of verb morphology errors in Table 3.

2.2. Stimuli

Seventeen imageable regular transitive verbs whose lemma frequencies ranged from 30 to 70 per million (based on Francis & Kucera, 1982) were chosen. Word form frequencies of the different forms of these verbs ranged between 0 and 35 per million, permitting inspection of word form frequency effects. Lemma and word form frequencies of the stimuli are given in Appendix A.

Seventeen different black and white line drawings, each depicting two nouns (an animate agent and an animate or inanimate undergoer) and one of the 17 verbs were developed. Each of the 17 verbs were elicited in four different inflectional contexts, making a total of 68 stimuli. To elicit the various inflections of verbs, cue words (*yesterday* to elicit *V + ed*, *today* to elicit *V + ing*, *every day* to elicit *V + s*, and *tomorrow* for the *V* stem) were printed at the

top of each picture. Thus all verb forms, including the verb stem were elicited in a tensed context, requiring the selection of appropriate tense-marking diacritical features. The relevant nouns and verb stem were also printed on the pictures. This was done to eliminate any confounding effect of word retrieval problems in sentence production. The pictures also contained an arrow pointing towards the agent of the action to indicate the noun that had to occur first in the elicited sentences. This was done to avoid attempts at passive sentences. One of the stimuli is shown in Fig. 1.

Prior to the study, the stimuli were presented to a group of 10 normal university students with instructions to describe the pictures using single sentences and by beginning the sentences with the printed cue word. The normals produced active sentences with *V + ed*, *V*, and *V + s* verb forms for the cue words *yesterday*, *tomorrow*, and *every day*, respectively, 100% of the time. The cue word *today* elicited the *V + ing* verb form only 76% of the time, 24% of the responses were in the future tense, as in *Today the doctor will examine the boy.* For this reason, *today* was replaced by *now*. Five normal university students (different from the initial 10 university students) successfully produced *V + ing* in all instances when *now* was used.

Verb stems generally tend to be of higher frequency and also have the lowest semantic markedness compared to other verb forms. Thus it is possible that the effects of semantic markedness and word form frequency are not dissociable. Since Lapointe (1985) assigned numerical values to represent the amount of processing resources required to access each verb form (*V* stem = 1, *V + ing* = 2, *V + s* = 2.5, and *V + ed* = 3.5), these values were used to calculate the correlation between semantic markedness and word form frequencies of the various stimuli. The correlation between semantic markedness and word form frequency was low (Pearson $r = -.15$), which means that the two factors could potentially have an independent influence on accuracy.

2.3. Procedure

2.3.1. Pre-testing—The ability to comprehend and produce the four cue words and 17 verbs was tested. Comprehension of the cue words was tested by asking participants to point to *yesterday*, *every day*, etc. on a calendar. In addition, their ability to orally read these words was tested by presenting the words in 20-size font. All eight participants were unimpaired in their ability to understand the cue words and only one participant failed the reading test (RH). RH had a reading impairment for all words. For this participant, the experimenter read aloud the words printed on all stimuli.

Production of the verb stimuli was tested using a confrontation naming task. Two practice items were provided. Participants were instructed to tell '*what the*—(*man*, *woman*, *dog etc.*) *is doing.*' Ten seconds were allowed for a response. Scoring was done on-line. A verb was scored correct if it was produced within 10 s, was the target verb irrespective of the inflectional marking, and there was a recognizable phonemic error. In case of self-corrections within 10 s, the self-corrected response was scored. The number of verbs correctly named by each participant is given in Table 4. Appendix B lists the participants who correctly named each verb. Comprehension of the verbs was tested using a forced-choice picture pointing task where the target and three foils were presented. Participants were instructed to point to the picture that corresponded to the presented verb. Only those verbs that were correctly named and comprehended by a subject were included for further testing for that subject. This was done to eliminate the confounding effects of verb retrieval deficits on the production of inflectional verb morphology. Thus the number of verbs was different for each subject and ranged from 9 to 17 (*Mean* = 13.7, *SD* = 2.4).

2.3.2. Experimental task—Participants were instructed to describe the picture stimuli in a single sentence and to begin their response with the cue word that was provided. During test administration, the experimenter carefully avoided posing questions that provided cues to verb morphology (for example, *What happened yesterday?* or *What will happen tomorrow?*). Neutral questions such as *Tell me about this picture* were posed and the cue word was read aloud. To ascertain that the target verb inflection was elicited, specific attention was given to the interpretation of the meaning of the cue words *every day* and *now*. It was emphasized that *every day* in this context meant that the event to be described had occurred every day in the past and will continue to occur in the future. This was done to elicit third person singular inflection (*Every day the doctor examines the boy*) and to avoid sentences such as *Every day the doctor examined the boy* and *Every day the doctor will examine the boy.* Similarly to avoid production of the future tense for the cue word *now*, it was stressed that *now* should be interpreted to mean that the event was occurring even as the subject was speaking (i.e., *Now the doctor is examining the boy* and not *Now the doctor will examine the boy*). Prior to testing, four practice items were given. All practice items elicited the verb *lick* in different inflectional forms. Just as for the experimental stimuli, cue words were printed at the top of each picture in order to elicit four different verb inflections. During practice, the experimenter provided oral and written models of target sentences.

2.4. Scoring and analyses

All responses were transcribed on-line. The sessions were also tape-recorded for later verification. Transcription reliability was obtained for three of the eight participants. A trained Speech Language Pathologist observed the sessions and transcribed participants' responses on-line. Reliability between the primary experimenter and the second scorer was 98%. Differences between the two scorers were resolved by listening to the tape-recorded sample and arriving at a consensus.

Utterances with word order errors (e.g., *kick the man the cow* for the target *The man kicked the cow*), wrong aspect (*was V + ing* for *V + ed*), and those that consisted of a single word or a string of unconnected words, were excluded from analysis. Instances of verb substitutions such as *The man made soup* instead of *The man cooked soup* were also excluded because word form frequency of target verb inflections (i.e., *cooked*) was an independent variable. Although sentences were elicited, only the verb was considered for scoring. For all analyses, the verbs were inspected twice. First, the verbs were scored for accuracy by comparing with the target verb inflection. That is, *V + ed* was scored as correct if it was produced in response to the cue word *yesterday*, and so on. Second, errors were analyzed for the type of substitution by comparing the error response with the target response. For instance, if *cleaning* was produced for the target *cleaned* (as in *Yesterday the woman cleaning the table*), it was considered a substitution of a semantically less marked inflection (refer to Table 1 for semantic markedness), substitution of a higher frequency verb form (frequency of *cleaning*: 21/million vs. frequency of *cleaned*: 3/million; Francis & Kucera, 1982; see Appendix A for word form frequencies), and substitution of a less frequent affix (see Table 1 for affix frequencies).

2.4.1. Semantic markedness analyses—If verb inflections are produced according to Lapointe's conception of semantic markedness, the following hierarchy should be observed for accuracy: verb stems > *V + ing* > *V + s* > *V + ed* (going from least marked to most marked). The accuracy of each verb form was determined as a proportion of the number of participants correctly producing the verb form and the number of participants attempting that verb form. For example, four out of eight participants who attempted the verb form *cleaned* produced it correctly, giving *cleaned* an accuracy of 0.5. Proportion accuracies were then compared using a one-way analysis of variance (4 levels, *V* stem, *V + ing*, *V + s*, and *V*

+ *ed*). The analysis of variance that was used to test the influence of semantic markedness was used to examine the role of affix frequency as well as affixation analysis because differences between word forms are predicted by all three factors. Further, as per Lapointe's hierarchy, less marked verb forms should replace more marked verb forms significantly more often than the opposite pattern. Hence errors were analyzed for the number of times less marked verb forms replaced more marked forms and compared with the number of times more marked verb forms substituted less marked verb forms.

2.4.2. Word form frequency analyses—If production of inflected verbs is driven by ease of word form accessibility, then word form frequency would be a significant predictor of accuracy, and more frequent inflections of a verb would replace less frequent forms of the same verb significantly more often than less frequent inflections of a verb would replace the more frequent forms of the same verb. Proportion accuracy for each of the verb forms was calculated as the ratio of number of participants correctly producing the verb form and the number of participants attempting the verb form (described earlier under semantic markedness). Proportion accuracy of each verb form and its corresponding word form frequency were entered in a simple linear regression to examine the influence of word form frequency on accuracy. The number of times more frequent verb forms replaced less frequent forms, and the number of occurrences of less frequent forms substituting more frequent verb forms, were also counted for each subject and compared using a *t* test.

2.4.3. Affix frequency analysis—If the production of verb inflections in aphasia is determined by affix frequency, then more frequent affixes would be produced with higher accuracy. Further, more frequent affixes would replace less frequent affixes significantly more often than the opposite pattern (as per the affix frequencies given in Francis & Kucera, 1982; see Table 1). The analysis of variance that was performed to compare the accuracy of the different verb affixes for semantic markedness was used to examine the effect of affix frequency. Next, the number of times more frequent affixes replaced less frequent affixes and the number of occurrences of less frequent affixes substituting more frequent affixes were counted for each subject and compared statistically.

2.4.4. Affixation analyses—If agrammatic subjects are impaired in rule-based affixation when words are phonologically encoded, the overall proportion of inflected verbs should be signi.- cantly less than the overall proportion of verb stems. Further, verb stems, elicited here in the context of future tense, should be produced more accurately than all other verb inflections. The overall proportion of verb stems and verb inflections produced by each participant was calculated and compared using a *t* test. Differences in accuracy of verb stems relative to other verb inflections were determined by referring to the results of the ANOVA computed for semantic markedness analysis.

3. Results

Testing yielded a total of 440 responses of which 11 (2%) were excluded from further analysis because they consisted of either word order errors (4 responses), substitutions of the target verb (5 responses), or use of unintended aspect (2 responses). Of the 429 analyzable responses, 307 responses (Mean proportion across participants = .7, *SD* = .23) were inflected verbs, while the remaining 122 responses (Mean proportion across participants = .3, *SD* = . 23) were uninflected verbs. The distribution of responses for individual subjects is given in Table 5. The findings of the various analysis are given in the following paragraphs.

Semantic markedness analyses

The accuracy data for verb inflections sorted by the type of inflection are given in Fig. 2 for individual subjects and for the whole group. The data are arranged in increasing order of difficulty as predicted by Lapointe (1985). Repeated measures analysis of variance revealed no significant difference between different types of inflections (F (3, 28) = 1.35, p = .27) for the whole group. Fig. 2 shows that none of the patients demonstrated the hierarchy of difficulty predicted by Lapointe. Only three patients (MK, JP, and LD) produced uninflected verbs more accurately than inflected verbs. Three patients (CH, MR, and MD) produced present progressive with greatest accuracy, and two patients were most accurate with past tense inflections (JO and RH). Patient LD also produced a large number of past tense inflections with relatively high accuracy.

Fig. 3 shows the total percentage of verb inflections of a particular type produced by individual subjects and by the whole group, irrespective of the target inflection. These values to a large extent mirror the accuracy data in Fig. 2. There was no significant difference between the overall production rates of the different verb forms (one-way ANOVA, F (3, 28) = 1.06, p = .38). The same patients (CH, MR, and MD) that produced present progressive forms with greatest accuracy also produced the present progressive inflection most frequently. Similarly JO and RH produced past tense inflections most frequently, and MK, JP, and LD produced verb stems more often than any inflected verbs. Patient LD had high accuracy with both past tense and verb stems, and she produced both these verb forms in a high proportion. It is noteworthy that there was a general predominance of verb stems and *V + ing*, a pattern that is consistent with earlier reports of verb production in agrammatic aphasia. However, there was considerable individual variability, and all patients (except JO) seemed to favor a single verb inflection that was used most frequently, and perhaps sometimes overused. The best illustration of this is the patient CH who used the present progressive inflection with 80.2% of all his verbs (see Fig. 2). JO produced verb stems and *V + ed* in approximately equal numbers.

The number of times less marked verb inflections were substituted for more marked verb inflections and the number of times more marked verb inflections were substituted for less marked verb inflections are shown in Fig. 4 (based on Lapointe's (1985) hierarchy). When all patients were considered as a group, there was no significant difference in the substitution rates of more marked and less marked inflections (t(7) = .76, p = .23). However, as Fig. 4 shows, the lack of significance is caused by a single patient, RH, who produced a large number of *V + ed* substitutions (see Fig. 3).

To summarize, semantic markedness was not a significant predictor of accuracy of verb inflections. However, the errors of seven out of eight patients primarily consisted of substitutions by less marked inflections, primarily V stems and *V + ing* forms. As will be pointed out in the discussion, this could also be due to other factors such as tense marking and frequency. The data are characterized by considerable heterogeneity across patients, suggesting that semantic markedness is not a consistent determinant of accuracy.

Word form frequency analyses

Regression analysis revealed a significant effect of word form frequency on proportion accuracy (F (1, 66) = 4.91, p = .03; R^2 = .07). It is noteworthy that although word form frequency emerged a significant predictor of accuracy, the coefficient of variance (R^2) is low, indicating the relatively limited influence of this variable. Possible reasons for the low R^2 are discussed later. Analysis of verb substitution errors revealed that less frequent word forms were substituted by more frequent word forms significantly more often than more frequent word forms were substituted by less frequent word forms (t(7) = 2.2, p = .03).

Substitution patterns of individual participants are shown in Fig. 5. Six patients out of eight showed an effect of word form frequency by substituting less frequent forms of a verb by more frequent variations of the same verb (see Fig. 5). The difference between the occurrence of more frequent and less frequent substitutions was significant for five out of these six patients (MR, JO, LD, CH, and MD; χ^2 test, $p < .01$). Since verb stems tend to have higher word form frequencies and production of verb stems for inflected verbs could be due to an impairment of affixation during phonological encoding, the data were reanalyzed by excluding all verb stem substitutions. Word form frequency was still found to be a significant predictor of accuracy and the substitution patterns of individual participants remain unchanged.

To summarize, regression analysis revealed that word form frequency had an effect on the accuracy of verb inflections, although the variance was small. Further, a significant proportion of verb inflection errors consisted of substitutions by higher frequency word forms for lower frequency targets, and this effect was significant for six out of eight patients.

Affix frequency analyses

As reported earlier, there was no significant difference between the various verbal affixes either in accuracy (F (3, 28) = 1.35, $p = .27$) or overall production rates (F (3, 28) = 1.06, $p = .38$). When verb inflection errors were analyzed in terms of substitutions of more frequent affixes for less frequent affixes, and less frequent affixes for more frequent affixes, there was no significant difference ($t(7) = 1.2$, $p = .13$). Thus affix frequency was not a significant predictor of accuracy, overall production rate, or substitution errors.

Affixation analyses

The data in Table 5 reveal that agrammatic Broca's aphasic participants of this study were able to produce verb inflections almost 75% of the time (Mean across participants = 75, *SD* = 23), while verb stems constituted only 25% (Mean across participants = 25, *SD* = 22.5) of the total responses. This proportion is consistent with the proportion of inflected verbs that were elicited, since only 75% of the stimuli were targeted to elicit inflected verbs (i.e., three of the four verb forms, *V + ing*, *V + ed*, and *V + s*). There was a significant difference in the proportion of inflected and uninflected verbs produced ($t(7) = 2.3$, $p = .02$), with inflected verbs being produced in a larger proportion of the responses. However, there was no significant difference between the accuracy of inflected and uninflected verbs ($t(7) = .01$, $p = .49$). To summarize, participants in this study produced a large number of inflected verbs, suggesting success in the phonological process of affixation. Fig. 3 demonstrates that all patients (except MR and LD who did not produce V+s) produced all three inflectional affixes at least once. This suggests that access to the phonological form of specific inflectional affixes and affixation with the verb stem was not problematic.

4. Discussion

The primary purpose of this investigation was to examine the source of verb inflection errors in a group of 8 agrammatic individuals with mild-moderate Broca's aphasia. The pre-phonological process of diacritical marking and the phonological stage of affixation were evaluated as two potential loci of impairment. This was achieved by eliciting verb inflections in a cued sentence production task and examining accuracy and substitution errors for the effect of semantic markedness, word form frequency, and affix frequency. Nearly 75% of the verbs were inflected although the overall accuracy was only 36%. Semantic markedness failed to influence accuracy, and affix frequency had no significant effect either on accuracy or on substitution errors. Word form frequency was found to be a significant predictor of both the accuracy with which verb inflections were produced and the

pattern of substitution errors. The data were also characterized by considerable individual variability in production patterns.

Verb inflections and impaired diacritics

Although the agrammatic aphasic participants of this study demonstrated an understanding of words denoting temporal information (*yesterday*, *tomorrow*, etc.), the low accuracy in this sentence production task suggests that these patients failed to utilize temporal information to select the syntactically and semantically appropriate verb form during sentence planning. This conclusion is supported by the observation that patients often produced responses such as *Tomorrow the man lifted the box* (JO) and *Yesterday the man lifts the box* (RH). These errors suggest that agrammatic aphasic patients are either unable to use a temporal cue such as *Yesterday* to select a diacritical feature such as +PAST. Or, the difficulty lies in relating a diacritical feature such as +PAST with an inflectional affix such as *ed*.

As mentioned earlier, what differentiates a diacritical deficit from an affixation deficit in agrammatic aphasia is the accuracy of verb stems elicited in the future tense context since these encode tense information while not undergoing affixation. A deficit affecting the process of affixation of the verb stem with an affix would result in accurate production of verb stems in future tense sentences, while impairing the production of past, present progressive, and third person singular verb forms. In contrast, a diacritical deficit predicts no differences in the accuracy of verb stems and other verb forms, a prediction that is consistent with the findings of the present study (see Table 5). To summarize, three sources of evidence suggest a diacritical impairment: low accuracy despite high proportion of inflected responses, errors resulted in a mismatch between the temporal cue and inflectional affix, and no differences in the accuracy of verb stems and inflected verbs.

The conclusion of a diacritical deficit is also supported by other studies which report that verb inflection errors frequently differ from the target inflection by a single diacritical feature, such as tense, number, or person (e.g., Janssen & Penke, 2000). These results suggest that agrammatic aphasic individuals experience difficulty when they have to choose the syntactically and semantically appropriate feature from a set of features. Further, verbal infinitives are frequently produced in languages such as Italian, although infinitives in these languages are affixed and hence morphologically complex (Libben, 1990). In Italian, there are other verb forms such as imperatives that are not affixed and hence morphologically simple. However, the affixed infinitive forms are produced far more frequently than the unaffixed imperatives, suggesting a difficulty with tense marking rather than affixation per se. Evidence that Broca's aphasic subjects may be insensitive to the full semantic and syntactic information encoded in inflectional affixes also comes from word monitoring experiments in German where Broca's aphasic patients failed to detect incorrect inflections when these functioned as diacritical markers (second person singular versus third person singular). However, these subjects were sensitive to inflectional markers that denoted lexical category (noun versus verb; Friederici, Wessels, Emmorey, & Bellugi, 1992).

Earlier reports of the overuse of verb stems and *V + ing* verb forms in agrammatic narrative speech can also be explained by a deficit related to diacritical features marking tense. *V + ing* verbs denote progressive aspect, and do not directly convey tense information since tense is conveyed by the auxiliary (e.g., *He was kissing her*, *He is kissing her*, *He will be kissing her*). Hence we could postulate that the mental representation of the *ing* affix may be underspecified for tense diacritics, allowing *V + ing* forms to be used when tense diacritics are not selected (Ullman & Gopnik, 1999). The same argument can be made for verb stems because when verb stems occur in a tense-conveying context such as the future, tense is often indicated by the auxiliary. Further, at least in English, verb stems are used in a variety of other sentential contexts that are not directly related to tense, such as imperatives,

infinitives, and embedded under modals. Similarly in English, the verb participle affix for most verbs is homophonous with the past tense affix (e.g., *ed* as in *He would have kissed the nurse* and *He kissed the nurse*, respectively). Hence, the *ed* affix need not always convey tense information.[3] For these reasons, the only affix that conveys true tense information in English is the third person singular affix (*V* + *s*). With the exception of MK and RH, the agrammatic patients in the present study had significantly greater difficulty with *V* + *s* verb forms than with other verb forms (see Figs. 2 and 3). Therefore, it is likely that when tense-marking diacritics fail to guide affix selection, verb forms whose mental representations contain maximal tense-related (i.e., *V* + *s*) information are less likely to be produced. Since verb stems, *V* + *ing* and *V* + *ed* forms are less specific about tense, these are more likely to be produced in agrammatic aphasia. The poorer production of *V* + *s* forms compared to other verb forms can also be explained by frequency effects, as shown in the following discussion.

The influence of frequency on lexical retrieval is a well-known effect both in aphasic (e.g., Caramazza & Hillis, 1990; Nickels, 1994) and normal speakers (Jescheniak & Levelt, 1994; Oldfield & Wingfield, 1965). Stemberger (1984, 1985) suggested that verb inflection errors in agrammatic speech might be determined by frequency, since high frequency words have lower activation thresholds. Consistent with this prediction, word form frequency emerged as a significant predictor of both accuracy and substitution errors in the present study. Word form frequency has also been found to influence verb inflection errors in another clinical population known for errors of verb morphology, children with specific language impairment (SLI) (Ullman & Gopnik, 1999). However, the finding of a significant word form frequency effect in agrammatic speech production has to be interpreted with caution due to the following reasons: First, word form frequency accounted for only a small portion of the variance in the present study. Although this is most likely due to the narrow range of frequencies used (0/million to 35/million), the low variance necessitates replication of the frequency effect with a broader frequency range. Second, Janssen and Penke (2000) investigated the effect of word form frequency on SVA errors in agrammatism and failed to find any effect of word form frequency. The difference between our findings and those of Janssen and Penke is possibly because SVA is relatively spared in agrammatic aphasia and hence guided by syntactically appropriate mechanisms, rather than lexical accessibility. In contrast, tense marking is significantly impaired in our agrammatic participants, possibly making them rely on word form frequency to a greater degree than during the production of SVA.

Word form frequency may also provide an explanation for the relatively low occurrence of *V* + *s* verb forms in our participants since *V* + *s* forms of the verb stimuli were of considerably lower frequency (Mean word form frequency = 1.7/million, *SD* = 2.5) than *V* + *ed* (Mean word form frequency = 10.7/million, *SD* = 7.8) and *V* + *ing* (Mean word form frequency = 11/million, *SD* = 7.8) forms (cf. Appendix A). In general, *V* + *s* forms are the least frequent verb forms in English (Francis & Kucera, 1982; cf. Table 1).

Semantic markedness, as defined by Lapointe, did not influence accuracy of production. Across the whole group of participants, three of the four verb forms were produced in roughly equal proportions, showing the absence of any so-called “hierarchy.” Although substitution patterns were consistent with predictions for seven out of eight participants, these are also in accordance with word form frequency. The absence of an effect of semantic

[3]We thank an anonymous reviewer for pointing out the ambiguity of *ed* usage in English agrammatic speech. The reviewer suggested that the occurrence of *ed* affixes in our patients might have actually been attempts at producing participle verbs since participle usage was found to be relatively spared in a study of Dutch agrammatic aphasia (Bastiaanse & Hugen, 2002). Although this possibility cannot be ruled out in our data, we think it is unlikely because patients were given specific instructions to produce sentences appropriate to the temporal context cued for each trial (in this case, past tense). Further, patients did not produce other grammatical morphemes (e.g., modals, auxiliaries) that would have indicated the production of participles.

markedness based on Lapointe's (1985) hierarchy was also reported by Janssen and Penke (2000) for SVA. In fact, by Lapointe's own admission, the two Italian aphasic participants whose data were taken as support of the semantic markedness hierarchy were atypical Broca's aphasic patients, with only transient morphological deficits. In addition, Lapointe analyzed narrative data, and as mentioned earlier, the target verb inflection is often unknown in narratives, leading to guesswork about the kind of substitution error. Thus we can conclude that semantic markedness, as defined by Lapointe, may not determine the production of verb forms in agrammatic aphasia.

We did not find a statistically significant effect of affix frequency on accuracy or overall production, primarily because *V + ed* and *V + ing* forms were produced in roughly equal proportions. However, the least frequent affix, *V + s*, had the lowest accuracy and production rate. Our findings are in contrast with those of Centeno et al. (1996) for Spanish speaking and Penke (2003) for German speaking agrammatic aphasic patients. This difference is possibly related to task differences and language specific structure. Centeno et al. used a sentence repetition task, where frequency may be more likely to affect recall. The effect of frequency on recall in a sentential context has been demonstrated for normal speakers (Griffin & Bock, 1998). It is also possible that affix frequency is a more potent variable in Spanish and German due to the large number of affixes in those languages when compared with English, which has only four verbal affixes. Given our findings of a significant word form frequency effect in English, language specific factors, such as the number of affixes, may determine the relative role of affix and word form frequencies in aphasia. Aphasic production in languages with a greater number of affixes could be more likely to be influenced by affix frequency, while word form frequency could play a larger role in languages with a limited number of affixes. This interaction of affix frequency and word form frequency is beyond the scope of this study and warrants further investigation.

Verb inflections and impaired affixation

The participants in our study produced inflected verbs in 75% of their responses, although only 35% of the inflected verbs were produced accurately. If the ability to combine stems and affixes were impaired, such high occurrence of verb inflections would not have been observed. As mentioned earlier, the accuracy of verb stems in future tense contexts was not significantly better than the accuracy of other verb forms, further suggesting that affixation was not the primary difficulty for this group of Broca's aphasic participants. Our finding of relatively spared affixation is also supported by Bird, Lambon Ralph, Seidenberg, McClelland, and Patterson (2003) who found no differences between the production of regular (affixed) and irregular past tense verbs in English using sentence completion, word repetition, and reading tasks. If affixation were indeed impaired, Bird et al. would have found poorer production of regular verbs. On the surface, our findings may seem inconsistent with that of Ullman et al. (1997), who reported poorer accuracy with regular past tense verbs (20%) compared to irregular verbs (52%) in a group of five agrammatic Broca's aphasic individuals for a word reading task. The lower regular verb accuracy of Ullman et al.'s patients might be due to differences in severity given that their patients could only perform a word reading task. In addition, visual/orthographic confusions in word reading are more likely for regular than for irregular inflections. Although the accuracy of irregular verbs is better than that of regular verbs in Ullman et al.'s data, irregular verbs are still impaired (52% accuracy), a finding that cannot be explained by impaired affixation, but can be accomodated by a diacritical feature impairment.

In our study, a large proportion of errors consisted of substitutions of other affixed verb forms such as progressives and present singular (*V + ing*, *V + s*), and all eight patients produced affixed verbs. In other words, there was no patient who produced only verb stems. This pattern is inconsistent with an impairment of affixation in agrammatism since impaired

affixation would have resulted in primarily stem substitution errors. To summarize, the relative sparing of affixation is indicated by the following findings: the high proportion of verb inflections produced, the low accuracy of verb stems, and the predominance of inflectional substitutions.

Implications for lexical organization of inflected words

Patterns of production of verb inflections in aphasic and other neurologically impaired patients provide important insights about the mental representation and processing of inflected words and have played a pivotal role in the 'decompositional versus whole word' debate about the processing of English past tense (e.g., Bird et al., 2003; Joanisse & Seidenberg, 1999; Ullman et al., 1997). Our findings could be used to address this debate because we examined the effect of frequency on the production of regular inflections. Traditionally a facilitatory effect of frequency has been used to argue in favor of whole word representations for inflected words by drawing an analogy with frequency effects for morphologically simple words (Rumelhart & McClelland, 1986). More recently, however, it is acknowledged that frequency effects can be also accommodated by theories that propose on-line affixation since it is highly likely that inflected words are represented at some level of lexical or phonological representation. In Pinker and Ullman's (2002) words, "*It would be difficult to prohibit regular forms from ever being stored, given that human memory can acquire many forms of verbal material (e.g., idioms, clichés, poems)*." Thus it is possible to envision a view of the mental lexicon where verb stems and affixes are represented and accessed not only as separate entities, but also as affixed whole words at different levels of processing (Caramazza, Laudanna, & Romani, 1988). In other words, the frequency effects found in the present study can be accommodated by both whole word and decompositional views of the mental lexicon.

An interesting observation was that all patients tended to overuse one verb form (except MK who overused two verb forms) irrespective of the context (see Fig. 3). For example, RH used *V + ed* most frequently and CH used *V + ing* in most of his utterances, while JP preferred verb stems. These individual preferences suggest that agrammatic patients produce the most accessible verb form, and that accessibility varies across patients and is not determined by word form frequency alone. It is possible that production of an inflectional affix in one utterance raises its likelihood of being produced in succeeding utterances since diacritical information is unavailable to guide verb form production. These individual affix preferences and the effect of word form frequency and can be accommodated by Bybee's (1995) model of the mental lexicon, which proposes a network of mappings between various words that have overlapping morphemes. *Lexical connections* are believed to exist between words that share either phonological or semantic features (Bybee, 1985,1995). Thus, a lexical connection exists between *walked* and *kicked* due to phonological and semantic overlap of *ed*, just as between *walk* and *walk* ed. Further, each time a word is processed, its stored representation is reinforced, adding to its *lexical strength* (Bybee, 1985,1995). Thus higher frequency words have higher lexical strengths. The lexical strength of words varies for individuals depending on usage, allowing for individual differences. Accessibility of inflected verbs in agrammatic patients may be determined by spared and stronger lexical connections between words ending in a particular affix. Thus, for patients CH, MR, and MD, lexical connections between all verbs ending in *ing* may have been better preserved or relearned after brain damage than any other lexical connection, leading to the overuse of verbs ending in *ing* (see Fig. 3). For subjects JO and RH lexical connections between all words ending in *ed* may have been better preserved/re-learned.

A few other findings in aphasic literature could also be accommodated by Bybee's model. Centeno et al. (1996) found present and past tenses, the most frequently used tense forms in Spanish to be better preserved in Spanish agrammatic aphasic subjects. This effect of daily

usage frequency could be explained by assuming that stronger lexical connections between more frequent networks are preserved/re-learned in aphasia. Further, Penke et al. (1999) found that accuracy with which verb inflections were produced by German agrammatic aphasics was influenced by the cluster frequency of the ablaut pattern (i.e., the number of verbs, regular or irregular, having a particular vowel stem). It is possible that Penke et al.'s agrammatic subjects had stronger lexical connections for all verbs with a frequently occurring vowel stem. To summarize, the findings of the present study are conducive to whole-word views of the mental lexicon such as single-route models (Joanisse & Seidenberg, 1999) and Bybee's connectionstic model. The effect of word form frequency could be accommodated by decompositional models if these assume whole word representation at some lexical level (e.g., Pinker & Ullman, 2002).

Conclusion

Verb inflection errors observed in English- speaking agrammatic individuals are the most likely the consequence of a prephonological diacritical deficit, and less likely to be due to a failure of the phonological process of affixation. The difficulty may be either due a failure to utilize semantic context to select the appropriate tense-marking diacritical feature, or due to a failure to employ tense-marking diacritical information to retrieve the exact verbal affix from the mental lexicon. When there is a diacritical failure, production of utterances is influenced by word form frequency of individual verb forms and by individual verb form preferences. These results can be accommodated by both connectionistic and decompositional views of the mental lexicon.

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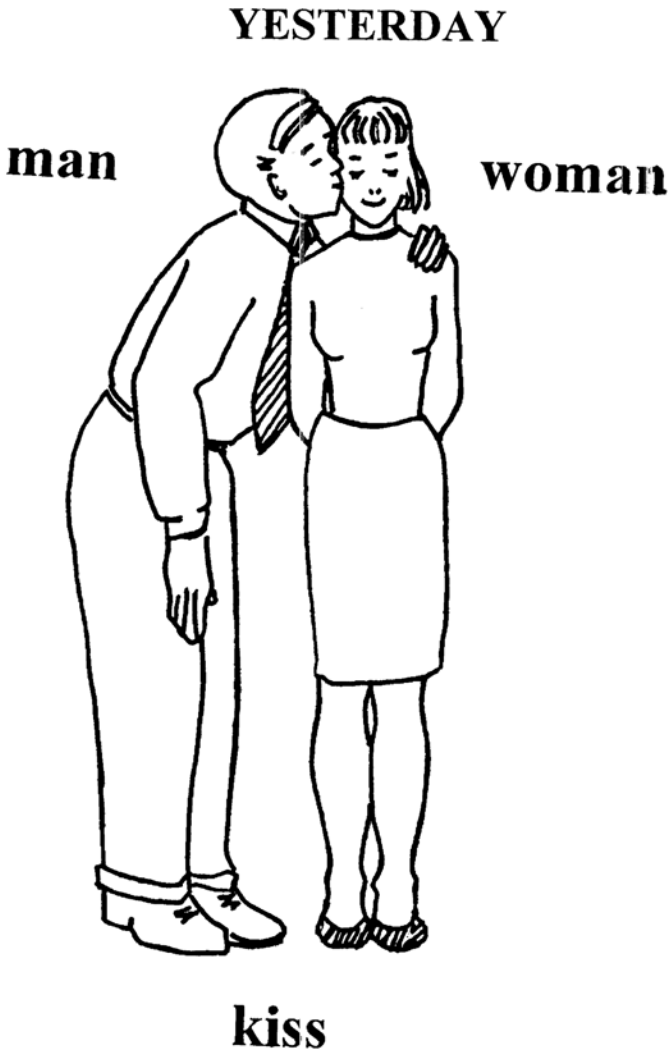

Fig. 1.
Example of a stimulus picture.

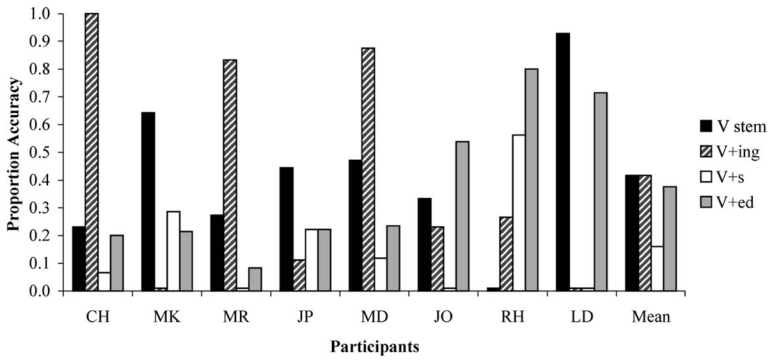

Fig. 2.
Proportion accuracy of different verb forms for individual participants and the group mean.

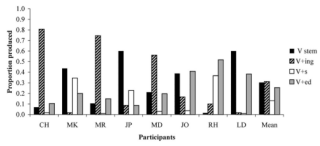

Fig. 3.
Proportion of different verb forms produced by individual participants and the group mean.

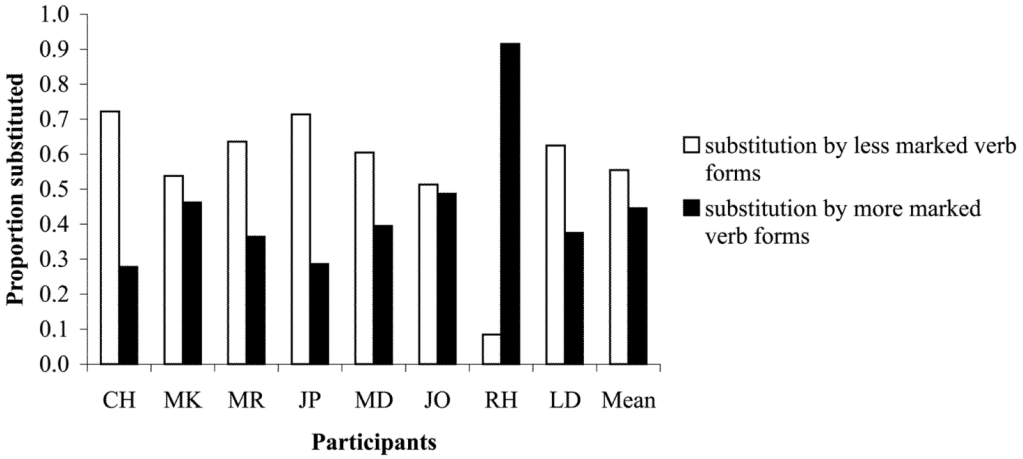

Fig. 4.

Effect of semantic markedness on substitution errors represented as a proportion of more marked and less marked verb form substitutions for individual participants and the group.

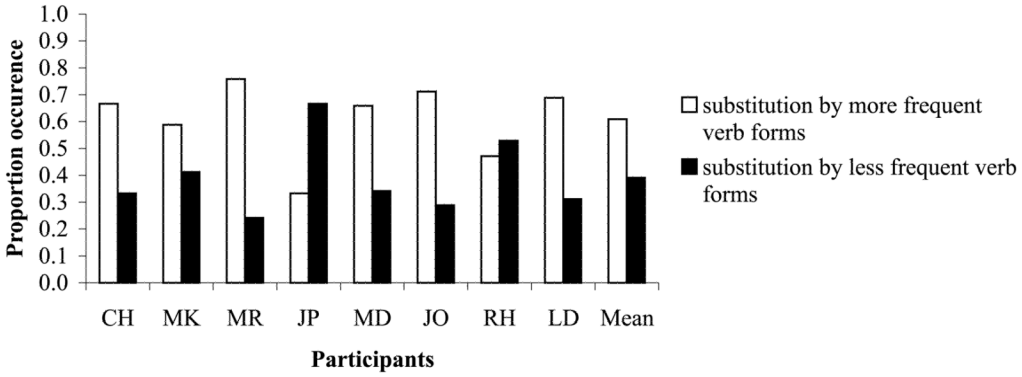

Fig. 5.

Effect of word form frequency on substitution errors represented as a proportion of less frequent and more frequent verb form substitutions for individual participants and the group.

Table 1

Numerical values of “energy units” involved in the production of each verb form assigned by Lapointe (1985), and the frequencies (per million words) of the different verbal affixes from the Francis and Kucera (1982) database

	V stem	ing	s	ed
Energy units	1	2	2.5	3.5
Frequency	—	18,210	7649	26,199

Table 2

Patient demographics

Participant	Age (years)	Gender	Handedness	Education (years)	Occupation	MPO	CT scan	AQ
CH	56	M	R	16	Restaurant manager	90	L. mca region	69.9
MK	54	M	R	18	Business man	12	L. fronto-parietal in mca region	65.1
MR	44	F	R	12	Leasing consultant	45	L. mca region	58
JP	65	M	R	16	Chemist	30	L. mca region	58.8
MD	62	M	L	20	Attorney	120	L. mca region	70
JO	69	M	R	13	Accountant	88	L. mca region	70.9
RH	64	M	R	16	Teacher	100	Large LH frontal and temporal	68
LD	52	F	R	17	Village treasurer	14	L. temporoparietal and arcuate fasciculus	85

MPO (months past onset) and AQ (aphasia quotient), Kertesz, 1982.

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Table 3

Results of the narrative analysis using the procedure of Thompson et al. (1995)

Participant	Total words	MLU	Proportion grammatical sentences	Open:closed ratio	% Correct vmi
CH	224	6.5	0.44	1.3	0.6
MK	32	2.8	5	1.7	0.7
MR	161	4.1	0.2	1.2	0.6
JP	121	4.5	0	1.3	0.4
MD	143	4.6	0.2	1.4	0.6
JO	33	2.9	0.4	1.8	0.7
RH	132	4.9	0.5	3.1	0.7
LD	70	7	0.4	1.7	0.5

vmi, verb morphology index.

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Table 4

Verb naming scores for each participant (Maximum score = 17)

Participant	Number of verbs
CH	15
MK	14
MR	12
JP	9
MD	17
JO	14
RH	15
LD	14

Table 5

Individual and group data describing the distribution of responses

Subject	Number of responses	Number of analyzable responses	Distribution of analyzable responses		Accuracy		
			Inflected	Uninflected	Inflected	Uninflected	Mean accuracy
CH	60	57	53 (.93)	4 (.07)	18 (.34)	3 (.75)	0.37
MK	56	55	31 (.56)	24 (.44)	14 (.45)	9 (.37)	0.42
MR	48	47	42 (.89)	5 (.11)	11 (.26)	5 (.24)	0.34
JP	36	35	14 (.4)	21 (.6)	3 (.21)	4 (.19)	0.2
MD	68	66	53 (.8)	13 (.2)	20 (.37)	8 (.61)	0.42
JO	56	54	33 (.61)	21 (.39)	10 (.3)	5 (.24)	0.27
RH	60	60	59 (.98)	1 (.02)	25 (.42)	0 (0)	0.42
LD	56	55	22 (.4)	33 (.6)	10 (.45)	13 (.39)	0.42
Total	440	429	307	122	111	47	—
Mean (of proportion)	55	53.63	0.75	0.25	0.35	0.35	0.36
SD	9.50	9.26	.23	.23	.01	.06	.08

Note. The numbers in parentheses are proportions.

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Appendix A

Lemma and word form frequencies (per million) of the stimuli used in the study (Francis & Kucera, 1982)

Verb	Lemma	V+ed	V+ing	V+s	V
Kiss	31	15	6	1	9
Weigh	33	11	9	4	4
Kick	34	10	11	1	4
Wipe	35	11	6	0	10
Stir	39	7	13	3	7
Pack	44	7	14	0	11
Thank	45	5	3	0	35
Pour	48	21	2	9	7
Cook	50	2	26	0	14
Tie	50	13	5	2	9
Print	53	9	10	0	4
Mix	56	1	8	0	11
Clean	58	3	21	1	18
Lock	63	9	30	0	2
Lift	69	34	7	1	18
Deliver	70	13	9	6	18
Examine	70	11	7	1	33
Median	50	10	9	1	10
Mean (*SD*)	49.9 (13.1)	10.7 (7.8)	11.0 (7.8)	1.7 (2.5)	12.6 (9.5)
Range	31–70	1–34	2–30	0–9	2–35

Appendix B

List of participants who correctly named each verb

Verb	Correctly named by
Kiss	CH, MK, MR, JP, MD, JO, RH, LD
Weigh	CH, MD, JO, RH, LD
Kick	CH, MK, MR, JP, MD, JO, RH, LD
Wipe	CH, MK, MR, MD, JO, RH, LD
Stir	CH, MK, MR, MD, JO, RH, LD
Pack	CH, MK, MR, MD, LD
Thank	CH, MK, MR, JP, MD
Pour	CH, MR, MD, RH, LD
Cook	CH, MK, MR, JP, MD, JO, RH, LD
Tie	CH, MK, JP, MD, JO, RH, LD
Print	MK, MR, JP, MD, JO, RH, LD
Mix	CH, MK, MR, JP, MD, JO, RH
Clean	CH, MK, MR, JP, MD, JO, RH, LD
Lock	CH, MR, JP, MD, JO, RH, LD
Lift	CH, MK, MD, JO, RH, LD
Deliver	CH, MK, MD, JO, RH
Examine	MK, MD, JO, RH, LD