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Production latencies of morphologically simple and complex verbs in aphasia

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Abstract

There are several accounts of why some individuals with post-stroke aphasia experience difficulty in producing morphologically complex verbs. Although a majority of these individuals also produce syntactically flawed utterances, at least two accounts focus on word-level encoding operations. One account proposes a difficulty with rule-governed affixation, predicting that verbs without affixes (stems and irregular past) should be produced with ease. The second account emphasises the contribution of phonological encoding, noting that morphological complexity is often confounded by phonological complexity. The present study investigated the effect of morphological complexity (presence vs. absence of affixes) on verb production when phonological complexity and lexical frequency was controlled. A novel delayed repetition paradigm was used, accuracy and latency of production were the dependent measures. Data from nine agrammatic aphasic and nine unimpaired participants revealed no effects of morphological complexity, but a significant effect of frequency on production latency. The results indicate that morphological complexity plays little role, if any, in production difficulty, at least for this experimental task and this group of non-apraxic agrammatic aphasic individuals. A difficulty in usage of contextually appropriate verb inflections, rather than in morphophonological encoding, is suggested.

Keywords: *agrammatism, dual route model, phonology*

Introduction

Phonological errors frequently occur in the speech of individuals with aphasia. These include substitutions (cartoon → tartoon), omissions (bell → ell), additions (tack → tackt), as well as (phonetic) distortions of phonemes (examples from Kohn & Melvold, 2000). Morphological errors, although less common than phonological errors, are also characterised as substitutions (halted → halts), omissions (frequently → frequent), and additions (rustle → rustled) (Badeckar & Caramazza, 1998). Some aphasic individuals may produce errors that are both morphological and phonological, such as a phonological error in the word root and a morphological error in the affix, as in **bu**stl**ed** for rustles. A similar example cited in Italian is **rin*cottere for **per**co**rrere** (to go along) (in Miceli, Capasso, & Caramazza, 2004). These errors can alternatively be construed

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as two phonological errors, one of which mimics a morphological error. As is evident from the preceding examples, the distinction between morphological and phonological errors is often ambiguous due to phonological similarity of morphological variants (Braber, Patterson, Ellis, & Lambon Ralph, 2005). It is also pointed out that there are no published reports of patients who present with a pure morphological deficit in the absence of phonological errors (Badeckar & Caramazza, 1998; Miceli et al., 2004). This interdependence between phonology and morphology is also recognised in unimpaired (normal) word production (Stemberger, 1995; 2002) as well as in generative linguistics (Kiparsky, 1982; Burzio, 2002).

Broca's aphasia is a category in which such ambiguity is typical. Although a few earlier descriptions characterised Broca's aphasia as primarily a phonological impairment (Kean, 1977), additional linguistic impairments, particularly those of the morphosyntax are now well recognised (Goodglass, Gleason, Bernholtz, & Hyde, 1972; Saffran, Berndt, & Schwartz, 1989). During the past two decades there has been intense interest in agrammatism, which is a set of symptoms commonly (but not exclusively) associated with Broca's aphasia. Language production in agrammatic aphasia is characterised by morphosyntactically ill-formed utterances. Not surprisingly, the underlying source of morphological errors in agrammatic Broca's aphasia is highly controversial. One theory implicates an impairment in rule-based affixation operations (verb + ed → verbed) (Ullman et al., 1997) and is an offshoot of models of inflectional morphology in which word stems and affixes are decomposed in the mental lexicon (Pinker, 1999). This theory faces the challenge of explaining errors in the production of undecomposed words such as irregular past tense verbs (Bird, Lambon Ralph, Seidenberg, McClelland, & Patterson, 2003; Penke & Westermann, 2006; Faroqi-Shah, 2007), over-use of progressive aspectual forms (verbing), and performance differential based on grammatical category (verb morphology worse than noun morphology) or syntactic function (tense marking worse than agreement morphology) (Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Goodglass, Christiansen, & Gallagher, 1993; Kohn & Melvold, 2000). Another view, which follows from connectionistic models (Joannise & Seidenberg, 1999; McClelland & Patterson, 2002) is that errors in producing morphologically complex words, particularly verb inflections in English, are inflated by phonological complexity (Bird et al., 2003; Braber et al., 2005). That is, regular past verbs are often produced with lower accuracy than irregulars by aphasic individuals because the two verb types are not always matched for phonological complexity in prior studies. This phonological view is challenged by over-regularisations that bear little resemblance to the target (sang → singed) and by errors that are phonologically more complex than the target morphological form. For example, infinitives are often substituted for imperatives in German and Hindi, although the former are phonologically more complex (Lorch, 1990). Finally, there are a variety of theories that focus on syntactic (sentential) formulation (Burchert, Swoboda-Moll, & deBlesser, 2005; Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Kegl, 1995; Wenzlaff & Clahsen, 2004). Although the various syntactic accounts differ in specifics, most are unable to account for errors in single word production or task-related performance differences (see Fix & Thompson, 2006; Kok, van Doorn, & Kolk, 2007).

The possibility that morphological errors in agrammatic Broca's aphasia could be a manifestation of multiple impairments is less acknowledged and warrants further investigation. In addition to the earlier mentioned co-morbidity of morphological, phonological and syntactic impairments in Broca's aphasia, there are methodological challenges when addressing this question. Stimulus selection is complicated by the conflation of phonological and morphological complexity in English because most past and simple present verb forms end in consonant clusters (Burzio, 2002; Bird et al., 2003; Stemberger, 2004; for studies that have attempted to address this, see Mathews & Obler, 1997; Kohn & Melvold, 2000; Mathews, Obler, Harris, & Bradley, 2001).

There is also the need to control for variables that can independently influence ease of production, such as lexical frequency (Gagnon, Schwartz, Martin, Dell, & Saffran, 1997). The linguistic demands of different experimental tasks can differentially affect production success. Performance on single word tasks such as repetition is often used to examine morphophonological processes while limiting syntactic demands. However, at least for some patients, single word repetition may not challenge the language production mechanism sufficiently to reveal performance differences related to morphological complexity.

The aim of the present study was to delineate if morphological encoding contributes to errors of verb morphology that occur in agrammatic aphasia. The study was motivated by the two word-level accounts described earlier: impaired rule-based affixation and phonological impairment (Bird et al., 2003; Braber et al., 2005; Ullman et al., 1997). In this study, morphological encoding specifically refers to post-lexical processes such as rule-governed affixation that are assumed to occur for inflected verbs (Pinker, 1999), and does not refer to conceptual-semantic or syntactic processes that guide selection of certain verb forms over others. A word repetition task was used in which stimuli were comparable in phonological structure while varying in morphological complexity. Phonological structure was operationally defined as the number of phonemes. Morphological complexity was defined as the presence of decomposable inflectional affixes (verb+ed or verb+ing). Stimuli across morphological categories were also matched for lexical frequency, as this variable can have an independent effect on production (Gagnon et al., 1997). The phonological account of morphological errors predicts that there should be no difference in performance across morphological categories if stimuli are similar in phonological structure. In contrast the impaired affixation account of morphological errors predicts a deterioration in performance as a function of morphological complexity.

In this study word repetition was used rather than reading because of the frequent occurrence of reading errors in aphasic individuals and the greater transparency of inflectional affixes in written words (Kohn & Melvold, 2000). In order to magnify subtle differences across morphological categories, the difficulty of the repetition task was increased by imposing a temporal delay between presentation of the stimulus and production of the response. Similar delayed response paradigms have been used in psycholinguistic studies of unimpaired participants (Balota & Chumbley, 1985; Jescheniak & Levelt, 1994; Savage, Bradley, & Forster, 1990). In our study, participants performed an unrelated verbal filler task in the time period between stimulus presentation and response production in order to prevent rehearsal and memorisation of the stimulus. Production latencies were measured (in addition to accuracy and error patterns) in order to achieve a finer measurement granularity than had been achieved with prior studies. The premise behind accuracy and latency measures is that words which place greater computational demands on the production mechanism will be produced less accurately and more slowly compared to words that require fewer encoding operations. To summarise, the primary question of this study was whether morphological complexity can influence the production of words otherwise comparable in phonological structure and lexical frequency in agrammatic aphasic individuals. Performance was also compared with a matched group of unimpaired non-brain damaged adults.

Methods

Participants

Nine aphasic participants (three female) were included in this study. All aphasic participants had a single left hemisphere lesion resulting from a cerebrovascular accident (CVA) at least

1year prior to participation. Eight out of nine patients had an ischemic lesion in the region of the left middle cerebral artery. A9 had a haemorrhagic lesion primarily in the basal ganglia that extended to the temporal and parietal lobe. None of the aphasic participants had complicating medical/neurological conditions such as alcohol/drug abuse, dementia and psychiatric disturbances. All were native speakers of standard American English, had at least high school education, passed a puretone audiometric screening at 500, 1000 and 2000 Hz at 40 dBHL ANSI:1969 in both ears, and their visual acuity measured at least 20/40 on the Snellen's chart.[1] One participant's (A8) hearing was not tested because he used a hearing aid to correct his hearing to normal, as per his audiological report. Demographic and neurological details of all participants are given in Table I. None of the participants demonstrated significant symptoms of apraxia of speech as defined by Duffy (1995), the symptom checklist of the Apraxia Battery for Adults (Dabul, 1979) and the oral expression sub-test of the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass, Kaplan, & Barresi, 2001).

Nine non-brain damaged unimpaired participants (three female), who were matched in age and approximate education with the aphasic participants, were recruited (see Table I). As per their self-report, none of the participants had a history of speech and language disorders or complicating medical/neurological conditions. They were all native speakers of standard American English, had at least high school education, passed puretone audiometric screening at 500, 1000 and 2000 Hz at 40 dBHL ANSI:1969 in both ears, and their visual acuity measured at least 20/40 on the Snellen's chart.

Language testing

All aphasic participants completed a set of tests that were intended to establish their diagnosis of Broca's aphasia with agrammatic speech, characterised by errors in the production of inflectional morphology. Individual participant scores for each participant are given in Table II. The diagnosis of Broca's aphasia was made using the Western Aphasia Battery (WAB) (Kertesz, 1982) and clinical judgement. As per the WAB, all participants had impaired sentence structure and fluency, relatively spared auditory comprehension, and oral repetition. Samples of narrative speech were elicited by having participants describe the cookie theft picture, which is a part of the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass, Kaplan, & Barresi, 2001), and narrate the Cinderella fairy tale. Rate of speech was calculated as the number of words produced per minute (WPM). Mean length of utterance, proportion grammatical sentences, and proportion of verbs with correct morphology were calculated using the procedure of Thompson, Shapiro, Tait, Jacobs, Schneider, & Ballard (1995). All participants showed evidence of non-fluency and agrammatic speech, as revealed by a reduction in the above measures in comparison to the narratives of 10 age-matched normal individuals (Kim & Thompson, 2004).

Two tasks were used to determine difficulty with verb morphology in sentence production. The Verb inflection test consists of 20 picture stimuli designed to elicit verbal forms using word cues that are printed on the stimuli (*tomorrow*, *now*, *yesterday* and *everyday*)[2] (Faroqi-Shah, 2004; see also Faroqi-Shah & Thompson, 2004 for detailed description of these stimuli). Additionally, a forced choice sentence completion task ($n = 45$) was used in which participants were required to select context appropriate verb morphology in sentences such as *Last year I ______ in New York* (see Faroqi-Shah & Thompson, 2007). For this completion task, participants could respond by pointing to the verb morphology, and hence performance was not dependent on oral production. All participants displayed a marked difficulty in

Table I. Demographic details of aphasic and unimpaired participants.

Aphasia							Non-brain damaged				
Code	Age (years)	Gender	Handed-ness	Education (years)	Years post onset	Lesion	Code	Age (years)	Gender	Handed-ness	Education (years)
A1	58	M	R	18	4	LCVA	N1	53	F	L	20
A2	59	M	R	16	14	LCVA	N2	50	M	R	18
A3	64	M	R	16	5	LCVA	N3	55	M	R	16
A4	55	F	R	14	9	LCVA	N4	69	F	R	18
A5	68	M	R	16	10	LCVA	N5	52	F	R	14
A6	59	F	R	15	8	LCVA	N6	74	M	R	16
A7	63	M	R	18	9	LCVA	N7	53	M	R	17
A8	66	M	L	20	5	[a]LCVA	N8	64	M	R	16
A9	55	F	R	12	6	[b]LCVA	N9	64	M	L	18
Mean (*SD*)	60.7 (4.7)			16.1 (2.4)	7.7 (3.1)		Mean (*SD*)	59.3 (8.6)			17 (1.7)

LCVA = left hemisphere cerebrovascular accident;
[a]A8 had two seizures in the years following his initial stroke;
[b]As mentioned in the text, A9 had a haemorrhagic stroke of the basal ganglia.

Table II. Language scores of each participant. See text for details of tests.

	Western aphasia battery					Narratives				VIT	SC	Rhym	Discr		NNB verb noun	
Code	AQ	Flu	Comp	Rep	Nam	WPM	MLU	Gram	Morph	$n = 20$	$n = 45$	$n = 48$	$n = 20$	DS F	$n = 31$	$n = 63$
A1	81.4	5	9.4	9	8.3	56	2.8	0.5	0.7	4	28	25	18	6	25	58
A2	70.8	4	8.4	7.4	6.6	49	4.1	0.4	0.3	11	24	19	16	3	22	27
A3	81.8	5	7.8	8.6	7.5	32	6	0.5	0.5	8	26	32	17	4	20	47
A4	58.1	5	8.1	6.2	3.7	43	3.5	0.1	0.2	4	22	35	15	1	19	20
A5	75.6	4	9.7	6.3	7.8	65	2.9	0.2	0.3	4	14	15	19	3	22	54
A6	66	5	9.1	3	6.9	95	5.1	0.4	0.4	3	22	18	12	2	14	22
A7	77.1	4	9.2	7.1	8.2	56	5.9	0.33	0.8	6	26	20	19	4	12	44
A8	68.2	4	8	5	8.1	26	2.8	0.18	0.6	5	22	30	15	2	15	42
A9	78.6	5	8.3	7	9	80	9	0.65	0.6	5	29	32	20	5	27	59

AQ = Aphasia Quotient (max = 100); Comp = auditory comprehension; Discr = auditory discrimination; DS F = digit span forward; Flu = Fluency; Gram = proportion grammatical sentences; MLU = mean length of utterance; Morph = proportion of verbs with correct morphology; Nam = naming; NNB = Northwestern naming battery; Rep = repetition; Rhym = rhyme judgment; SC = sentence completion; WPM = words per minute; VIT = verb inflection test producing verbal inflectional morphology, with no significant accuracy difference between regular and irregular morphology ($t(8) = .2$, $p > 0.05$).

Other administered tests included the Northwestern naming battery for confrontation naming of verbs and nouns (Thompson & Weintraub, unpublished), an auditory discrimination task to test ability to discriminate auditorily between verb endings (e.g. *kicked* vs. *kicks*; Faroqi-Shah, 2004), rhyme judgement sub-test to document phonological skills (Kay, Lesser, & Coltheart, 1992), and digit span forward to document short-term verbal memory span (Weschler memory scale, Stone & Weschler, 1948).

Stimuli

The stimuli consisted of 40 words, with 10 words in each of the following categories: (1) verb stems (e.g. *fix*), (2) irregular past verbs (e.g. *froze*), (3) regular past verbs (e.g. *wrapped*) and (4) progressive aspectual verbs (also gerunds) with *ing* affixes (e.g. *dozing*)[3] (see Appendix). Verb stems and irregular past were exemplars of morphologically simple verbs, while regular past and progressive verbs were considered morphologically complex verbs due to the presence of a decomposable affix. In order to minimise noun–verb homophone ambiguity, all selected verbs had a higher verb than noun usage frequency using CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). Words were matched for logarithm of lexeme frequencies across word categories using the CELEX database, $F(3,36) = 0.04$, $p > 0.05$. Half the words in each word category were of high frequency (lexeme frequency > 70/million) and the other half had low lexeme frequencies (lexeme frequency < 10/million). Matching phonological complexity across the four categories was challenging because the addition of *ing* introduced an additional syllable, and there are very few bi(multisyllabic) irregular past verbs that fall within the frequency range of other verbs. Hence verbs across the four categories were matched for the mean number of phonemes, $F(3,36) = 1.3$, $p > 0.05$, but could not be matched for number of syllables.

The words were digitally recorded by native female speaker of North American English. The recordings were checked for loudness, naturalness of intonation and pronunciation, and comprehensibility by two native speakers of North American English.

Procedure

Participants were tested individually in a quiet room. Informed consent and the experimental procedure were approved by the Institutional Review Board of Northwestern University, where this study was conducted. The experiment consisted of five runs. Each run consisted of all the 40 words listed in a different random order.[4] Thus, there were a total of 200 experimental trials (40 words × 5 runs). No two successive trials had words from the same category. Each trial started with the two successive presentations of the target word, with a 300-millisecond pause between the two presentations. This was followed by an unrelated oral production task that consisted of repetition of automatic sequences that remained on the screen for 6 seconds (letters or digits that varied in length from one (e.g. *1*, *A*) to four (e.g. *1234*, *ABCD*). The purpose of the unrelated oral production task was to prevent verbal rehearsal of the target word. The number of letters or digits and the total number of letter/digit trials in this unrelated filler task were balanced across word types. This was followed by an electronically generated beep that lasted for 200 milliseconds. A 4-second time window was allowed for the response. Each ended with a fixation cross that remained on the screen for 1 second. A sample trial sequence is illustrated in Figure 1(a). Thus, the experiment proceeded at an automatically timed pace using Microsoft Powerpoint 2000.

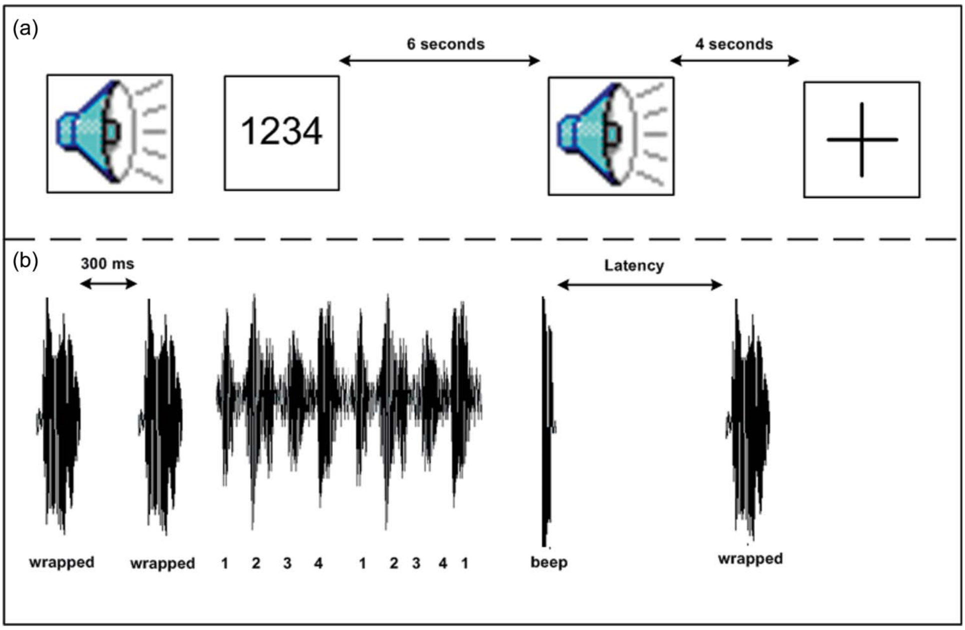

Figure 1. (a) The set up of the experiment is shown in the upper panel. (b) The sound waves are displayed using Pratt in the lower panel. Production latency was measured from onset of beep to onset of correct response. The time window is not to scale.

Participants were instructed to listen to the experimental word (presented twice), repeatedly utter the letters or digits appearing on the computer monitor until they heard a beep, upon which they produced the experimental word as quickly and accurately as possible. Clear articulation of the word was emphasised in order to decrease ambiguity associated with accuracy scoring and error analysis. Participants were given a minimum of four practice trials. Testing was completed in a single session for the unimpaired participants, with short breaks after each run. Aphasic participants were given a break after each run, and also whenever they indicated a need to pause in order to minimise fatigue effects. For aphasic participants, in general, there were other language tests interspersed between runs, and the runs were completed across two sessions. The testing sessions were audio-recorded using a digital recorder placed directly in front of the participant.

Data analysis

Audio-recorded responses were played and analysed for accuracy and production latency using Pratt version 4.4.9 software (Boersma & Weenik, 2005). Minor dysarthrias were accepted as correct responses as long as the response was unambiguous. Production latency was measured only for accurate responses using the soundwave displayed in Pratt. Latency was defined as the time (in milliseconds) that elapsed between onset of the beep and onset of the correct oral response (see Figure 1b). Responses in which the participant produced intervening utterances between the beep and target word, such as false starts (e.g. *wri uh wrote*), self-corrections (e.g. *write no wrote*) and dysfluencies (e.g. *wro wro wrote*), were excluded from latency analysis. This is because the time elapsing between beep and target word in such instances does not accurately reflect morphophonological encoding of the target word. Responses longer than 3000 milliseconds and outliers (latencies exceeding two standard deviations of each participant's grand mean) were deleted. These criteria resulted in exclusion of 5.7% of the responses for unimpaired participants and 10.1% of the responses for aphasic participants. Accuracy scoring and latency measurement was completed by two trained research assistants. Inter-rater reliability was obtained for two randomly selected audio samples. Inter-rater reliability for accuracy measures was very high (Cohen's Kappa statistic, 1960, $\kappa = .952$). Cronbach's alpha was used to determine inter-rater reliability for latency measures and this was also high ($\alpha = .979$). One aphasic participant's responses (A6) were excluded from all analyses due to very low accuracy (< 10%) which resulted in no analysable responses in certain word categories and less than three responses in other word categories.

Participants' errors were classified into five different categories: stem substitutions, inflection substitutions, inflection additions, repetition of an earlier response, and others. *Stem substitutions* are defined as production of the verb stem for an inflected target, such as *doze* for *dozing*. *Inflection substitutions* are defined as production of an incorrect inflectional affix, such as *dozed* for *dozing*. *Inflection additions* involve production of inflected verbs for a verb stem, such as *helping* for *help*. When participants repeated a stimulus word from an earlier trial, the error was called *repetition of an earlier response*. Errors classified as *other* included no responses, semantic substitutions and misperception errors, such as hearing *flaking* for the target *liking*.

Results

Accuracy

Unimpaired participants' accuracy was at ceiling for all word types ($M = 92.8\%$, $SD = 9.5$) while aphasic participants were significantly less accurate ($M = 47.8\%$, $SD = 17.3$; $t(47) = 13$, $p < 0.000$ unequal variances assumed). Both groups differed significantly in their variances (Levene's test of homogeneity of variance, $p < 0.01$) and hence separate statistical analyses were computed for each group. The primary research question of the influence of morphological complexity on oral production was addressed by comparing the accuracy of unaffixed and affixed verbs. The difference was not statistically significant for either participant group (unimpaired group: unaffixed $M = 94.4\%$, $SD = 4.3$; affixed $M = 91.3\%$, $SD = 12.8$, $t(17) > .05$; aphasic group: unaffixed $M = 43.2\%$, $SD = 16.5$; affixed $M = 51.6\%$, $SD = 16.4$, $t(15) = .09$). Unexpectedly, the aphasic group showed a near significant trend of higher accuracy for affixed verbs. Because affixed and unaffixed categories each comprised two different word types, a one-way ANOVA was computed for word type (four levels: verb stem, irregular past, regular past, and progressive) to examine if any one word category was influencing the results. Accuracy differences between word types were not significant for the unimpaired group, $F(3, 32) = 1.4$, $p > 0.05$ or the aphasic group, $F(3, 28) = 1.6$, $p > 0.05$. The aphasic group showed a trend of higher accuracies for progressive verbs compared to verb stems (post-hoc Tamahane's test comparing verb stems with progressives: Mean difference = 17.9%, *SE* 6.5, $p = 0.08$). Individual participant scores revealed that seven out of eight participants showed this pattern. Two-factor ANOVAs with frequency (two levels: low, high) and word type (four levels) revealed no main effects of frequency (unimpaired group: $F(1, 64) = .2$, $p > 0.05$; aphasic group: $F(1, 55) = 1.9$, $p > 0.05$), word type (unimpaired group: $F(3, 64) = 1.8$, $p > 0.05$; aphasic group: $F(3, 55) = .9$, $p > 0.05$), and no frequency*word type interaction (unimpaired group: $F(3, 64) = .9$, $p > 0.05$; aphasic group: $F(3, 55) = 1.5$, $p > 0.05$). The group accuracies for each word type by frequency are plotted in Figure 2.

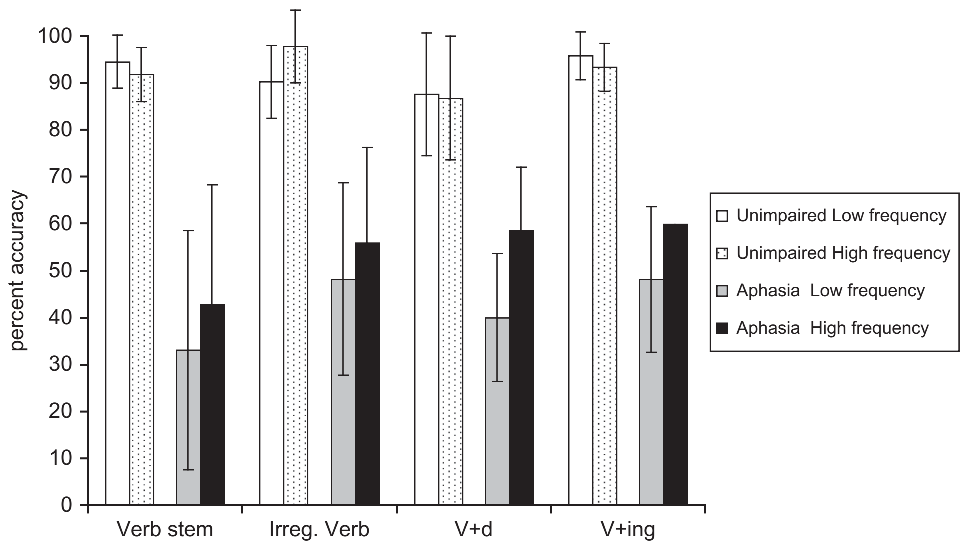

Figure 2. Mean percent accuracies (and standard error) are displayed for each word type sorted by frequency.

Production latency

The statistical analyses parallelled those for accuracy described earlier. The mean production latency of unimpaired individuals was 597.7 milliseconds (SD = 157.8), which was 747.6 milliseconds shorter than that of aphasic individuals (M = 1345.3 ms, SD = 479). This difference was statistically significant, (47) = 26, p<0.000 (unequal variances assumed). The comparison of unaffixed and affixed latencies was not significant for the unimpaired (unaffixed M = 594.3ms SD = 148; affixed M = 601.1ms SD = 150, $t(17)$ >0.05) and aphasic (unaffixed M = 1413ms SD = 612.6; affixed M = 1277ms SD = 460.5, $t(15) > 0.05$) groups. Two-factor ANOVA (frequency × word type) for the unimpaired group revealed a main effect of frequency $F(1,8) = 3.1$, $p < 0.05$,but no effect of word type ($F(3,64) = 0.03$, $p > 0.05$) and no interaction between frequency and word type ($F(3,64) = 0.09$, $p > 0.05$). On average, high frequency words were produced 62.5 ms faster than low frequency words. Aphasic participants also demonstrated a main effect of frequency $F(1,54) = 3.1$, $p < 0.05$. The mean difference between high and low frequency words was 204 ms. The effect of word type was not significant, $F(3,54) = 0.05$, $p > 0.05$. The interaction between frequency and word type was not significant $F(3,54) = 0.2$, $p > 0.05$. The mean group latencies for each word type and frequency are illustrated in Figure 3.

Error analysis

Aphasic and unimpaired participants produced 940 and 120 errors respectively. The proportion of errors that were classified into each category is given in Table III. As can be seen from Table III, for both groups, most errors were classified as repetitions of earlier stimuli and others. Overall, the normal control group produced inflection substitutions and inflection additions in approximately equal proportions (13% and 12% respectively), while the proportion of stem substitutions was the least (7.1%). Aphasic participants showed individual variation in the actual proportion of each error type. On average, the aphasic group produced

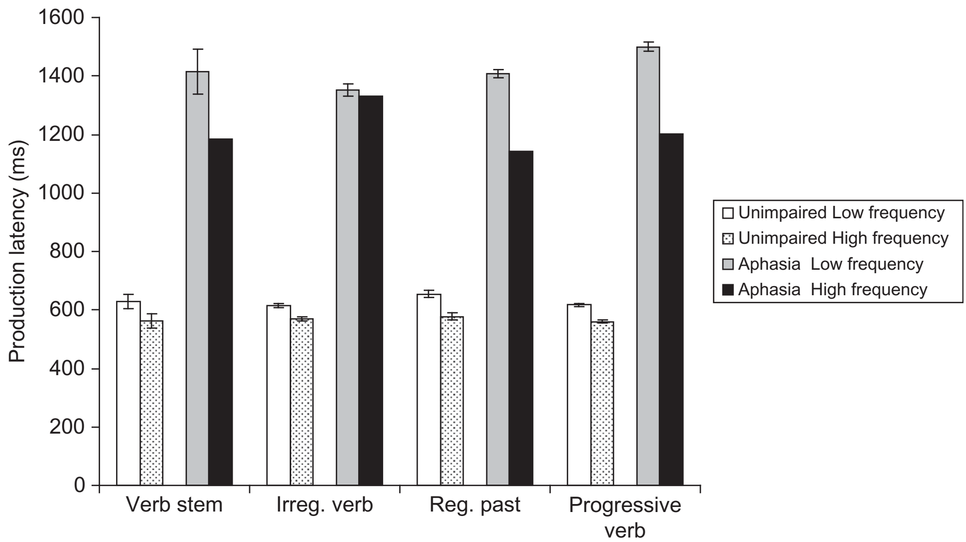

Figure 3. Mean production latencies in milliseconds (and standard error) are displayed for each word type sorted by frequency.

Table III. Distribution of errors in each category for aphasic patients ($n = 940$ errors total) and the unimpaired group ($n = 120$ errors total).

Participant	Stem substitutions	Inflection substitutions	Inflection additions	Earlier stimulus	Others
A1			12/102	69/102	21/102
A2		1/78	5/78	42/78	30/78
A3	2/110	2/110	11/110	77/110	18/110
A4	2/78	2/78	7/78	46	21/78
A5		5/119	8/119	54/119	52/119
A6	39/111	25/111	30/111		17/111
A7	35/97			29/97	33/97
A8	15/134	17/134	3/134	52/134	45/134
A9	4/111	7/111	25/111	21/111	54/111
Mean% (*SD*)	13.8 (15.2)	7.1 (8.1)	15.7 (13.6)	44.8 (19.7)	30.8 (11.5)
Unimpaired					
Number errors	9/120	15/120	15/120	64/120	17/120
Mean % (*SD*)	9.3 (2.1)	12.5 (5.4)	12.5 (10.2)	53.3 (20.1)	14.2 (3.1)

stem substitutions and inflection additions in roughly equal proportions, followed by inflection substitutions (13.8%, 15.7% and 7.1% respectively).

Discussion

This study investigated whether morphological complexity influenced verb production in individuals with agrammatic aphasia. The aim was to delineate if a post-lexical account of morphological impairment in aphasia could account for difficulty with verb inflections in aphasia. Accuracy and speed of production were examined using delayed repetition in which the stimuli were controlled for the number of phonemes and lexical frequency. The premise was that word categories that involve more complex encoding operations, either due to inherent properties (such as affixation) or due to aphasic impairment, would present with lower accuracies and slower production latencies than words categories that are less complex. Not surprisingly, aphasic participants were less accurate and slower in production latencies compared to the unimpaired group. Lower overall performance in language tasks is a replicated finding in aphasia and is considered to be the consequence of left hemisphere damage. There was no effect of morphological complexity or word type on accuracy or production latency for either group. However, there was a robust frequency effect for both participant groups for production latency.

Before discussing the implications of the findings, a legitimate question is whether the task and dependent variables used in the present study were sensitive to the mental operations involved in word encoding. The longer production latencies for lower frequency words for both participant groups is not only consistent with decades of prior research, but is also widely interpreted to be a consequence of lexical accessibility (Balota & Chumbley, 1985; Gagnon, et al., 1997; Jescheniak & Levelt, 1994; Oldfield & Wingfield, 1965; Penke, Janssen, & Krause, 1999; Silver & Halpern, 1992). Hence the frequency effect observed in the present study can be taken to suggest that the experimental task was sensitive to word encoding processes such as morphological complexity. Therefore the lack of an effect of morphological complexity on accuracy and production latencies can be interpreted as indicating that the process of affixation did not significantly hinder word production for this group of individuals with agrammatic aphasia.

The primary finding of this study is that affixed verbs (V+d, V+ing) did not differ from morphologically simple verbs (verb stems and irregular inflections) in accuracy or latency of production (see Figures 2 and 3). This finding is consistent with a few prior studies of accuracy on word repetition (Bird et al., 2003; Braber et al., 2005; Lambon Ralph et al., 2005), all of which controlled for phonological structure and frequency of occurrence between different word categories. Our findings contradict other studies that found lower accuracy for affixed words, which can be explained by differences in phonological structure and lexical frequency between word categories that were not controlled (Ullman et al., 1997), differences in the severity of phonological deficits among aphasic participants (Kohn and Melvold, 2000), or the use of a reading task, in which affixes are more transparent and hence likely to be decomposed during oral production (Mathews et al., 2001).

In several studies, Obler and colleagues have also demonstrated the effect of phonological variables (syllable length and consonant clusters) on the production of morphologically complex words, suggesting that at least part of the difficulty with morphologically complex words can be attributed to phonological processes (Centeno, Obler, Cairns, Garro, & Merrifield, 1996; Mathews et al., 2001; Obler, Harris, Meth, Centeno, & Mathews, 1999). As mentioned earlier, Miceli et al. (2002) failed to find participants with purely morphological errors and no phonological errors. Lambon Ralph et al. (2005) also demonstrated that nonfluent aphasic patients with phonological deficits are more impaired in the production of affixed (regular past) compared to unaffixed (irregular past) verbs. In other words, the overall pattern is one in which, if phonological variables are controlled and aphasic participants do not have significant phonological impairments, there is little effect of morphological complexity on word production. These findings fail to support the impaired affixation account of morphological errors in agrammatic aphasia, and highlight the importance of controlling for phonological variables.

While most prior studies of morphological complexity compared only regular and irregular past morphology, the present study extends the findings to verb stems and progressive verb forms. An interesting but unsurprising observation was the trend of higher accuracy for V+ing verbs compared to other verb categories for individuals with aphasia. In English, V+ing forms have the highest family frequency of all verb forms (Franci & Kucera, 1982). Hence the higher accuracy could be attributed to usage frequency (see Centeno et al., 1996 for the same argument for Spanish verb forms). Other explanations proposed for ease and even overuse of V+ing forms are the absence of allomorphs (unlike V+d) and the lack of tense marking (Menn & Obler, 1990). Another interesting finding was that verb stems were not produced with any greater accuracy or speed compared to other verb forms (see also Faroqi-Shah & Thompson, 2004). This pattern is inconsistent with the impaired affixation account of morphological deficits, or the impression that (agrammatic) aphasia is characterised by morphological omissions. The lack of a production advantage for verb stems can be explained by factors that were identified earlier: family frequency of verb stems in English is lower than that of other forms (Francis & Kucera, 1982), stimuli were comparable across categories in number of phonemes, and our participants did not have severe phonological or apraxic impairments.

The distribution of errors also fails to support a failure of affixation because inflection additions and substitutions occurred as frequently as stem substitutions (Table III). A failure of affixation would have predicted a higher incidence of stem substitutions. In an earlier study that elicited morphologically complex verbs in a constrained picture description task, we found that error patterns could be predicted by word form (lexeme) frequency (Faroqi-Shah & Thompson, 2004). Moreover, individual patients had a "favorite" verb form that they overused. In some cases, this favorite form was phonologically and morphologically more complex than the target verb form. The most frequently occurring error pattern of this study was perseveration of an earlier stimulus. This could be due to the specific nature of the experimental task because it was observed for both unimpaired and aphasic participants. Delayed repetition with a verbal filler task is cognitively demanding both from a short term memory and task switching perspective and hence it is not surprising that unimpaired participants performance was not perfect. In about one third of the instances ($n = 145$ for aphasia and $n = 25$ for unimpaired participants) the error was a combination of the preceding stimulus' verb stem and the target verb morphology even when the preceding stimulus or target was an irregular past. For instance, an error for the target <u>began</u> was <u>changed</u> when the preceding stimulus was <u>changing</u>. This could be taken to suggest that target verbs were decomposed into component morphemes at some level of processing.

Given that all aphasic participants in this study were significantly impaired in the usage and selection of verb forms in elicited sentence production and in sentence completion (Table II), the question about why verb morphology errors occur in agrammatism still needs to be addressed. As mentioned earlier, several authors propose morphosyntactic or morphosemantic planning impairments (Bastiaanse, 2008; Burchert et al., 2005; Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Kegl, 1995; Wenzlaff & Clahsen, 2004). These accounts focus on aphasic individuals' inability to determine the contextual appropriateness of specific verb forms. The findings of the present study suggest these morphosyntactic and morphosemantic processes are more likely to be the source of morphological errors than failed affixation. It is also likely that during continuous speech, the difficulty in encoding verb morphology is compounded by the need to rapidly encode morphosemantic, morphosyntactic, as well as morphophonological aspects. In other words, although morphophonological impairment, by itself, may be insufficient to result in the magnitude of difficulty agrammatic individuals experience with verb morphology, morphophonological encoding could intensify the overall demands on an already weakened language production mechanism in agrammatic aphasia. In concluding, it should be noted that the findings of the present study pertain to individuals with agrammatic aphasia with no severe phonological or apraxic impairments, and the generalisability of results is limited to individuals with a similar language profile. Future research with more heterogeneous participants will help elucidate if these conclusions can be applied to all aphasic individuals who produce morphological errors and in speakers of languages other than English. A meta-analysis of morphological production studies in aphasia which included data from multiple languages (but mostly from English) revealed that majority of aphasic participants do not differ in the production of regular and irregular verbs (Faroqi-Shah, 2007).

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Notes

1. Normal vision is 20/20. 20/40 indicates that the person can read letters twice as large as those on the 20/20 line.
2. All participants were pre-tested for comprehension of temporal adverbs by asking them to point to *yesterday, today, tomorrow, next month* etc. on a calendar.
3. Simple present verbs (Verb+s) were not used because of noun-verb ambiguity (e.g. cooks) and paucity of sufficient high frequency exemplars.
4. There were also 10 nouns matched in CV structure to a random set of stimuli (e.g. raft - wrapped). These served as fillers and were not matched for frequency of occurrence.

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Appendix

Stimuli used for the study. The logarithmic lexeme frequencies are from CELEX database (Baayen, Peipenbrok, and VanRijn, 1993)

	Log *F*	Number of phonemes		Log *F*	Number of phonemes
Verb stems			Irregular		
High Frequency			High Frequency		
believe	1.86	5	found	1.98	5
help	1.78	4	gave	1.86	3
talk	1.74	3	told	1.99	4
want	2.21	4	felt	1.91	4
try	1.83	4	began	1.95	5
Low Frequency			Low Frequency		
crush	0.00	4	froze	0.00	4
mix	0.60	4	crept	0.30	5
stir	0.60	4	dug	0.48	3
weigh	0.30	3	swam	0.30	4
fix	0.60	4	forgave	0.00	6

(*Continued*)

Appendix. (Continued)

	Log *F*	Number of phonemes		Log *F*	Number of phonemes
Verb +ed			V+ing		
High Frequency			High Frequency		
called	1.92	4	changing	1.75	6
asked	1.97	4	carrying	1.83	6
seemed	1.92	4	moving	2.00	5
used	1.87	4	learning	1.81	6
turned	1.81	5	walking	1.84	5
Low Frequency			Low Frequency		
spilled	0.00	5	liking	0.60	6
baked	0.30	4	knitting	0.48	5
crawled	0.30	5	dozing	0.30	5
fixed	0.48	5	locking	0.70	5
wrapped	0.00	4	tying	0.70	5