Selective treatment of regular versus irregular verbs in agrammatic aphasia: Efficacy data

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Selective treatment of regular versus irregular verbs in agrammatic aphasia: Efficacy data

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Background: Production of verb morphology, especially tense marking, is frequently impaired in persons with agrammatic aphasia. Very little research has examined theoretically driven treatments for verb morphology deficits in aphasia.

Aims: This study examined the relative efficacy of using regular (wash-washed, rob-robbed) versus irregular (drink-drank, keep-kept) verbs as stimuli to treat morphological impairments in individuals with aphasia. This comparison was motivated by differences in the lexical organisation of regular and irregular verbs proposed in psycholinguistic theory.

Methods & Procedures: A single-participant multiple-baseline design was used to examine treatment outcomes in six individuals with agrammatic aphasia. Participants received training to produce tense morphology using only either regular or irregular verbs, and the crucial outcome measure was generalisation to untrained past tense forms (regular to irregular and vice versa).

Outcomes & Results: All participants improved in the trained tenses and generalised to the production of regular tense morphology on untrained verbs. Generalisation to untrained irregular past tense was relatively modest, irrespective of whether regular or irregular verbs were trained.

Conclusions: The results replicate previous findings that verb morphology deficits respond to intervention, and extend the findings by suggesting that choice of stimuli may have consequences for generalisation effects. The implication for aphasia rehabilitation is that tense training using irregularly inflected verbs generalises to a greater variety of untrained verb inflections (including regular past) than does the use of regular verbs.

Keywords: Aphasia; Brain damage; Inflection; Morphology; Language production; Treatment efficacy; Verb.
Agrammatic Broca’s aphasia is characterised by syntactic and morphological difficulties that frequently encompass verbs. For example, verb morphology is severely impaired while noun morphology is relatively spared (Goodglass, Christiansen, & Gallagher, 1993; Tsapkini, Jarema, & Kehayia, 2002). A cross-linguistic pattern that has generated considerable interest among aphasiologists is that verb morphology is selectively more impaired when expressing semantic notions such as tense rather than when marking syntactic constraints such as subject–verb agreement. For instance, completing sentences that demand temporal referencing, such as Tomorrow, the boys will swim, is significantly more difficult than completing sentences in which local syntactic constraints cue verb form, as in The boy(s) swim(s) or The boys will swim (Arabatzi & Edwards, 2002; Benedet, Christiansen, & Goodglass, 1998; Faroqi-Shah & Dickey, 2009; Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Kok, van Doorn, & Kolk, 2007; Varlakosta et al., 2006; Wenzlaff & Clahsen, 2004). This paper presents efficacy data for a treatment approach for verb morphology deficits that focused on temporal reference. The treatment paradigm is a replication and extension of an earlier study (Faroqi-Shah, 2008). This study extends previous work by examining whether the type of stimuli used for treatment (verb with regular versus irregular past morphology) can impact treatment outcomes. A background on relevant theoretical frameworks and empirical evidence is presented in the next section. This is followed by research questions and an overview of prior treatment research of verb morphology in aphasia.

THEORETICAL AND EMPIRICAL BACKGROUND

This selective impairment of tense morphology has been attributed either to a representational deficit for tense or to a processing limitation. Proponents of the representational deficit use the syntactic tree framework of generative grammarians to claim that the tense node in the mental syntactic tree is erased (Friedmann & Grodzinsky, 1997). The processing argument attributes the greater difficulty with tense morphology to the need to integrate information between two levels of computation: conceptual intent and syntactic formulation (Avrutin, 2000, Goodglass et al., 1993). Several recent proposals have focused on the semantic functions of verb inflections because at least two syntactic functions are relatively less affected: agrammatic individuals perform better on verb forms that can be selected solely by syntactic rules (Faroqi-Shah & Thompson, 2007; Goodglass et al., 1993), and judgement of syntactic violations is relatively spared (Linebarger et al., 1983). That is, the process of translating temporal information into verb morphology has been identified by multiple authors as a potential source of difficulty in agrammatic production (Bastiaanse, 2008; Diacritical encoding and retrieval hypothesis of Faroqi-Shah & Thompson, 2007; Tense Underspecification Hypothesis of Wenzlaff & Clahsen, 2004; Tense and Agreement Underspecification Hypothesis of Burchert, Swoboda-Moll, & De Bleser, 2005; see also Penke, 2003, for a similar explanation based on accessing inflectional morphology).

Although there is a rather productive mapping between semantic notions (such as tense/mood) and morphological structure, it is somewhat inconsistent in several Germanic languages due to the existence of irregular verbs such as go-went, sleep-slept, and drink-drank. Patterns of performance on regular and irregular verbs have been variable in aphasia: some studies reported worse performance on irregulars (Balaguer, Costa, Sebastian-Galles, Juncadella, & Caramazza, 2004; Inglis, 2005; Kok et al.,
2007; Miozzo, 2003; O’Connor, Obler, & Goral, 2007; Penke & Janssen, 1999), others reported worse performance on regulars (Ullman et al., 1997), or no differences between regular and irregular past (Bird, Lambon Ralph, Seidenberg, McClelland, & Patterson, 2003; Drucks, 2006; Faroqi-Shah & Thompson, 2007; Wenzlaff & Clahsen, 2004). A meta-analysis of studies that compared regular and irregular verb performance revealed that more than half of the published 110 datasets showed no differences (Faroqi-Shah, 2007). The meta-analysis also revealed that data sets that found worse performance on regulars were from English speakers and the stimuli were confounded by phonological complexity of regulars compared to irregulars. The general trend is for irregular verb morphology to be more difficult than regular morphology for agrammatic individuals in languages where irregulars have a subregular affix (Penke & Janssen, 1999 in German; Balaguer et al., 2004, and O’Connor et al., 2007 in Spanish; Kok et al., 2007 for Dutch). Subregular refers to semi-productive patterns within the class of irregulars, such as *ring-rang, sing-sang, drink-drank* in English, and *-e(n)* suffix for feminine nouns in German irregular plurals. The crucial point is that the putative performance differences between regulars and irregulars are over and above the difficulty with tense morphology. That is, the tense information conveyed by both regular and irregular verb forms (past tense in English) is essentially the same, but what differs is whether there is an additional influence of morphological complexity.

There is considerable debate about the extent to which regular and irregular words differ in lexical representation, and providing a comprehensive review is beyond the scope of this paper (Bybee, 1995; Clahsen, 1999; Halle & Marantz, 1993; McClelland & Patterson, 2002; Pinker & Prince, 1991; Rumelhart & McClelland, 1986; Ullman & Pinker, 2002). Although it is not the intention of this paper to validate any one theory of morphological processing, a review of experimental results from a variety of sources such as frequency effects, priming, and child language acquisition indicates that morphologically regular forms are generally generated by a default mechanism of applying affixation rules, such as $\text{Verb (+PAST) = Verbed}$, while irregular forms are generally retrieved from the mental lexicon1 (see also Okrent, 2004; Zimmermann, 2001). Experimental evidence from tasks such as inflectional priming and sentence matching indicates that lexical entries are morphologically underspecified for redundant features that can be represented by a parsimonious rule, such as $\text{Verb (+PAST) = Verbed}$ (Clahsen, Eisenbeiss, Hadler, & Sonnenstuhl, 2001; Janssen & Penke, 2002; Penke, Janssen, & Eisenbeiss, 2004). In contrast, the lexical entries of irregular verbs include additional specification for word structure. For instance, the lexical entry of *give* will specify the perfect form (*give(+PERFECT) = given*) and for the simple past form (*give(+PAST) = gave*). The Unique Entry Principle assumes that a general rule such as $\text{Verb(+PAST) = Verbed}$ is replaced by specific rules such as *give(+PAST) = gave* for irregular verbs (Pinker, 1984; Pinker & Prince, 1988). In order to explain why (or how) default rules are not universally applied to irregular verbs, thus preventing words such as *singed* or *sanged* in adult speakers, a blocking mechanism is proposed (Aronoff, 1976; Glass & Lau, 2003; Kiparsky, 1982; Pinker, 1999). The Blocking Principle allows the affixation rule to apply to irregular verbs, however, the existence of lexically stored irregular (past tense) forms blocks an over-regularised form from being produced.

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1 Exceptional situations where regular forms may be stored include very high frequency forms (Alegre & Gordon, 1999). Conversely, nonword past tense generation tasks suggest the existence of subregular schemas for irregular verbs that are partially based on phonological form (Bybee & Slobin, 1982; Stemberger, 2002).
Figure 1. Illustration contrasting the lexical entries and morphological encoding mechanisms of regular (rake) and irregular (drink) verbs. The rectangular boxes representing lexical entries illustrate the under-specification of regular verb entries and lexical representation of irregular verb forms (unique entry principle). The shaded arrows represent the default affixation rule, which is proposed to be activated for both regular and irregular verb production. The figure illustrates that production of an irregular verb entails default affixation (arrows 1 & 2 for drink), and selection of the lexical entry (arrow 3 for drank) blocks (arrow 4) the regularised form from entering phonological encoding (represented in ovals). The blocking mechanism is denoted by ⊗. Affixation rule activation during both regular and irregular verb retrieval can be used to predict generalisation effects for aphasia.

Figure 1 illustrates the more complex nature of irregular verb lexical entries and the application of the blocking mechanism on an over-regularised verb after successful retrieval of an irregular past.

The above principles can be used to make predictions about directionality effects upon treatment of verb inflections in agrammatic aphasia. It can be hypothesised that, when irregular verb production is practiced by an agrammatic individual, this not only strengthens the practised irregular verb, but is also likely to re-activate and strengthen the past tense affixation rule (the shaded arrows in Figure 1). Hence, the effects of treatment with irregular inflection, via strengthening of the affixation rule, could trickle down to the production of regular past tense forms. This predicts that treatment of irregular verb inflections could potentially improve both irregular and regular verb production. However, practice with regular verb inflections is unlikely to automatically benefit irregular verb production. Specifically, there is a theoretical possibility of asymmetrical generalisation effects, that is, treatment of tense marking using irregular verbs may result in generalised improvement of tense marking on regulars, but not vice versa.

Another aspect that has the potential of influencing treatment effects is the presence of subregular structural patterns within the class of irregulars (Bybee & Slobin, 1982). One notable subregular group in English is irregulars that undergo a vowel change (drank, sank, rang). Another subregular group is one that includes both vowel change and addition of an alveolar consonant (henceforth referred to as suffixed irregulars: kept, slept, felt, and sold, told, lost). According to theories such as Distributed Morphology (Halle & Marantz, 1993), suffixed irregulars pattern both with vowel-change-only irregulars as well as regulars (due to alveolar consonant addition). In support of this view, a priming study with unimpaired participants found that suffixed irregulars patterned with regulars rather than with vowel-change irregulars.
(Kierlar, Joanisse, & Hare, 2008). By this logic, treatment using suffixed irregulars would be more likely to generalise to production of regulars than treatment that used vowel-change irregular stimuli.

This treatment study addresses the above predictions by comparing the relative efficacy of using regular versus irregular verb stimuli in achieving within- and between-verb type generalisation. Of course, with English-speaking aphasic participants as is the case in this study, the question is only valid for past tense (simple and perfective) since present and future tense morphology is highly regular. The first question addressed in the present study pertained to within-verb type generalisation; that is, if tense training for any one verb type (e.g., regulars) would generalise to untrained exemplars of the same verb type (regulars). Based on principles of affixation rules versus storage for regular versus irregular morphology, it was predicted that training regular inflections would generalise to other verbs using regular inflections (past, present, and future). However, the uniqueness of lexical entries of irregular verbs would preclude generalisation of irregular past tense training to untrained irregular past verbs. The second question was whether tense training would result in between-verb type generalisation (regular to irregular morphology and vice versa). The blocking and unique entry principles were used to predict that training of irregular past tense would inadvertently improve regular past tense production. However, between verb type generalisation would be less likely with regular verb training due to the absence of mapping between the underspecified entries of regular verbs and those of irregular verbs. In other words, it was hypothesised that tense training with regular verbs would promote within verb type generalisation, while tense training with irregular verbs would result in between verb type generalisation.

These two questions were addressed by training participants with either regular verbs (three participants) or with irregular verbs (three participants), while generalisation to untrained regular and irregular verbs was tested. Given the subregularities among irregulars, participants who received training with irregulars were exposed to a homogeneous set of irregulars, either vowel-change only or suffixed irregulars only. Given the proposal that suffixed irregulars actually encompass features of both vowel-change irregulars and rule based regular affixation (addition of t/d) (Halle & Marantz, 1993), we decided to train vowel-change irregulars to ensure no “contamination” by affixation rules. Hence, two out of three participants received irregular verb training with vowel-change irregulars. We trained suffixed irregulars in one participant in order to verify if the generalisation patterns obtained with vowel change irregulars were replicable with suffixed irregulars.

PRIOR TREATMENTS OF INFLECTIONAL MORPHOLOGY

In spite of the pervasive occurrence of verb inflection impairments in nonfluent aphasia, and the widespread empirical and theoretical interest in this impairment, there has been a relative dearth of treatment studies for inflectional deficits. The earliest treatment study for verb inflections used Garrett’s (1988) framework of language production (Mitchum & Berndt, 1994). As per Garrett’s proposal that verb inflections are embedded in sentence frames, Mitchum and Berndt trained present, past, and future tenses such as The noun is verbing, The noun has verbed, and The noun will verb in one aphasic individual. It is noteworthy that the trained sentences were
morphosyntactically similar in including an auxiliary and verb, but were semantically varied in the type of aspectual markers, with progressive aspect for present tense, and perfective aspect for past tense, but no aspect trained for future tense. One half of the trained verbs had a regular perfective marker (has closed) while the other half were irregular (has eaten). After treatment the patient improved in the production of both untrained regular and irregular past perfect tense. Another tense treatment study used computerised icons and trained a combination of regular and irregular verbs in three nonfluent aphasic individuals (Weinrich, Shelton, Cox, & McCall, 1997; see also Boser, Weinrich, & McCall, 2000). The stimuli differed in two aspects from those of Mitchum and Berndt. First, simple past tense was trained, and second, irregular verbs with a variety of transformations were used. All participants improved in the production of untrained regular past tense, while improvements for untrained irregular past tense were limited. Weinrich and colleagues attributed the limited generalisability of irregulars to the use of heterogeneous irregulars in treatment. The present study differs from these two past studies by training only regular or irregular verbs in any one aphasic participant. Also, all training was strictly for simple tense forms and no aspectual marking was included.

In a prior study, the relative efficacy of training verb form production (morphophonological treatment) versus semantic aspects of verb forms (morphosemantic treatment) was compared in four individuals with agrammatic aphasia (Faroqi-Shah, 2008). Only the morphosemantic treatment resulted in increased accuracy of verb inflections, although both treatments improved the number and variety of inflected verbs produced. Hence agrammatic individuals benefited maximally from practice in mapping tense features (e.g., +PAST, +PRESENT, +FUTURE) onto semantically matched verb forms (folded, folds, will fold). Practice with verb form production in the absence of semantic context was less successful. Hence the present study used the morphosemantic procedure of tense training proposed by Faroqi-Shah (2008).

**METHOD**

**Participants**

Six individuals with aphasia were recruited for the current study (age range: 44–65 years). All participants gave written informed consent using procedures approved by the institutional review board of the University of Maryland, College Park, and hence this study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All participants had a single left hemisphere lesion in the region of the middle cerebral artery resulting from a cerebrovascular accident (CVA) and were at least 1 year post-onset of the CVA. One of the participants (P6) had a history of grand mal seizures, and none of the other participants had any complicating neurological conditions such as prior neurosurgery, degenerative or psychiatric conditions, or a history of substance abuse. They passed puretone audiometric screening at 500, 1000, 2000, and 4000 Hz at 40 dBHL ANSI: 1969 in both ears and passed a vision screen, defined as at least 20/40 corrected or uncorrected vision on a Snellen’s chart and the absence of spatial neglect and visual field deficits (as per self-report). All participants were native speakers of English, right-handed before the CVA, and had at least a high school diploma. Demographic and neurological details of all participants are given in Table 1.
TABLE 1
Demographic and neurological information of participants, sorted by treatment verb type

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age/gender</th>
<th>Years education</th>
<th>Occupation</th>
<th>Lesion</th>
<th>Months post-onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular verb treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>37/M</td>
<td>18</td>
<td>Police officer</td>
<td>Left MCA infarct involving the frontal and parietal regions</td>
<td>84</td>
</tr>
<tr>
<td>P2</td>
<td>44/M</td>
<td>19</td>
<td>Software engineer</td>
<td>Left MCA infarct, involving frontal, subcortical, and basal ganglia</td>
<td>16</td>
</tr>
<tr>
<td>P3</td>
<td>55/M</td>
<td>18</td>
<td>Admiral in Navy</td>
<td>Left MCA involving the temporo-parietal and extending into the occipital region</td>
<td>29</td>
</tr>
<tr>
<td>Irregular verb treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>56/M</td>
<td>17</td>
<td>Insurance adjuster</td>
<td>Left MCA infarct</td>
<td>19</td>
</tr>
<tr>
<td>P5</td>
<td>55/F</td>
<td>18</td>
<td>Homemaker</td>
<td>Left MCA territory infarct and occlusion of the left ICA</td>
<td>26</td>
</tr>
<tr>
<td>P6</td>
<td>39/M</td>
<td>14</td>
<td>Financial analyst</td>
<td>Left MCA territory infarct resulting in a paucity of distal branches. No major branch occlusion</td>
<td>25</td>
</tr>
</tbody>
</table>

MCA = middle cerebral artery; ICA = internal carotid artery.

Language testing

In order to establish their diagnosis of non-fluent aphasia with agrammatic speech and morphological impairments, all aphasic participants completed a variety of tests including: (1) Western Aphasia Battery (WAB, Kertesz, 1982), (2) narrative and oral expression sections of the Boston Diagnostic Aphasia Examination (BDAE, Goodglass, Kaplan, & Barresi, 2001), (3) six sequences from the Narrative Story Cards (Helm-Estabrooks & Nicholas, 2003), and (4) Verb Inflection Test (Faroqi-Shah, unpublished). The narratives obtained from the tests described above were transcribed and coded using the Systematic Analysis of Language Transcripts (SALT) (Miller, 2004) for lexical and syntactic measures as described in Faroqi-Shah (2008). Using SALT the narratives were analysed to determine rate of speech and mean length of utterance. The first 50 utterances were used to compute the proportion of sentences, proportion of grammatical sentences, noun–verb ratio, open–closed class ratio, proportion of suffixed verbs (the ratio of suffixed verbs to the total number of verbs that require affixation in contexts where affixation was possible), diversity of tense marking (type–token ratio of tense computed as the ratio of unique tense-aspect markings to the total number of verbs), and accuracy of tense marking. The first 50 utterances were used to compute these values so that comparisons across participants and pre- versus post-treatment measures could be made over a consistent number of utterances. These measures were used not only to determine the presence of agrammatic speech, but also as general outcome measures that could be compared across studies in the future. The Verb Inflection Test (Faroqi-Shah, unpublished) elicited 20 sentences in past, present, and future tenses using a picture description with adverbial cues (Tomorrow,
Right now, Yesterday, and Every day/Nowadays). In addition single word repetition of 20 regular and irregular past tense verbs was tested using stimuli matched for phonological structure (taken from Bird et al., 2003). Individual participant scores are given in Table 2.

Inclusionary criteria from these tests were: (1) a profile of non-fluent aphasia with relatively spared comprehension (all participants were classified as having Broca’s aphasia as per the WAB), (2) agrammatic sentence production gleaned from narratives and defined as the presence of fragmented utterances, decreased proportion of sentences, paucity of grammatical morphemes and verbs, (3) difficulty with verb morphology, defined as an accuracy below 60% on the Verb Inflection Test, (4) no significant differences in the production of regular and irregular past tense verbs, determined from tests of sentence production and single word repetition, (5) absence of significant apraxia or dysarthria as per the oral expression subtests of the BDAE and the checklist of apraxic symptoms listed in the Apraxia Battery for Adults-2nd edition (Dabul, 2000), and (6) functional reading abilities as per the single word reading subtests of the WAB. The inclusionary criterion of comparable performance for regular and irregular past verbs prior to the onset of treatment was necessary to examine between-verb type generalisation effects after treatment and also because of discussions in prior literature about whether regular and irregular verbs are dissociated in aphasia (Bird et al., 2003; Faroqi-Shah, 2007; Faroqi-Shah & Thompson, 2007).

Upon determination of eligibility, participants were assigned to receive treatment with either irregular or regular verbs. Although it was not possible to make exact pairwise matches, we used a pseudo-random assignment method so that participants receiving regular versus irregular treatment did not vary dramatically in three respects: severity of the aphasia quotient (AQ) calculated from the WAB, accuracy of verb tense production calculated from the Verb Inflection Test, and age at the time of the study. This is evident from the language scores in Table 2: participants who received treatment with regular past tense verbs (P1, P2, P3) did not differ in the above criteria from the participants who received treatment with irregular past tense verbs (P4, P5, P6) in terms of overall aphasia severity.

Stimuli

Black and white line drawings in three tenses were made by an artist for 40 regular and 40 irregular imageable verbs (an example of the verb steal is shown in Figure 2 and the verb list is given in Appendix A). A total of 20 regular verbs were used as treatment stimuli and the remaining 20 regular verbs were used to test generalisation. The irregular verbs included an equal number of verbs with vowel change and suffixed verbs. Verbs with two acceptable past tense forms (such as dove-dived) were avoided to the extent possible. As explained earlier, one research question pertained to between-verb type generalisation: whether training of irregulars would generalise to regulars, and so we wanted to train irregulars that had little overlap with regulars. Hence two participants (P4, P5) received training on vowel-change irregulars. The third participant (P6) received training on suffixed irregulars in order to replicate the generalisation patterns obtained with vowel change irregulars. Treatment and generalisation verbs were matched in logarithmic lemma frequency as per CELEX word frequency counts (Baayen, Piepenbrock, & van Rijn, 1993).

2 All participants were pre-tested for comprehension of temporal adverbs using a calendar pointing task, on which they had to identify yesterday, today, tomorrow, next month, etc.
### TABLE 2
Pre- and post-treatment scores on language outcome measures

<table>
<thead>
<tr>
<th></th>
<th>Regular verbs trained</th>
<th></th>
<th>Irregular verbs trained</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>P1</strong></td>
<td><strong>P2</strong></td>
<td><strong>P3</strong></td>
<td><strong>P4</strong></td>
</tr>
<tr>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td><strong>a</strong> WAB AQ (max. = 100)</td>
<td>77.4</td>
<td>92.1</td>
<td>45.6</td>
<td>75.8</td>
</tr>
<tr>
<td><strong>b</strong> Verb inflection Test (%)</td>
<td>55</td>
<td>25</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Word repetition (max=10)</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Regular past</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Irregular past</td>
<td>21.6</td>
<td>49.2</td>
<td>58.8</td>
<td>44.4</td>
</tr>
<tr>
<td>Mean length of utterance</td>
<td>3.74</td>
<td>3.12</td>
<td>1.92</td>
<td>3.61</td>
</tr>
<tr>
<td>Proportion sentences</td>
<td>0.48</td>
<td>0.46</td>
<td>0.22</td>
<td>0.61*</td>
</tr>
<tr>
<td>Open: Closed Class</td>
<td>1.14</td>
<td>1.3</td>
<td>4.33</td>
<td>1.95*</td>
</tr>
<tr>
<td>Proportion verbs</td>
<td>0.16</td>
<td>0.19</td>
<td>0.19</td>
<td>0.2</td>
</tr>
<tr>
<td>Proportion suffixed verbs</td>
<td>0.63</td>
<td>0.66</td>
<td>0.83</td>
<td>0.77</td>
</tr>
<tr>
<td>Variety of tense</td>
<td>0.82</td>
<td>0.77</td>
<td>0.08</td>
<td>0.18*</td>
</tr>
<tr>
<td>Accuracy of tense</td>
<td>0.22</td>
<td>0.2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*a* Western Aphasia Battery (Kertesz, 1982); **AQ**-Aphasia Quotient; **b**Farooqi-Shah (unpublished); **c**Normative values are given in Appendix B. **g**McNemar’s change test, $p < .05$; *change greater than 2 standard deviations of normative sample.
Design and procedures

This study primarily used a single-participant design, although descriptive between-group comparisons were made to assess generalisation patterns. Data collection consisted of three phases: baseline, treatment, and follow-up. During each baseline probe, a picture description task was used to elicit 30 sentences distributed across present, past, and future tenses with the treatment and generalisation verbs. Participants received between four and eight baseline probes (ranging from 120 to 240 sentences total) in order to demonstrate that treatment effects were unrelated to repetitive exposure to baseline probes. The number of baseline sessions was randomly assigned to each participant. Participants received individual morphosemantic treatment 4 days a week in 1–2-hour sessions. Criteria for cessation of treatment were treatment probe accuracies exceeding 80% over at least two sessions and a minimum of 12 sessions. Post-treatment testing was conducted immediately following the cessation of treatment and consisted of a re-administration of treatment and generalisation probes, WAB, and narrative measures. Follow-up testing was done twice, at 2 weeks (F1) and 2 months (F2) after the cessation of treatment, during which treatment and generalisation probes were administered. The typical duration of involvement in the study (excluding follow-up testing) was 6 weeks.

Experimental control was achieved using varying numbers of baseline measures across participants, thus documenting the absence of spontaneous improvement and demonstrating treatment-induced improvement regardless of the amount of exposure to baseline measures.

Treatment. Each treatment session began with administration of the treatment probes, in which the 20 sentences with training verbs were elicited in various tenses. Generalisation probes were administered every fourth session and consisted of regular and irregular past tense as well as present and future tenses of these verbs. The procedure for morphosemantic treatment focused on learning the semantic implications of various verb forms and has been described in detail elsewhere (Faroqi-Shah, 2008). The following steps were completed for each verb using three pictures, which depicted past, present, and future actions. (1) Confrontation naming:
In this step the participant was asked to name the action depicted in the three picture sequences (e.g., steal or stealing for Figure 2). (2) **Grammaticality judgement**: The experimenter read sentences that contained the action elicited in step (1) and the participant responded whether or not the sentences were grammatically correct (e.g., *Yesterday the woman rang the bell, Tomorrow the woman rang the bell*). The primary emphasis was on learning to match the temporal adverb with the verb inflection. (3) **Comprehension**: In this step the experimenter randomly staggered the three pictures and read a sentence. The participant was asked to match the sentence with its corresponding picture (e.g., *The man steals the wallet*). (4) In the **written sentence completion** task the participant was given a printed sentence with the inflected verb omitted (e.g., *Yesterday the lion _________*) and the participant was asked to write the appropriate verb inflection that matched a given picture. Assistance with spelling was provided. (5) **Sentence anagram**: In this step the participant was asked to select word anagrams (The man/stole/steals/will steal/the wallet) that matched a given picture and arrange these to form a sentence. Each step was followed by feedback regarding accuracy and an accompanying explanation. The above steps were repeated for each of the 20 treatment verbs. After the first few treatment sessions all participants were able to complete two iterations of 20 verbs during each session. Consistent with the procedure of Faroqi-Shah (2008), none of the steps listed above required extensive oral production of verb morphology. All three tenses were trained in the following sequence: past, present (third person singular, Verb+s), and future (will Verb). Only simple tenses were trained without introducing aspectual markers. Participants had to achieve an accuracy of 90% in the written sentence completion step (see (iv) above) to proceed to the next tense.

**Outcome measures and scoring**

The measure that determined cessation of treatment was tense accuracy of treatment sentences. Generalisation probes—that is, tense accuracy of both regular and irregular generalisation verbs (in all three tenses)—were the primary dependent variable that specifically addressed the research questions. A significant generalisation effect was operationally defined as a statistically significant difference between baseline and post-treatment probes (McNemar’s change test, \( p < .05 \)). Generalisation probes were administered every fourth session for two reasons: to limit improvement in accuracy as a result of repetitive daily exposure, and because of the time required to administer the very large number of generalisation items (\( N = 120 \)). The method of eliciting sentences for these treatment and generalisation probes was identical and involved describing one of three pictures in a sequence (see Figure 2). The nouns and verbs in the pictures were provided by the experimenter in order to avoid confounds created by lexical retrieval difficulties. Responses that minimally contained a noun and a verb were scored, and the target verb was scored as correct if the verb morphology matched the tense being elicited even if the entire sentence was not grammatically well formed. That is, “Woman peeled” was considered for scoring and scored as correct because the
target past tense morphology was produced even though the determiner for “woman” and the noun argument (the potatoes) were not produced.

Participants were given the choice of writing their responses if they experienced difficulty with oral production, and both oral and written responses were accepted. All participants preferred orally producing their responses. However, three participants were limited by intermittent oral production difficulties specifically for verb endings (P2, P5, and P6) and would orally perseverate on a single ending. All three participants would self-correct after oral production by writing out their intended verb morphology (this happened for a total of 5%, 20%, and 17% of all probes for P2, P5, and P6 respectively). No feedback regarding accuracy was provided. Additionally, narrative measures and the WAB were repeated at the end of treatment as general outcome measures that would enable future comparison with the outcomes of other treatment studies.

Reliability

Inter-rater reliability was obtained for 30% of all selected dependent measures, including scoring of treatment and generalisation probes, as well as transcription and coding of narrative samples. Additionally, reliability was obtained for 30% of treatment sessions for accuracy of administration of the treatment procedure, which is the independent variable. Reliability measures were obtained using audio recordings, video recordings and/or on-line scoring. Point to point inter-rater agreement for all measures exceeded 90% (Cohen’s Kappa statistic, 1960, $K > 0.95$).

Data analysis

Each participant’s percent accuracy scores were calculated for treatment and generalisation probes for each of the three phases of the study (i.e., baseline, treatment, and follow-up). Our primary research question pertained to generalisation to untrained verb morphology and hence the percent accuracy of past tense sentences among the generalisation probes was also separately calculated. McNemar’s change test was used to determine statistically significant change in level for each participant by comparing mean baseline accuracy with post-treatment accuracy (see Boo & Rose, 2011; Conroy, Sage, & Lambon Ralph, 2009; Edmonds & Babb, 2011; for a similar use of McNemar’s test). Two effect size measures were computed, effect size for change in level (SMD$_{pre-post}$) was computed by subtracting each participant’s mean baseline accuracy from the final treatment session accuracy. This difference was divided by that participant’s baseline standard deviation. To compute the effect size for slope, mean accuracy was computed over all treatment sessions (hence SMD$_{all}$). This effect size (SMD$_{all}$) was calculated by subtracting mean baseline accuracy from mean treatment accuracy and dividing this number by the baseline standard deviation (Olive & Smith, 2005). SMD$_{all}$ values are typically smaller than SMD$_{pre-post}$ because probe accuracies during the treatment phase are lower than post-treatment accuracy. One participant (P4) had zero percent accuracy for baseline probes and hence effect sizes could not be calculated.4

4 In cases of zero-standard deviation during baseline, Busk and Serlin (1992) proposed calculation of standard deviation by combining baseline and follow-up scores if both phases have similar performance. Since P4 improved significantly following treatment, Busk and Serlin’s condition for calculation of pooled standard deviation was not met.
RESULTS

The mean accuracy of baseline sessions was 3.4% (range: 0–35), and all participants showed relatively stable baselines with a small standard deviation. During baseline testing, regular and irregular past tense probes were of comparable accuracy for all participants with the exception of P1 who showed better performance in irregular past compared to regular past (14/20 versus 6/20); \( \chi^2(N = 40) = 4.9, p < .05 \). The numbers of baseline sessions, treatment sessions, and total hours of treatment are given for each participant in Table 3. The average number of treatment sessions was 15. The average final treatment accuracy for trained verbs was 93.4% (range: 87–100) showing a significant treatment effect, Paired t-test, \( t(5) = 9.9, = p < .001 \). In the following sections results of each treatment verb type will be presented separately. This is followed by scores on general outcome measures, namely narratives and WAB.

Regular verb treatment

The treatment trajectories of P1, P2, and P3 are presented in Figure 3. The duration of treatment and effect sizes are given in Table 3. All three participants showed significant gains in trained verbs (McNemar’s change test, \( p < .001 \) ) with an average final treatment accuracy of 95%. As for the first research question (within-verb type generalisation), Figure 3 shows that all three participants generalised treatment effects to untrained regular past tense, and the scores for untrained regular past in the final treatment session were near ceiling (Mean = 96.7%). Effect sizes did not differ from that of trained regular past tense (Fisher’s exact test, \( p > 1 \) for all three participants). The data for other trained tenses (which includes combined scores for simple present and future tenses) were also near ceiling (Mean = 96.6%), and effect sizes did not differ from that of trained regular past tense (Fisher’s exact test, \( p > 1 \) for all participants). The second research question regarding between-verb type generalisation was examined with accuracy of irregular past tense. The effects are mixed: P1 and P2 improved by 30% points in the production of irregular past tense (pre- to final-treatment accuracy for P1 is 70% to 100%; McNemar’s change test, \( p < .05 \); pre- to final-treatment accuracy for P2 is 0% to 30%; McNemar’s change test, \( p < .05 \) ). P3 remained unchanged for irregular verbs (pre- and final-treatment accuracy = 0%). To summarise, participants were able to apply trained morphology (regular past, simple present, future) to untrained verbs, but did not improve consistently in untrained morphology (irregular past).

All participants maintained the effects of treatment in follow-up testing (data points F1 and F2 in Figure 3), with a mean follow up accuracy score of 87.1% (range = 75–100). This accuracy was significantly greater than baseline accuracy (McNemar’s change test, \( p < .05 \)). While there was a slight decline from final treatment session accuracy, this difference was not statistically significant (McNemar’s change test, \( p > 1 \)).

Irregular verb treatment

Figure 4 and Table 3 show the treatment trajectories of P4, P5, P6, and other relevant data respectively. All three participants achieved 80% accuracy criterion for treatment probes with an average final treatment accuracy of 95% (McNemar’s change test, \( p < .01 \) ). Data pertaining to the first research question (within-verb type generalisation), show that all three participants improved significantly in accuracy of untrained
TABLE 3
Treatment data for each participant, sorted by type of treatment verb

<table>
<thead>
<tr>
<th></th>
<th>Baseline sessions</th>
<th>Treatment sessions</th>
<th>Treatment hours</th>
<th>Effect sizes for slope (SMD_{all})</th>
<th>Effect sizes for level (SMD_{pre-post})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tx</td>
<td>GenReg</td>
</tr>
<tr>
<td><strong>Regular verb treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>4</td>
<td>8</td>
<td>23.75</td>
<td>6.4</td>
<td>7.8</td>
</tr>
<tr>
<td>P2</td>
<td>8</td>
<td>18</td>
<td>24</td>
<td>25.6</td>
<td>48</td>
</tr>
<tr>
<td>P3</td>
<td>6</td>
<td>17</td>
<td>25.75</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>Group Mean</td>
<td>14.37</td>
<td>24.5</td>
<td>35.6</td>
<td>45.2</td>
<td>5.8</td>
</tr>
<tr>
<td><strong>Irregular verb treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>8</td>
<td>17</td>
<td>26.25</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>P5</td>
<td>4</td>
<td>15</td>
<td>12.5</td>
<td>6.6</td>
<td>7.4</td>
</tr>
<tr>
<td>P6</td>
<td>6</td>
<td>15</td>
<td>19</td>
<td>7</td>
<td>5.4</td>
</tr>
<tr>
<td>Group Mean</td>
<td>15.6</td>
<td>19.2</td>
<td>19.2</td>
<td>6.8</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Notes: The effect sizes in the left panel reflect slope (SMD_{all}), which includes the accuracy of every treatment session. The values on the right reflect change in level (SMD_{pre-post}). Tx = trained verbs, all tenses; GenReg = Untrained verbs, regular past tense; GenIrreg = Untrained verbs, irregular past tense; GenOther = Untrained verbs, third person singular present and future tenses. As described in the text, effect sizes could not be calculated for P4 because he had zero percent accuracy for all baseline probes.
Figure 3. Percent accuracy for participants who received tense training with regular verbs (P1, P2, P3) during baseline (B), treatment (T), and follow-up (F). During baseline, combined scores for both verb types (regular, irregular) and all three tenses (simple past, simple present, future) are plotted for the sake of visual simplicity. The treatment data (Tx Reg All tense) reflect combined accuracies for all trained verbs (three tenses). The generalisation data are separately plotted for regular and irregular past (Gen Reg Past, Gen Irr Past) and for other tenses, which include simple present and future tense (Gen Other Tense).
Figure 4. Percent accuracy for participants who received tense training with irregular verbs (P4, P5, P6) during baseline (B), treatment (T), and follow-up (F). During baseline, combined scores for both verb types (regular, irregular) and all three tenses (simple past, simple present, future) are plotted for the sake of visual simplicity. The treatment data (Tx Reg All tense) reflect combined accuracies for all trained verbs (three tenses). The generalisation data are separately plotted for regular and irregular past (Gen Reg Past, Gen Irr Past) and for other tenses, which include simple present and future tense (Gen Other Tense).
irregular past forms (overall pre- to final-treatment accuracy: 0–48.3%; P4: 0–80%; P5: 0–30%; P6: 0–35%; McNemar’s change test, \( p < .01 \) for P4, \( p < .05 \) for P5 and P6). Table 3 shows that the effect sizes for untrained irregulars were relatively small when compared to the effect sizes for trained irregulars (0.5 versus 6.6 for P5 and 1.9 versus 7 for P6). For the second research question (between-verb type generalisation), accuracy of regular past tense showed a statistically significant gain for all three participants, with a mean final treatment accuracy of 93.3% compared to 7.7% at baseline testing (McNemar’s change test, \( p < .01 \)). The effect sizes for regular past are larger in magnitude than the corresponding trained irregular and untrained irregular effect sizes (see Table 3). Production of future and present tense morphology on untrained verbs also improved significantly for all three participants (Mean pre- and final treatment scores are: 12% and 87.6%; McNemar’s change test, \( p < .01 \) for all three participants). The participant who received treatment with suffixed irregulars (P6) showed no significant advantage over the participants who received treatment on vowel-change irregulars (P4, P5). To summarise, treatment using irregular verbs produced generalisations in untrained regular and irregular verb morphology. However, the gain in untrained irregular past verb forms was lower in magnitude than that for regular morphology.

All participants maintained the effects of treatment in follow-up testing, with an average accuracy score of 80.8% for trained irregulars (data points F1 and F2 in Figure 4; range = 66–100). While mean follow-up accuracy was significantly greater than baseline accuracy (McNemar’s change test, \( p < .05 \)), the decline from final-treatment session accuracy was significant (McNemar’s change test, \( p < .05 \)).

**Regular versus irregular verb treatment**

Table 3 shows that quantitative aspects such as the mean number treatment sessions required to reach criterion (14.4 versus 15.6), treatment effect sizes (SMD\(_{\text{pre-post}}\): 11.1 versus 11.8), and the number of treatment hours (24.5 versus 19.2) showed no consistent advantage for any group. However, there were differences in the pattern and magnitude of generalisation to untrained verb types, which can be compared in the accuracy scores of final treatment and follow-up sessions across Figures 3 and 4. As for the first research question, the mean within-verb type generalisation, computed as the difference between average baseline and final treatment session accuracy, was 99.5% for the regular-trained group (gains of 100%, 99%, and 99.5% for P1, P2, and P3 respectively) and 48.3% for the irregular-trained group (gains of 80%, 30%, and 35% for P4, P5, and P6 respectively). Mean between-verb type generalisation (regular trained → irregular tested, and vice versa) was 20% for the regular trained group (gains of 30%, 30%, and 0% for P1, P2, and P3 respectively) and 79% for the irregular trained group (gains of 60%, 98%, and 79% for P4, P5, and P6 respectively). That is, while within-verb type generalisation was of higher magnitude for the regular trained group, between-verb type generalisation was larger for the irregular trained group. In other words, irrespective of whether regular or irregular verbs are used in training, generalisation to untrained regular morphology was consistently found and was larger in magnitude than for irregular verb morphology. It is also noteworthy that there were no remarkable differences in generalisation patterns between the two participants who received treatment with vowel change irregulars and the participant who received treatment on suffixed irregulars.
Other outcome measures

Post-treatment scores of the WAB and narratives are given in Table 2. Five out of six participants (with the exception of P6) significantly improved in their WAB AQ (McNemar’s change test, \( p < .05 \)). For the most part, these changes were in the fluency score, and additionally in a variety of subtests. Normative values of narrative measures are given in Appendix B for comparison. Given that typical statistical tests cannot be used for most narrative measures, an a priori criterion of change greater than two standard deviations of the normative sample was used as threshold for significant change (Rochon, Laird, Bose, & Scofield, 2005). The post-treatment narrative measures in Table 2 show that rate of speech was higher than the pre-treatment sample for three participants (P1, P3, P4) and was decreased for the other three participants (P2, P5, P6). All participants except one (P1) showed a quantitative increase in mean length of utterance (MLU) although this was not a significant change (\(< 2 \text{ SD}\) of normative sample). All except one participant (P1) had a higher proportion of sentences in the post-treatment sample, and this was significant for P2, P5, and P6. The ratio of open-class to closed-class words showed a significant post-treatment decrease (agrammatic participants have abnormally high ratios, hence a decrease is a favourable change) in four participants (all except P1 and P6). All participants except P4 showed a quantitative increase in the proportion of verbs, and this change was significant for one participant (P6). Three participants (P3, P4, P5) increased significantly in the proportion of suffixed verbs. Four participants improved significantly in the variety of tense (all except P1 and P6). Only one participant (P3) improved significantly on the accuracy of tense measure. The pre-treatment accuracy of tense is relatively high in some participants (P2) because of the over-use of the present progressive morphology (is Ving).

DISCUSSION

The primary aim of this study was to investigate the relative extent of within- and between-verb generalisation that could be achieved with morphosemantic treatment of tense using regular or irregular verb stimuli. This is a first study that directly compares the relative efficacy of using regular and irregular verbs in verb tense training, and is a phase II investigation of morphosemantic treatment (Robey, Schultz, Crawford, & Sinner, 1999; WHO). The data show that morphosemantic training of both verb types results in significant gains in trained items for all participants. The morphosemantic treatment also promotes generalised improvement in tenses that are conveyed by predictable and regular morphological markers (such as \(V+d\), \(V+s\), will \(V\)). On the other hand, generalisation to untrained irregular past forms is partial, irrespective of whether regular or irregular verbs are trained. For most participants there were also changes in related narrative measures such as variety of tense. In the following sections we discuss the implications of these findings for aphasia rehabilitation, the understanding of verb tense impairments in agrammatism, and the lexical representation of verb morphology.

Implications for aphasia therapy

First, this study adds to the body of research that demonstrates the efficacy of targeted aphasia treatment in individuals with chronic aphasia (Holland, Fromm, DeRuyter, & Stein, 1996). Morphosemantic treatment, as described here and in previous work
REGULAR AND IRREGULAR VERB TREATMENT

(Faroqi-Shah, 2008), results in significantly improved production of verb tense morphology in elicited speech and modest improvements in narrative speech. The data on regular rule recovery and generalisation show that all six aphasic individuals were able to re-learn rules or patterns and generalise the use of $V+d$, $V+s$, and $will V$ in the correct temporal context to untrained items.

Given that three tenses for each verb were sequentially trained, it is worth questioning if it is even necessary to train all tenses (or verb forms). In other words, if it is sufficient to train only one tense and obtain generalisation to untrained tenses (or verb forms). Two prior studies provide answers to this question. Bastiaanse, Hurkmans, and Links, (2006) trained only non-finite or finite verbs in two Dutch-speaking participants. The key treatment step was sentence completion and training of temporal reference was not a part of this treatment. The authors used the Complexity Account of Treatment Efficacy (Thompson, Shapiro, Kiran, & Sobecks, 2003) to predict that finite verb treatment would generalise to non-finite verbs since the former are syntactically more complex than the latter. Both participants showed limited improvement of trained verb types and failed to improve in the untrained verb type. Thompson et al. (2006) trained either past tense morphology ($V+ed$) or agreement morphology ($V+s$) in a group of 12 participants, and examined generalisation to the untrained morphology. Temporal context was utilised in this treatment with adverbs Yesterday and Nowadays. Thompson et al. found mixed patterns of generalisation, with an equal number of participants generalising or failing to generalise to the untrained morphology. To summarise, the results so far reveal weak generalisation across verb forms, suggesting that each verb tense and its corresponding form ($V+ed$, $V+s$, $will V$) might need to be trained before participants will apply the morphological pattern to untrained verbs in the appropriate temporal context. The exception in generalisation to untrained verb forms are the three participants (P4, P5, P6) who improved significantly in the regular past form even though regular past was not trained and one participant (P1) who improved on irregular past when only regulars were trained. This finding of generalisation across past tense verb forms is further discussed in the following sections.

This study differed from previous verb morphology treatment research in several respects (Bastiaanse et al., 2006; Mitchum & Berndt, 1994; Thompson et al., 2006; Weinrich et al., 1997). First, past tense training involved only one verb type for any participant, making it relatively straightforward to examine production of past tense across untrained regular and irregular verbs. Another previous study examined generalisation across regular-irregular morphology (Weinrich et al., 1997), and differed from the present study in three ways: training used computerised icons, both regular and irregular verbs, and trained six irregular verbs which had different subpatterns (while the present study trained a homogeneous set of irregulars: vowel change only or suffixed only). The findings were consistent with the present study: improved production of regular past morphology on untrained verbs, but limited improvements with untrained irregular past (see also participants TP, PP and SK in Faroqi-Shah, 2008, for similar findings). While rule-based generalisation for regular morphology was discussed earlier, there are at least two possible explanations for irregular verb outcomes. From a psycholinguistic perspective, irregular verbs are unlikely to have strong interlinkages with each other in the mental lexicon (Pinker, 1999) and hence exert limited influence on other irregulars. Second, composition of stimuli used for irregular verb training presents a caveat: while the present study tested generalisation for irregular verb types that were not used for training (that is, suffixed irregulars were tested when
vowel change irregulars were trained and vice versa), Weinrich et al. (1997) trained six heterogeneous irregulars. No study has yet trained and tested generalisation within the same subfamily of irregulars, and therefore this possibility for stronger irregular verb generalisation remains to be explored.

A second difference with prior treatment studies is the de-emphasis on oral production in the treatment steps. The outcomes showed that there was a general improvement in oral production of verb morphology even though this was not an explicit part of the treatment (as mentioned in the section on scoring, P2, P5, and P6 provided written responses for 5–20% of probes). This finding is consistent with Faroqi-Shah (2008), who found that accuracy of tense production failed to improve when participants received extensive oral practice (morphophonological training) but training on temporal context was not provided. A third difference from prior studies was the inclusion of treatment steps that tapped input processing (grammaticality judgement and comprehension). The motivation for including these steps was drawn from prior research showing poor performance in such tasks (Dickey, Milman, & Thompson, 2008; Faroqi-Shah & Dickey, 2009). Given that Bastiaanse et al. (2006) failed to find significant treatment gains, and their treatment included oral sentence completion without any input processing steps, one can infer that the input steps used in the present study may be augmenting the treatment outcomes. However, it is preliminary to make definitive statements about the benefit of using input processing steps without systematically comparing outcomes of morphosemantic treatment with and without input steps. A final difference with prior treatment studies is the robust improvement in narrative measures across most participants (except P1).

The implications for aphasia therapy based on the current study and previous findings are that: (1) morphosemantic training of verb morphology is a promising treatment approach for tense deficits for participants whose aphasia profile is similar to those reported in this study and Faroqi-Shah (2008), that is, those with agrammatic aphasia and minimal apraxia of speech, (2) contextually accurate use of regular verb morphology can be trained quite successfully. Further, use of regular past ending is highly likely to improve even when it is not explicitly trained. Findings to date are less conclusive about generalisation to untrained irregular verb stimuli, irrespective of whether regular or irregular verbs are used for training, (3) oral practice may not be necessary for improved outcomes, (4) use of input processing steps may be responsible for the positive outcomes (although this final point needs further verification), and (5) each tense may need to be trained for generalisation of that tense to untrained verbs.

The findings of this study also have implications for the Complexity Account of Treatment Efficacy, which states that the “linguistic complexity of materials selected for treatment will influence learning and generalisation patterns” (Thompson et al., 2003, p. 602). In other words, treatment of complex linguistic processes is expected to produce generalised improvement of linguistically related less complex processes. Most evidence for the complexity account comes from syntactic (Thompson & Shapiro, 2007) and semantic treatments (Kiran, 2007). The present study adds morphological treatment to the body of research that supports the complexity account; namely, the mental representation of irregular verbs is more complex (as per the evidence presented in the Introduction) and treatment of irregular past tense generalises to the production of regular past tense. Given that P1, the patient with least severe pre-treatment verb inflection scores, showed improvement for the more complex irregulars following regular training, further research is necessary to examine the applicability of CATE to intervention of verb morphology.
Obviously much more research is warranted to validate the above clinical recommendations. First, although we found improvement in regular past tense for patients who were trained on irregulars, a caveat is that all patients were also trained on future and present tenses, which are morphologically regular. In future work, we intend to examine the potential for generalisation to regular past following exposure to irregular past and no training of other regular morphology. It also remains to be seen if morphosemantic treatment is a viable treatment approach for individuals who speak inflectionally rich languages (such as Italian, French, Spanish, Kannada) where verb morphology represents additional information such as mood, number, and person. The patterns of generalisation across regular and irregular verbs and verbs with different conjugations in other languages are also worth investigating. Finally, morphosemantic treatment in its current form does not emphasise oral production. It remains to be seen if incorporating oral practice (such as oral sentence completion or sentence repetition) would enhance treatment outcomes.

Implications for lexical organisation and theories of morphological processing

The significant improvement in regular past tense production in the irregular trained group provides neuropsychological support for activation of the regularisation rule during irregular production and is consistent with theories that invoke either the Blocking mechanism (Aronoff, 1976; Kiparsky, 1982; Pinker, 1999) or parallel access of rule-based and storage mechanisms (Augmented Addressed Morphology: Caramazza, Laudanna, & Romani, 1988; Frauenfelder & Schreuder, 1992; Schreuder & Baayen, 1995). However, a confound that limits the interpretation of automatic activation of regularisation rules in the presence of irregulars is that the irregular treatment group was exposed to other regularisation rules (V+s). In future research exclusively training irregular past without accompanying simple present or future tense training will better elucidate if regularisation rules are automatically strengthened with exposure to irregulars. A second point from these results is that the effectiveness of generalisation to regulars did not vary with the type of irregular trained (vowel change for P4 and P5 versus suffixed irregulars for P6). This is inconsistent with models that postulate a gradation between regulars and irregulars on the basis of phonological shape (such as the Distributed Morphology of Halle & Marantz, 1993; and the single route account of Eddington, 2002). This finding is also inconsistent with priming data on unimpaired individuals where suffixed irregulars patterned with regulars while vowel change irregulars did not (Kielar et al., 2008). It is likely that there are multiple principles of organisation in the mental lexicon and the various experimental tasks tapped different organisational principles. The third theoretical implication comes from the finding that untrained irregulars only partially improved with irregular treatment. The Unique Entry Principle and its recent variants (Glass & Lau, 2003) propose the relative independence of each irregular verb entry and hence can accommodate this finding related to limited irregular verb generalisation.

Implications for theories of tense deficits in agrammatism

The patterns of acquisition and generalisation obtained in this study and prior treatment studies provide some insight into the nature of tense deficits in agrammatic aphasia. Given that training on associating temporal context with verb morphology
resulted in improved production of tense morphology, the findings are generally consistent with theoretical accounts of agrammatic aphasia that attribute difficulty with semantic or extrasentential aspects of tense morphology (Faroqi-Shah & Thompson, 2007; Wenzlaff & Clahsen, 2004). The pattern of tense deficits in this study is inconsistent with Bastiaanse’s (2008) proposal that only computation of past tense morphology is impaired in agrammatic aphasia. Our findings of impaired present, future, and past tense morphology are instead consistent with findings of a generalised tense impairment (Burchert et al., 2005; Thompson et al., 2006; Wenzlaff & Clahsen, 2004).

The occurrence of over-regularisation errors for irregular targets during the course of treatment and generalisation testing needs to be accounted for. After producing an over-regularised verb, participants frequently commented on their unfamiliarity with the uttered word, but were still unable to generate the correct form. Less frequently, production of an over-regularised form was followed by production of an accurate irregular target. Although this over-regularisation pattern has not been reported for English-speaking agrammatic participants, it is consistent with data from German and Dutch agrammatic participants described by Penke and Westermann (2006). Their data, obtained using a sentence completion task (for example in German: Ich schreibe. Ich habe __ [geschrieben] [I am writing. I have ___ [written]]), revealed 81% and 98% over-regularisation errors for German and Dutch participles respectively. It is also noteworthy that the difficulty with irregulars was reported for participles, which are non-finite (untensed), with the tense information having been conveyed by an already existing auxiliary (habe or hebben) in the sentence completion task. This predominant pattern of over-regularisation errors cannot be explained without invoking difficulties with word form access. A further indication of difficulty with word form access comes from the limited generalisation to untrained irregulars found in our study. That is, production of irregular morphology was not facilitated by tense training alone. A third pointer to word form access is the influence of lexical frequency on the production of irregular (Penke & Westermann, 2006) and regular verb inflections (Faroqi-Shah & Thompson, 2004). It is widely reported in psycholinguistic literature that the language production process most robustly influenced by lexical frequency is word form access (e.g., Levelt, Roelofs, & Meyer, 1999).

In their present form, two accounts can accommodate a verb form retrieval deficit. Penke (2003), using the framework of lexicalist approaches to inflectional morphology, proposed that problems in accessing inflectional affixes were at the core of agrammatic speech. Penke cited two patterns of data in German agrammatic patients to support this argument: inflectional errors were more likely with lower-frequency verb forms and in inflectional paradigms with fewer members. Agrammatic errors in German, such as clause-final verb placement and inflectional errors in the second verb were argued to be accommodated by this account (Penke, 2001). Additionally, the Diacritical Encoding and Retrieval (DER) hypothesis can accommodate a word form retrieval problem that is likely to underlie the over-regularisation errors with irregular targets. The DER identifies two potential deficits: selection of diacritical features that correspond to the intended message (+PAST, +PLURAL, etc.) and/or selection of verb forms that correspond to these diacritics (Faroqi-Shah & Thompson, 2007). The latter deficit can explain why, despite training with (and knowledge of) past tense, our participants were unable to retrieve the irregular past and instead applied the default past tense affixation rule. Faroqi-Shah and Thompson (2004) argued that agrammatic participants are unable to retrieve verb forms that match the intended tense, and hence
resort to producing the most easily accessible verb form. In most cases verb forms with higher word frequencies or higher affix frequencies are thus produced (see also Centeno, Obler, Cairns, Garro, & Merrifield, 1996 for consistent data from Spanish, and Luzzatti, Mondini, & Semenza, 2001 for data from Italian). The data with irregular verbs suggest that representational differences between verbs add another level of complexity that can impact the production of inflections.

Accounts of verb inflection deficits are incomplete if they fail to address another facet: that of morphophonological complexity, which is often implicated to undermine the production of regular inflections in English (Bird et al., 2003; Braber, Patterson, Ellis, & Lambon Ralph, 2005; Druks, 2006; Ullman et al., 1997). Druks (2006) suggested that morphosyntactic (tense and agreement encoding) difficulties might interact with morphophonological encoding such that only those inflections that are morphosyntactically impaired experience additional deficits at the level of morphophonology. This was proposed to account for the relatively spared production of plural and progressive markers in comparison to that of past tense inflections, and a greater deficit for regular past versus irregular past tense inflections observed for Druks’ patient.

In sum, agrammatic participants described here and in previous studies evince multiple levels of difficulties with verb inflections: morphosemantic (diacritical feature specification), morphosyntactic (as in subject–verb agreement), morpholexical (as in verb form access/encoding), and morphophonological (Bird et al., 2003; Burchert et al., 2005; Druks, 2006; Faroqi-Shah & Thompson, 2004, 2007; Friedmann & Grodzinsky, 1997; Luzzatti & De Blaser, 1996; Wenzlaff & Clahsen, 2004). The emerging pattern is that, while morphosemantic deficits are pervasive (with tense diacritics most frequently impaired), these may or may not co-occur with other deficits in varying combinations. There is a cascading complexity effect, where deficits at any level get magnified by deficits at ensuing levels. The recent computational load account of agrammatic production (Kok et al., 2007) reveals that task demands add another dimension to this complexity cascade and is not incompatible with the data presented here.

Conclusions

Psycholinguistic, neuroimaging, and neuropsychological differences in the processing of regularly and irregularly inflected verbs in Germanic languages have played a central role in theories of linguistic processing. However, there have been hardly any attempts to apply these findings to rehabilitation of morphological deficits in aphasia (but see Thompson et al., 2006, for application of linguistic theory). This study presents one such attempt in which representational differences between verbs were used as a framework to guide treatment. The primary finding is that re-learning of morphological rules is quite successful in persons with agrammatic aphasia with morphosemantic treatment (within-verb type generalisation). The potential for improvement in rule-based morphology following training with irregular verbs (between-verb type generalisation) is promising, but needs further research before conclusive statements can be made.
REFERENCES


APPENDIX A

Verbs used for treatment and generalisation testing, listed by verb type and participant conditions.

<table>
<thead>
<tr>
<th>Regular verbs</th>
<th>Irregular verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment for P1, P2, P3</strong></td>
<td><strong>Generalisation for all participants</strong></td>
</tr>
<tr>
<td>rake</td>
<td>iron</td>
</tr>
<tr>
<td>peel</td>
<td>water</td>
</tr>
<tr>
<td>wrap</td>
<td>plant</td>
</tr>
<tr>
<td>shave</td>
<td>climb</td>
</tr>
<tr>
<td>pull</td>
<td>mow</td>
</tr>
<tr>
<td>wash</td>
<td>comb</td>
</tr>
<tr>
<td>kick</td>
<td>push</td>
</tr>
<tr>
<td>smoke</td>
<td>empty</td>
</tr>
<tr>
<td>hug</td>
<td>kiss</td>
</tr>
<tr>
<td>rob</td>
<td>vacuum</td>
</tr>
<tr>
<td>play</td>
<td>jump</td>
</tr>
<tr>
<td>fold</td>
<td>open</td>
</tr>
<tr>
<td>juggle</td>
<td>bake</td>
</tr>
<tr>
<td>sew</td>
<td>clean</td>
</tr>
<tr>
<td>ski</td>
<td>cross</td>
</tr>
<tr>
<td>paint</td>
<td>pour</td>
</tr>
<tr>
<td>carry</td>
<td>sail</td>
</tr>
<tr>
<td>dry</td>
<td>wipe</td>
</tr>
<tr>
<td>tie</td>
<td>save</td>
</tr>
<tr>
<td>skate</td>
<td>scrub</td>
</tr>
</tbody>
</table>
APPENDIX B

Normative values for narrative speech obtained from 13 age-matched healthy normal adults.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Rate (words per minute)</td>
<td>136.06</td>
<td>26.53</td>
</tr>
<tr>
<td>MLU</td>
<td>10.80</td>
<td>1.63</td>
</tr>
<tr>
<td>Proportion sentences</td>
<td>0.97</td>
<td>0.03</td>
</tr>
<tr>
<td>Open:closed class ratio</td>
<td>0.79</td>
<td>0.07</td>
</tr>
<tr>
<td>Proportion verbs</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Proportion suffixed verbs</td>
<td>0.63</td>
<td>0.07</td>
</tr>
<tr>
<td>Variety of tense</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>Accuracy of tense</td>
<td>0.94</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Age range = 46 to 66 years, Mean age: 56.6; seven females, Mean years of education = 18.1.