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Judgment of functional morphology in agrammatic aphasia

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Abstract

Individuals with agrammatic Broca's aphasia show deficits in production of functional morphemes like complementizers (e.g., *that* and *if*) and tense and agreement markers (e.g., *-ed* and *-s*), with complementizers often being more impaired than verbal morphology. However, there has been comparatively little work examining patients' ability to comprehend or judge the grammaticality of these morphemes. This paper investigates comprehension of complementizers and verb inflections in two timed grammaticality-judgment experiments. In Experiment 1, participants with agrammatic Broca's aphasia and grammatical-morphology production deficits ($n=10$) and unimpaired controls ($n=10$) heard complement clause sentences, subject relative clause sentences, and conjoined sentences. In Experiment 2, the same participants heard sentences with finite auxiliaries, sentences with finite main verbs, and sentences with uninflected verbs. Results showed above-chance accuracy in aphasic participants' judgments for complementizer sentences in Experiment 1, but chance performance for verb inflections in Experiment 2. This pattern held regardless of whether the verb inflections were affixes or free-standing auxiliaries. Implications of these results for theories of agrammatic morphological impairments, including feature underspecification accounts (Wenzlaff & Clahsen, 2004; Burchert, Swoboda-Moll & DeBleser, 2005a) and hierarchical structure-based accounts (Friedmann & Grodzinsky, 1997; Izvorski & Ullman, 1999), are discussed.

Keywords

Aphasia; agrammatism; grammatical morphology; functional categories; perception; grammaticality judgment

1. INTRODUCTION

One of the hallmarks of agrammatic-type Broca's aphasia is a deficit in the production of functional morphology. Both free-standing function words and bound morphemes used to mark grammatical functions are impaired in this population, crosslinguistically. For example, nominal functional morphemes such as possessive “-s” and the definite determiner “the” are often missing from aphasic individuals' elicited or spontaneous speech (Avrutin, 2000; Berndt

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& Caramazza, 1980; Goodglass, 1976; Schwartz, Saffran & Marin, 1980). Verbal inflections such as subject-verb agreement (marked in third-person singular present-tense “-s” in English) and tense marking (such as English past-tense “-ed”) are often omitted or incorrectly substituted in agrammatic individuals’ productions, as are auxiliaries such as “is” or “was” (Benedet, Christiansen & Goodglass, 1998; De Villiers, 1978; Pettit, McNeil & Keith, 1989). Similarly, subordinating conjunctions or complementizers such as “if,” “that,” and “whether” are systematically missing from agrammatic individuals’ speech (Friedmann, 2001; Milman, Dickey & Thompson, under review). These patterns appear to hold not only for English-speaking agrammatic aphasic individuals but for aphasic speakers of other languages as well (Menn & Obler, 1990; Hagiwara, 1995; Benedet, et al., 1998; Friedmann, 2001; Wenzlaff & Clahsen, 2004, 2005).

However, recent work has shown that not all functional morphemes are equally likely to be impaired in aphasia. Bound and free morphemes associated with verbal and clausal syntactic functions appear to be particularly vulnerable in agrammatism. More specifically, complementizers and tense marking are especially likely to be impaired (Friedmann, 1998, 2001; Friedmann & Grodzinsky, 1997). In contemporary linguistic theory, these functional morphemes are associated with distinct functional projections in a clause’s syntactic tree, as illustrated in Figure 1.

Complementizers are associated with the highest syntactic projection in the clause, CP (or Complementizer Phrase), while tense marking (as well as subject-verb agreement) is associated with an intermediate syntactic projection, here labeled TP (for Tense Phrase). While there is debate regarding whether there are additional syntactic projections besides TP below CP (Bobaljik & Thrainsson, 1998; Chomsky, 1989, 1995, 2001; Cinque, 1999; Ouhalla, 1990; Pollock, 1989), there is broad agreement that TP-type projections (responsible for licensing inflectional morphology) lie in between CP and VP. VP is the lowest syntactic projection in a clause, and it is responsible for introducing the verb and its arguments. In this paper, we will assume with Chomsky (2001, 2004) that there is a single syntactic projection which is responsible for inflectional morphology, TP, which bears both interpretable Tense features and uninterpretable Agreement features (see Bhatt, 2005; Chomsky, 1995, 2001 for discussion). Regardless of the finer structure of either CP (viz. Rizzi, 1997) or TP (see Bobaljik & Thrainsson, 1998 for useful discussion), all current generative analyses agree that CP is higher in the clause’s syntactic structure than TP.¹

Considerable evidence from agrammatic production suggests that the level of impairment associated with a grammatical morpheme is closely related to the relative “height” of the syntactic projection which licenses it. For example, in examining narrative data from a small group of Japanese agrammatic individuals, Hagiwara (1995) found that elements related to CP (such as question particles) were more likely to be missing than elements related to TP (such as tense markers). She found similar patterns for a separate set of Italian agrammatic speakers. Similarly, Friedmann (Friedmann & Grodzinsky, 1997; Friedmann, 1998, 2001) found that for

¹In the interests of space, a number of important theoretical issues regarding the functional structure of clauses are being ignored here. For example, many have argued that CP may be divided into a more finely articulated set of functional projections at the left edge of a clause (Cinque 1999, e.g.), or that VP may be decomposed into smaller sub-projections such as vP and (lexical) VP (Hale & Keyser 1993, Pesetsky 1994, e.g.). Furthermore, there is good semantic and syntactic evidence that a further level of syntactic structure intervenes between TP and VP: AspectP, which is responsible for licensing morphology associated with grammatical aspect, such as English progressive and Germanic Perfekt (Hendrick 1991, Dickey 2001). However, for current purposes, the distinction between CP-level projections and TP-level projections is sufficient. If the logic of the TPH is correct, any individual who exhibits good performance with CP-level phenomena should also exhibit good performance with TP-level phenomena. Similarly, any individual who is impaired with TP-level phenomena should be impaired with CP-level phenomena, since CP is hierarchically higher than TP. Failure to project or fully specify TP should result in impairment for the syntactically higher CP, and capacity to successfully project the higher CP should entail the capacity to project the lower TP as well. See Burchert, Swoboda-Moll and De Bleser (2005b) for work examining the effects of the finer structure of CP-level projections on German-speaking agrammatic individuals’ sentence production.

both Hebrew-speaking and Palestinian-Arabic speaking agrammatic aphasic individuals, CP-related elements (such as fronted wh-phrases and complementizers) were more likely to be impaired than either tense or agreement marking. Examining a set of narratives elicited from English-speaking aphasic individuals, Milman, Dickey & Thompson (under review) found that complementizers were more likely to be missing from their speech than either tense or agreement marking, and that both tense and agreement were more impaired than grammatical aspect marking (such as progressive “-ing”). The relative preservation of aspect morphology is interesting given that aspect is argued to be licensed by a very low functional projection immediately dominating VP (Hendrick, 1991; Dickey, 2001).

This evidence suggests that the hierarchical position of a syntactic phrase is important for characterizing the relative vulnerability of the grammatical morphology associated with it. In particular, it suggests that grammatical morphology associated with higher clausal functional projections (such as CP) will be more impaired than that associated with lower functional projections (such as TP, or AspectP). This insight is at the heart of Friedmann’s Tree-Pruning Hypothesis (TPH; Friedmann & Grodzinsky, 1997; Friedmann, 1998, 2001, 2002). The TPH claims that the higher a syntactic projection is in the tree, the more likely it is to be “pruned.” More specifically, the higher a node in the tree, the more likely it is that the morphosyntactic features associated with that node will be underspecified. Underspecified nodes cannot project higher levels of structure. Further, pruning a given layer of structure disrupts both morphological and syntactic operations associated with that projection, as well as all projections above it, since (by hypothesis) pruned or underspecified projections are unable to license higher projections. This connection is illustrated in Figure 2.

Patients who are unable to generate a TP layer will be unable to license grammatical morphology associated with TP, such as tense marking. They will also be unable to generate a CP layer, and they should therefore be unable to license complementizers as well. The TPH thus predicts two patterns: higher syntactic projections (and the grammatical morphology associated with them) are more likely to be impaired in agrammatic aphasia than lower ones, and impairment in a lower-level projection (such as TP) should entail impairment in higher-level projections (such as CP).²

An alternative possibility is that the underspecification of morphosyntactic features and the projection of syntactic structure are not directly (and causally) associated in agrammatism, as they are under the TPH. Under this alternative view, the morphosyntactic features associated with a given projection (for example, TP) might be underspecified, but this underspecification need not block projection of higher levels of syntactic structure. This insight underlies feature-underspecification theories of agrammatic morphological impairments (Wenzlaff & Clahsen, 2004; Burchert, et al., 2005a). These accounts claim that some subset of the features associated with TP (on T^0 , the head of TP) are underspecified. This underspecification results in an impairment in production and judgment for the associated morphology (e.g., tense marking), since the grammatical information responsible for the morphology is absent from the agrammatic individuals’ representations. However, the underspecification of these

²The original formulation of the TPH was also designed to capture another dissociation reported by Friedmann and Grodzinsky (1997) and others (Goodglass, 1976; Menn & Obler, 1990, e.g.): production of tense marking appears to be more impaired than production of subject-verb agreement marking among agrammatic individuals crosslinguistically. On the assumption that tense morphology is licensed by a separate and higher projection (TP) than agreement morphology (AgrP; see Pollock 1989), tense morphology is more likely to be impaired than agreement morphology in agrammatism under the TPH. However, more recent work on clausal syntax has assumed that tense and (subject-verb) agreement morphology is associated with a single projection, at least in English (Bobaljik & Thrainsson 1998; Chomsky 1995, 2001). This change in representational assumptions makes the TPH’s original explanation of the tense-agreement asymmetry difficult to maintain. See Avrutin (1999), Burchert, Swoboda-Moll and De Bleser (2005a), and Wenzlaff and Clahsen (2004) for alternative accounts of why tense morphology should be more impaired than agreement morphology in agrammatism. In light of these more recent theoretical developments, and because the stimuli in Experiment 2 do not separately manipulate tense and agreement processes, this paper will not consider any possible differences between tense and agreement further.

morphosyntactic features leaves agrammatic individuals' ability to project hierarchical syntactic structure intact.

These accounts shift the burden of explanation for agrammatic morphological deficits from independent syntactic impairments to more specifically morphological (or morphosyntactic) ones. This difference means that feature-underspecification accounts are compatible with some kinds of evidence which the TPH is not. For example, they are compatible in principle with evidence showing that grammatical morphology associated with higher syntactic projections (like CP) is intact while morphology associated with lower-level projections (like TP) is impaired (see Lee, Milman & Thompson, 2005). Such a pattern is not compatible with the TPH, which predicts that if an aphasic individual is impaired for TP-level processes, s/he must also be impaired for higher CP-level processes. However, it is also worth noting that feature-underspecification hypotheses (at least in their current form) do not have any explanation for impairments of CP-related morphemes, since they limit the scope of the feature underspecification to TP.

While much of the discussion of grammatical morphology deficits in aphasia has focused on production, the question of whether there are parallel deficits in comprehension or grammaticality judgment for such morphology has received less attention. The question of whether grammatical morphology impairments appear in both language modalities is important because it bears on whether there is a central representation deficit for grammatical morphology in agrammatism. In representational deficits, the grammatical representations themselves are impaired rather than access to them via one modality or another. For example, in feature-underspecification hypotheses, the morphosyntactic features associated with a syntactic node are impaired. This impairment results in deficits in both the production and comprehension of the morphemes associated with those morphosyntactic features, as well as grammaticality judgment for the same morphemes (see Wenzlaff & Clahsen, 2004; Burchert, et al., 2005a). Similarly, many have argued that agrammatic syntactic deficits are due to impaired syntactic representations, which cause impaired syntactic comprehension and production as well as impaired grammaticality judgments for some sentence types (e.g., Grodzinsky, 1984, 2000a; Grodzinsky & Finkel, 1998; though see also Linebarger, Schwarz & Saffran, 1983).

Such a central representation deficit for morphology also seems consistent with the spirit of the TPH, even though the original formulation of the TPH limited its scope to production (see Friedmann & Grodzinsky, 1997). The TPH reduces agrammatic morphological deficits to independently attested syntactic ones, which appear in production, comprehension, and grammaticality judgments. Therefore, it seems plausible that the morphological deficits which arise as a side-effect of the modality-independent syntactic ones should appear in multiple modalities as well. In line with this, recent discussions have explicitly suggested extending the TPH to comprehension phenomena (see Grodzinsky, 2000b; Friedmann, 2006). For example, Friedmann (2006) surveys a set of studies examining agrammatic comprehension of object relative clauses and reversible passives, and points out that object relatives appear to be more impaired than passives, across languages and individuals. She suggests that this difference may be straightforwardly explained by extending the TPH to comprehension: object relatives are more impaired precisely because they involve CP-level syntax, while passives do not. Given this extension of the TPH's empirical claims, this paper tests the hypothesis that the TPH may be extended to grammaticality judgment as well.

The current study examined grammaticality judgment of CP-related and TP-related functional morphology among English-speaking agrammatic individuals. The first purpose of the study was to examine whether agrammatic individuals' judgments regarding CP-related and TP-related grammatical morphemes are intact or impaired, as well whether they demonstrate sensitivity to the syntactic structure associated with different functional morphemes and

sentence types. The second purpose of the study was to examine whether their judgment of CP-related morphology is more impaired than TP-related morphology. Experiment 1 examined judgment of complementizers, while Experiment 2 examined judgment of verb inflections. Agrammatic individuals' impairments for CP- and TP-related morphology can be assessed by comparing their accuracy to chance, and to the accuracy of control participants in Experiments 1 and 2 respectively. Whether CP-related morphology is more impaired than TP-related morphology can be assessed by comparing aphasic individuals' accuracy across the two experiments.

If the TPH can be extended to comprehension or judgment of grammatical morphology, grammaticality judgment of CP-related morphology is expected to be more impaired for these individuals than judgment for TP-related morphology. Alternatively, if feature-underspecification accounts are correct, judgment for TP-related morphology should be impaired, since the underlying morphosyntactic features on TP are impaired. Judgment for CP-related morphology may or may not be impaired, since existing feature-underspecification hypotheses do not make any direct predictions regarding the impairment of non-TP grammatical morphology.

2. EXPERIMENT 1: COMPLEMENTIZERS

This experiment used timed grammaticality-judgment to test agrammatic individuals' sensitivity to CP-level grammatical structure and functional morphology. This method has been used effectively with agrammatic individuals (Linebarger, et al., 1983, *inter alia*), with results showing that aphasic individuals are sensitive to some but not all types of grammatical structure (see Frazier & MacNamara, 1995, Grodzinsky & Finkel, 1998, and sources cited above, among many others).

2.1 Methods

2.1.1 Participants—Ten individuals diagnosed with agrammatic Broca's aphasia (eight male) and ten unimpaired controls (three male) participated in this experiment. All participants were native monolingual speakers of American English. The control participants ranged in age from 18 to 71 and reported no prior history of speech-language, learning, or neurological disorders. Aphasic participants were mildly to moderately impaired based on their scores on the Western Aphasia Battery (WAB; Kertesz 1982), with WAB Aphasia Quotients ranging from 60.8 to 87.4. They ranged in age from 36 to 68 and were between 2 and 15 years post-onset at the time of testing. All aphasic participants but one were pre-morbidly right-handed. In addition, all exhibited difficulty in the production of grammatical morphology. Evidence for this difficulty comes from linguistic analyses of their narrative production (Thompson, Shapiro, Tait, Jacobs, Schneider & Ballard, 1995) in a retelling of the Cinderella story, and their performance on two elicited-production tasks: the Verb Inflection Test (Bastiaanse & Thompson, 2005) and functional category production probes (Thompson, et al., 2006). Demographic and general language-testing data for the aphasic participants are provided in Table 1, and data regarding their grammatical morphology production are found in Table 2.

2.1.2 Materials—Participants judged the grammaticality of 158 auditorily-presented sentences in Experiment 1. Four sentence types were used in the experiment. Forty-eight of the sentences involved embedded complement clauses introduced by complementizers or an ungrammatical preposition substitute (1a-b), forty involved subject relative clauses introduced by the complementizer "that" or an ungrammatical preposition substitute (2a-b). Forty were conjoined sentences involving VPs conjoined by "and" or "but" or an ungrammatical preposition substitute (3a-b).

1. Complementizers (COMP)

- a. They see that the man was lifting the woman.
 - b. They see *for the man was lifting the woman.
2. Subject Relative Clauses (SubjRC)
- a. (10) They see the man that was lifting the woman.
 - b. They see the man *for was lifting the woman.
3. Conjoined sentences (CONJ)
- a. They see the man and lift the woman.
 - b. They see the man *to lift the woman.

In addition, there were thirty fillers involving verb-particle constructions, which served as distractors and ensured that the prepositions which served as ungrammatical substitutes in the main experimental items also occurred in grammatical sentence contexts. The ratio of grammatical to ungrammatical sentences was 2 to 1 for complement clause sentences, and 4 to 1 for subject relative-clause and conjoined-clause sentences.³

Experimental sentences (COMP, SubjRC, and CONJ sets) contained two propositions. The COMP and SubjRC were both 9 words in length, and the CONJ sentences were 8 words in length (since they did not contain an auxiliary). Grammatical COMP sentences contained the complementizers “that,” “if,” or “whether.” The SubjRC items had the same functional morphology (“that”) as the COMP sentences, but they involved additional syntactic complexity since they also contain an extracted subject (associated in this case with a phonologically null operator). The CONJ items were included because previous work (Friedmann, 1998; Goodglass, 1976) has shown that aphasic individuals are relatively unimpaired in their production of conjunctions like “and.”

2.1.3 Procedures—Participants were tested either in a quiet room in the Aphasia and Neurolinguistics Research Laboratory at Northwestern University or in their homes. Stimuli were presented using SuperLab 2.0 (Cedrus Corporation) on a desktop or laptop PC. All participants listened to the sentences over stereo loudspeakers and responded by pressing one of two buttons on a keyboard, one marked “G” for “good sentence” and the other marked “B” for “bad sentence.”

In the experiment, each trial began with a central fixation cross presented on a blank screen. This fixation cross was displayed for 300 milliseconds and was then replaced by a blank screen, at which point the stimulus sentence was played. The screen remained blank for the duration of the sentence plus an additional 5000 milliseconds. Each trial ended with the appearance of a new fixation cross indicating the start of another trial. Participants were told to press “G” if the sentence sounded like a “good” or “natural” sentence, and to press “B” if it did not. They were instructed to respond to each one as accurately as possible while responding as quickly as they could. Participants had from the start of the trial (the disappearance of the fixation cross) until the end of the 5000 additional milliseconds (the appearance of the next fixation cross) to respond.

After informed consent was obtained, participants were seated in front of the computer and oriented to the response keys. A series of practice trials was then administered to familiarize participants with the task. Participants first listened to four practice sentences read aloud by the experimenter, then five sentences played by the computer, and finally five practice trials

³A full set of materials for this experiment and Experiment 2 are available at:
http://www.communication.northwestern.edu/upload/FCGJ_stimuli.pdf.

with a maximum of 5000 milliseconds to respond, as in the experimental trials. They were given feedback on the first two sets of practice trials but not the final set.

Once these practice trials were complete, the main experiment was begun. The experiment terminated automatically once participants had heard all 158 sentences. Responses and reaction times for each response were collected for later analysis. The entire session lasted approximately 35 minutes.

2.2 Results

Response accuracy was the primary dependent variable in this experiment. Reaction time (RT) was a secondary dependent variable. Mean accuracy and RTs for each aphasic participant are presented in Table 3. Statistical analyses of accuracy and RT data are presented below.

Because the control group was comprised of both young and older participants, accuracy and reaction-time means for the older and younger control cohorts were computed and compared and did not differ statistically (both $p > 0.05$, t -test). Consequently, data from the older and younger control participants were collapsed for subsequent analysis.

2.2.1 Accuracy—The mean accuracy for control and aphasic participants is presented by condition in Figure 3.

Control participants were at ceiling in their accuracy, with accuracy of over 95% in all three conditions (COMP: 96%, SubjRC: 96%, CONJ: 95%). Aphasic participants exhibited lower accuracy levels than controls (COMP: 80%, SubjRC: 81%, CONJ: 72%). However, their accuracy was above chance for all three conditions (COMP: $t_1(9)=6.25$, $p < 0.001$, $t_2(47)=13.84$, $p < 0.001$; SubjRC: $t_1(9)=9.51$, $p < 0.001$, $t_2(39)=13.37$, $p < 0.001$; CONJ: $t_1(9)=4.35$, $p < 0.001$, $t_2(39)=8.31$, $p < 0.001$).

The accuracy data were submitted to a pair of mixed-design ANOVAs, with sentence type as a within-participants factor (3 levels) and participant group as a between-participants factor (2 levels). There were main effects of both sentence type ($F_1[2,36]=3.66$, $p < 0.05$; $F_2[2,76]=4.13$, $p < 0.05$) and group ($F_1[1,18]=1.95$, $p > 0.05$; $F_2[1,76]=111.17$, $p < 0.001$). Aphasic participants had lower accuracy than control participants, and accuracy was lower overall for CONJ sentences than for COMP and SubjRC sentences. However, there was no evidence of an interaction of group and sentence type ($F_1[2,36]=1.95$, $p > 0.05$, $F_2[2,76]=2.31$, $p > 0.05$). The two groups thus exhibited similar accuracy across conditions.

A series of planned comparisons was also carried out comparing the two groups' performance for sentences with complementizers (COMP and SubjRC) to their performance for sentences without complementizers (CONJ). For control participants, neither sentence type with complementizers differed significantly from the control CONJ condition (COMP vs. CONJ: $t_1(9)=0.91$, $p > 0.05$, $t_2(38)=0.552$, $p > 0.05$; SubjRC vs. CONJ: $t_1(9)=0.95$, $p > 0.05$, $t_2(38)=1.03$, $p > 0.05$). For the aphasic participants, there was a significant difference between SubjRC (81%) and CONJ (72%) sentences ($t_1(9)=2.57$, $p < 0.05$; $t_2(38)=2.31$, $p < 0.05$). There was not a significant difference between COMP and CONJ sentences for aphasic participants, however ($t_1(9)=1.61$, $p > 0.05$; $t_2(38)=2.22$, $p < 0.05$). These differences were unexpected; possible explanations for them are presented in the General Discussion below.

To check whether a response bias was responsible for the aphasic participants' lower accuracy, an additional analysis of variance was carried out on the aphasic participants' accuracy data, with grammaticality as a within-participants factor. If aphasic participants exhibited a yes-bias in this experiment, there should be a main effect of grammaticality, with lower accuracy for ungrammatical sentences (which should be incorrectly accepted due to the yes-bias). However,

there was no evidence of a main effect of grammaticality ($F(1[2,36])=0.10$, $p>0.05$, $F(2[2,74])=0.31$, $p>0.05$): grammatical sentences were no more accurate overall than ungrammatical sentences.

2.2.2 Reaction Times—Reaction times were measured from the offset of the sentence to compensate for length differences across the different sentence tokens and types. RTs were analyzed only for correct responses. These RTs were trimmed by excluding RTs of more than 6000 milliseconds or less than 600 milliseconds, as well as outliers more than two standard deviations above or below the mean RT for each condition for each participant. This process excluded 4.9% of the data for control participants and 4.6% of the data for aphasic participants. The mean RTs are presented by condition in Figure 4.

These data were submitted to a mixed-design ANOVA treating sentence type as a within-participant factor (three levels) and participant group as a between-participant factor (two levels). There was a significant effect of sentence type ($F(1[2,36])=11.93$, $p<0.001$, $F(2[2,152])=23.50$, $p<0.001$) and a main effect of group ($F(1[1,18])=4.17$, $p<0.05$, $F(2[1,76])=127.37$, $p<0.001$). Aphasic participants' RTs were significantly slower than controls'. However, there was no evidence of an interaction of group and sentence type ($F(1[2,36])=0.74$, $p>0.05$, $F(2[2,152])=3.02$, $p>0.05$). Here again, control and aphasic participants again exhibited similar patterns.

A series of planned comparisons was also carried out, comparing the two conditions with complementizer morphemes (COMP, SubjRC) to the control conjoined condition (CONJ) and to each other. Both aphasic and control participants were slower to respond to the syntactically more-complex SubjRC sentences than the otherwise similar COMP sentences (control participants, 786 milliseconds vs. 607 milliseconds: $t(9)=4.36$, $p<0.05$, $t(39)=3.22$, $p<0.05$; aphasic participants, 1184 milliseconds vs. 968 milliseconds: $t(9)=3.70$, $p<0.05$, $t(39)=4.20$, $p<0.05$). Somewhat puzzlingly, both groups of participants were also slow in their responses to the CONJ sentences: they both responded to CONJ sentence more slowly than COMP sentences (control participants, 760 milliseconds vs. 607 milliseconds: $t(9)=2.73$, $p<0.05$, $t(39)=3.36$, $p<0.05$; aphasic participants, 1259 milliseconds vs. 968 milliseconds: $t(9)=2.99$, $p<0.05$, $t(38)=5.82$, $p<0.05$). This difference was unexpected; possible explanations for it are presented in the General Discussion below. Nonetheless, the two groups showed identical RT patterns in this regard.

2.3 Discussion

Results from Experiment 1 showed that aphasic participants had relatively intact judgment for the grammaticality of complementizer sentences. Even though the aphasic participants performed more poorly than the unimpaired controls, they were above chance in their accuracy for all three sentence types. Furthermore, aphasic participants were similarly accurate for grammatical and ungrammatical sentences. This indicates that their high accuracy in this experiment was not likely due to a "yes" bias created by the high ratio of grammatical to ungrammatical sentences in this experiment. A yes-bias would cause participants to over-accept grammatical sentences and under-accept ungrammatical ones.

In addition, aphasic participants responded more slowly to the syntactically more-complex SubjRC items than they did to the otherwise comparable COMP items, as did controls. Their RT patterns were also very similar to controls' across conditions, suggesting that they were parsing the sentences in roughly similar ways.

Together, these results indicate that grammaticality judgments of CP-related complementizer morphemes was relatively spared in this group of aphasic individuals, who showed impaired production of these grammatical morphemes. In addition, the RT data suggest that aphasic

participants may have parsed the sentences similarly to controls, and that their responses were sensitive to manipulations of syntactic complexity. Experiment 2 examined whether a similar pattern held for judgment of TP-related morphology.

3. EXPERIMENT 2: VERB INFLECTIONS

This experiment tested the same aphasic participants' judgments for TP-related morphology. We tested both tense and agreement morphology, which are often conflated in English, with tense morphemes either underspecified for agreement (as in past-tense *-ed*) or simultaneously marking both tense and agreement (as in third-person singular present-tense *-s*). See Halle and Marantz (1993) for discussion of this tense-agreement syncretism. Given our participants' relatively spared performance with CP-related morphemes in Experiment 1, they were expected to perform well with TP-related morphemes as well, if the TPH can be extended to grammaticality judgment. Under the TPH, any individual who can successfully project a CP must also be able to project and fully specify all levels of structure underneath it, including TP. In contrast, feature-underspecification accounts (Wenzlaff & Clahsen, 2004; Burchert, et al., 2005a) predict that individuals who exhibited intact performance with CP-related morphemes might nonetheless be impaired in their judgment of TP-related morphemes. Under such accounts, poor performance with TP-related morphology (like tense morphemes) is due to problems with morphosyntactic features within TP, and is therefore unrelated to CP-level projections or performance.

3.1 Methods

3.1.1 Participants—The same ten agrammatic aphasic individuals and ten unimpaired controls from Experiment 1 served as participants for this experiment. See Tables 1 and 2 for demographic and language-testing data.

3.1.2 Materials—Participants listened to 150 auditorily-presented sentences in Experiment 2. Sixty sentences had tense and agreement inflections marked on auxiliaries. Of these, thirty sentences were introduced by the preposed adverbial “yesterday” and contained a tensed auxiliary followed by a progressive participle (4a-b); the other thirty were preceded by “nowadays” and also had a tensed auxiliary and a progressive participle (5a-b). Sixty of the sentences had tense and agreement marking on the main verb. Of these, thirty sentences were preceded by “yesterday” (6a-b) and thirty by “nowadays” (7a-b). In the “nowadays” main-verb sentences, the “-s” affix overtly marked both present tense and third-person singular agreement, while in the “yesterday” main-verb sentences, the “-ed” affix marked only tense. In addition, there were thirty uninflected bare-verb controls (8a-b), involving a small-clause complement to a verb of perception. The embedded verb in these constructions is obligatorily bare: it may not grammatically co-occur with an auxiliary or be marked for inflection.

(4) Aux_PAST

- a. Yesterday the man was lifting the woman.
- b. Yesterday the man *is lifting the woman.

(5) Aux_PRES

- a. Nowadays the man is lifting the woman.
- b. Nowadays the man *was lifting the woman.

(6) V+ed

- a. Yesterday the man lifted the woman.
- b. Yesterday the man *lifts the woman.

(7) V+s

- a. Nowadays the man lifts the woman.
- b. Nowadays the man *lifted the woman.

(8) BareV

- a. They saw the man lift the woman.
- b. They saw the man *is lift the woman.

The ratio of grammatical to ungrammatical sentences was 2 to 1 within each item subset.⁴

All the experimental items involved a single sentence preceded by a preposed temporal adverbial. The Aux_PAST and Aux_PRES items involved exactly the same number of words, and the V+ed and V+s items had one word fewer than the other two experimental item sets (since they did not contain an auxiliary). The uninflected BareV controls involved two propositions. However, the distance in words between the material requiring that the verb be bare in this condition (“They saw”) was the same as in the other conditions: only the subject of the target verb (“the man”) intervened.

The auxiliary Aux_PAST and Aux_PRES sentences involved the same match or mismatch between the verb inflection and the preposed adverbial as the main-verb sentences, but in the auxiliary sentences, the inflection was carried on a free-standing auxiliary. These free-standing words are presumably more salient than the bound inflectional morphemes in the main-verb conditions. Comparing performance in the main-verb and auxiliary conditions should therefore cast light on whether any impairments found for the aphasic participants are specific to the perceptually less-salient bound inflectional morphemes, or apply to verb inflections more generally, independent of their status as words.

3.1.3 Procedures—The procedure for Experiment 2 was identical to that for Experiment 1. Participants performed Experiments 1 and 2 either in the same session or within 3 days of each other. The entire session for Experiment 2 lasted approximately 35 minutes.

3.2 Results

Response accuracy and RT were the primary and secondary dependent variables in this experiment. Mean accuracy and RTs for each aphasic participant are presented in Table 4. Statistical analyses of accuracy and RT data are presented below.

Because the control group was comprised of both young and older participants, accuracy and reaction-time means for the older and younger control cohorts were computed and compared and did not differ statistically (both $p > 0.05$, t -test). Consequently, data from the older and younger control participants were collapsed for subsequent analysis.

3.2.1 Accuracy—The mean accuracy for control and aphasic participants is presented by condition in Figure 5.

Control participants were at ceiling for all conditions (Aux_PAST: 92%, Aux_PRES: 89%, V+ed: 96%, V+s: 95%, BareV: 94%). Aphasic participants had lower accuracy for all conditions than controls (Aux_PAST: 55%, Aux_PRES: 53%, V+ed: 57%, V+s: 51%, BareV: 69%). Their performance was at chance for all conditions except the BareV condition (Aux_PAST: $t(9) = 0.9$, $p > 0.05$, $t(29) = 1.37$, $p > 0.05$; Aux_PRES: $t(9) = 0.66$, $p > 0.05$, $t(29) = 0.47$, $p > 0.05$; V

⁴A full set of materials for this experiment and Experiment 1 are available at: http://www.communication.northwestern.edu/upload/FCGJ_stimuli.pdf.

+ed: $t_1(9)=1.05$, $p>0.05$, $t_2(29)=1.54$, $p>0.05$; V+s: $t_1(9)=0.4$, $p>0.05$, $t_2(29)=0.39$, $p>0.05$; BareV: $t_1(9)=2.93$, $p<0.05$, $t_2(29)=5.81$, $p<0.05$)

The accuracy data were submitted to two pairs of mixed-design ANOVAs. The first pair of ANOVAs treated sentence type as a single, five-level factor, which was crossed with participant group. There were significant main effects of sentence type ($F_1[4,72]=4.07$, $p<0.01$, $F_2[4,232]=3.71$, $p<0.05$) and group ($F_1[1,18]=41.52$, $p<0.001$, $F_2[1,58]=9.07$, $p<0.01$) and a significant interaction of group and sentence type ($F_1[4,72]=3.17$, $p<0.05$, $F_2[4,232]=2.36$, $p=0.054$). Aphasic participants had lower accuracy overall than controls, and furthermore, their lower accuracy level interacted with sentence type: their disadvantage was larger for inflected sentences than for uninflected BareV sentences.

The second ANOVA targeted only the inflected conditions (Aux_PAST, Aux_PRES, V+ed, V+s). This ANOVA tested whether there were any differences among inflected sentence types. There were two factors, auxiliary (two levels: auxiliary vs. main verb) and tense (two levels: past vs. present), crossed with participant group. The only significant effect in this analysis was a main effect of group ($F_1[1,18]=45.94$, $p<0.001$, $F_2[1,58]=206.3$, $p<0.001$). All other main effects and interactions were not significant (auxiliary: $F_1[1,18]=1.49$, $p>0.05$, $F_2[1,58]=1.22$, $p>0.05$; tense: $F_1[1,18]=2.83$, $p>0.05$, $F_2[1,58]=2.75$, $p>0.05$; auxiliary x tense: $F_1[1,18]=0.042$, $p>0.05$, $F_2[1,58]=0.01$, $p>0.05$; auxiliary x group: $F_1[1,18]=1.29$, $p>0.05$, $F_2[1,58]=0.75$, $p>0.05$; tense x group: $F_1[1,18]=0.03$, $p>0.05$, $F_2[1,58]=0.43$, $p>0.05$; auxiliary x tense x group: $F_1[1,18]=0.80$, $p>0.05$, $F_2[1,58]=0.85$, $p>0.05$). Aphasic participants were less accurate than controls for sentences with inflectional morphology, but their lower accuracy was not affected by sentence type. Furthermore, there was no evidence that either auxiliary status (i.e., whether the inflection appeared as a suffix or on a free-standing auxiliary) or tense affected aphasic or control participants' accuracy levels.

A series of planned comparisons was also carried out comparing the two groups' performance for sentences with inflection to the BareV condition without inflection. The control participants showed no reliable differences between any of the inflected conditions and the uninflected BareV condition (Aux_PAST vs. BareV, 92% vs. 94%: $t_1(9)=0.3$, $p>0.05$, $t_2(29)=1.24$, $p>0.05$; Aux_PRES vs. BareV, 89% vs. 94%: $t_1(9)=1.03$, $p>0.05$, $t_2(29)=2.14$, $p>0.05$; V+ed vs. BareV, 96% vs. 94%: $t_1(9)=2.08$, $p>0.05$, $t_2(29)=1.02$, $p>0.05$; V+s vs. BareV, 95% vs. 94%: $t_1(9)=0.59$, $p>0.05$, $t_2(29)=0.11$, $p>0.05$). Controls were just as accurate in judging the grammaticality of sentences with verb inflection as sentences without it. Aphasic participants, in contrast, were significantly less accurate for each of the inflected conditions than they were for the uninflected BareV controls (Aux_PAST vs. BareV, 55% vs. 69%: $t_1(9)=3.83$, $p<0.05$, $t_2(29)=2.28$, $p<0.05$; Aux_PRES vs. BareV, 53% vs. 69%: $t_1(9)=2.76$, $p<0.05$, $t_2(29)=3.09$, $p<0.05$; V+ed vs. BareV, 57% vs. 69%: $t_1(9)=2.39$, $p<0.05$, $t_2(29)=2.27$, $p<0.05$; V+s vs. BareV, 51% vs. 69%: $t_1(9)=3.09$, $p<0.05$, $t_2(29)=3.31$, $p<0.05$). Aphasic participants were thus less accurate in judging the grammaticality of sentences with verb inflection than sentences without it.

To check whether a response bias was responsible for the aphasic participants' lower accuracy, an additional analysis of variance was carried out on the aphasic participants' accuracy data, with grammaticality as a within-participants factor. In contrast to Experiment 1, there was a main effect of grammaticality ($F_1[1,18]=21.34$, $p<0.001$, $F_2[4,112]=27.98$, $p<0.001$), with higher accuracy for grammatical than ungrammatical sentences. However, this difference appeared only for sentences with verb inflection. For sentences with verb inflection (Aux_PAST, Aux_PRES, V+ed, V+s), the aphasic participants were more accurate for grammatical than ungrammatical sentences (71.5% vs. 21%, averaging across sentence types), but for BareV sentences without inflection, they were less accurate for grammatical than ungrammatical sentences (65% vs. 78%). The difference between grammatical and

ungrammatical BareV sentences was not significant ($t_1(18)=1.27$, $p>0.05$, $t_2(28)=1.9$, $p>0.05$). Thus, the aphasic participants' asymmetry between grammatical and ungrammatical sentences was confined to sentences with verb inflection.

3.2.2 Reaction Times—Mean reaction-time data are presented by condition in Figure 6.

RT means were once again calculated only for correct responses. As in Experiment 1, RTs were trimmed by excluding RTs of more than 6000 milliseconds or less than 600 milliseconds, as well as outliers more than two standard deviations above or below the mean RT for each condition for each participant. This process excluded 4.1% of the data for control participants and 3.9% of the data for aphasic participants. Also as in Experiment 1, reaction times were measured from the offset of the sentence, to compensate for length differences across the different sentence tokens and types.

The RT data were submitted to a pair of mixed-design ANOVAs. The first ANOVA treated sentence type as a single, five-level within-participants factor which was crossed with participant group (between-participants factor, two levels). There were significant main effects of sentence type ($F_1[4,72]=4.46$, $p<0.01$, $F_2[4,224]=4.48$, $p<0.01$) and group ($F_1[1,18]=4.94$, $p<0.05$, $F_2[1,56]=154.77$, $p<0.001$). However, there was no evidence of an interaction of group and sentence type ($F_1[4,72]=0.83$, $p>0.05$, $F_2[4,224]=2.14$, $p>0.05$). Uninflected BareV sentences elicited faster RTs than inflected sentences, and aphasic participants had longer RTs than controls. However, the aphasic participants' RT disadvantage did not interact with sentence type: it was not larger for inflected verbs than for uninflected verbs, for example.

The second ANOVA targeted only the inflected conditions (Aux_PAST, Aux_PRES, V+ed, V+s). This ANOVA tested whether there were any differences among inflected sentence types. There were two within-participant factors, auxiliary (two levels: auxiliary vs. main verb) and tense (two levels: past vs. present), crossed with the between-participants factor of participant group. The only significant effects in this analysis were main effects of group ($F_1[1,18]=4.49$, $p<0.05$, $F_2[1,56]=112.59$, $p<0.05$) and auxiliary ($F_1[1,18]=5.76$, $p<0.05$, $F_2[1,56]=4.40$, $p<0.05$). All other main effects and interactions were not significant (tense: $F_1[1,18]=0.93$, $p>0.05$, $F_2[1,56]=1.22$, $p>0.05$; auxiliary x tense: $F_1[1,18]=0.45$, $p>0.05$, $F_2[1,56]=0.01$, $p>0.05$; auxiliary x group: $F_1[1,18]=2.48$, $p>0.05$, $F_2[1,56]=0.93$, $p>0.05$; tense x group: $F_1[1,18]=1.73$, $p>0.05$, $F_2[1,56]=3.66$, $p>0.05$; auxiliary x tense x group: $F_1[1,18]=0.003$, $p>0.05$, $F_2[1,56]=0.24$, $p>0.05$). Aphasic participants were slower than controls, and sentences with auxiliaries elicited faster RTs than sentences with main-verb inflections. However, the aphasic participants' RT disadvantage did not interact with either tense or auxiliary status, nor was the auxiliary conditions' RT advantage affected by participant group or tense.

A series of planned comparisons was also carried out, comparing each of the inflected conditions to the uninflected BareV condition for both groups. For control participants, the uninflected BareV condition elicited faster RTs than all the inflected conditions, but this difference was statistically significant only for the V+ed and V+s conditions (Aux_PAST vs. BareV, 814 milliseconds vs. 707 milliseconds: $t_1(9)=1.79$, $p>0.05$, $t_2(29)=2.41$, $p<0.05$; Aux_PRES vs. BareV, 821 milliseconds vs. 707 milliseconds: $t_1(9)=2.20$, $p>0.05$, $t_2(29)=2.36$, $p<0.05$; V+ed vs. BareV, 829 milliseconds vs. 707 milliseconds: $t_1(9)=2.48$, $p<0.05$, $t_2(29)=2.39$, $p<0.05$; V+s vs. BareV, 893 milliseconds vs. 707 milliseconds: $t_1(9)=3.16$, $p<0.05$, $t_2(29)=3.79$, $p<0.05$). For aphasic participants, the same pattern held numerically, with slower responses for the inflected conditions compared to the uninflected controls, but this pattern was not statistically significant in any condition (Aux_PAST vs. BareV, 1182 milliseconds vs. 1067 milliseconds: $t_1(9)=0.77$, $p>0.05$, $t_2(28)=2.06$, $p<0.05$; Aux_PRES vs. BareV, 1126 milliseconds vs. 1067 milliseconds: $t_1(9)=0.39$, $p>0.05$, $t_2(28)=0.84$, $p>0.05$; V+ed vs. BareV, 1244 milliseconds vs. 1067 milliseconds: $t_1(9)=1.96$, $p>0.05$, $t_2(27)=2.89$,

$p < 0.05$; V+s vs. BareV, 1242 milliseconds vs. 1067 milliseconds: $t(9) = 1.05$, $p > 0.05$, $t(28) = 2.14$, $p < 0.05$). Thus, the two groups were both numerically faster in rendering judgments about uninflected forms, and both groups were faster in their judgments about auxiliaries than about main-V inflections.

3.3 Discussion

The results from Experiment 2 are in contrast to those for Experiment 1. In Experiment 1, aphasic participants exhibited relatively intact judgment for CP-related complementizer morphology. In Experiment 2, the same participants exhibited impaired judgment for TP-related verb inflection morphology. They were at chance in their accuracy for all categories except the BareV condition, which simply required them to identify whether the target verb was uninflected. When they were required to decide whether the verb inflection was consistent with the temporal information provided by the preposed adverbial, they were significantly impaired. This pattern held regardless of whether the verb inflection was spelled out as an affix on a main verb or was incorporated in a free-standing auxiliary. This suggests that the aphasic participants' impairments with verb inflections are unlikely to be due to the relative perceptual salience of affixes.

Also in contrast to Experiment 1, the aphasic participants showed an effect of grammaticality in their accuracy data. They were more accurate for grammatical sentences than for ungrammatical sentences, particularly for sentences with inflection. This effect is consistent with a response bias in this experiment, arising from the relatively high ratio of grammatical to ungrammatical sentences: a response bias created by the greater number of acceptable sentences should inflate the number of correct 'yes' responses for grammatical sentences, and reduce the number of correct 'no' responses for ungrammatical sentences. However, the fact that this effect appeared only for inflected sentences, and not for uninflected BareV controls, argues against such an interpretation. The BareV sentences had the same two-to-one ratio of grammatical to ungrammatical sentences, but they did not exhibit the same asymmetry.

Turning to RTs, the aphasic and control participants again showed similar patterns in the RTs in this experiment. The two groups showed similar RT advantages for judging uninflected BareV controls compared to inflected sentences.

4. GENERAL DISCUSSION

The results of Experiments 1 and 2 show that these agrammatic individuals were impaired in their grammaticality judgments for both classes of grammatical morphemes (complementizers, verb inflections) tested here. This impairment appeared most dramatically for TP-related morphology: their judgments for complementizers were markedly better than their judgments for verbal inflection. This difference can be seen by comparing the accuracy data from Experiment 1 to those from Experiment 2, averaging across experimental conditions. These data are shown in Figure 7.

For control participants, there was no difference in mean accuracy between the complementizer sentences and the verb-inflection sentences ($p > 0.05$, t-test). In contrast, the aphasic participants were significantly less accurate overall for the verb-inflection sentences than for the complementizer sentences ($p < 0.05$, t-test). This pattern is consistent with previous grammaticality judgment results, which have shown preserved sensitivity among aphasic individuals for some, but not all, morphosyntactic structures (Linebarger, et al., 1983, Grodzinsky & Finkel, 1998).

Considering the contrasting results between Experiments 1 and 2, it is worth considering several potential factors which could have impacted participants' judgments. First, the higher

accuracy for complementizers compared to verb inflections is unlikely to be due to their being free-standing words. There was no reliable difference in accuracy between main-verb inflections and their auxiliary counterparts in Experiment 2, even though the auxiliaries were also free-standing words and were presumably perceptually more salient. Second, the advantage for the complementizers is unlikely to be due to other general properties of the sentences being judged. Complementizer sentences were longer in words and propositions than the verb-inflection sentences, but judgments for the verb-inflection sentences were nonetheless less accurate. (Consistent with this, aphasic participants' RTs for the verb-inflection sentences were longer as well, even though the sentences were shorter than the Experiment 1 sentences.) Third, the relative disadvantage for verb inflection sentences is unlikely to be due to simple distance. The element which selects the complementizer in the COMP condition, the matrix verb, is immediately adjacent to the functional morpheme being judged ("saw that the man ..."), while the element which must match the verb inflection is two words away in verb-inflection sentences ("Yesterday the man lifted ..."). However, as noted earlier, the target verb is equally distant from the element it must match in the BareV condition ("They saw the man lift ..."), in which aphasic participants performed above chance. Simple distance thus also seems unlikely to explain aphasic participants' poor performance with verb inflections relative to complementizers. The impairment for judgment of verb inflections – and in particular, the impairment in judging whether a given verb inflection is grammatical in the context of an adverbial – appears to be due to their linguistic properties as verb inflections, rather to any of these other properties.

The patterns found in this study also indicate that morphological judgment and production do not pattern together for at least some of the aphasic participants. As can be seen in Table 5, seven of the participants (a01, a02, a05, a07, a08, a09, a10) exhibited either equal or worse impairments in the production of complementizers than in the production of verb inflections. However, all ten showed better accuracy in their judgments for complementizers compared to verb inflections.

Furthermore, eight participants (all but a04 and a06) exhibited markedly impaired production of complementizer morphemes (under 50% accuracy) but far better judgment of the same morphemes.

This mixed pattern is in line with the mixed pattern of results found in the literature. Some work has found evidence of co-occurring impairments in production and judgment of grammatical morphology. For example, Wenzlaff and Clahsen (2004) reported impaired production and grammaticality judgment for tense marking in a group of German-speaking agrammatic aphasic individuals. Similarly, Lee (2003) found parallel impairments for elicited production and judgment for tense and mood marking in a group of Korean agrammatic individuals. However, there is also evidence of impaired production of functional morphology with intact judgment of the same morphology. Stavrakaki & Kouvava (2003) found impaired production but intact grammaticality judgment of tense and mood marking in two Greek-speaking agrammatic aphasic individuals. Friedmann & Grodzinsky (1997) also reported intact grammaticality judgment but impaired production for complementizers and tense marking for a group of Hebrew-speaking agrammatic individuals.

Together, the current data suggest that the TPH does not extend to input processes such as grammaticality judgment, since the TPH would predict the opposite pattern of impairments from that found in the current study: better-preserved judgment for TP-related morphology than for CP-related morphology. While the TPH does predict that some aphasic individuals should be impaired in their performance with TP-related morphology, the same individuals should also be impaired in their performance with CP-related morphology, which was not true for any of the participants in this study. The current results thus appear inconsistent with

extending the TPH from production to judgment, at least for these English-speaking agrammatic individuals, all of whom (except participant a04) showed impaired production of both TP-related and CP-related morphology.

These data also do not fully support central-representation deficit approaches to functional morphology in aphasia, such as Lee's (2003) top-down hypothesis, or Wenzlaff and Clahsen's (2004) Tense Underspecification Hypothesis and Burchert, et al.'s (2005a) modification of it. If the functional morphology deficits found in agrammatic aphasia are due to a deficit in abstract linguistic representations, we should expect them to appear not only in production, but also in grammaticality judgment for the same categories. That pattern did not hold for CP-related morphology for the majority of participants in this study (see Table 5): participants a01, a02, a03, a05, a07, a09, and a10 showed above-chance accuracy (70% or better) for complementizer judgment but below 50% accuracy for production of the same morphemes. (See Wenzlaff & Clahsen, 2005, for parallel evidence of dissociated production and judgment for CP-level processes among a group of German agrammatic individuals.) The parallels between production and judgment are stronger for TP-related morphology: while some individuals exhibited large numerical differences in accuracy for judgment and production of verb inflections (e.g., a02 and a10 – see Table 5), most aphasic participants exhibited impaired production accuracy (below 50%) and at-chance judgment accuracy for verb inflection.

Overall, these findings appear to be more in line with the predictions of the Tense Underspecification Hypothesis, which explains agrammatic individuals' poor performance with tense morphology in terms of underspecified morphosyntactic (tense) features. These central representational impairments should affect both production and judgment. These results are inconsistent with a number of previous results showing impaired production of functional morphology with intact judgment of the same morphology (e.g., Friedmann & Grodzinsky, 1997). However, as noted in the Introduction, such feature underspecification hypotheses are silent about CP-related morphology. The current data suggest that a similar representational-deficit account cannot extend to deficits in production of CP-related morphology.

Taken together, the current results suggest that neither a central syntactic deficit (as in hierarchical accounts like the TPH; see also Izvorski & Ullman, 1999) nor a morphosyntactic feature deficit (as in the Tense Underspecification Hypothesis; see also Burchert, et al., 2005a) can explain both the TP-related and the CP-related morphological deficits seen for many agrammatic individuals. Instead, it may be the case that these individuals' morphological insertion processes – the process of selecting morphemes to match the syntactic structures and morphosyntactic features of a particular sentence – are impaired (see Arabatzi & Edwards, 2002; Fix, 2005; and Thompson, Fix & Gitelman, 2002). This view is in line with recent developments in linguistic theory. Distributed Morphology (Halle & Marantz, 1993) argues that morphology is an independent grammatical component which interprets bundles of concatenated syntactic features. These feature bundles are the result of the syntactic operations responsible for building hierarchical phrase structure, such as Merge, Move, and AGREE (Chomsky, 1995, 2001, 2004). Under this view, the morphological component operates separately from the syntactic component, but it takes the results of syntactic computations (hierarchical phrase structures and feature bundles) as input for its computations. (See also Anderson, 1992, for a similar proposal.)

These computations have their own properties and combinatoric structure, selecting which syntactic features will be spelled out and which ignored (via language-specific impoverishment rules) in morphological insertion transactions (viz. Halle & Marantz, 1993; Harley & Noyer, 2003). These morphology-specific representations and operations may also be independently impaired in agrammatism (Fix, 2005; Fix, Dickey & Thompson, 2005). Given this interpretive view of morphology, successful computation of the relevant hierarchical syntactic structure is

a prerequisite for successful insertion of grammatical morphemes (such as complementizers or verb inflections). However, insertion of these morphemes may still fail if the relevant morphological operations are compromised (Fix, 2005). See Arabatzi & Edwards (2002) and Thompson, Fix & Gitelman (2002) for a similar conclusion, that syntactic processes related to production of tense may be intact for agrammatic individuals but that the implementation of the relevant morphological rules may be faulty.

However, more data are needed to settle the question of whether agrammatic morphological deficits are due to central (syntactic, morphosyntactic, or morphological) representational deficits. In particular, it would be important to know whether training targeting morphological deficits appearing in one domain (for instance in production, where the deficit appears more prominent) improves performance in other linguistic tasks which must draw on the same abstract representations (in this case, grammaticality judgment). Research addressing this question for functional morphology is currently in progress (see Thompson, et al., 2006).

Finally, two of the findings described above are in need of further explanation. The first finding is the contrast between CP-related and TP-related morphology: judgment of TP-related morphology is more impaired than judgment of CP-related morphology, for all the aphasic participants in this study. As already discussed, this asymmetry appears to be inconsistent with the extended version of the TPH being tested here. It is also unlikely to be due to other lower-level properties of the sentences being judged, such as the perceptual salience of free-standing complementizer morphemes, the length of the sentences involved, or the linear distance between the grammatical morpheme (verbal inflection or complementizer) and the element it must agree with (fronted adverb or matrix verb). However, the relative advantage of CP-related morphology over TP-related morphology in grammaticality judgment remains unaccounted for.

One possible explanation of this advantage lies in the syntactic relationships involved. Looking across the sentence types in the two experiments, aphasic participants were above chance in their judgments for just those sentences where there is a local syntactic dependency (where the nodes involved are in a sisterhood relation) mediated by the grammatical morphemes. This is true for all three sentence types in Experiment 1: in complement-clause sentences, the complementizer heads a CP which is syntactically selected by (and is sister to) the matrix V; in subject relative-clause sentences, the CP must be directly adjoined to the NP and enters into an agreement relationship with it (Chomsky, 1986; Browning, 1987); and in conjoined sentences, the conjunction coordinates two phrases which must be of the same category (Williams, 1978, among others). Interestingly, this is also true for bare-V sentences, the only sentences in Experiment 2 with above-chance performance: the uninflected verb is head of a non-finite verbal projection that is directly selected by “see” (Felser, 1999; Guasti, 1993; and Safir, 1993). The sentence types which elicited chance performance (the remaining sentences from Experiment 2) involve a non-local referential relationship between a clause-initial adverb and the head of TP (Dickey, 2001), rather than a local syntactic one.

This pattern suggests that the advantage of the CP-related morphology tested in Experiment 1 may be due to its reflecting local syntactic dependencies, rather than any inherent advantage CP-related morphemes may have over TP-related morphemes in judgment. This pattern also suggests that agrammatic individuals may be relatively unimpaired in their judgments for (and computations of) local morphosyntactic dependencies. This generalization appears consistent with previous findings for agrammatic individuals. Linebarger et al. (1983) report that the English-speaking aphasic individuals they tested were sensitive to mismatches between auxiliaries and main verbs, even when the auxiliaries were fronted: their participants rejected both “The girl was enjoy the show” and “Was the girl enjoy the show?” (In the latter case, the uninflected verb is separated from the mismatching auxiliary selecting it by the subject, just

as in the bare V sentences in Experiment 2.) Crosslinguistically, agrammatic individuals are also typically more sensitive to subject-verb agreement than tense (Friedmann & Grodzinsky, 1997; Menn & Obler, 1990). Subject-verb agreement reflects a local syntactic relationship, AGREE (Bhatt, 2005; Chomsky, 2001), while tense involves an intersentential referential dependency (Dickey, 2001; Enç, 1987; Partee, 1973).

This explanation of the relative advantage for CP-related morphology found in this study predicts that this advantage should be diminished when the CP morpheme being judged is not in a local syntactic (selection) relationship. For example, aphasic individuals' judgments for complementizers heading adjoined, unselected CPs (9c-d) should be less accurate than their judgments for complementizers which head directly selected CPs (9a-b).

- (9) a. Alana will wonder if Nolan is coming to the party. (CP selected by wonder)
- b. *Alana will wonder of Nolan is coming to the party.
- c. Alana will leave if Nolan is coming to the party. (CP not selected by leave)
- d. *Alana will leave of Nolan is coming to the party.

To the best of our knowledge, this contrast has not been tested. Confirmation of the above prediction would provide converging evidence for this explanation of the CP advantage found in the current study. It would also provide novel evidence that intact judgment of morphology in agrammatic aphasia arises when the morphology reflects or mediates a local syntactic dependency.

The second finding still in need of an explanation comes from Experiment 1: the unexpected disadvantage of conjoined sentences compared to the syntactically more complex complement-clause and subject relative clause sentences. This disadvantage appeared in the accuracy data for aphasic participants, with aphasic individuals being reliably more accurate for subject relative-clause sentences than conjoined sentences. It also appears in the RT data for both groups, with both aphasic and control participants responding to conjoined sentences more slowly than complement-clause sentences. The latter finding is particularly striking because it appears for both groups. In that way, it is parallel to the RT advantage found for syntactically simpler complement-clause sentences compared to subject relative-clause stimuli. This difference also appeared for both control and aphasic participants, even though these sentence types were well-matched in terms of length in words and propositions.

One possible explanation of this unanticipated finding is that the slower RTs reflect greater syntactic processing complexity for the conjoined sentences, due to the presence of a temporary syntactic ambiguity and resulting garden path.⁵ This interpretation makes this RT difference even more directly parallel to the relative clause-complement clause RT difference, which may reflect differences in the syntactic complexity of the two sentence types (viz. Forster, 1970). The conjoined sentences are temporarily ambiguous in regard to where the conjunction 'and' should attach:

They see the man and ...

- a. ... the woman (NP conjunction)
- b. ... lift the woman (VP conjunction)
- c. ... they lift the woman (TP conjunction)

The NP attachment of 'and' (10a) is the most local and structurally simplest possible continuation, and it should therefore be preferred during comprehension (Frazier 1987). In

⁵We are grateful to an anonymous reviewer for pointing out this possibility.

addition, previous results have found that attaching ‘and’ to the last constituent is the analysis preferred and first computed by unimpaired readers (Schutze & Gibson, 1999, Desmet & Gibson, 2003). This initial preference for the NP attachment of ‘and’ is inconsistent with the actual continuation of the sentence (10b), which should create a garden path and processing difficulty.

This processing difficulty may underlie the unexpected RT disadvantage for conjoined sentences in Experiment 1: they involve temporary syntactic ambiguities which are resolved to an initially dispreferred analysis, while the other sentence types tested in Experiment 1 do not. Furthermore, this temporary ambiguity may be partly responsible for the aphasic participants’ low accuracy for these items. Friedmann and Gvion (2007) found that some aphasic individuals exhibit lower accuracy in their grammaticality judgments for temporarily ambiguous sentences requiring syntactic reanalysis. If this explanation of the unexpected disadvantage for conjoined sentences is correct, it predicts that agrammatic individuals should also exhibit slowed RTs (and perhaps also higher rejection rates) for sentences with other temporary syntactic ambiguities. It also suggests that agrammatic individuals may use similar parsing strategies to unimpaired individuals, at least for the types of local syntactic parsing decisions involved here. We leave this interesting speculation for future study.

5. CONCLUSIONS

The results of the current experiment suggest that the Tree-Pruning Hypothesis cannot be extended to judgment of English functional morphology. As noted above, the original formulations of the TPH (Friedmann & Grodzinsky, 1997; Friedmann, 1998) explicitly limited it to production, but others have proposed extending it to comprehension (Grodzinsky, 2000b; Friedmann, 2006). Such an extension would seem to be in the spirit of the TPH, which claims that deficits in morphology are due to (modality-independent) deficits in syntax, which may also appear in grammaticality judgment (Grodzinsky & Finkel, 1998). However, given the current data, such a move seems untenable, at least for these English-speaking agrammatic individuals. (See also Dickey & Thompson, 2007, for treatment-based evidence that morphological deficits in at least one aphasic individual are relatively unlikely to be reducible to co-occurring syntactic deficits.)

Furthermore, the mismatch between judgment and production of grammatical morphemes found for a number of the individuals tested here casts doubt on some aspects of central representational deficit accounts of agrammatic morphological deficits, such as Lee’s (2003) top-down hypothesis and Wenzlaff and Clahsen’s (2004) feature underspecification hypothesis (or Burchert, et al.’s, 2005a, modification of it). These accounts claim that agrammatic morphological production deficits are due to underspecified morphosyntactic features, which create impairments in both production and input processes (like grammaticality judgment). The absence of a CP deficit for grammaticality judgment is consistent with many feature-underspecification hypotheses, which claim that agrammatic individuals’ morphological deficits are due to problems with the morphosyntactic features on TP and are therefore specific to tense morphology. However, these hypotheses do not provide an explanation of many agrammatic individuals’ marked deficits in complementizer production, as discussed above. Some additional mechanism – perhaps an impairment related to morphological processes – is required to explain this co-occurring deficit.

The mismatch between judgment and production of grammatical morphology found here (particularly for CP-related morphology) also raises the question of how to interpret the existing production data described in the Introduction. Those data suggest that there is a connection between the syntactic projections which license grammatical morphemes and the relative impairment of those morphemes in aphasia. In particular, it suggests that morphemes associated

with higher syntactic projections are more impaired. The opposite pattern was found here for judgment of English grammatical morphology. (It is also worth noting that the opposite pattern has been reported for some agrammatic individuals, such as participant a04 in the current study; see also Lee, Milman & Thompson, 2005.)

There is a more conservative interpretation of the existing production data which would still capture this pattern, however. Perhaps the ability to project higher levels of clausal structure is a *necessary* but not a *sufficient* condition for producing the related morphemes. Due to their well-attested syntactic deficits, patients will often be unable to project higher levels of structure, particularly in narrative tasks. This will result in their not creating sentences which are complex enough to host morphemes such as complementizers, for instance. However, even being able to produce such levels of structure may not be sufficient to guarantee that they can produce the relevant morphemes correctly (as under the TPH, which reduces morphological deficits to syntactic ones). Instead, there are additional morphological operations which are required in order to guarantee proper selection and insertion of grammatical morphology to match a syntactic structure.

If this view of the morphological component is correct, these independent morphological rules and operations may be impaired and recovered separately, as suggested in the General Discussion above. This would open the way for linguistically-motivated treatment of functional categories, parallel to previous linguistically-motivated training for syntactic deficits in aphasia (such as Treatment of Underlying Forms, Thompson & Shapiro, 2005). Such a program of treatment (Thompson, et al., 2006) may hold significant promise for ameliorating grammatical morphology deficits, the other hallmark of agrammatic aphasia.

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Figure 1.
Clausal functional projections and their morphological functions

Figure 2.
Clausal functional projections and the Tree-Pruning Hypothesis

Figure 3. Mean accuracy for grammaticality judgment by condition, Experiment 1
COMP = Complement clause sentences, SubjRC = Subject relative clause sentences, CONJ = Conjoined sentences. Error bars represent standard errors (SE).

Figure 4. Mean RTs by condition, Experiment 1

COMP = Complement clause sentences, SubjRC = Subject relative clause sentences, CONJ = Conjoined sentences. Error bars represent standard errors (SE).

Figure 5. Mean accuracy for grammaticality judgment by condition, Experiment 2

Aux_PAST = Past-tense auxiliary sentences (“was V+ing”), Aux-PRES = Present-tense auxiliary sentences (“is V+ing”), V+ed = Past-tense main V sentences, V+s = Present-tense main V sentences, BareV = Uninflected verb sentences (“see the woman V”). Error bars represent standard errors (SE).

Figure 6. Mean RTs by condition, Experiment 2

Aux_PAST = Past-tense auxiliary sentences (“was V+ing”), Aux-PRES = Present-tense auxiliary sentences (“is V+ing”), V+ed = Past-tense main V sentences, V+s = Present-tense main V sentences, BareV = Uninflected verb sentences (“see the woman V”). Error bars represent standard errors (SE).

Figure 7. Mean judgment accuracy for complementizer and verb-inflection sentences, Experiments 1 and 2, Aphasic and control participants

C = mean accuracy for sentences with complementizers (COMP and SubjRC), Experiment 1, Vinfl = mean accuracy for sentences with verb inflection (Aux_PAST, Aux_PRES, V+ed, V+s), Experiment 2. Error bars represent standard errors (SE).

Table 1

Aphasic participants' demographic and general language testing data

Participant	Age	Gender	Demographic variables		Years post-onset	BNT	WAB	Info. Content	Fluency	Comprehension	Repetition	Naming
			Years of education									
a01	60	M	16		15	47	AQ 71.8	8	4	8.5	7.8	7.6
a02	63	M	18		11	65	75	8	4	8.8	8	8.7
a03	56	M	20		14	78	78.6	6	5	9	6.6	8.7
a04	57	M	18		4	68	69.8	6	4	8.1	9.3	7.5
a05	50	F	12		9	25	60.8	8	2	8	6.6	5.8
a06	36	M	18		3	87	74.4	8	5	8.6	7.2	8.4
a07	68	M	16		12	73	75	8	4	9.9	7	8.6
a08	66	M	18		7	92	87.6	9	6	10	9.7	9.1
a09	57	F	16		4	75	73.5	9	4	9.35	6.5	7.9
a10	36	M	18		2	72	81.1	9	6	8.35	8.6	8.6

Table 2

Aphasic participants' grammatical morphology production data

Participant	VIT score	% grammatical sentences	Narrative production measures			% sentences w/ complementizers	Functional Category Production Tests	
			% correct V form	% correct pres tense	% correct past tense use		Verb Inflection	Accuracy for Complementizers
A01	22%	36%	85%	25%	100%	0%	20%	0%
A02	35%	16%	53%	0%	100%	0%	0%	0%
A03	n/a	34%	70%	43%	60%	0%	18%	40%
A04	76%	71%	100%	100%	0%	0%	45%	100%
A05	39%	33%	0%	0%	0%	0%	0%	0%
A06	0%	73%	0%	0%	0%	0%	35%	65%
A07	60%	20%	0%	0%	0%	0%	48%	30%
A08	51%	39%	0%	71%	86%	0%	33%	0%
A09	39%	0%	0%	0%	0%	0%	3%	0%
A10	40%	28%	73%	0%	100%	0%	0%	0%

Note: VIT = Verb Inflection Test (Bastiaanse & Thompson, 2005)

Table 3

Aphasic participants' individual accuracy and RTs by condition, Experiment 1

	COMP						SubjRC						CONJ					
	Grammatical			Ungrammatical			Grammatical			Ungrammatical			Grammatical			Ungrammatical		
	PC	RT		PC	RT		PC	RT		PC	RT		PC	RT		PC	RT	
A01	84%	903		100%	531		81%	1288		100%	711		81%	983		100%	725	
A02	100%	133		100%	464		97%	277		88%	57		100%	140		88%	231	
A03	88%	1170		94%	610		66%	1566		88%	1123		39%	2395		88%	885	
A04	69%	1884		38%	1666		77%	1997		25%	2523		77%	2033		75%	2571	
A05	94%	880		63%	657		75%	1077		100%	609		52%	952		100%	642	
A06	72%	1820		31%	669		84%	1706		25%	1331		55%	1465		50%	1834	
A07	84%	682		100%	568		90%	758		88%	624		77%	1445		100%	662	
A08	97%	684		88%	670		94%	743		100%	1104		90%	694		88%	1884	
A09	88%	1571		38%	1833		87%	1704		50%	1870		68%	2194		63%	1908	
A10	75%	1430		50%	1067		71%	1640		88%	953		55%	1809		88%	1180	
Mean	85%	1116		70%	873		82%	1276		75%	1090		69%	1411		84%	1252	

PC = proportion correct (accuracy); RT = reaction time (in milliseconds); COMP = complement clause ("see that the man is lifting the woman"); CONJ = conjoined clauses ("see the man and lift the woman").

Aphasic participants' individual accuracy and RTs by condition, Experiment 2

Table 4

	Aux_PAST				Aux_PRESENT				V+ed				V+s				BareV			
	Grammatical		Ungrammatical		Grammatical		Ungrammatical		Grammatical		Ungrammatical		Grammatical		Ungrammatical		Grammatical		Ungrammatical	
	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT	PC	RT
A01	52%	1167	45%	1314	43%	1213	33%	973	65%	1041	10%	1288	39%	1033	64%	1001	90%	1173	91%	959
A02	100%	253	9%	311	100%	302	9%	397	100%	252	0%	n/a	100%	288	9%	459	95%	538	91%	432
A03	86%	1351	60%	1496	48%	1759	50%	878	85%	1326	10%	1719	30%	2247	60%	1067	80%	1235	91%	649
A04	70%	1916	10%	2242	80%	1864	20%	1966	80%	2268	20%	2219	85%	2076	10%	2193	55%	2250	82%	1600
A05	60%	1352	20%	1723	80%	1049	10%	1686	80%	1473	0%	n/a	90%	1312	0%	n/a	20%	1284	100%	676
A06	70%	1300	20%	875	80%	1372	10%	244	80%	1342	30%	2364	80%	1191	10%	1848	60%	946	64%	947
A07	90%	997	20%	1426	85%	968	20%	1385	90%	1015	10%	1679	85%	979	10%	942	60%	1170	91%	696
A08	70%	488	50%	1854	100%	723	20%	1828	90%	954	50%	1238	65%	868	40%	1977	80%	759	73%	826
A09	20%	1228	0%	n/a	15%	1124	10%	2003	5%	1755	0%	n/a	25%	1668	0%	n/a	30%	1905	18%	1461
A10	90%	1428	10%	1992	75%	1217	20%	1515	85%	1100	60%	1913	85%	1589	10%	1194	75%	1700	82%	908
Mean	71%	1148	24%	1470	71%	1159	20%	1287	76%	1253	19%	1774	68%	1325	21%	1335	65%	1296	78%	915

PC = proportion correct (accuracy); RT = reaction time (in milliseconds); Aux_PAST = past-tense auxiliary (“was V+ing”); Aux_PRESENT = present-tense auxiliary (“is V+ing”); V+ed = past-tense main V inflection; BareV = uninflected main V (“See the man V”)

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Table 5

Production versus judgment of complementizers and verb inflections, Aphasic participants

<i>Participant</i>	Judgment		Production	
	Verb Inflection	Complementizers	Verb Inflection	Complementizers
a01	46%	87%	20%	0%
a02	67%	97%	0%	0%
a03	56%	80%	18%	40%
a04	58%	63%	45%	100%
a05	54%	82%	0%	0%
a06	58%	65%	35%	65%
a07	63%	90%	48%	30%
a08	68%	94%	33%	0%
a09	10%	75%	3%	0%
a10	64%	71%	0%	0%

Note: Judgment accuracy scores represent mean accuracy for both conditions with complementizers in Experiment 1 (COMP, Subj_RC) and all inflected conditions in Experiment 2 (Aux_PRES, Aux_PAST, V+s, V+ed). Production accuracy scores represent participants' performance on functional category production probes (Thompson, et al., 2006).