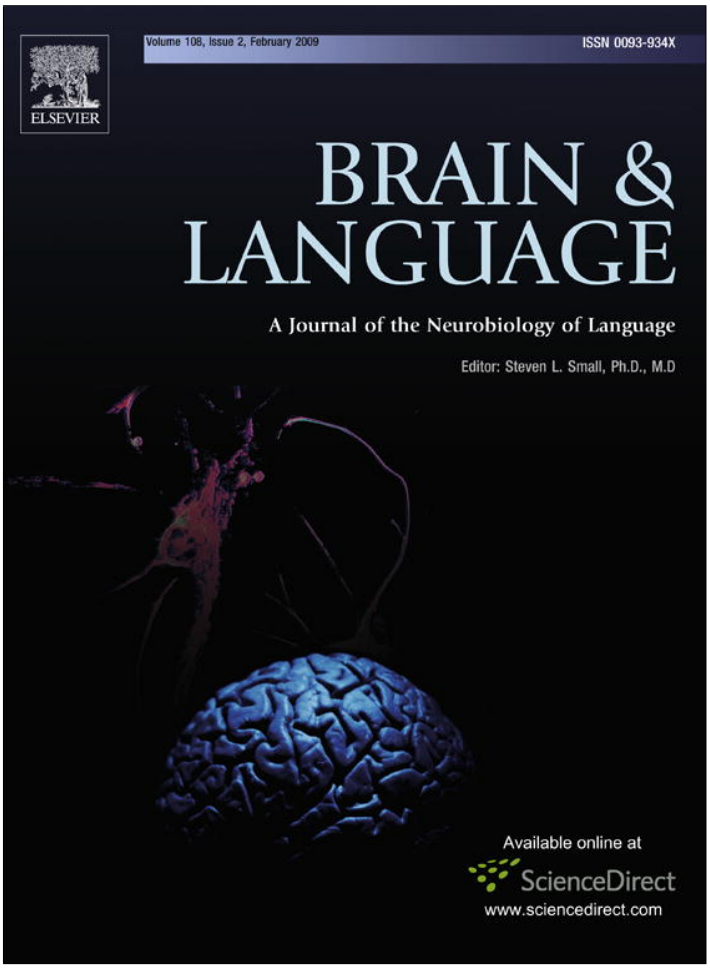

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On-line processing of tense and temporality in agrammatic aphasia

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ABSTRACT

Agrammatic aphasic individuals exhibit marked production deficits for tense morphology. This paper presents three experiments examining whether a group of English-speaking agrammatic individuals (n = 10) exhibit parallel deficits in their comprehension of tense. Results from two comprehension experiments (on-line grammaticality judgment studies) suggest that these individuals are impaired for tense comprehension, and furthermore that their deficit is more pronounced for morphosemantic rather than morphosyntactic aspects of tense processing. Results from a third experiment (an elicited production study) indicate that these individuals exhibit parallel production and comprehension impairments for tense. Across the three experiments, the consistent pattern was that of a significant difficulty in associating verb forms with a pre-specified temporal context when compared to all other processes. Implications for current models of agrammatic tense and morphological deficits are discussed.

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1. Introduction

Agrammatism, commonly associated with Broca's aphasia and other non-fluent aphasias, was initially thought to be an expressive language deficit characterized by ill-formed sentences and errors of grammatical morphology (Goodglass, 1976; Kean, 1977; Kleist, 1916). This view was revised during the 1970s, when it was reported that individuals with agrammatic speech also had difficulties in the comprehension of noncanonical, syntactically complex sentences in a sentence-picture matching task when they had to rely solely on morphosyntactic cues (VonStockert and Bader, 1976; Caramazza and Zurif, 1976). This finding of parallel asyntactic comprehension in agrammatic speakers spurred the notion of a central, modality-neutral grammatical impairment for syntactically complex sentences (Grodzinsky, 1986; Kean, 1995). However, the centrality of this impairment for complex sentences was questioned in the 1990s by extensive meta-analyses that found little association between asyntactic comprehension and agrammatic speech production (Berndt and Caramazza, 1999; Berndt, Mitchum, & Haendiges, 1996; Grodzinsky, Pinango, Zurif, & Drai, 1999). During the past decade, the question of centrality is increasingly being addressed for another symptom of agrammatism: errors in inflectional morphology (Dickey, Milman, & Thompson, 2008; Nanousi, Masterson, Druks, & Atkinson, 2006; Varlokosta et al., 2006; Wenzlaff and Clahsen, 2005).

Interestingly, production of all inflections is not equally impaired in agrammatism. Noun plural morphology (*dog-dogs*) is consistently preserved (Goodglass, Christiansen, & Gallagher, 1993; Milman, Dickey, & Thompson, 2008), and performance on subject–verb agreement morphology (*He walks, They walk*) is mostly preserved (Friedmann and Grodzinsky, 1997; Wenzlaff & Clahsen, 2004; but see Burchert, Swoboda-Moll, & De Bleser, 2005 for variable performance). In contrast, there is considerable crosslinguistic evidence that the expression of tense morphology on verbs is often compromised, with errors such as **Yesterday Mary walk to work* in a variety of tasks including spontaneous speech, elicited picture description, sentence completion, and writing (Bates, Friederici, & Wulfeck, 1987; Druks & Carroll, 2005; Faroqi-Shah & Thompson, 2003; Faroqi-Shah & Thompson, 2004; Faroqi-Shah & Thompson, 2007; Fix & Thompson, 2006; Jarema & Kehayia, 1992; Kean, 1977; Menn & Obler, 1990; Miceli, Capasso, & Caramazza, 2002; Miceli, Silveri, Romani, & Caramazza, 1989; Rochon, Saffran, Berndt, & Schwartz, 2000; Kok, van Doorn, & Kolk, 2007). Earlier hypotheses regarding tense production deficits, such as the Tree Pruning Hypothesis (TPH, Friedmann & Grodzinsky, 1997), suggested that these were restricted to the output modality, because the participant whose performance motivated the TPH had spared input processing of tense in comprehension and grammaticality judgment tasks.

However, recent data on input processing of tense morphology have been mixed. It is not clear if difficulties in the perception of

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tense morphology are invariably present in agrammatic individuals who produce errors in tense morphology. While some studies have reported preserved ability to detect tense violations (Benedet, Christiansen, & Goodglass, 1998; Friedmann and Grodzinsky, 1997; Goodglass et al., 1993; Hagiwara, 1995; Tsapkini, Jarema, & Kehayia, 2001), others have found impaired judgment of tense violations (Arabatzi & Edwards, 2002; Dickey et al., 2008; Lee, 2003; Nanousi et al., 2006; Parisi & Pizzamiglio, 1970; Wenzlaff & Clahsen, 2004). It should be pointed out that there is considerable methodological variability among these studies: the variety of tasks includes picture pointing, sentence completion, contrastive judgment (deciding which of two sentences is better), and grammaticality judgment (off-line and on-line). These task differences may be responsible for some of the variation across studies.

Most importantly, studies have also varied in the linguistic relationships they tested in connection with tense morphology. Some studies have examined adverb–verb morphology mismatches (**Tomorrow he walked*) (Dickey et al., 2008; Nanousi et al., 2006; Stavrakaki & Kouvava, 2003; Tyler, Behrens, Cobb, & Marslen-Wilson, 1990; Wenzlaff & Clahsen, 2004), while others used local syntactic violations of verb morphology (**He will walked*) (Friederici, Wessels, Emmorey, & Bellugi, 1992; Goodglass et al., 1993; Linebarger, Schwartz & Saffran, 1983). Still others do not specify the kind of violations used (e.g., Varlokosta et al., 2006). Adverb–verb morphology mismatches (henceforth called *morphosemantic mismatches*) involve a different grammatical mechanism than local syntactic mismatches: they involve an indirect semantic relationship between tense morphology and the adverb, with an optional adverb providing a temporal context which the tense form must fit with (Partee, 1984, 1973; Dickey 2001). In contrast, local mismatches involve direct syntactic relationships, with one morphosyntactic category selecting another (see Dickey et al., 2008, for discussion).

It is unclear if the contradictory findings regarding input processing of tense in agrammatic aphasia are because previous studies differed in the type of violations that were tested, or because input and output tense difficulties do not always co-occur in agrammatic aphasia. In other words, previous studies have left two questions unanswered: (1) whether the tense impairment in agrammatic aphasia is *central* and hence consistently observed in both input and output modalities, and (2) whether tense input processing deficits are morphosemantic rather than morphosyntactic[1] in nature.

1.1. The centrality of tense deficits

The empirical data regarding the centrality of tense impairments in aphasia are mixed, much like the results on input tense processing. A few previous studies have examined both sentence completion and grammaticality judgment in the same group of participants (Lee, 2003; Varlokosta et al., 2006; Wenzlaff & Clahsen, 2004). In the Wenzlaff and Clahsen (2004) study of seven German individuals with agrammatism, the correlation between sentence completion and grammaticality judgment scores for tense was weak and not significant (Pearson $r = 0.3$; $p = 0.5$).[2] In contrast, the correlation between these two measures was statistically significant in the Varlokosta et al. (2006) study of seven Greek participants (Pearson $r = 0.9$, $p < 0.01$)[2]. It should be noted however, that in the latter study, none of the participants were described as having an agrammatic speech production profile and three participants actually had fluent varieties of aphasia that are not typically associated with agrammatism (Wernicke's aphasia and anomia). Further, the correlation score may have been inflated by some participants who performed flawlessly on both tasks. Hence the issue of centrality of tense deficits in agrammatism is unresolved and needs further empirical investigation.

From a theoretical standpoint, current accounts differ regarding whether they predict a central deficit. The Tense Underspecification Hypothesis (TUH; Wenzlaff & Clahsen, 2004) and the Tense and Agreement Underspecification Hypothesis (TAUH; Burchert et al., 2005) clearly assume a central impairment and predict parallel deficits in production and comprehension of tense features. The TUH and TAUH claim that the morphosyntactic features required to license tense morphology (and possibly other features; Burchert et al., 2005) are underspecified in agrammatic individuals' syntactic representations. This underspecification should create deficits in all processes (output and input) which make reference to these features. As mentioned earlier, this is in contrast to the TPH. The original formulation of the TPH proposed a production-specific impairment, although a more recent version of the hypothesis extends it to input processing of other syntactic structures (Friedmann, 2002, 2006). The TPH claims that agrammatic individuals are often impaired in their generation of the hierarchical syntactic structure required to license tense morphology. Failure to project (or fully specify) this syntactic structure during production results in failure to produce tense morphology. The TPH thus predicts a non-central deficit, one appearing in production only.

The Diacritical Encoding and Retrieval Hypothesis (DER; Faroqi-Shah & Thompson, 2007) is based on forced-choice sentence completion and picture description (Faroqi-Shah & Thompson, 2004) data from English-speaking agrammatic individuals. In contrast to the other hypotheses described above, the DER claims that difficulties in production arise from a higher level morphosemantic deficit, rather than from deficits in morphosyntactic well-formedness constraints. More specifically, the morphosemantic impairment is described as a difficulty in translating the tense encoded in the message into diacritical features such as +PAST, and/or in selecting and retrieving verb forms that correspond to the encoded tense. Although no statements are made regarding input processing or the centrality of tense deficits in DER, the claim of a morphosemantic impairment implies that input processing tasks that rely on selection of a verb form are likely to be compromised. That is, comprehension processes which depend on selecting a verb form given some conceptual-semantic information (such an adverb) may be expected to be impaired.

To summarize, the TUH and TAUH assume that the tense deficit is central, the TPH assumes that it is more production based, while the DER does not explicitly state its position on centrality. Instead, it refers to the type of mental operation that is impaired. The question of centrality of tense impairments needs further investigation.

1.2. The nature of tense processing deficits

Recent research has unraveled some interesting and yet unresolved issues about tense deficits in agrammatism. First, as mentioned earlier, it is unclear if contradictory findings reported in previous studies are an artifact of the type of tense violations that were used (morphosemantic versus morphosyntactic). This issue can be resolved by comparing the judgment of morphosemantic and morphosyntactic violations in the same group of individuals. It is important to address this question in light of the dissociation between morphosemantic and morphosyntactic manipulations

[1] Not all authors distinguish between morphosyntax and morphosemantics, preferring to use the term morphosyntax for all higher level non-morphophonological operations (Badeckar, 1997; Druks, 2006; Friedmann & Grodzinsky, 1997). However, recent findings warrant a distinction between these two aspects (Faroqi-Shah & Thompson, 2007). In this paper, *morphosyntax* refers to well-formedness constraints, and *morphosemantics* refers to conceptual-semantic aspects such as temporal reference (tense and aspect) and mood.

[2] These correlations were computed by us on the basis of scores provided in the original articles (Wenzlaff & Clahsen, 2004: Tables 2 and 3; Varlokosta et al., 2006: Tables 6 and 9).

reported in a recent study using a sentence completion paradigm (Faroqi-Shah & Thompson, 2007). Using a forced-choice sentence completion task, Faroqi-Shah and Thompson found that deficits of verb morphology are significantly greater for stimuli that demand morphosemantic processing (*Tomorrow, the theatre* _____ [was closing, will close, closed]) when compared to morphosyntactic processing (*The theatre will* ____ [close, closing, closed]). This issue is also important for distinguishing among the theories of agrammatic tense deficits described above. The TPH, TUH, and TAUH all assume that tense deficits are morphosyntactic in nature, due to underspecified morphosyntactic features or impaired hierarchical syntactic structure. In contrast, the DER claims that tense deficits are morphosemantic in nature. Knowing whether the same individuals are more (or less) impaired for morphosyntactic or morphosemantic violations will help decide among these competing hypotheses.

The second unresolved issue relates to the position of the adverb in the sentence. In experimental paradigms, morphosemantic violations are created by a mismatch between the temporal adverb and the verb form (Dickey et al., 2008; Nanousi et al., 2006; Stavrakaki & Kouvava, 2003; Tyler et al., 1990; Wenzlaff & Clahsen, 2004). In English and in many other languages, adverbials can either precede (henceforth *pre-posed*) or follow (*post-posed*) the verb phrase. The mental operations required to detect adverb–verb mismatches in each of these positions are not identical, especially if a timed on-line task is used. The temporal context of the sentence is laid out by the adverb when it is pre-posed, but by the verb morphology when the adverb is post-posed. This difference in listener expectancy (assuming that there is no deficit in interpreting the meaning of temporal adverbs) can provide insights into the nature of tense processing deficits. Significantly greater difficulty in interpreting pre-posed versus post-posed sentences indicates difficulty in accurately retrieving/encoding verbal morphology that corresponds to a specific tense (for example, past tense is expressed with *pushed*), while poorer performance with post-posed adverbial sentences indicates a deficit in extracting tense information specifically from verbal morphology (*pushed* denotes past tense). If performance of pre-posed and post-posed sentences is comparable, the interpretation is a more general difficulty in processing all temporal aspects of a linguistic message (the notion of past tense can be conveyed by *yesterday* and by *pushed*).

This comparison is particularly relevant because sentence completion data indicate an asymmetric pattern of performance for morphosemantic processing during production (Faroqi-Shah, 2006). Agrammatic aphasic individuals were significantly more impaired in tasks that required selection of verb morphology when provided temporal information (*Tomorrow, the dog* _____ [will bark, barks, is barking]) when compared to selection of temporal information when provided with verb morphology (_____ *the dog will bark* [Tomorrow, Yesterday, Nowadays]). These findings indicate a relatively spared ability to interpret the tense conveyed by verb morphology, but an impairment in translating encoded tense into verb morphology, (See also Arabatzi & Edwards, 2002; Dickey et al., 2008; Thompson, Fix, & Gitelman, 2002; for a similar suggestion regarding difficulty in selecting morphemes that match the morphosyntactic features of a sentence).

The third unresolved issue addressed in the present study concerns the type of tense. One theoretical account predicts a semantic hierarchy of difficulty across tense types and hence a differential breakdown in aphasia for production tasks (Lapointe, 1985; Lapointe & Dell, 1989). According to this hierarchy, verb stems are the least marked, followed by present progressive tense, present third person singular (present) tense, and past tense, in that order. Lapointe proposed that verb inflection errors in agrammatic aphasia result from a reduction in available processing resources which limits the ability to perform an extensive search through the mental lexicon, resulting in substitution errors that conform to the above mentioned markedness hierarchy. Some studies have indeed found a greater error rate in the production of past tense (Bastiaanse, 2008 [Dutch]; Stavrakaki & Kouvava, 2003 [Greek]). However, most studies do not report differential impairments of tense in production (Burchert et al., 2005; Faroqi-Shah, 2006; Faroqi-Shah & Thompson, 2004, 2007; Wenzlaff & Clahsen, 2004, 2005). Examining the question of tense hierarchies in production data can be tricky, partly because of the occurrence of "homoaffixes" (identical phonological verb form used for semantically distinct finite or non-finite verbs, such as [d] for past tense and past participle in English and [en] for third person present plural and infinitive in Dutch), "polyaffixes" (single affix representing multiple functional categories, such as [s] in English which marks both singular present tense and subject–verb agreement), and tense marking on the auxiliary in many languages. This makes it difficult to unambiguously tally accuracy and interpret substitution errors. Further, verb form substitutions may be influenced by other downstream production phenomena such as frequency of occurrence (surface or affix) and phonological complexity (Centeno, Obler, Cairns, Garro, & Merrifield, 1996; Kohn & Melvold, 2000; Penke, 2003). Hence the question of tense effects may be better examined using an input task where "homoaffixes" can be disambiguated by the temporal context of the sentence. A recent study that compared on-line grammaticality judgment of various functional categories in agrammatic aphasia found no difference across tenses (Dickey et al., 2008). In the present study, we examined this question further.

The fourth unresolved issue addressed in the present study concerns the location of tense marking. In English, tense may be marked either on a free-standing auxiliary or as an affix on a verb. Affixes are often phonologically reduced, or create clusters which are difficult to pronounce or perceive. The markedness hierarchy described by Lapointe (1985) reflects these factors: the two most marked tense forms (third-person singular present tense, past tense) involve phonetically minimal affixes which create word-final consonant clusters. This phonological complexity may contribute to these tense forms' relative impairment in aphasia (see den Ouden & Thompson, 2006). However, there is also evidence suggesting that tense impairments are not reducible to any difficulty associated with bound affixes. Dickey et al. (2008) directly compared English-speaking agrammatic individuals' accuracy in judging tense violations marked on verbs and auxiliaries and found no difference between tense markers in the two locations. This finding suggests that agrammatic tense deficits (at least as they appear in comprehension) are not due to perceptual salience or other lower-level factors, but instead target tense morphology, wherever it is marked. Replicating this finding would strengthen the case that agrammatic tense deficits are the result of deficits in translating morphosyntactic or morphosemantic features into surface grammatical forms (Faroqi-Shah & Thompson, 2007).

To summarize, further research is needed to disambiguate morphosyntactic versus morphosemantic aspects of tense processing in agrammatic aphasia. The existing results are unclear regarding what role, if any, is played by three factors: the position of the adverb, type of tense, and location of the tense marker. Furthermore, the issue of centrality of tense deficits is also unresolved, as noted above.

1.3. Purpose

This study investigated three aspects of tense processing in individuals with agrammatic aphasia. The first purpose was to examine whether agrammatic aphasic individuals were impaired in morphosyntactic processing, and whether variables such as the location of tense marking influenced performance. These

questions were addressed in Experiment 1. The second purpose was to examine the extent and nature of morphosemantic processing in the same group of agrammatic aphasic individuals (Experiment 2). In addition, the influence of variables such as the type of tense, location of the tense marker, and the position of the adverb was examined. The third purpose of this study was to examine the question of centrality of tense deficits. That is, whether the production of tense in narrative and picture description tasks correlated with morphosyntactic and morphosemantic processing. This question was addressed in Experiment 3, where tense production scores were correlated with accuracy scores obtained from Experiments 1 and 2.

2. Experiment 1: Judgment of morphosyntactic constraints

This experiment used an on-line grammaticality judgment task to investigate agrammatic aphasic individuals' ability to detect local violations of verb morphology. Their accuracy was compared to sentences with semantic or plural marking anomalies (within group factor) and with that of age and education-matched individuals with no brain damage (between group factor). Based on previous findings, it was expected that the agrammatic inidviduals' ability to detect morphosyntactic violations, while being worse than age-matched control participants, would be relatively preserved (Faroqi-Shah & Thompson, 2007; see also Goodglass et al., 1993).

2.2. Methods

2.2.1. Participants

Ten individuals with aphasia and ten age-matched normal volunteers participated in the study. The ten normal volunteers (6 female) were matched in approximate age (range: 46–67 years; mean: 67 years) and education (range: 12–24 years; mean: 16 years) to the aphasic participants. All participants were right-handed, native speakers of North American English, with at least high school education. None of the normal participants reported hearing loss, prior speech–language difficulties, prior history of substance abuse, neurological disorders, or psychiatric conditions.

Aphasic participants (3 female) had a mean age of 55.9 years (range: 37- 68 years) and an average of 16.8 years of education (range: 13- 20+ years). All participants were native speakers of North American English. AP-1 was a Chinese–English bilingual, but he considered English to be his primary language. Nine were pre-morbidly right-handed and one was left-handed. All aphasic participants had a single left hemisphere lesion resulting from a cerebrovascular accident (CVA) in the region of the middle cerebral artery and were all at least one year post-onset. With the exception of AP-8, all had a lesion of the left middle cerebral artery. None of the aphasic participants had complicating medical or neurological conditions such as alcohol/drug abuse, dementia, or psychiatric disturbances. All participants passed a puretone audiometric screening at 500, 1000 and 2000 Hz at 40dBHL ANSI:1969 in at least one ear. One participant's (AP-1) hearing was not tested because he used a hearing aid in his left ear to correct his hearing to normal, as per his audiological report. The corrected visual acuity of all participants measured at least 20/40 on the Snellen's chart. Demographic details of all aphasic participants are provided in Table 1.

2.2.2. Language testing

All aphasic participants completed a set of pre-tests that were intended to establish their diagnosis of Broca's aphasia with agrammatic speech, characterized by errors in the production of inflectional morphology. The tests and their findings are described below and summarized in Table 2. Inclusionary criteria were: a profile of Broca's aphasia, absence of significant apraxia or dysarthria, functional reading abilities, and difficulty with verbal morphology as determined from narrative speech and a verb inflection pretest. The diagnosis of Broca's aphasia was made by a speech–language pathologist using a standardized aphasia test, the Western Aphasia Battery (WAB) (Kertesz, 1982). As per the WAB, all participants had impaired sentence structure and fluency (a fluency score of 5 or lower on the WAB), with relatively spared auditory comprehension (score of 6.9 or higher on the comprehension subtests), and oral repetition (score of 3 or higher on the WAB). Three single word reading subtests of the WAB, subtests C (written word stimulus-object choice matching), D (written word stimulus-picture matching), and E (picture stimulus-written word choice matching) were also administered to test overall single word reading capability, and all participant scores exceeded 80%. Aphasic individuals were screened for motor speech disorders such as dysarthria and apraxia using the oral expression subtest of the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass, Kaplan, & Barresi, 2001). This subtest includes measures of verbal and non-verbal agility. The maximum score for the verbal and non-verbal agility subtests are 14 and 8, respectively.

Narrative speech was elicited by having participants describe the cookie theft picture, which is a part of the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass et al., 2001) and four other unpublished pictures. Narratives were transcribed and coded for lexical and syntactic measures using SALT V8 (Systematic Analysis of Language Transcripts; Miller, 2004). SALT was used to calculate rate of speech, mean length of utterance, proportion of sentences, proportion of grammatical sentences, noun–verb ratio, open-closed class ratio, proportion of affixed verbs, type-token ratio of tense, and accuracy of tense marking. These values are given in Table 2. All participants had a reduced speech rate when compared to normal individuals (107 to 232, Rochon et al., 2000). The speech of all participants showed features of agrammatic speech as revealed by reduced proportions of sentences, grammatical sentences, affixed verbs, and accurate tense marking, as well as by increased values for noun–verb ratio and open-closed class ratio (Saffran, Berndt, & Schwartz, 1989).

Table 1
Demographic details of participants.

Participant	Age (years)	Gender	Premorbid handedness	Education years/ highest degree	Premorbid occupation	Etiology	Years post-onset
AP1	59	M	R	20+/Ph.D.	Self-owned business	CVA of left internal carotid artery	3
AP2	68	F	R	18/ M.S.	Elementary School counsellor	CVA of left middle cerebral artery	1
AP3	65	M	R	18/M.S.	Mechanical Engineer	CVA of left hemisphere	1.5
AP6	66	F	R	16/B.A.	Office Clerk	CVA of left middle cerebral artery	9
AP8	48	F	L	16/B.A.	Audit Coordinator (Analyst)	CVA of right middle cerebral artery	2
AP10	37	M	R	16/B.A.	Police Officer	CVA of left middle cerebral artery	7
AP12	61	M	R	15/High School Diploma	Mortgage Consultant	CVA of left hemisphere	1
AP13	56	M	R	18/M.A.	Office manager	CVA of left hemisphere	3
AP14	44	M	R	18/M.S.	Software Engineer	CVA of left hemisphere	1
AP15	55	M	R	13/High School Diploma	Insurance Adjuster	Multiple CVAs of left hemisphere	1

Table 2
Language performance of aphasic participants.

Measure	Participants									
	AP1	AP2	AP3	AP6	AP8	AP10	AP12	AP13	AP14	AP15
[a]*WAB AQ (maximum = 100)*	66.8	65.4	65.9	53.9	84.6	77.4	57.2	72.9	45.6	80.5
Fluency (maximum = 10)	4	1.5	4	5	6	5	5	3	4	4
Comprehension (maximum = 10)	7.6	6.72	8.8	6.45	10	8.5	6.6	8.55	9.3	9.45
Repetition (maximum = 10)	6.4	9	6.8	9	7.8	7.8	4.5	9.6	5.9	9.2
Naming (maximum = 10)	6.4	7.5	6.1	3.5	8.4	8.4	6.5	5.3	7.6	8.6
[b]*Verb inflection sentences*	30%	10%	0%	0%	35%	55%	15%	17%	0%	25%
[c]*Word repetition*										
Regular verbs	85%	80%	80%	90%	97%	83%	96%	63%	91%	100%
Irregular verbs	90%	95%	70%	63%	93%	97%	73%	97%	100%	100%
Narrative speech										
Rate (words per minute)	58.81	57.73	29.04	53.09	36.04	30.3	74.93	55.81	56.12	68.75
Mean length of utterance (words)	4.78	4.67	5.57	4.29	5.43	4.29	5.28	6.38	4.25	4.29
Proportion sentences	0.35	0.42	0.48	0.66	0.44	0.77	0.88	0.80	0.71	0.60
Proportion grammatical sentences	.55	0.35	0.38	0.20	0.60	0.45	0.67	0.56	0.06	0.48
Open: closed class ratio	1.03	3.2	2.5	0.95	0.99	1.7	3.4	2.8	2.42	1.92
Proportion verbs	0.26	0.23	0.33	0.48	0.15	0.41	0.33	0.16	0.09	0.22
Proportion affixed verbs	0.76	0.81	0.86	0.25	0.88	0.84	0.80	0.65	0.77	0.65
Accuracy of tense	0.62	1.00	0.92	0.23	0.94	0.72	0.92	0.84	0.14	0.88
Type-token ratio of tense	0.25	0.17	0.17	0.38	0.10	0.22	0.17	0.14	0.11	0.28

[a] Western Aphasia Battery (Kertesz, 1982); AQ, Aphasia Quotient.
[b] Faroqi-Shah (in press).
[c] Stimuli taken from Bird, Ralph, Seidenberg, McClelland, Patterson (2003).

2.2.3. Materials

Ten regularly inflected mid-frequency agentive verbs were used to create 100 sentences. A variety of affixes and auxiliaries (past, present, and future, in the case of auxiliaries) were used in the sentences, and the location of the tense marker in the sentences was specifically manipulated (auxiliary, main verb). Anomalous sentences were created in two ways: changing the auxiliary (in cases where tense was marked on the auxiliary) such that the resulting auxiliary-verb inflection combination was ill-formed (such as, *The nurse (will→) is call a doctor*). This was called the auxiliary violation. The second manner in which anomalous sentences were created was by using a verb form that did not grammatically occur without a preceding auxiliary/modal (such as *The nurse calling a doctor*). This was called the main verb condition. A small proportion of sentences in the main verb condition (7/40sentences) contained errors that could also be agreement violations (*The baby spill the milk*[3]). However, for the purpose of this experiment, the crucial point is that all sentences contained a syntactic violation in rule-based expectancy. Since correct identification of verb endings is crucial for accurate performance in this experiment (as well as in Experiment 2), care was taken to follow verbs with words that made the verb ending auditorily salient by limiting the possibility of coarticulation. So *called a doctor* was used instead of *called the doctor*. The experimental sentences were an average of 6.7 words long (range: 4–9). In addition, 75 anomalous filler sentences were created using either semantically implausible sentences or plural marking errors on nouns (range of words in each sentence: 4–10 words, mean: 7.1). These filler sentences served as control comparisons.

All the sentences were digitally recorded in a sound treated room by a male native speaker of North American English. All sentences were read with natural intonation and a slightly slower than normal rate of speech. The sentences were pseudo-randomized by including the 200 stimuli of Experiment 2 and sorted into four presentation lists, such that the same experimental condition or verb did not occur twice in succession. The ratio of correct to incorrect sentences was 2:3. The distribution of stimuli and examples are given in Table 3.

[3] We thank an anonymous reviewer for pointing this out.

2.2.4. Procedure

The experiment was approved by the Institutional Review Board of the University of Maryland, College Park. All participants gave informed consent and were paid for their participation. Participants were tested individually in a room free of distractions. The experimenter sat in the room during the session. The experimenter verbally instructed participants to press a key (the *Z* key on the keyboard coded with a smiley face sticker for the purpose of this experiment) if the sentences were correct and to press a different key (*X* key) if the sentences were incorrect or did not make sense. They were instructed to respond as quickly and accurately as they could. All participants sat facing the computer monitor during the experiment and were instructed to respond with their left index (*X* key) and middle (*Z* key) fingers.

The experiment was presented using Superlab Pro version 2.0.4 (Cedrus Corporation) running on a desktop or laptop PC with external speakers. Five practice items preceded the actual experimental stimuli. Practice items were repeated for aphasic participants at their request. Each trial began with an auditory signal (beep) and the stimulus sentence played 300 ms after signal onset. The next trial began 7500 ms after the onset of the stimulus sentence, giving sufficient time for delayed responses. The computer screen displayed a fixation cross during the entire duration of the experiment. Participants were given a break at the end of each block, with a total of four blocks in the experiment. Age-matched control participants completed the entire experiment in a single session. Testing for aphasic participants was typically spread over two sessions, each on a different day. The entire experiment took about 75–80 min to complete. No feedback regarding accuracy was provided.

2.2.5. Data Analysis

The two dependent measures were accuracy and reaction time. Reaction times were measured from the offset of the verb (either inflected or uninflected) to correct for differences in length across experimental stimuli. The timing of the verb offset was measured manually by two trained researchers (both native speakers of American English) using Praat version 4.3.02 (Boersma & Weenik, 2005). These measurements were carried out for the experimental

Table 3
Conditions and examples of stimuli for Experiments 1 and 2. The ^ indicates the critical sentence position used to measure reaction time. *N* refers to the number of stimuli.

Experiment	Adverb position	Tense marking	Tense	*N*	Example
Experiment 1					
Morphosyntactic processing		Main verb		40	The nurse called ^/calling^a doctor
					The nurse calls^/call^ a doctor
		Auxiliary		60	The nurse has called^/does not called^ a doctor
					The nurse is calling^/will calling^ a doctor
					The nurse will call^/is call^ a doctor
Experiment 2					
Morphosemantic processing	Pre-posed	Main verb	Past	20	Last year/next year, my sister lived^ in New Hampshire
					Yesterday/tomorrow, the cancer patient needed^ an X-ray
			Present	20	These days/last year, my sister lives^ in Boston
					Today/yesterday, the student knows^ the answer
		Auxiliary	Past	20	Last year/next year, my younger step-sister did^ not live in Boston
					Yesterday/tomorrow the car crash victim did^ not have an X-ray
			Present	20	These days/last month, my younger sister does^ not live in Boston
					Today/yesterday, the new honors student does^ not know the answer
			Future	20	Next year/Last year, my sister will^ live in Boston
					Tomorrow/yesterday, the honors student will^ know an answer
	Post-posed	Main verb	Past	20	My sister lived in New Hampshire last^ year/next^ year
					The ban on swimming remained in force yesterday^ /tomorrow^
			Present	20	My sister lives in New Hampshire these^ days/last^ month
					The patient has chest pain today^/ yesterday^
		Auxiliary	Past	20	My sister did not live in Boston last^ year/next year^
			Present	20	My sister does not live in Boston these^ days/last^ year
			Future	20	My sister will live in Boston next^ year/last^ year
Experiment 1 and 2					
Filler sentences				75	The old table ran to the zoo
					I waited five hour for the concert tickets
					The girl ate many cookie

stimuli from Experiments 1 and 2 together (a total of 300 sentences). Point-to-point inter-rater agreement was calculated for these measurements, with two measurements counting as agreeing if they were within 50 ms of one another. Inter-rater reliability using this criterion was 88.3%, with a mean disagreement of 2 ms. In cases of conflict, the judgment of the first coder was used.

2.3. Results

The accuracy and RT data for the aphasic and control participants are presented by condition in Fig. 1.

The bars represent mean accuracy (scale on the left-hand side of the graph) and the connected lines represent mean RT (scale on the right-hand side of the graph). The left-hand set of figures represents the aphasic participants' performance, while the right-hand set of figures represents control participants' performance. Since reaction times for the filler items were not corrected by measuring from the position of a potential violation, they are not plotted here or analyzed below.

Accuracy data were analyzed first. The first analysis compared accuracy for fillers and the experimental sentences as a group. Aphasic and control participants' mean accuracy for experimental and filler sentences was compared in a two-way analysis of variance, with sentence type (experimental vs. filler) as a within-participants factor and group as a between-participants factor. This analysis revealed significant main effects of group ($F[1,18]=21.51$, $p < 0.05$) and sentence type ($F[1,18]=68.61$, $p < 0.05$), with aphasic participants being less accurate than controls overall (aphasic group mean: 69%, control group mean: 86%) and experimental sentences eliciting less accurate responses than fillers (77% vs. 96%). Furthermore, there was a significant interaction of group and sentence type ($F[1,18]=15.92$, $p < 0.05$). A pair of planned comparisons revealed that while the two groups did not differ in their performance on the fillers (aphasic group mean: 96%, control group mean: 96%; $t(18)=0.44$, $p > 0.05$), they did differ significantly in their performance on the experimental sentences (aphasic group mean: 68%, control group mean: 86%; $t(18)=4.40$, $p < 0.05$).

A second analysis examined the experimental sentences alone, looking at the effect of main-verb versus auxiliary tense violations. Aphasic and control participants' mean accuracy for both conditions was compared in a two-way analysis of variance, with tense marker position (main-verb vs. auxiliary) as a within-participants factor and group as a between-participants factor. This analysis revealed a significant main effect of group ($F[1,18]=19.35$, $p < 0.05$), with aphasic participants being less accurate than controls overall (aphasic group mean: 69%, control group mean: 86%). However, there was no evidence of a main effect of violation position ($F[1,18]=2.15$, $p > 0.05$) or of an interaction of group and violation position ($F[1,18]=0.48$, $p > 0.05$).

Reaction times were analyzed next. The effect of main-verb versus auxiliary tense violations was examined in a two-way analysis of variance, with tense marker position (main-verb vs. auxiliary) as a within-participants factor and group as a between-participants factor. This analysis revealed significant main effects of group ($F[1,18]=6.15$, $p < 0.05$) and violation position ($F[1,18]=5.17$, $p < 0.05$). Aphasic participants were slower than controls overall (aphasic group mean: 1753 ms, control group mean: 1199 ms) and main-verb violations were detected more slowly than auxiliaries (1536 vs. 1415 ms). However, there was no evidence of an interaction of group and violation position ($F[1,18]=0.49$, $p > 0.05$). The two groups thus exhibited similar patterns.

2.4. Discussion

Several important generalizations emerge from the results. First, the judgment of morphosyntactic violations was a challenging task, even for normal speakers, attested by their 86% accuracy. Although agrammatic individuals were significantly impaired compared to controls for the judgment of tense anomalies, the overall aphasic performance was above chance (69%). In addition, when the anomalies were created by either mismatching plural marking or pragmatic implausibility (as in the fillers), there was not a difference between aphasic participants and controls and the average accuracy exceeded 95% for both groups.

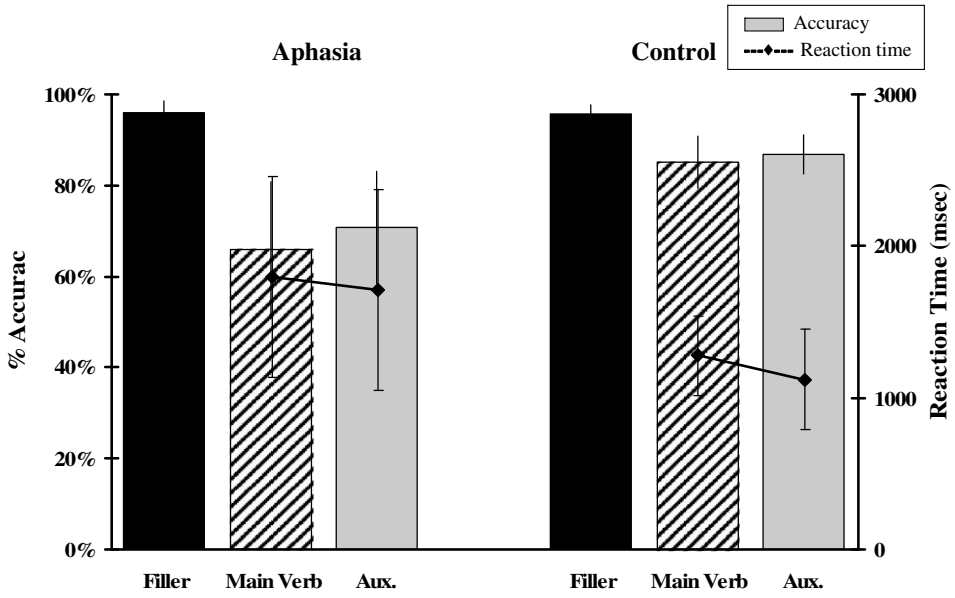

Fig. 1. Mean accuracy and reaction time of control and aphasic participants for Experiment 1. The bars represent mean percent accuracy (scale on left) and the lines represent mean reaction time in milliseconds (scale on right).

Second, morphosyntactic factors relevant to tense processing did not strongly affect aphasic participants' performance in this experiment. The aphasic participants performed equally accurately when the inappropriate verb morphology was associated with a main verb as when it involved a mismatch between a main verb and an auxiliary. The lack of a difference between main-verb and auxiliary conditions suggests that this morphosyntactic difference was relatively unimportant for these aphasic individuals. It is also consistent with previous results finding no clear evidence of a difference between main-verb and auxiliary marking among English-speaking agrammatic individuals (Dickey et al., 2008). Furthermore, it shows that these agrammatic individuals' impairments with tense marking were not specific to main verb affixal morphology. They are therefore unlikely to be reducible to issues of phonetic or perceptual salience, or to morphological decomposition of regular verbs (Tyler, Randall, & Marsel-Wilson, 2002; Ullman, Corkin, Coppola, & Hickok, 1997).

Third, reaction times did provide some evidence of a difference between main-verb and auxiliary mismatches, with main-verb mismatches eliciting slower judgments than auxiliary mismatches. However, this difference was not specific to aphasic participants: both aphasic and control participants were slower with main-verb conditions, to a comparable degree. Although there is no straightforward explanation for this difference, it is possible that the presentation of an auxiliary builds up a strong expectancy for a particular verb affix, and hence violations in the auxiliary condition are rejected more quickly. Main verb violations do not possess this expectancy advantage and hence may be associated with longer response times. Given that a small proportion of the sentences in the main verb condition (7/40) contained violations that could also be interpreted as agreement violations (e.g., *The baby spill milk* could be repaired as *The babies spill milk* or *The baby spills milk*, and additionally *The baby spilled milk*), one might have expectedmain verb errors to be detected faster, not slower, than auxiliary errors, since agreement has been reported to be less impaired than tense marking among agrammatic individuals (e.g., Friedmann & Grodzinsky, 1997). The fact that main-verb violations were detected slower suggests that the agreement factor was not relevant. Furthermore, although auxiliaries are more frequent than the main verbs used in this experiment, this frequency difference is unlikely to be the source of the results, because the error could only be detected (and reaction times were measured) from the offset of the verb in both conditions (see Table 3).

To summarize, the results of this experiment provide evidence that the agrammatic aphasic individuals exhibit a deficit in input processing of tense morphology, not simply any grammatical morphology (such a plural marking) or any sentential anomaly (such as pragmatic anomalies). There is little evidence that this impairment is affected by factors such as position of tense marking, at least for this group of individuals. Experiment 2 tested for morphosemantic effects on tense processing.

3. Experiment 2: Judgment of morphosemantic anomalies

The purpose of this experiment was to examine agrammatic aphasic individuals' ability to judge sentences with long distance tense violations, using the on-line grammaticality judgment methodology used in Experiment 1. As discussed in the Introduction, these violations are associated with morphosemantic processing, checking whether a tense marker is compatible with the temporal information provided by an (optional) adverb. These morphosemantic violations were the primary cases tested in this experiment. Furthermore, the position of the adverb (pre-posed versus post-posed) was manipulated. Recent results have shown that aphasic individuals are more impaired in finding the appropriate tense marker given an adverb than in locating an appropriate adverb given a tense marker (Faroqi-Shah, 2006). As discussed above, differences in processing of pre-posed and post-posed adverbs can throw light on the nature of the tense deficit, helping to diagnose whether it is specific to locating the right morphology given temporal information (viz. Faroqi-Shah & Thompson, 2007), or whether processing of all temporal information is impaired.

In addition, tense form (another morphosemantic factor) was specifically manipulated in this experiment, comparing performance with past tense, present tense and future tense sentences. Some studies (Bastiaanse, 2008, Stavrakaki & Kouvava, 2003) have found that agrammatic aphasic individuals have particular difficulty with past-tense sentences, while others (Dickey et al., 2008; Faroqi-Shah & Thompson, 2007) have not. Finally, tense marker position (main verb vs. auxiliary) was also manipulated in this study.

3.1. Methods

3.1.1. Participants

The ten aphasic and matched normal individuals of Experiment 1 participated in this experiment.

3.1.2. Materials

A set of ten mid-frequency verbs stative verbs were used in the long distance condition to create 200 sentences with the following three nested factors: (a) position of the adverb (pre-posed, post-posed), (b) location of tense marker (auxiliary or main verb), and (c) type of tense (past, future, present). Stative verbs were chosen to ensure that the simple present tense (used in present-tense main verb conditions) would sound natural, since previous studies have found that unimpaired control participants are less likely to accept agentive/eventive verbs in the simple present (Dickey et al., 2008). The stimuli were developed such that there were no significant differences in the number of intervening words across the factors being compared. This was achieved by inserting "padding elements" such as adjectival phrases (*the young step-sister* in Table 3) and phrasal nouns (such as *New Hampshire* versus *Boston*, where *New Hampshire* was counted as two words). Phrasal adverbs were treated as consisting of two words. There was no significant difference in the number of words that occurred between the adverb and tense marking element (auxiliary/main verb) in both the pre-posed (mean = 3.3 words, $SD = 1.03$) and post-posed (mean = 3.0 words, $SD = 1.07$) conditions ($t(1,48) = 1.1$, $p > 0.05$). This manipulation ensured that any differences between the pre-posed and post-posed conditions would not be due to differences in simple linear distance between the tense marker and the adverb. In each of the three tense conditions, an equal number of lexical (yesterday, tomorrow, now) and phrasal (next week/month/year, last week/month/year) adverbs were used. Although there was a marginal difference in the mean number of intervening words between the tense marker and temporal adverb for lexical and phrasal stimuli (3.3 versus 2.95), this difference was not significant ($t(1, 48) = 1.8$, $p = 0.09$), and was constant across the experimental conditions. As is shown in Table 3, anomalous sentences were created by using adverbs that did not match the verb tense. The same ten verbs were used in all the long distance conditions to ensure that performance differences between items were not the result of any lower-level verb specific lexical factors such as frequency, argument structure and syllable number. The experimental sentences were an average of 8.3 words long (range: 5–12 words).

All the sentences were digitally recorded in a sound treated room by a male native speaker of North American English and were read with natural intonation and a slightly slower than normal rate of speech. The sentences were pseudo-randomized by including the 100 stimuli of Experiment 1 and the 75 control sentences and sorted into four presentation lists, such that the same experimental condition or verb did not occur twice in succession.

Reaction times were measured from the offset of the critical word (as in Experiment 1). In pre-posed sentences, the critical word was the verb offset, while in post-posed sentences, it was the offset of the temporal adverb. As shown in Table 3, temporal adverb offset was measured from the first word in phrasal adverbs because this word conveys the crucial temporal information (next, last, etc.).

3.1.3. Procedure

Data were collected in the same session as Experiment 1. Once again, two dependent measures were used, accuracy and reaction time. Reaction times in this experiment were measured from the offset of either the verb (in pre-posed conditions) or the adverb (in post-posed conditions) to correct for differences in length across experimental stimuli (see Table 3). The procedures and data analysis were otherwise identical to those of Experiment 1. See Section 2.1.4 and 2.1.5 above for further detail.

3.2. Results

The accuracy and reaction-time data for the aphasic and control participants are presented by condition in Fig. 2.

The bars represent mean accuracy (scale on the left-hand side of the graph) while the connected lines represent mean RT (scale on the right-hand side of the graph). The left-hand set of figures represents the aphasic participants' performance, while the right-hand set of figures represents control participants' performance.

Accuracy data were analyzed first. The first analysis compared the effects of pre-posed and post-posed adverbs on both groups' accuracy. Aphasic and control participants' mean accuracy for pre-posed and post-posed sentences was compared in a two-way analysis of variance, with adverb position (pre-posed vs. post-posed) as a within-participants factor and group as a between-participants factor. This analysis revealed a significant main effect of group ($F[1,18] = 54.04$, $p < 0.05$), with aphasic participants being less accurate than controls overall (aphasic group mean: 63%, control group mean: 88%), but no evidence of a main effect of adverb

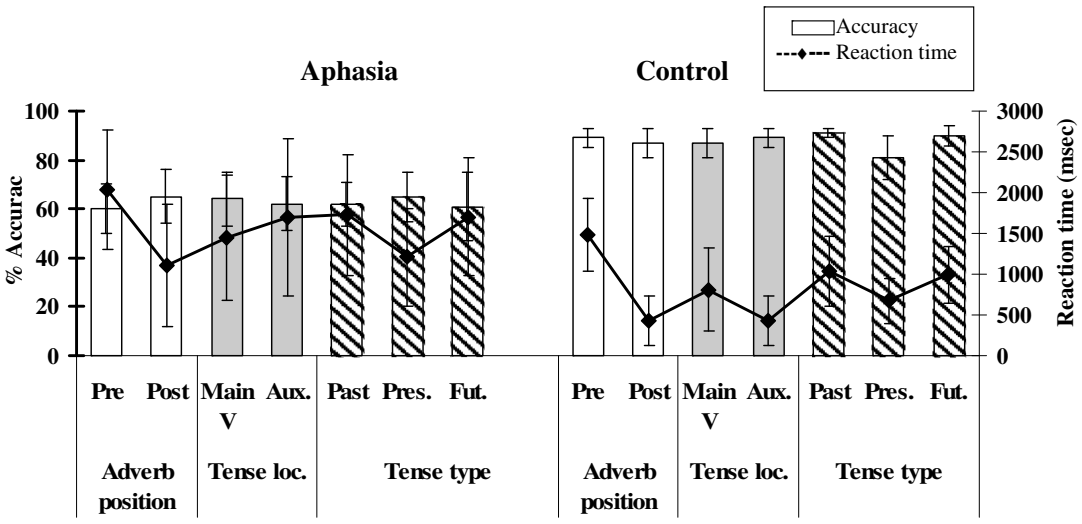

Fig. 2. Mean accuracy and reaction time of control and aphasic participants for various conditions in Experiment 2. The bars represent mean percent accuracy (scale on left) and the lines represent mean reaction time in milliseconds (scale on right).

position ($F[1,18] = 2.05$, $p > 0.05$). However, there was a significant interaction of group and adverb position ($F[1,18] = 12.40$, $p < 0.05$). A pair of planned comparisons revealed that while control participants did not differ in their accuracy for pre-posed and post-posed conditions (pre-posed: 90%, post-posed: 88%; $t(9) = 1.68$, $p > 0.05$), the aphasic participants did show significantly worse performance for pre-posed conditions (pre-posed: 61%, post-posed: 65%; $t(9) = 3.16$, $p < 0.05$).

A second analysis compared the effects of tense form on aphasic and control participants' performance. Aphasic and control participants' mean accuracy was compared in a two-way analysis of variance, with tense form (present vs. past vs. future) as a within-participants factor and group as a between-participants factor. This analysis again revealed a significant main effect of group ($F[1,18] = 48.09$, $p < 0.05$), but no evidence of a main effect of tense form ($F[1,18] = 1.60$, $p > 0.05$). However, there was a significant interaction of group and tense form ($F[1,18] = 6.89$, $p < 0.05$). Planned comparisons revealed that aphasic participants did not differ in their accuracy for past, present, and future conditions (past: 62%, present: 65%, future: 62%; past vs. present, $t(9) = 1.07$, $p > 0.05$; future vs. present, $t(9) = 1.05$, $p > 0.05$; past vs. future, $t(9) = 0.62$, $p > 0.05$). Unexpectedly, however, control participants were significantly less accurate for present-tense than for past or future sentences (past: 92%, present: 82%, future: 90%; past vs. present, $t(9) = 3.42$, $p < 0.05$; future vs. present, $t(9) = 3.00$, $p < 0.05$; past vs. future, $t(9) = 0.92$, $p > 0.05$).

A third analysis compared the effects of tense location (main verb vs. auxiliary) on aphasic and control participants' performance. Aphasic and control participants' mean accuracy for main-verb and auxiliary tense marking was compared in a two-way analysis of variance, with tense location (main-verb vs. auxiliary) as a within-participants factor and group as a between-participants factor. This analysis again revealed a significant main effect of group ($F[1,18] = 51.53$, $p < 0.05$), but no evidence of a main effect of tense location ($F[1,18] = 0.03$, $p > 0.05$). There was a significant interaction of group and tense location ($F[1,18] = 6.44$, $p < 0.05$). However, planned comparisons showed that neither aphasic participants nor control participants differed reliably in their accuracy for main-verb vs. auxiliary conditions (aphasic participants, 64% vs. 62%, $t(9) = 1.80$, $p > 0.05$; control participants, 87% vs. 90%, $t(9) = 1.80$, $p > 0.05$).

Reaction times were analyzed next. The effects of tense form and adverb position (two morphosemantic factors) were examined in separate two-way analyses of variance. The first analysis, treating adverb position as a within-participants factor and group as a between-participants factor, found significant main effects of adverb position ($F[1,18] = 356.42$, $p < 0.05$) and group ($F[1,18] = 7.14$, $p < 0.05$). Aphasic participants were slower than controls (aphasic group mean: 1561 ms, control group mean: 906 ms, ($F[1,18] = 2.67$, $p < 0.05$), and pre-posed conditions elicited slower RTs than post-posed conditions (1709 versus 771 ms, ($F[1,18] = 108.3$, $p < 0.05$). However, there was no evidence of an interaction ($F[1,18] = 0.09$, $p > 0.05$): aphasic and control participants exhibited a similar disadvantage for pre-posed conditions. The second analysis, treating tense form as a within-participants factor and group as a between-participants factor, again found a significant main effect of group ($F[1,18] = 6.79$, $p < 0.05$) as well as a significant main effect of tense form ($F[1,18] = 48.62$, $p < 0.05$), but no evidence of an interaction of tense form and group ($F[1,18] = 1.74$, $p > 0.05$). For both groups, present-tense sentences (aphasic mean = 1210 ms, control mean = 672 ms) elicited faster responses than either past-tense (aphasic mean = 1725 ms, control mean = 1041 ms $t(9) = 6.7$ and 4.1 respectively, $p < 0.05$) or future-tense (aphasic mean = 1705 ms, control mean = 994 ms, $t(9) = 6.9$ and 4.3 respectively, $p < 0.05$) sentences. There was no significant difference between past and future tenses for both groups ($t(9) = 0.3$ and 1.09 for aphasic and control respectively, $p > 0.05$).

A final two-way analysis of variance examined effects of tense position (a morphosyntactic factor), treating tense position as a within-participants factor and group as a between-participants factor. There were main effects of group ($F[1,18] = 5.17$, $p < 0.05$) and tense position ($F[1,18] = 6.15$, $p < 0.05$), with aphasic participants again being slower than controls and auxiliary tense markers eliciting faster responses than main-verb tense marking. However, there was no evidence of an interaction: aphasic and control participants were similarly slower for main-verb tense markers than for auxiliaries.

3.3. Comparing Experiments 1 and 2

In order to further compare the effects of morphosyntactic and morphosemantic factors on the aphasic participants' accuracy, a further analysis was performed comparing their overall accuracy for the Experiment 1 and Experiment 2 experimental sentences. A two-way analysis of variance compared aphasic and control participants' accuracy for Experiments 1 and 2, treating experiment as a within-participants factor and group as a between-participants factor. This analysis found a main effect of group ($F[1,18] = 40.06$, $p < 0.05$) but no evidence of an overall main effect of experiment ($F[1,18] = 0.71$, $p > 0.05$). However, there was a significant interaction of experiment and group ($F[1,18] = 5.52$, $p < 0.05$). Aphasic participants were less accurate in their responses to Experiment 2 stimuli (with morphosemantic violations) than Experiment 1 stimuli (with morphosyntactic violations), 63% vs. 69%. In contrast, control participants were more accurate in their responses to Experiment 2 stimuli than Experiment 1 stimuli, 88% vs. 85%.

3.4. Discussion

Several important patterns emerge from the results of Experiment 2. First, the aphasic participants once again exhibited a deficit in the processing of tense morphology. As in Experiment 1, they were less accurate than control participants in their judgments for tense markers. In this case, the deficit appeared for morphosemantic tense violations.

Second, morphosemantic factors associated with tense processing had a strong effect on the aphasic participants' performance. Aphasic participants were less accurate and slower in their judgments of pre-posed adverb sentences. At the individual patient level, this pattern was found for all ten participants for reaction time data and nine out of ten participants for accuracy data. That is, verifying a match between a particular tense morpheme and the temporal context established by an adverb was more difficult when the adverb was sentence-initial. This asymmetry suggests that selecting tense morphemes is putatively more challenging than interpreting the temporal content conveyed by tense morphemes, at least for this group of agrammatic participants. This is consistent with forced-choice sentence completion results for English-speaking agrammatic individuals, where marked accuracy differences were found when participants had to select verb morphology versus temporal adverbs in an off-line forced-choice sentence completion task (*The college will close for spring break* _____ versus *The college* _____ *for spring break next week*) (Faroqi-Shah, 2006). This particular difficulty in translating conceptual-semantic information conveyed into tense morphology is consistent with the morphosemantic deficit posited by the DER (Faroqi-Shah & Thompson, 2007). It may also be consistent with approaches like the Tense Underspecification Hypothesis (Wenzlaff & Clahsen, 2004), which claims that the morphosyntactic features responsible for tense and temporal interpretation are missing from agrammatic individuals' sentential representations. Poor performance

in tasks requiring agrammatic participants to match a tense form and an adverb is expected under this hypothesis. However, the TUH would predict similarly poor performance in pre- and post-posed conditions, since the relevant morphosyntactic features are missing in both cases.

Furthermore, the aphasic participants showed some sensitivity to tense form, another morphosemantic feature. While they were not less accurate for any tense forms, they were slower in their judgments of non-present-tense sentences. This result is consistent with some previous results showing that agrammatic speakers have difficulty with tense forms that refer to a time other than the present (Bastiaanse, 2008; Stavrakaki & Kouvava, 2003). However, the current results differ from previous studies in suggesting that the difficulty is not specific to the past tense, but also extends to the future tense. Furthermore, the same RT disadvantage for the past and future appeared for control participants. To the extent that referring to a non-present time is difficult, not only aphasic but unimpaired speakers show effects of this difficulty.

Third, morphosyntactic factors relevant to tense morphology again had relatively little effect on aphasic participants' performance in this experiment. While both control and aphasic participants were faster to judge auxiliary tense markers than main-verb tense marking, aphasic participants were not less accurate in their judgment of main-verb morphology. This finding suggests that morphosyntactic factors have relatively weak effects and are unlikely to be the source of aphasic participants' impairments. It also suggests that perceptual or phonetic salience is relatively unlikely to be the source of difficulty for these individuals' deficits in processing tense morphology, since the free-standing auxiliaries are presumably more perceptually salient than the main-verb affixes. This result is also inconsistent with findings of impairments in parsing stems and affixes for regularly inflected (but not irregular) verbs (Tyler et al., 2002) in single word lexical decision tasks.

Fourth, consistent with the weak effects of morphosyntactic factors in this experiment, aphasic participants were more sensitive to morphosyntactic violations than morphosemantic ones across the two experiments. Their accuracy was lower for the Experiment 2 stimuli overall than for the Experiment 1 stimuli (63 vs. 69%). At the individual participant level, this pattern was seen for nine out of ten aphasic participants (see Table 4). Although the mean differences are not large, these were statistically reliable and are likely a valid difference given that the reverse pattern was found for control participants. The findings are consistent with forced-choice sentence completion data where markedly higher accuracy was reported for morphosyntactic constraints than morphosemantic constraints (Faroqi-Shah & Thompson, 2007).

Table 4
Individual participant accuracies (in %) of tense production from Experiment 3 and grammaticality judgment from Experiments 1 and 2.

Participant	Production accuracy		Judgment accuracy	
	Narratives	Picture Description	Morphosyntactic	Morphosemantic
AP1	62.1	28	49	47.1
AP2	89.0	12	68	62.3
AP3	62.0	2	51	50.7
AP6	23.3	2	67	50.2
AP8	93.5	42	84	76.9
AP10	71.9	48	81	70.6
AP12	52.0	34	65	72.2
AP13	64.0	16	65	60.7
AP14	13.6	2	72	60.2
AP15	88.0	21	87	75.9

To summarize, the results of Experiment 2 provide clear evidence of effects of morphosemantic factors on aphasic participants' processing of tense morphology, and little evidence of effects of morphosyntactic factors. Manipulations relevant to translating conceptual-semantic information into tense morphology decreased aphasic participants' accuracy and increased their reaction times. The comparison of the results of Experiment 1 and Experiment 2 points in a similar direction, finding lower aphasic accuracy for morphosemantic tense violations than morphosyntactic ones. Experiment 3 examined whether these deficits were central ones for this group of agrammatic aphasic individuals.

4. Experiment 3: Production of tense

This analysis addressed the question of centrality of tense impairments in individuals with agrammatic aphasia by investigating the correspondence between measures of tense production and tense judgment scores (obtained from Experiments 1 and 2). Tense production measures were obtained using both narrative and constrained picture description tasks because variations in task demands are reported to influence various production measures in aphasia (Hofstede, Harman, & Kolk, 1994; Kok et al., 2007; Martin, Wetzel et al., 1989).

4.1. Methods

4.1.1. Participants

The ten agrammatic aphasic and ten age-matched normal individuals who participated in Experiments 1 and 2 were tested.

4.1.2. Stimuli and procedure

Narratives. Narrative speech was elicited by asking participants to describe six different picture sequences from the *Narrative Story cards* (Helm-Estabrooks & Nicholas, 2003). The picture sequences of the Narrative Story cards varied from three to six pictures in length. As per the standardized administration protocol, the experimenter placed the picture card sequence in front of the participant and read the standard story that accompanied each picture sequence. The participant was instructed to narrate the story in his/her own words. Narrative speech was audio-recorded during the testing session and transcribed after the session. The first 150 words were coded for accuracy of tense marking. A verb was considered to be accurately marked for tense if it was produced with the grammatical morphology required for that tense. Accuracy of tense marking was then computed as a ratio of the number of correctly inflected tense markings to the total number of verbs produced. Reliability measures for transcription, coding, and scoring were obtained for all the narrative samples by an independent rater. Inter-rater consistency exceeded 95% for all the samples. Differences were resolved by consensus between the two raters.

Elicited picture description. Black and white line drawings of forty regularly inflected imageable verbs were drawn by an artist in a three tense sequence (example shown in Fig. 3). Each of the forty verbs were elicited in three tenses (future, present, and past), yielding a total of 120 sentences. The experimenter randomly pointed to any one drawing in the three tense sequence and provided a cue word (*Tomorrow, Nowadays, Yesterday* respectively to elicit future, present and past tenses). Participants were instructed to describe the picture stimuli using a single-sentence. Participants' responses were audio-recorded, transcribed, and scored for accuracy. Minimally, the utterances needed a noun and verb to be scored. Utterances were scored as correct if the tense conveyed by the verb morphology matched the elicited tense. The entire set of 120 pictures was used only for the aphasic participants. Age-matched control participants performed flawlessly with a smaller subset of these stimuli ($N = 40$) and hence further testing was dis-

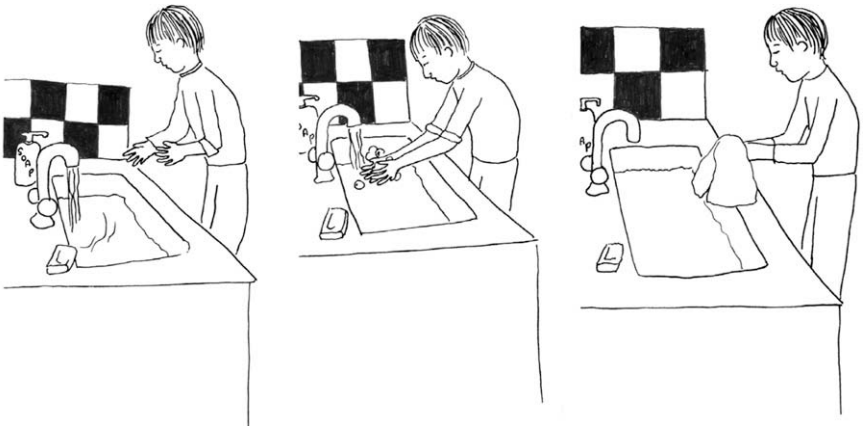

Fig. 3. Sample stimuli used to elicit picture description.

continued for the control group. Thirty percent of the aphasic samples were independently transcribed and scored by a second rater. Inter-rater consistency exceeded 95%.

4.2. Results

The mean accuracy of tense in narratives was 62% for agrammatic aphasic participants (*SD* = 26.7; range = 13.6–93.5) and 100% for the control group. This group difference in narrative tense production accuracy was statistically significant [$t(18) = 2.9$, $p = 0.009$]. In the picture description task, agrammatic aphasic individuals showed a marked deficit, with a mean accuracy score of 21% (*SD* = 16.9, range = 2–48%]. The accuracy of tense production for the picture description task was significantly lower than the accuracy for narrative samples [$t(9) = 3.7$, $p = 0.004$] and this pattern was found for every participant. Individual participant values for these two accuracy measures as well as their judgment accuracies for Experiments 1 and 2 are given in Table 4.

Accuracy of morphosyntactic judgments by aphasic participants did not significantly correlate with either their narrative tense accuracy [Pearson's $r = 0.06$; $p = 0.8$] or picture description accuracy [Pearson's $r = 0.4$; $p = 0.24$]. There was also no significant correlation between accuracy of morphosemantic judgments and tense in narratives [Pearson's $r = 0.44$, $p = 0.19$]. However, the correlation between accuracy of morphosemantic judgments and picture description approached significance [Pearson's $r = 0.62$; $p = 0.052$]. Since aphasic participants revealed a marked deficit in the judgment of sentences with pre-posed adverbials when compared to all other conditions (Section 3.2), additional correlations were computed between accuracy of pre-posed adverbials and tense production measures. The correlation between accuracy of pre-posed adverbial judgments and picture description was statistically significant (Pearson's $r = 0.64$, $p = 0.04$; for narratives: Pearson's $r = 0.52$, $p = 0.12$, n.s.). Table 4 shows that the highest three scorers for picture description (AP8, AP10, AP12) were also the only ones who scored above chance on the morphosemantic violations, while all other participants were at chance (binomial test, $p < 0.05$) (with the exception of AP15, who was above chance). The same pattern was observed for pre-posed sentences.

4.3. Discussion

This experiment revealed two notable results. First, not surprisingly, aphasic participants were significantly impaired in their tense production, and the degree of impairment varied with the task used. Second, there was a statistically significant correlation between picture description performance and judgment of sentences with pre-posed adverbials. However, there was not such a significant correlation for other production-judgment comparisons. The implications of these findings are discussed below.

The production data confirmed previous findings that agrammatic individuals have a significant deficit in the production of tense (Faroqi-Shah & Thompson, 2007; Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2005). Table 4 reveals that all participants showed a severe impairment in the picture description task, while tense production in the narrative task was significantly more successful. The relatively better performance on the narrative task can be explained by the difference in task demands and tense scoring criteria. In the narrative task, no constraints were placed on the type of tense to be produced and credit was given to any verb that was produced with all the required tense morphology. Hence the frequently reported strategy of using (and overusing) a single tense marker, such as the present progressive *is V+ing*, gave a high success rate for most of our participants (especially for AP2, AP8, and AP10: see Table 4). Several previous studies have reported agrammatic individuals' tendency to overuse a specific verb form (Centeno & Obler, 2001; Faroqi-Shah & Thompson, 2004; Goodglass, 1976; Menn & Obler, 1990). However, this strategy was unhelpful in the picture description task where a specific tense was elicited. This specificity made the picture description task more challenging for our participants, although only a single-sentence response was required.

Previous studies of the impact of task variation on agrammatic speech have reported the converse pattern of worse performance in narratives when compared to constrained picture description tasks (Hofstede et al., 1994; Martin, Wetzel, et al., 1989) and have interpreted those findings in terms of strategic variation (Kolk & vanGrunsven, 1985; Kolk & Heeschen, 1992) or limited processing resources (Martin et al., 1989). However these findings cannot be directly compared with the present study because of the differences in analysis procedures and task requirements. These previous studies elicited sentences that required a variety of argument structures, adjuncts, and adjectival phrases with no specific constraints on the type of tense. Further, these studies reported rates of substitutions and omissions of grammatical morphemes rather than the accuracy with which tense was produced.

The second and more interesting finding of this experiment was the differential correlation pattern between production and judgment measures. None of the correlations with narrative or morphosyntactic measures were statistically significant. However, accuracy of tense in picture description significantly correlated with the accuracy of pre-posed adverbial judgments (and was marginally significant for overall morphosemantic judgments). This is an interesting and relevant association because the demands of

the picture description task parallel the processing demands of the pre-posed adverbial condition of Experiment 2. In both these tasks, the tense was pre-specified by a temporal adverb, followed by either matching (for judgment) or retrieval (for production) of verb morphology. Thus, in both cases, aphasic participants exhibited poor performance when forced to select an appropriate verb form given preceding temporal context (an adverbial). The specificity of this correlation is noteworthy because judgment accuracy for post-posed sentences failed to correlate significantly with production.

To summarize, the results of this experiment indicate that the tense deficit in agrammatism does in fact have a centralized component that affects both production and comprehension. However this central impairment is not an across the board one, affecting all comprehension and production processes equally, but is instead specific to tasks that call for a selection of verb forms based on conceptual-semantic information.

5. General discussion

The literature on morphological impairments in agrammatism consistently reports that agrammatic aphasic individuals exhibit marked impairments in their production of tense morphology. However, results to date on the comprehension of this morphology are much more mixed, with some studies suggesting that aphasic individuals are impaired in their comprehension of tense morphology (Arabatzi & Edwards, 2002; Dickey et al., 2008; Lee, 2003; Linebarger, Schwartz & Saffran, 1983; Nanousi et al., 2006; Parisi & Pizzamiglio, 1970; Wenzlaff & Clahsen, 2004) and other studies suggesting that they have relatively intact comprehension or judgment of tense (Benedet et al., 1998; Friedman & Grodzinsky, 1997; Goodglass et al., 1993; Hagiwara, 1995; Tsapkini et al., 2001). The current study examined comprehension and production deficits in a group of English-speaking agrammatic aphasic individuals, directly manipulating morphosyntactic and morphosemantic factors which have been shown to be important in determining aphasic individuals' tense processing.

One possible reason for the varied performance across comprehension studies is that these studies have varied in whether they tested morphosyntactic or morphosemantic processes related to the morphological expression of tense. Matching a tense morpheme with a temporal context (as provided by an adverb, for example) is a linguistically and psycholingustically distinct process from selecting the right tense morpheme in a given syntactic position (as selected by an auxiliary, for instance). Recent work which tested these two processes separately for agrammatic individuals has found that they do not pattern together in production (Faroqi-Shah & Thompson, 2007[4]). In particular, morphosemantic processes appear to be much more impaired than morphosyntactic ones.

The current studies directly compared morphosyntactic and morphosemantic processes in the comprehension domain. Results revealed that the agrammatic individuals tested here were impaired in their judgment of both classes of violations, performing more poorly than controls in both experiments and much more poorly in their judgments of tense violations than in their judgments of pragmatic/plausibility or number-agreement violations. However, across the studies, the agrammatic participants were also more sensitive to morphosyntactic violations and manipulations than morphosemantic ones. For example, they were less accurate in their judgments of the morphosemantic violations tested in Experiment 2 than they were for the morphosyntactic violations from Experiment 1. Checking whether a tense morpheme matched the temporal context was more difficult for these aphasic participants than checking whether it matched the local syntactic context, parallel to Faroqi-Shah and Thompson's (2007) findings for production. Control participants exhibited the opposite pattern.

Consistent with this, the aphasic participants' performance also appeared to be more strongly affected by morphosemantic manipulations than by morphosyntactic ones. For example, the presence and position of an adverb (providing temporal-semantic context) affected aphasic participants' accuracy and reaction times, and the choice of tense form (referring to past, present, or future) affected their reaction times as well. In contrast, the choice of whether tense morphology appeared on a main verb or an auxiliary did not appear to affect their accuracy (though it did affect their reaction times). Again, these results indicate that morphosemantic factors relevant to tense marking were relatively more important in determining agrammatic individuals' performance than morphosyntactic ones were.

As noted above, the finding of stronger effects for morphosemantic information/violations is consistent with Faroqi-Shah and Thompson's (2007) findings for production. Interestingly, the contrasting effects of morphosemantic and morphsyntactic information may also help make sense of the mixed pattern of results for tense comprehension reported in the literature. Many of the studies which report intact judgment for tense morphology in agrammatism tested morphosyntactic violations (e.g., Goodglass et al., 1993). In contrast, most or all of the studies which have reported impaired judgment for tense morphology have tested morphosemantic violations such as adverb-tense morpheme mismatches (e.g., Dickey et al., 2008; Nanousi et al., 2006; Wenzlaff & Clahsen, 2004). Testing the same group of individuals separately for the two classes of violations/processes, as in the current study, removes this potential confound.

A secondary variable that may have contributed to differences across studies is whether off-line or on-line responses were elicited. With the exception of this study and Dickey et al. (2008), most studies examined off-line, untimed judgments, which are likely to be less challenging for both normal and aphasic participants. The overall difficulty of providing on-line responses may have contributed to the relatively small numerical difference in accuracy between morphosyntactic and morphosemantic violations in the present experiments. There are two reasons that lead us to suggest this explanation. First, control participants also found tense judgments challenging, attested by their accuracy levels in comparison to fillers. Second, the accuracy differences between morphosemantic and morphosyntactic processing for off-line forced-choice sentence completion are far more dramatic (Faroqi-Shah & Thompson, 2007).

The results from the current studies also provide more detailed insight into the nature of the tense deficit in agrammatism. As noted above, the patterns from Experiments 1 and 2 indicate that morphosemantic aspects of tense marking are a primary issue. However, the contrast between pre-posed and post-posed adverb conditions indicates that the deficit may be even more specific. The agrammatic participants in this study were much faster and more accurate for judging whether a post-posed adverb matched the tense picked out by a given tense morpheme (as in post-posed conditions) than in checking whether a particular morpheme matched the temporal context provided by a pre-posed adverb (as in pre-posed conditions). This finding is consistent with the production results reported by Faroqi-Shah (2006), who found that agrammatic individuals were more impaired in producing the right tense form given an adverb than in producing the right adverb given a tense form. This asymmetry indicates that not all encoding or decoding of temporal information in a sentence is impaired in

[4] The ten agrammatic aphasic participants of the present study are different from the participants included in the Faroqi-Shah and Thompson (2007) study. Hence the consistent findings across these two studies cannot be attributed to participant overlap.

agrammatism. Rather, the locus of the problem is in choosing a particular tense form given conceptual-semantic temporal information, as participants had to do in the pre-posed conditions.

This conclusion suggests that the difficulty in agrammatism is in translating conceptual-semantic information into surface grammatical forms, in this case tense morphology (Goodglass et al., 1993). This perspective is most consistent with the Diacritical Encoding and Retrieval Hypothesis (Faroqi-Shah & Thompson, 2007), which points to morphosemantic factors as being the locus of agrammatic tense deficits. The DER also claims that agrammatic tense deficits are specific to choosing a tense morpheme given tense information, because of a deficit associated with encoding diacritical tense features such as [+PAST]. This is the pattern of results reported by Faroqi-Shah (2006) and found in Experiments 1 and 2 above. A few other theories also acknowledge the role of morphosemantic aspects in the production of verb inflections (e.g., Goodglass et al., 1993; Wenzlaff & Clahsen, 2004). In contrast, these results seem less consistent with theories which pin agrammatic tense deficits on solely on morphosyntactic factors, such as the TUH, the TAUH and the TPH (Burchert et al., 2005; Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2004),. The TAUH and TUH both claim that agrammatic individuals have a central deficit in the morphosyntactic features on functional heads which are relevant for producing or comprehending tense morphology. These features are what underlie performance for both the morphosyntactic violations in Experiment 1 and the morphosemantic violations in Experiment 2, meaning that the differences found here between the two types of violation remain unexplained under such approaches. Similarly, these features are presumably equally impaired or intact for pre-posed and post-posed adverb sentences, leaving this difference also unexplained under such accounts. Nonetheless, the current results are consistent with the TUH's emphasis on semantically interpretable (tense) features as being important in explaining agrammatic individuals' tense morphology deficits.

In contrast to the TUH and TAUH, the TPH claims that agrammatic individuals have a (production-specific) deficit in generating the syntactic structure required for tense morphology. As originally formulated, the TPH does not apply to comprehension or input processes, meaning that the comprehension impairments found here are unexplained (and perhaps unexpected) under the TPH. However, if the TPH may be extended to input processes, the differences found here remain unexplained. For example, if agrammatic individuals are unable to generate the syntactic structure relevant to tense morphology, this deficit should affect pre-posed and post-posed adverb sentences (as well as different tense forms) equally.[5]

The results reported here also bear on another theoretical and empirical controversy described in the Introduction, whether the tense morphology deficit seen in agrammatic aphasia is a central one. Previous studies have varied as to whether the aphasic individuals they tested exhibited deficits in both input and output processes for tense morphology, with some studies finding strong evidence of such a relationship (Lee, 2003; Varlokosta, et al., 2006) and others finding weaker or no relationship (Wenzlaff & Clahsen, 2004). The current study also found a mixed pattern of results. There were no strong correlations for the aphasic participants between their performance in Experiments 1 and 3. The correlations between Experiments 2 and 3 revealed a very specific pattern: input (pre-posed adverbial judgment) and output (picture description) tasks that entail verb form selection for a pre-specified tense were correlated, while other input and output measures were not correlated. This pattern of results supports the notion of a central *morphosemantic* tense impairment. Of course, we are using a rather simplistic metric here: a central impairment need not necessarily be captured by a linear correlation between percent accuracies. It is worth examining published studies for which individual aphasic participant data for production and input tasks are available to see whether this implicational relation holds more broadly.

Before concluding, it is worth considering a few of the results above in more detail. First, there is the non-effect of tense location: aphasic participants did not show reliable differences in accuracy between main-verb and auxiliary tense marking. This finding replicates previous results by Dickey et al. (2008). Importantly, it suggests that the difficulties these agrammatic individuals experienced in judging tense morphology were general to any tense marking, not specific to either syntactically prominent non-lexical auxiliaries or to phonetically reduced affixes on lexical verbs. This result thus casts doubt on simple perceptual salience, phonological or morphological decompositional accounts of tense-marking deficits in agrammatic aphasia (Tyler et al., 2002; Ullman et al., 1997; see also production evidence pointing in the same direction by Den Ouden & Thompson, 2006).

Second, there is the effect of adverb position, pre-posed versus post-posed. As discussed above, the post-posed adverb advantage fits well with the existing aphasic production results (Faroqi-Shah, 2006) as well as the DER model of agrammatic tense encoding difficulty (Faroqi-Shah & Thompson, 2007). However, the fact that unimpaired controls exhibited the same post-posed advantage in their RT data suggests that this difference might not be uniquely attributable to an encoding deficit found in agrammatism. Perhaps the process of extracting temporal-semantic information from an adverb and using that information to guide selection of the proper tense morphology is an inherently difficult one, pathologically so for aphasic individuals. However, the difference between pre-posed and post-posed conditions found here (or between morphosemantic violations and more local morphosyntactic ones, for that matter) cannot be reduced to simple distance or information-processing. The linear distance between verb and adverb was exactly matched in pre-posed and post-posed conditions, and pre-posed conditions nonetheless elicited slower and less accurate responses from aphasic individuals. Linear distance was thus a poor predictor of aphasic individuals' performance in this experiment, contrary to what would be expected under simple information-processing accounts of aphasic language deficits (e.g., Kolk, 1995). Additional appeal must be made to the specific linguistic and psycholinguistic processes involved to explain the results found here.

It is also worth pointing out that although adverbs are frequently used to fix temporal reference in empirical investigations of tense in agrammatic aphasia, like the current one, the presence of adverbs is not a prerequisite for tense errors. Nor is it a requirement for a morphosemantic account such as DER. Adverbs are convenient and easily manipulated markers of temporal reference, which provide a temporal context that must be encoded by tense morphology. However, such temporal context may come from other sources. For example, in naturalistic contexts, temporal reference may be specified by a preceding utterance or the conversational partner. The DER predicts similar verb form selection difficulties in these contexts (see Tyler et al., 1990, for a task with such temporal cues and consistent findings in a single patient).

Finally, there are the effects of tense form. While aphasic participants in these experiments did not exhibit accuracy differences among tense forms, both the aphasic and the control participants exhibited a robust difference in reaction times, with non-present tense forms eliciting slower RTs. This result is consistent with

[5] Furthermore, the TPH would seem to predict that auxiliaries would be more impaired than main-verb tense marking. Auxiliaries are base-generated in higher functional projections, which should be more impaired under the TPH, while inflected main verbs remain in their base position in VP (Chomsky, 1986).

previous results indicating that reference to times other than the present is difficult for agrammatic aphasic individuals (Bastiaanse, 2008). However, as discussed above, this finding also suggests that this difference is not specific to the past tense (contra Bastiaanse, 2008) or to agrammatic individuals. The ultimate source of this difference remains unclear—perhaps reference to any time other than the moment of utterance requires construction or reference to a more complex mental model (Miller & Johnson-Laird, 1976). This interesting question will be left open here.

6. Conclusions

The results here show that morphological deficits in agrammatic aphasia, much like syntactic deficits, are psycholinguistically specific. Morphosemantic processes relevant to tense encoding appear to be the primary locus of the deficit, with a lesser contribution from morphosyntactic processes, at least for the agrammatic aphasic individuals tested here. Furthermore, the deficit appeared most prominently when the aphasic individuals were asked to translate message-level information relevant to tense into specific morphological forms and was evident in both production as well as judgment tasks. This conclusion suggests that treatment for morphological deficits may most profitably target morphosemantic aspects of the impairment. Treatment-based research testing this possibility would provide strong converging evidence in favor of this conclusion (Faroqi-Shah, in press).

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