

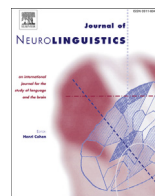


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Parallel functional category deficits in clauses and nominal phrases: The case of English agrammatism



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ABSTRACT

Individuals with agrammatic aphasia exhibit restricted patterns of impairment of functional morphemes, however, syntactic characterization of the impairment is controversial. Previous studies have focused on functional morphology in clauses only. This study extends the empirical domain by testing functional morphemes in English nominal phrases in aphasia and comparing patients' impairment to their impairment of functional morphemes in English clauses. In the linguistics literature, it is assumed that clauses and nominal phrases are structurally parallel but exhibit inflectional differences. The results of the present study indicated that aphasic speakers evinced similar impairment patterns in clauses and nominal phrases. These findings are consistent with the Distributed Morphology Hypothesis (DMH), suggesting that the source of functional morphology deficits among agrammatics relates to difficulty implementing rules that convert inflectional features into morphemes. Our findings, however, are inconsistent with the Tree Pruning Hypothesis

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(TPH), which suggests that patients have difficulty building complex hierarchical structures.

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1. Introduction

It is well known that individuals with agrammatic aphasia have difficulty with functional morphemes, including both free standing function words and bound morphemes, in production as well as in comprehension and grammaticality judgment tasks in some cases (Benedet, Christiansen, & Goodglass, 1998; Berndt & Caramazza, 1980; Caramazza & Zurif, 1976; Damasio, 1992; Marshall, 1986; Parisi & Pizzamiglio, 1970). In English, these elements include tense markers (e.g. *-ed*), the plural marker (e.g. *-s*), auxiliaries (e.g. *is* and *was*), etc. This observation has attracted researchers' attention because patterns of deficit may shed light on the linguistic and associated neural mechanisms that compute grammatical morphology (Avrutin, 2001; Friedmann, 2001, 2006; Friedmann & Grodzinsky, 1997; Grodzinsky, 1990, chap. 1). The research so far has revealed that a similar deficit can be seen in a wide variety of languages, including Dutch (Bastiaanse, 2008), English (Dickey, Milman, & Thompson, 2005, 2008; Lee, Milman, & Thompson, 2005, 2008), German (Wenzlaff & Clahsen, 2004, 2005), Hebrew (Friedmann, 2001, 2006; Friedmann & Grodzinsky, 1997), Japanese (Hagiwara, 1995) and other languages.

One explanation of these deficit patterns is the Tree Pruning Hypothesis (TPH) (Friedmann, 2001, 2002; Friedmann & Grodzinsky, 1997), which attributes the impairment of functional morphemes to damage to the nodes in the syntactic tree. Specifically, the TPH predicts that functional morphemes on the higher nodes of a syntactic structure are more likely to be impaired than those on lower nodes. Even though the TPH explains some deficit patterns, subsequent studies have reported many deficit patterns that the TPH fails to capture (e.g. Arabatzi & Edwards, 2002; Bastiaanse & Thompson, 2003; Burchert, Swoboda-Moll, & De Bleser, 2005; Nanousi, Masterson, Druks, & Atkinson, 2006; Wenzlaff & Clahsen, 2004, 2005). Various alternative explanations to the TPH have been proposed in the literature (see Thompson, Kielar, & Fix, 2012; for review). One explanation is what we term the Distributed Morphology Hypothesis (DMH), proposed in Dickey et al. (2008), Lee et al. (2008) and Thompson, Fix, and Gitelman (2002). Based on the theoretical framework of Distributed Morphology (Embick & Noyer, 2007; Halle & Marantz, 1993; Harley & Noyer, 1999), this hypothesis claims that impairment of morphemes is not constrained by the structure of the sentence itself, but rather by rules of morphology which are independent of syntactic structure.

Several prior studies have examined functional morphology deficits in aphasia, interpreting the findings in light of these two hypotheses (i.e. the TPH and the DMH). However, these studies have primarily focused on functional morpheme in clauses (e.g. Friedmann & Grodzinsky, 1997; Lee et al., 2008; Wenzlaff & Clahsen, 2004, 2005). Furthermore, these studies have resulted in inconsistent findings, leaving the underlying source of functional category impairments unclear. In order to further examine these two hypotheses, this study extends the empirical domain by testing English nominal phrases. In the theoretical linguistics literature (Abney, 1987; Bernstein, 1993; Brame, 1981, 1982; Horrocks & Stavrou, 1987; Stowell, 1991; Szabolcsi, 1983, 1994), it has been revealed that nominal phrases exhibit a hierarchical structure parallel to clauses. On the other hand, a major distinction between the two is, as far as English is concerned, that morphological inflection patterns differ between nominal phrases and clauses. For example, the functional morphemes in the top node of the nominal structure (i.e. demonstratives) exhibit inflectional alternations (the singular demonstrative *this* vs. the plural demonstrative *these*) (Leu, 2008). The similarities in the hierarchical structure and the differences in the functional morphology between clauses and nominal phrases thus can potentially provide a good testing ground for the two hypotheses because these two hypotheses predict patterns of impairment of functional morphemes in nominal phrases which will be different from those in clauses. As an attempt to bring new evidence to distinguish the TPH and the DMH, this study aims to

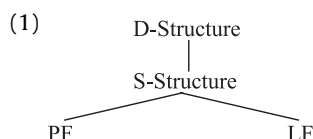
investigate agrammatic speakers' impairment of functional morphemes inside nominal phrases (demonstratives and numerals), in comparison to functional morphemes in clauses (complementizers and auxiliary verbs).

2. Theoretical background

This section presents an introduction to the theoretical background assumed in this study. Details about the two hypotheses to be tested will be introduced first, followed by the parallels and differences between clauses and nominal phrases. The section ends with a summary of the predictions of impairment patterns on clauses and nominal phrases made by the two hypotheses.

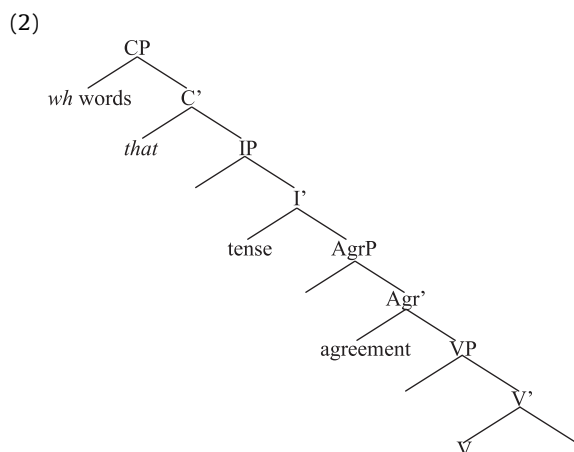
2.1. Two hypotheses of functional category deficits

One hypothesis is the Tree Pruning Hypothesis (TPH), which relates the deficits of functional morphemes to the hierarchical structure of sentences (Friedmann, 1998, 2001, 2002, 2006; Friedmann & Grodzinsky, 1997, 2000; Grodzinsky, 2000a, 2000b; also see Hagiwara, 1995). Essentially, the TPH is built on the following model of grammar (Chomsky, 1981, chap. 1):



According to this model, the derivation of syntactic structures goes through four levels of representation. The derivation starts at D-Structure, where logical-thematic theta roles match the grammatical functions of sentences. Afterwards, S-Structure is derived from D-Structure via application of transformations. Subsequently, the syntactic derivation splits, obtaining the phonological representation at PF and obtaining the semantic representation at LF.

Based on this model of grammar, an example of the TPH adopted by Friedmann and Grodzinsky (1997) assumes the following hierarchical structure for a clause in order to give a systematic account of aphasic patients' impaired syntactic abilities:



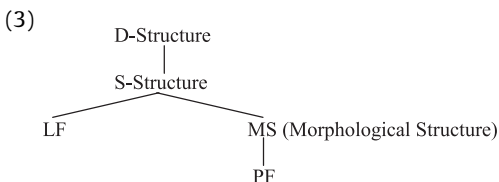
Within this hierarchical structure, function words and bound functional morphemes may be represented in different functional projections. For example, CP hosts both complementizers (e.g. *that*) and

wh words. Complementizers are in the head position of CP and *wh* words are in the specifier position of CP. Other functional projections include IP, which is responsible for the tense inflection of the verb and AgrP, which is responsible for the agreement in person, gender, and number between the subject and the verb. Finite verbs move from V, their base-generated position within the VP, to Agr and then to T in order to check (or collect) their inflection (Chomsky, 1992).

Specifically, the TPH makes the following predictions. First, the higher a syntactic projection is in the structure in (2), the more likely it is that the projection (including whatever occurs in this projection) will be impaired. Moreover, once a projection is impaired, any node above it will also be impaired. For example, CP is more likely to be impaired than IP, which is more likely to be impaired than AgrP; and if IP is impaired, CP will also be impaired.¹ These predictions were confirmed by the results reported in Friedmann and Grodzinsky (1997), which tested a female Hebrew-speaking agrammatic patient on speech production tasks. They found that the patient was able to produce verbal, adjectival and nominal agreement but had difficulty with verbal tense inflections, copulas, and word order alternations between negation and the copula. For example, in sentence completion tasks, the patient was able to choose a correct verb form inflected for agreement but not able to choose a correct verb form inflected for tense. Additionally, her difficulty with CP-related elements (i.e. *wh* words, complementizers and embedded sentence structures) was noted. In a word, the patient had no difficulty with AgrP-related properties, but had difficulty with TP-related properties and those above TP (i.e. CP-related phenomena). Furthermore, the TPH predicts that breakdown at any node along the tree structure in (2) will disrupt both morphological and syntactic operations associated with that projection (Thompson, Kiellar, et al., 2012). Impairment of CP, for instance, will lead to impairment of whatever occurs in CP (e.g. complementizers generated at C or *wh* words moved to Spec CP).

Although the predictions of the TPH have been supported by subsequent studies (Benedet et al., 1998; Friedmann, 2002; Gavarró & Martínez-Ferreiro, 2007; Hagiwara, 1995; Kolk, 2000), more recent research has produced results that are not predicted by the TPH. For example, some studies (Dickey et al., 2008; Lee et al., 2005, 2008; Thompson et al., 2002) have shown that patients' accuracy for verb inflections was significantly lower than that for complementizers in English and other studies (e.g. Burchert et al., 2005) did not find a significant difference between tense and agreement for the tested patients.

In particular, Thompson and colleagues (Dickey et al., 2008; Lee et al., 2005, 2008; Thompson et al., 2002) found that aphasic individuals presented no difficulty with CP-related elements but had difficulty with tense inflections. For example, in both production and grammaticality judgment tasks, agrammatic participants had significantly higher accuracy for complementizers than for tense inflections. In addition, their tense inflection errors were dominated by substitutions of incorrect morphemes rather than omissions of morphemes, indicating their ability to project verb inflection and to implement inflectional rules in their grammar. These studies went on to propose an alternative account based on the theory of Distributed Morphology (DM) (Embick & Noyer, 2007; Halle & Marantz, 1993; Harley & Noyer, 1999). We refer to this hypothesis as the Distributed Morphology Hypothesis (DMH), which adopts the following model of grammar (Halle & Marantz, 1993: 114):



¹ The TPH focuses on the selective impairment of functional morphemes, therefore, it does not address whether the node of VP may be impaired.

In contrast to the model of grammar in (1), Distributed Morphology assumes that there is an interface called Morphological Structure (MS) located between S-Structure and PF. The basic idea of Distributed Morphology is that the machinery of what has traditionally been called morphology is computed among the several components of the grammar. Specifically, DM assumes that the entries that make up the Vocabulary of a language are each composed of two distinct sets of features: morphosyntactic/semantic and phonological. Moreover, at the syntactic levels of LF, D-Structure and S-Structure, terminal nodes in the syntactic structure possess morphosyntactic/semantic features but lack phonological features. It is at MS that terminal nodes obtain their phonological features through the mechanism of Vocabulary Insertion (VI), which converts morphosyntactic/semantic features into phonological features. An example to illustrate this process is the formation of *talked*: during VI, the suffix *-ed* is inserted to replace the feature [+PAST] possessed by *talk* and after the process of VI, the combination of *talk* with *-ed* is interpreted at PF. The DMH claims that even if aphasic individuals have intact hierarchical syntactic structure, impairment still results if they have flawed feature-to-morpheme mapping in MS. Therefore, the DMH predicts that aphasic individuals show impairment on those functional morphemes that involve inflectional alternations.

2.2. The structure of nominal phrases in relation to the structure of clauses

These two hypotheses (the TPH and the DMH) attempt to explain agrammatic patients' impairment of functional projections by referring to different theoretical linguistic models, thus generating different predictions regarding deficit patterns. To date, these predictions have been tested exclusively on functional projections in clauses. In theoretical syntax, close parallelisms have been observed between clauses and nominal phrases in terms of their hierarchical functional projections (Abney, 1987; Bernstein, 1993; Brame, 1981, 1982; Horrocks & Stavrou, 1987; Stowell, 1991; Szabolcsi, 1983, 1994). This makes nominal phrases appropriate for testing the TPH, because this hypothesis reduces aphasic deficits to difficulty with building complex hierarchical structures. Meanwhile, inflections among functional morphemes in English nominal phrases are different from those in English clauses. This is appropriate for testing the DMH, as this hypothesis predicts that within the same node, only those functional morphemes that involve inflection will be impaired.

2.2.1. Parallelisms between clauses and nominal phrases in English

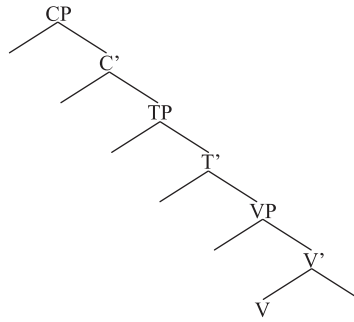
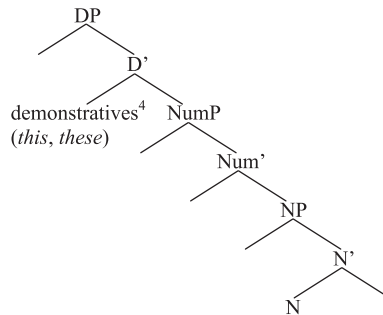
It has been established in generative syntax that the structure of clauses is analyzed as consisting of functional projections on top of the Verb Phrase, as illustrated in (2) (Chomsky, 1986, chap. 1; Pollock, 1989). Since the 1980s, numerous studies have proposed that nominal structure should also consist of functional projections on top of Noun Phrase in order to capture systematic parallelisms between clauses and nominal phrases (see Bernstein, 2003; for review). Specifically, Abney (1987) proposed that in nominal structure, a functional projection called the Determiner Phrase (DP) hosts determiner elements (for example, *the* in English) (Bernstein, 2003). In addition, subsequent research indicates that a Number Phrase intervenes between DP and NP (Lobeck, 1995, chap. 2; Ritter, 1991).

For the sake of highlighting the parallelism between clauses and nominal phrases, we assume clauses and nominal phrases have the following structures, respectively:

(4) Clauses^{2,3}

² Under the structure in (4), we assume that auxiliary verbs like *have* and *had* move to TP to check the relevant tense feature (Lasnik, 1995, 1999; Lasnik, Depiante, & Stepanov, 2000, chap. 3; Omaki, 2007).

³ The specific formulation of the TPH by Friedmann and Grodzinsky (1997) assumes AgrP in the clausal structure. But AgrP is not assumed in the recent minimalist framework (Chomsky, 1995, chap. 4, 2001), and the existence of the Agr node is not crucial for our current discussion of the parallelisms between clauses and nominal phrases. As a result, the structure in (4) does not include AgrP.

(5) Nominal phrases⁴

The structural parallelisms between clauses (4) and nominal phrases (5) are motivated by parallel properties between clauses and nominal phrases, as summarized in Table 1 and illustrated by the examples that follow.

First, nominal phrases and clauses are similar in terms of the external distribution. For example, both nominal phrases and clauses can occur as subjects ((6a) and (6b)) or direct objects ((6c) and (6d)) (Abney, 1987; Lees, 1960):

- (6) a. The prisoner's murder of a policeman surprised me.
 b. That the prisoner murdered a policeman surprised me.
 c. I learned the prisoner's murder of a policeman.
 d. I learned that the prisoner murdered a policeman.

Second, nominal phrases have a similar internal structure to clauses in that both can take arguments such as an agent and a theme (Abney, 1987; Lees, 1960).

- (7) a. Rome's destruction of the city
 b. Rome destroyed the city.

Third, nominal phrases and clauses are similar with respect to binding and control relations (Abney, 1987). In (8), *John* and *himself* can refer to the same individual, but the co-reference relation between *John* and *him* is not possible in (9). The contrast applies identically in both clauses and nominal phrases.

⁴ We assume with Abney (1987) that demonstratives occupy the head of DP based on the evidence that demonstratives and articles in English do not co-occur.

Table 1
Parallelisms between clauses and nominal phrases.

Parallelisms	Examples
External distributions	(6a) and (6b) (6c) and (6d)
Taking the agent and the theme	(7)
Binding relations	(8) and (9)
Control relations	(10) and (11)
Selectional relations	(12), (13), (14) and (15)
Head movements	(16) and (17)
Phrase movements	(18)
Ellipsis patterns	(19)

- (8) a. John_i portrayed himself_i.
 b. John_i's portrayal of himself_i
 (9) a. *John_i portrayed him_i.
 b. *John_i's portrayal of him_i

Moreover, the empty (i.e. unpronounced) pronoun (PRO) in an adjunct can refer to the subject *John* (10) but not the object *Bill* (11). The contrast, again, obtains in both clauses and nominal phrases.

- (10) a. John_i criticized Bill after PRO_i talking.
 b. John_i's criticism of Bill after PRO_i talking
 (11) a. *John criticized Bill_i after PRO_i talking.
 b. *John's criticism of Bill_i after PRO_i talking

This indicates that both clauses and nominal phrases establish a domain for binding and control relations and that there is an asymmetric relation between the subject and the object in both clauses and nominal phrases.

Another parallelism is that within both nominal phrases and clauses, there is a selectional relation between the heads of two projections. In sentences, the complementizer *that* selects an embedded clause that contains a tensed verb (12) and the complementizer/preposition *for* selects an infinitival complement (13).

- (12) a. I think [_{CP} that [_{IP} they will go home]].
 b. *I think [_{CP} that [_{IP} them to go home]].
 (13) a. It is strange [_{CP} for [_{IP} them to go home]].
 b. *It is strange [_{CP} for [_{IP} they will go home]].

In nominal phrases, a singular demonstrative selects a singular numeral (14) and a plural demonstrative selects a plural numeral (15):

- (14) a. [_{DP} this [_{NumP} one [_{NP} table]]]
 b. * [_{DP} this [_{NumP} two [_{NP} tables]]]
 (15) a. [_{DP} these [_{NumP} two [_{NP} tables]]]
 b. * [_{DP} these [_{NumP} one [_{NP} table]]]

Moreover, similar movement patterns in clauses and nominal phrases also indicate that there must be a structural position in both clauses and nominal phrases to host the moved elements (Ihsane, 2008, chap. 1). The first kind of movement is head movement. One of the well documented examples is exhibited by the difference in word order within clauses in English and French: certain adverbs precede verbs in English but follow verbs in French:

- (16) a. My friends all love Mary.
 b. Mes amis aiment tous Marie.
 my friends love all Mary
 'My friends all love Mary.'

Pollock (1989) suggests that the underlying word order in both languages is that adverbs precede verbs. The deviation of French from this underlying word order is due to movement of the verb to a higher position in the hierarchical structure of the clause. A similar movement is also observed in the nominal phrases of the two languages: for example, adjectives precede nouns in English (17a) but adjectives follow nouns in French (17b).

- (17) a. the red flower
 b. le fleur_i rouge t_i
 the flower red
 'the red flower'

One analysis advanced in many studies (e.g. Cinque, 1995) is that in French, the noun may move leftward, bypassing the adjective, in the same way that verbs move across adverbs in the same language.

Additionally, *wh* phrases in both clauses and nominal phrases may move to their left periphery, which indicates a structural position on the left periphery for moved phrases (Alexiadou, Haegeman, & Stavrou, 2007, Part II, chap. 1).

- (18) a. [_{CP} [_{IP} I like this book the best]].
 b. [_{CP} Which book [_C do [_{IP} you like the best]]]?
 c. This is [_{DP} [_D a [_{AP} very important] decision]].
 d. [_{DP} [_{AP} How important] [_D a decision]] is this?

In (18b), *which book* moves to the specifier position of CP and in (18d), the phrase *how important* moves to the specifier position of DP.

Finally, ellipsis patterns reveal the presence of functional projections in the structures of both clauses and nominal phrases.

- (19) a. Mary likes swimming but John [_{IP} doesn't [_{VP} like swimming]].
 b. My sister's two boys are wild but [_{DP} John's [_{NumP} two [_{NP} boys]]] are really quite well-behaved.

In (19a), the verb phrase in the second conjunct, *like swimming*, is deleted and according to Lobeck (1995, chap. 2), the existence of a functional category (IP) is crucial for licensing the ellipsis of the verb phrase. Similarly, the ellipsis of the noun phrase in the second conjunct of (19b), *boys*, must be licensed by a functional category, which is NumP in this case.

2.2.2. Differences between clauses and nominal phrases

Despite the structural parallelisms between clauses and nominal phrases in English illustrated above, there are some differences in terms of functional morphemes between clauses and nominal phrases. The first difference concerns those words that fill the top nodes of nominal phrases and clauses, i.e. DP and CP, respectively. English demonstratives, which are associated with DP, exhibit a difference between a plural form (such as *these*) and a singular form (such as *this*), depending on whether the following Number Phrase indicates a singular number or a plural number (Leu, 2008). But in clauses, complementizers, like *that*, *if* and *whether*, do not exhibit inflectional alternations. The second difference concerns the words that fill the intermediate projections in nominal phrases and clauses, i.e. NumP and TP, respectively. Within nominal phrases, numerals, which are located at Number Phrase, do not inflect for number ((20a) and (20b)). Within clauses, however, auxiliaries, which fill the node of Tense Phrase, may inflect for tense ((21a) and (21b)).

- (20) a. one apple
 b. two(*s) apples
- (21) a. The men have finished the work.
 b. The men had finished the work.

2.3. The predictions

So far, we have illustrated the structural parallelisms and differences in inflectional properties between clauses and nominal phrases in English. The two hypotheses (the TPH and the DMH) predict different impairment patterns on nominal phrases, as compared to the impairment patterns in clauses. The main focus of this paper is to test these predictions in order to tease apart the TPH and the DMH. Referring to the clausal structure in (4) and the nominal structure in (5), let us spell out the impairment patterns in clauses and nominal phrases predicted by these two hypotheses.

The TPH claims that the higher a functional projection is along the hierarchical syntactic structure, the more likely it is to be impaired, and that the impairment of a node implies impairment of all the nodes above it. Moreover, the TPH claims that impairment of any projection will lead to the impairment of whatever is in that projection. Specifically, the TPH generates the following predictions: complementizers, which occur in CP, such as *that*, *if* and *whether*, are more likely to be impaired than auxiliaries (such as *have* and *had*), which occur in TP. In the nominal domain, demonstratives, which occur in DP (such as *this* and *these*), are more likely to be impaired than numerals, which occur in NumP (such as *one* and *two*).

In contrast, the DMH claims that aphasic patients have faulty implementation of feature-to-morpheme mapping rules, which leads to the prediction that aphasic patients will encounter difficulty whenever they have to implement a morphological rule. As far as clauses are concerned, because complementizers in English (like *that*, *if* and *whether*) do not undergo morphological inflection, it is predicted that aphasic patients will perform normally on these morphemes. On the other hand, as *had* is the past tense inflected form of *have*, it is predicted that aphasic patients will be impaired on *had*. Regarding the nominal phrase, if we assume that the plural demonstrative (*these*) is the inflected form of the singular demonstratives (*this*) (Leu, 2008), it is predicted that aphasic patients will exhibit impaired performance on *these*. But the singular demonstrative *this* and numerals are very likely to be preserved because they do not undergo morphological inflection.

In order to test these predictions, we designed four experiments to test aphasic participants' performance on four functional categories in clauses and nominal phrases: complementizers, auxiliary verbs, demonstratives and numerals. Moreover, these experiments included two kinds of tasks: sentence completion and grammaticality judgment. We tested patients on these two modalities as there is a debate regarding whether deficits in aphasic patients are the same across modalities (Burchert et al., 2005; Grodzinsky, 1984, 2000a, 2000b; Grodzinsky & Finkel, 1998; Linebarger, Schwartz, & Saffran, 1983; Nanousi et al., 2006). For example, it is reported that patients exhibited similar patterns of impairment in both sentence completion and grammaticality judgment tasks (Varlokosta et al., 2006; Wenzlaff & Clahsen, 2004) and it is reported in Faroqi-Shah and Dickey (2009) that patients had difficulty with tense inflections in both grammaticality judgment and production (narration and elicited picture description). By including two types of tasks, we hope to address the question of whether grammatical morphology impairment is due to a deficit of the central grammatical representation or due to impaired access to the central representation via a particular modality (Dickey et al., 2008). In the former case, we would expect the same impairment pattern in both sentence completion and grammaticality judgment. In the latter case, we may find different deficit patterns in the two tasks.

3. Sentence completion experiments

3.1. Experiment 1: sentence completion testing complementizers and tense inflections in clauses

This experiment examined patients' use of complementizers and tense inflections in a task requiring participants to select from a response set a missing word in sentences presented. The TPH

predicts that response accuracy (expressed as the percentage of correct responses) will be significantly higher for complementizers than for auxiliary verbs. Conversely, the DMH predicts that response accuracy for complementizers and *have* will be close to ceiling and that response accuracy for *had* will be below chance.

3.1.1. Participants

A total of twenty individuals, ten agrammatic aphasic and ten healthy control participants, were included in the experiment. All participants were native monolingual speakers of American English. The aphasic individuals, recruited from the subject pool of the Aphasia and Neurolinguistic Research Laboratory at Northwestern University, presented with a single left hemisphere stroke, with the exception of one patient (DSG), who presented with aphasia secondary to a single right hemisphere stroke; all were between 2 and 15 years post-onset of stroke at the time of the study (Mean age = 55.1; range = 48–75). MR scans (T1 images) were obtained for five participants (see Fig. 1), with lesions involving inferior frontal and surrounding regions, extending to temporoparietal regions and including subcortical white matter. For health reasons, the remaining patients were unable to undergo MR scanning, however, previous medical history revealed that all experienced ischemic middle cerebral artery events. All patients had normal visual and hearing acuity. All except one patient (MD) were premorbidly right-handed. These patients were mildly or moderately impaired according to their scores on the Western Aphasia Battery (WAB) (Kertesz, 1982), with WAB Aphasia Quotients ranging from 60.8 to 87.4. Demographic information and WAB scores for the aphasic participants are included in Table 2. Reading scores derived from administration of various tests, presented in Table 3, also showed that all patients could read at least single words.⁵ The control participants had no prior history of speech-language, learning or neurological disorders (Mean age = 50.2; range = 50–71).⁶

The aphasic participants were diagnosed with agrammatic aphasia based on production patterns observed in their narration of the Cinderella story as well as scores derived from administration of tests of grammatical morphology production (i.e., the *Northwestern Assessment of Verb Inflection* (NAVI), Lee & Thompson, 2009, experimental version) and production and comprehension of verbs and sentences (i.e., the *Northwestern Assessment of Verbs and Sentences* (NAVS), Thompson, 2011). Analysis of the narrative data, using a method developed by Thompson et al. (1995) (also see Thomspson, Cho, et al., 2012), indicated that (compared to cognitively healthy controls from Thomspson, Cho, et al., 2012) the aphasic participants evinced reduced mean length of utterance, ranging from 4.8 to 10.39 words ($M = 7.5$), decreased words per minute, ranging from 26.55 to 85.67 ($M = 60.16$), and a lowered proportion of grammatically correct sentences, ranging from 22% to 82% ($M = 65%$) (see Table 4). On the NAVI (Table 5), patients showed greater difficulty with finite compared to nonfinite forms, and on the NAVS (Table 6), patients showed spared verb comprehension, but poorer production of three-argument compared to one- and two-argument verbs as well as difficulty producing verb arguments in sentence contexts as tested by the Argument Structure Production Test (ASPT) of the NAVS. In addition, aphasic participants showed better comprehension and production of canonical than noncanonical sentences (see Table 6).

3.1.2. Stimuli

In this experiment, we constructed fifty-five sentences, with each containing a blank, which could be filled by one of four candidate words presented. To construct these sentences, we selected three complementizers (*that*, *if* and *whether*), five complement taking verbs (*ask*, *care*, *know*, *see* and *wonder*) and two auxiliary verbs (*have* and *had*). We also selected sixteen verbs and twenty-two nouns (see List 1 in the Appendix). All verbs and nouns were one- or two-syllable high-frequency words, selected from CELEX (Baayen, Pieenbrock, & van Rij, 1993).

The stimulus sentences were distributed across three conditions. Fifteen lacked complementizers (22) with the correct response *if* required for these sentences. Fifteen contained the temporal adverb

⁵ No reading scores were available for two participants (JY and MK), however, all demonstrated ability to read single words and phrases.

⁶ A paired *T*-test indicated that there was no significant difference between the patients and the normal controls in terms of their age.

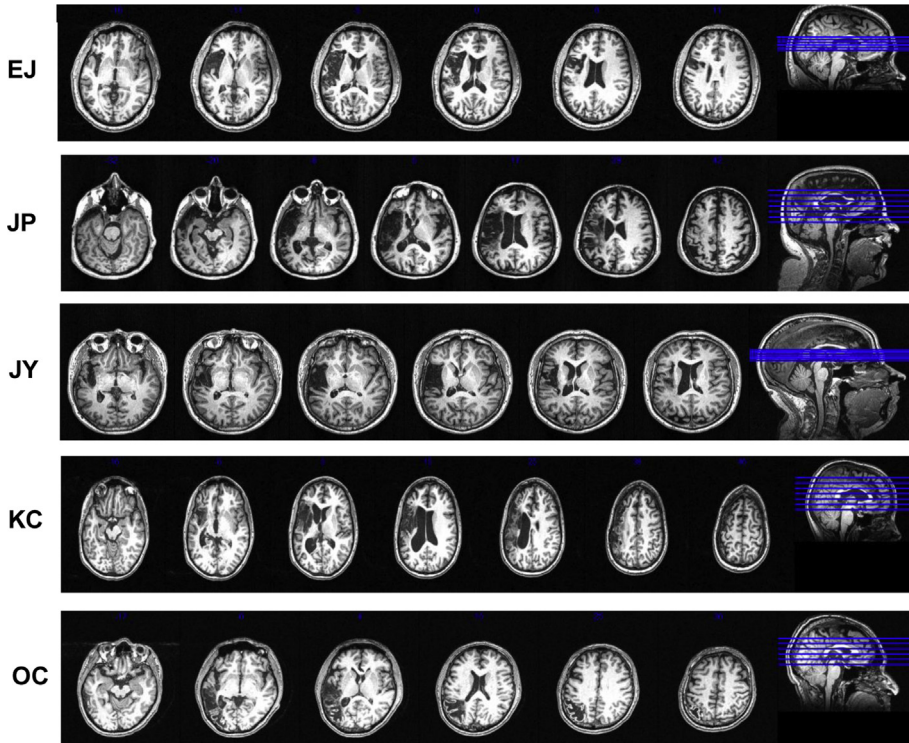


Fig. 1. Selected slices from T1 MRI images of aphasic participants showing lesion sites. MRI scans were not available for the other five patients for health reasons.

today (23) and lacked the auxiliary verb *have*, therefore the correct response was *have*. Another fifteen sentences contained the temporal adverb *yesterday* and lacked the auxiliary verb *had* (24) so the correct response was *had* in these sentences. Another ten sentences were filler sentences, which lacked other kinds of words, for example, prepositions (25).

(22) They wonder ___ the man is covering the box. (in, **if**, too, but)

(23) Today the girls ___ covered the box. (**have**, in, and, had)

Table 2
Demographic information and the Western Aphasia Battery scores of aphasic participants.

	Demographic information				WAB					
	Age	Gender	Handedness	Years of post-onset	Information content	Fluency	Comprehension	Repetition	Naming	Aphasia quotient
DSG	58	M	R	6	10	5	10	10	9.8	89.6
EAS	75	F	R	3	9	5	9.8	8.8	8.9	83
EJ	41	M	R	3	10	9	8.9	9	9.7	93.2
JN	55	F	R	7	10	10	10	9.8	9.2	98
JP	51	F	R	4	8	5	7.45	8.4	8.3	74.3
JY	48	M	R	5	9	9	9.85	9.2	9.8	93.7
KC	35	M	R	4	9	5	7.8	9.4	7.6	77.6
MD	64	M	L	22	9	4	8.45	5.1	9.3	71.7
MK	67	M	R	13	8	4	9.4	9	8.3	77.4
OC	57	M	R	6	10	5	7.9	7.6	8.5	78

^a All patients except MD was pre-morbidly right-handed.

Table 3
The patients' reading scores.

Participant	WAB-R reading commands score (20)	PALPA subtest 34	NAVI pre-test reading
DGS	19	100.00%	100%
EAS	NA	NA	92%
EJ	NA	NA	70%
JN	NA	NA	83%
JP	20	98.00%	100%
JY	NA	NA	NA
KC	19	83.33%	58%
MD	17	65.60%	83%
MK	NA	NA	NA
OC	17	NA	75%

PALPA = Psycholinguistic Assessments of Language Processing in Aphasia. Subtest 34 tests 'Lexical Morphology and Reading'; NAVI Pre-Test Reading examined participants' ability to read single nouns and verbs as well as active subject-verb-object sentences; NA = not administered.

(24) By yesterday the girls ___ covered the box. (have, in, and, **had**)

(25) The cup is ___ the desk. (this, are, **on**, that)

In both the embedded clause in (22) and the sentences in (23) and (24), the subjects were animate nouns and the objects were inanimate nouns, so all the sentences were semantically non-reversible.

3.1.3. Procedures

Each stimulus sentence, together with four candidate words, was printed on a separate sheet. Participants read the stimulus sentence and chose a word to complete the sentence. Whenever patients encountered difficulty, experimenters read aloud the sentence and the four candidate words. The response accuracy was calculated as the percent of correct responses for each task. Before the experiment, aphasic patients were tested for comprehension of the words used in the experiment, including the three complementizers, the five complement taking verbs, the two auxiliary verbs, the sixteen verbs and the twenty-two nouns. They were asked to point to the word pronounced by the experimenter. Moreover, using a calendar, they were asked to demonstrate their understanding of *yesterday* and *today*. Additionally, participants were provided four practice items prior to administering the experimental sentences to insure their understanding of the task. The experiment stimuli were presented in a pseudo random order and they remained the same across participants.

3.1.4. Results

The response accuracies for the two groups of participants across conditions are shown in Table 7 and Fig. 2. Because the accuracy data were not normally distributed, we performed rationalized arcsine transformation prior to further statistical analysis according to formulas proposed in Studebaker (1985) and Thornton and Raffin (1978).⁷ The transformed accuracy data were entered into a mixed design ANOVA, with three test conditions (Comp, *have* and *had*) as the within subject factor and the two groups (aphasic participants and controls) as the between subject factor. Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 6.596, p = 0.037$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimate of sphericity ($\epsilon = 0.76$). There was a significant main effect of test condition, $F(1.513, 27.24) = 20.21, p < 0.001$ as well as a significant main effect of group, $F(1, 18) = 54.13, p < 0.001$ and there was also a significant interaction effect for group and test condition, $F(1.513, 27.24) = 9.85, p = 0.001$. Response accuracy for the condition testing complementizers was significantly higher than for auxiliary verbs, $t(1, 9) = 3.47, p = 0.007$. In addition, response accuracy for *have* was significantly higher than for *had*, $t(1, 9) = 8.18, p < 0.001$.

⁷ Thanks for the anonymous reviewer for this suggestion.

Table 4

Narrative scores of aphasic participants.

Participant	MLU – Words	WPM	%Grammatically correct sentences
DSG	8.07	58.19	82%
EAS	5.91	56.68	55%
EJ	10.08	90	70%
JN	8.78	85.67	71%
JP	6.15	26.55	74%
JY	7.28	36.15	81%
KC	6.06	33.06	79%
MD	4.8	73.48	22%
MK	NA	NA	NA
OC	10.39	81.65	48%
Aphasic mean (SD)	7.5 (1.96)	60.16 (24.08)	65% (0.2)
Normal mean (SD)	11.11 (0.56)	133.22 (5.22)	93.02% (1.21)

MLU = Mean length of utterance; WPM = words per minute; vmi = verbal morphology inflection. NA = not administered. The normal mean is from cognitively healthy speakers ($n = 13$) from [Thomson, Cho, et al. \(2012\)](#).

Because the stimuli in the three conditions ((22), (23) and (24)) have different lengths, respectively, we also carried out a one-way ANOVA on the accuracy data with the three kinds of sentence length (8 words in (22), 6 words in (23) and 7 words in (24)) as the independent variable. The analysis revealed a significant effect, $F(2, 27) = 20.51, p < 0.001$. We found a significant difference between the complementizer condition and the *had* condition ($t(1, 9) = 6.7, p < 0.001$), plus a significant difference between the *have* condition and the *had* condition, $t(1, 9) = 8.18, p < 0.001$. There was, however, no significant difference between the complementizer condition and the *have* condition, $t(1, 9) = 1.01, p = 0.337$. Although sentence length appeared to have a significant effect on accuracy, the significant differences among the three conditions in this experiment are better attributable to the experimental manipulation among complementizers, *have* and *had*. As demonstrated in [Fig. 2](#), accuracy for the complementizer condition in (22), which contained the longest stimuli, was the highest while the accuracy for the *had* condition in (24), which included stimuli of medium length among the three conditions, was the lowest.

3.2. Experiment 2: sentence completion testing demonstratives and numerals in nominal phrases

This experiment examined patients' use of demonstratives and numerals, employing the same task as in Experiment 1. The TPH predicts that response accuracy will be significantly lower for demonstratives than for numerals. Conversely, the DMH predicts that response accuracy for *this* and numerals will be close to ceiling and that response accuracy for *these* will be below chance.

Table 5

Aphasic participants' scores on the Northwestern assessment of verb inflection.

Participant	Infinitive	Progressive	Total nonfinite	Present singular	Present plural	Regular past	Irregular past	Future	Total finite
DSG	100%	100%	100%	90%	80%	80%	100%	100%	90%
EAS	100%	100%	100%	90%	60%	100%	60%	80%	78%
EJ	100%	80%	90%	90%	20%	0%	40%	0%	30%
JN	100%	100%	100%	90%	70%	80%	100%	90%	86%
JP	100%	100%	100%	10%	20%	60%	80%	100%	54%
JY	NA	NA	NA	NA	NA	NA	NA	NA	NA
KC	100%	100%	100%	100%	80%	40%	20%	0%	48%
MD	100%	100%	100%	60%	60%	40%	20%	30%	42%
MK	NA	NA	NA	NA	NA	NA	NA	NA	NA
OC	100%	100%	100%	100%	0%	100%	100%	90%	78%
Mean (SD)	100% (0)	97.5% (0.07)	98.75% (0.04)	78.75% (0.30)	48.75% (0.31)	62.5% (0.35)	65% (0.35)	61.25% (0.44)	63.25% (0.22)

NA = not administered. .

Table 6

Aphasic participants' scores on the Northwestern Assessment of Verbs and Sentences.

	DSG	EAS	EJ	JN	JP	JY	KC	MD	MK	OC	Mean (SD)
VNT (1Pl + 2Pl)	100%	95%	90%	100%	65%	100%	85%	100%	95%	100%	93% (0.11)
VNT (3Pl)	71%	71%	57%	100%	43%	71%	71%	100%	86%	43%	71.3% (0.2)
VCT (Total)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100% (0)
ASPT (Total)	97%	94%	94%	94%	88%	97%	88%	84%	94%	91%	92.1% (0.04)
SPPT Canonical	100%	93%	53%	100%	100%	93%	53%	33%	100%	93%	81.8% (0.25)
SPPT Non-canonical	100%	67%	7%	100%	27%	100%	20%	0	87%	60%	56.8% (0.4)
SCT Canonical	100%	87%	100%	100%	87%	100%	53%	87%	93%	40%	84.7% (0.21)
SCT Non-canonical	87%	73%	73%	100%	53%	87%	67%	80%	87%	73%	78% (0.13)

VNT = Verb Naming Test; VCT = Verb Comprehension Test; ASPT = Argument Structure Production Test; SPPT = Sentence Production Priming Test; SCT = Sentence Comprehension Test; 1Pl = 1 place verbs; 2Pl = 2 place verbs; 3Pl = 3 place verbs; Sub-wh = subject wh questions; Obj-wh = object wh questions; Sub relatives = subject relative clauses; Obj relatives = object relative clauses.

3.2.1. Participants

The same aphasic and healthy individuals participated in this experiment as in Experiment 1.

3.2.2. Stimuli

This experiment was aimed at testing participants' ability to choose a correct demonstrative or numeral. Each participant saw eighty sentences, with each sentence missing a word. The participants' task was to choose one from among four candidate words to complete the sentence. To construct these sentences, we selected fifteen verbs and twenty nouns (see List 2 in the Appendix), which were one- or two-syllable high frequency words selected from CELEX (Baayen et al., 1993). We also used two demonstratives (*this* and *these*), four numerals and four color adjectives (*green*, *yellow*, *black* and *red*). All stimulus sentences were semantically non-reversible.

Thirty stimuli lacked a demonstrative, half of them lacking *this* (26) and half of them lacking *these* (27).

(26)The man covered ___ car. (**this**, for, these, on)

(27)The man covered ___ cars. (this, for, **these**, on)

The two sentences were the same except that the noun in (26) (*car*) was singular and the noun in (27) (*cars*) was plural. The correct response for (26) was *this* and the correct response for (27) was *these*.

Another thirty of the sentences lacked a numeral. Each sentence in this set was presented with a picture depicting a different number of objects. Some pictures showed only one object (e.g., one shirt) ($n = 15$), whereas others showed four objects (e.g., four shirts) ($n = 15$). Sentences as in (28) and (29) were presented followed by four numerals. The task of the participants was to choose a numeral for the sentence based on what was depicted in the picture.

Table 7

Aphasic patients' individual accuracies in Experiment 1.

	Complementizers	have	had
DSG	93.3	93.3	80
EAS	100	93.3	86.7
EJ	100	93.3	86.7
JN	93.3	100	86.7
JP	93.3	100	86.7
JY	93.3	93.3	86.7
KC	93.3	93.3	80
MD	100	93.3	80
MK	93.3	86.7	73.3
OC	100	93.3	80
Mean	96	94	82.7

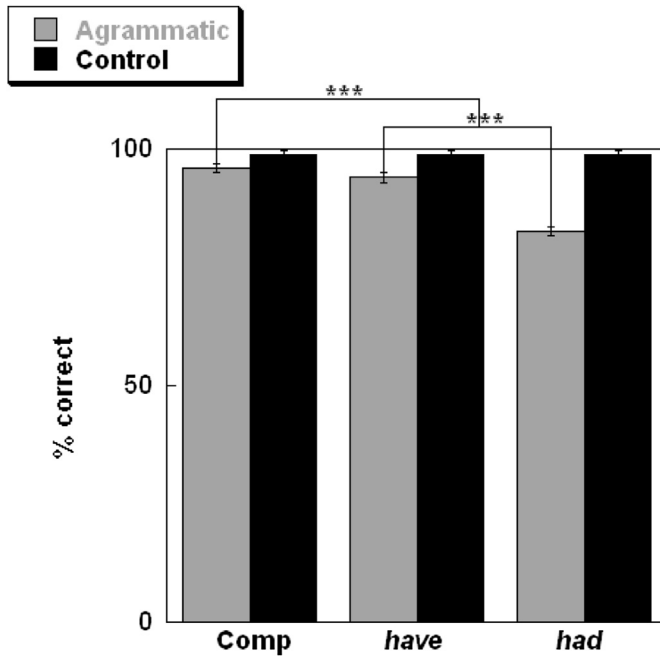


Fig. 2. Mean response accuracy in clauses by condition, Experiment 1. Comp = the condition testing complementizers. Error bars represent standard errors (SE).

(28) In this picture, we can see ___ shirt(s). (**one**, two three, four)

(29) In this picture, we can see ___ shirt(s). (one, two three, **four**)

Additionally, there were twenty fillers that were like the other stimuli except that a word in another position was missing:

(30) The clock is ___ the table. (this, three, these, **on**)

(31) In this picture, we can see ___ shirt(s). (yellow, black, green, black)

In (31), participants were asked to choose a word matching the color of the object depicted in the picture.

3.2.3. Procedures

Prior to the experiment, patients were tested on their comprehension of the fifteen verbs and twenty nouns used to construct the sentences in this experiment. Moreover, we also tested patients' understanding of numerals. Patients were presented with pictures that depicted different numbers of objects. Then patients were asked to choose the card that contains the numeral that correctly depicted the number of the objects in the picture. Additionally, patients were also tested on their comprehension of the color adjectives as used in the fillers in (31). As in Experiment 1, the stimuli were presented in a pseudo random order and were the same across participants.

3.2.4. Results

Results of the experiment for the two participant groups are shown in Table 8 and Fig. 3. After being transformed according to Studebaker (1985) and Thornton and Raffin (1978), the response accuracy

Table 8
Aphasic patients' individual accuracies in Experiment 2.

	this	these	Sg	PI
DSG	93.3	66.7	100	100
EAS	100	80	100	100
EJ	100	60	100	100
JN	100	80	100	100
JP	100	73.3	100	100
JY	100	80	93.3	100
KC	80	80	100	100
MD	93.3	66.7	93.3	86.7
MK	93.3	73.3	100	100
OC	93.3	73.3	93.3	93.3
Mean	95.3	73.3	98	98

data were entered into a mixed design ANOVA, with the four conditions as the within-subject factor and the two groups (aphasic participants and controls) as the between-subject factor. There was a significant main effect of test condition ($F(3, 54) = 21.24, p < 0.001$) and group ($F(1, 18) = 25.88, p < 0.001$). There also was a significant interaction effect of test condition and group, $F(3, 54) = 11.16, p < 0.001$. Pairwise comparisons indicated that accuracy for NumP was significantly higher than for DP, $t(1, 9) = 5.16, p = 0.001$. Among all the words that fill the category of DP, there was a dissociation between the singular demonstrative and the plural demonstrative, as accuracy for *this* was significantly higher than for *these*, $t(1, 9) = 7.08, p < 0.001$.

Additionally, we carried out an ANOVA of the accuracy data with the two kinds of sentence length as the independent variable (4 words in (26) and (27); 7 words in (28) and (29)), which revealed a significant effect, $F(1, 38) = 14.74, p < 0.001$. A pairwise comparison indicated a significant difference between the accuracy for the condition of demonstratives (*this* and *these*) and the condition of

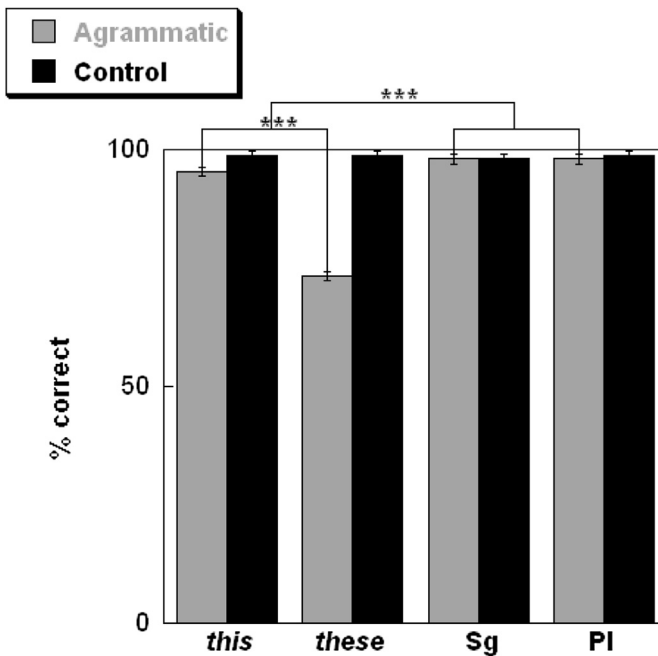


Fig. 3. Mean response accuracy in nominal phrases by condition, Experiment 2. Sg = the singular numeral, PI = plural numerals. Error bars represent standard errors (SE).

numerals, $t(1, 19) = 4.08$, $p = 0.001$, with the accuracy of the former condition significantly lower than that of the latter condition. This is because, as demonstrated in Fig. 3, the accuracy of the *these* condition was very low while the accuracy of the other three conditions was close to ceiling.

3.3. Interim summary and discussion

We designed two sentence completion experiments to test the TPH and the DMH regarding aphasic participants' impairment of functional morphemes in clauses and nominal phrases. Patient's response accuracy for complementizers was significantly higher than that for auxiliary verbs and this result goes against the prediction of the TPH, which predicts that morphemes in CP should be more impaired than those in TP. Meanwhile, response accuracy for *have* was significantly higher than that for *had*, and this result is consistent with the prediction of the DMH, which predicts that inflectionally derived forms will be more impaired than forms involving no inflection. In case of nominal phrases, accuracy for the category of DP (i.e. demonstratives) was significantly lower than that for the category of NumP (i.e. numerals), which seems to support the prediction of the TPH. On the other hand, among all the words that fill the category of DP, there was a dissociation between the singular demonstrative *this* and the plural demonstrative *these*, as accuracy for the former was significantly higher than that for the latter. This result is not predicted by the TPH, as it predicts that all functional morphemes in DP will be impaired. But this result supports the prediction of the DMH, which predicts that the plural demonstrative will be more impaired than the singular demonstrative. The dissociation between *this* and *these* in terms of accuracy may also explain why the accuracy for the category of DP was significantly lower than those for the category of NumP. In a word, in both clauses and nominal phrases, those functional morphemes that involve inflection (e.g. *had* and *these*) were more impaired than those that do not (e.g. *have*, *this*, complementizers and numerals). This result supports the DMH, instead of the TPH.

4. Grammaticality judgment experiments

4.1. Experiment 3: grammaticality judgment of functional morphemes in clauses

Experiment 3 tested grammaticality judgment of complementizers and tense-inflected auxiliary verbs in clauses. The TPH and the DMH have different predictions about participants' behavior. The TPH predicts that accuracy for complementizers will be significantly lower than that for auxiliary verbs (including *have* and *had*). The DMH makes the prediction that accuracy for complementizers and *have* will be close to ceiling but accuracy for *had* will be below chance.

4.1.1. Participants

The patients and non-impaired controls who participated in Experiments 1 and 2 also participated in this experiment.

4.1.2. Stimuli

In this experiment, participants' task was to judge the grammaticality of 85 sentences that involved complementizers and tense-inflected auxiliary verbs. 25 of the sentences included embedded complement clauses introduced by either a complementizer (32a) or an ungrammatical preposition substitute (32b); 25 included either *have* in the present perfective tense (33a) or an ungrammatical use of *have* (33b); 25 involved the use of *had* in the past perfective tense (34a) or an ungrammatical use of *had* (34b). The ratio of grammatical to ungrammatical sentences was 3 to 2 in each condition. In addition, there were 10 fillers involving bare verbs (35a, b). Among the fillers, the ratio of grammatical to ungrammatical sentences was 1 to 1.

(32) Complementizers

- a. They see that the man cuts the shirt.
- b. They see *for the man cuts the shirt.

- (33) *have*
 a. Today the men have cut the shirt.
 b. By yesterday the men *have cut the shirt.
- (34) *had*
 a. By yesterday the men had cut the shirt.
 b. Today the men *had cut the shirt.
- (35) Bare-V
 a. They saw the man cut the shirt.
 b. They saw the man *is cut the shirt.

To construct these sentences, we selected three complementizers (*that*, *if* and *whether*), five complement taking verbs (*ask*, *care*, *know*, *see* and *wonder*) and two auxiliary verbs (*have* and *had*). We also selected fifteen verbs and fifteen nouns (see List 3 in the Appendix) from CELEX (Baayen et al., 1993). All verbs and nouns were one- or two-syllable high-frequency words. The embedded sentences in (32) and all the other sentences were semantically non-reversible as the subjects were animate nouns and the objects were inanimate nouns.

4.1.3. Procedures

The experiment was implemented in Superlab 4.0., which can record participants' responses. Each sentence was presented visually and while the sentence appeared on the screen, it was read out so that participants could both see and hear the sentence. Immediately after participants heard a sentence stimulus, they were asked to press a response pad button (the red button was labeled grammatical and the blue button was labeled ungrammatical) to indicate whether the sentence was grammatical or not. The stimuli were pseudo-randomized and were the same for all participants.

Before the experiment, patients were familiarized with the nouns and the verbs used in the experiment. Moreover, they were presented with six practice items, three of them read by the experimenter and another three displayed by Superlab 4.0.

4.1.4. Results

Response accuracy data for the two participant groups across conditions are shown in Table 9 and Fig. 4. As in Experiments 1 and 2, the accuracy data, which was computed over both grammatical and ungrammatical sentences, were rationalized-arcsine transformed before they were subjected to a mixed design ANOVA, with the three conditions as the within subject factor and the two groups of participants as the between subject factor. The analysis revealed a significant main effect of test condition, $F(2, 36) = 62.76$, $p < 0.001$ and a significant group effect, $F(1, 18) = 212.15$, $p < 0.001$, as well as a significant interaction effect of group and condition, $F(2, 36) = 48.41$, $p < 0.001$. Pairwise comparisons indicated that the aphasic participants' accuracy for complementizers was significantly higher

Table 9
 Aphasic patients' individual accuracies in Experiment 3.

	Complementizers	have	had
DSC	88	88	80
EAS	92	92	76
EJ	96	96	80
JN	96	92	80
JP	96	92	68
JY	92	88	76
KC	92	92	76
MD	92	96	72
MK	92	96	84
OC	92	92	72
Mean	92.8	92.4	76.4

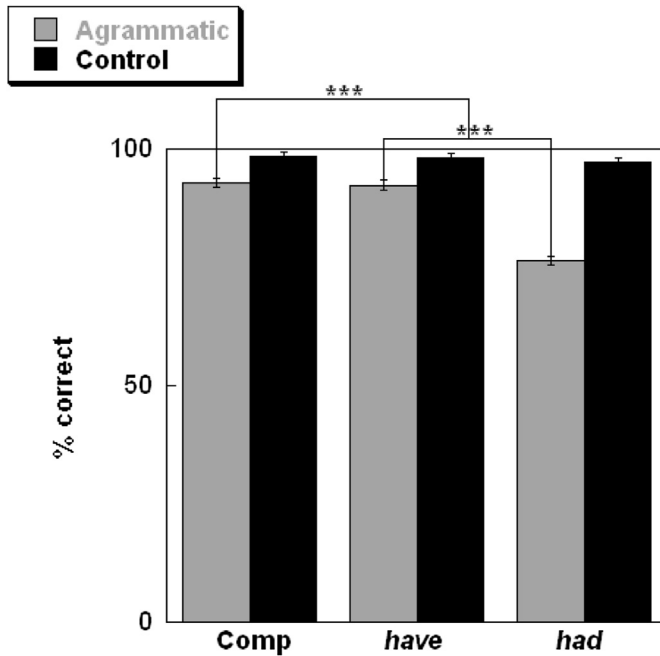


Fig. 4. Mean response accuracy in clauses by condition, Experiment 3. Comp = the condition testing complementizers. Error bars represent standard errors (SE).

than that for auxiliary verbs (including *have* and *had*), $t(1, 9) = 6.45, p < 0.001$. Patients' accuracy for *have* was significantly higher than that for *had*, $t(1, 9) = 9.97, p < 0.001$. There was no significant difference between the complementizer condition and the *have* condition, $t(1, 9) = 0.36, p = 0.726$.

In order to check whether patients exhibited any yes-bias in the judgment experiment, we carried out an ANOVA of the transformed accuracy data with grammaticality as a within subject factor and with the three conditions (complementizers, *have* and *had*) as a between-subject factor. We found no significant effect of grammaticality ($F(1, 27) = 2.91, p = 0.1$), although there was a significant effect of condition ($F(2, 27) = 56.32, p < 0.001$) and a significant interaction effect ($F(2, 27) = 7.17, p = 0.003$). This means that patients did not exhibit a yes-bias to grammatical sentences vs. ungrammatical sentences.

4.2. Experiment 4: grammaticality judgment of functional morphemes in nominal phrases

This experiment examined patients' performance regarding functional morphemes in nominal clauses. The two hypotheses have different predictions about aphasic patients' behavior. The TPH predicts that accuracy for both demonstratives (*this* and *these*) will be significantly lower than that for numerals (both *one* and plural numerals). The DMH makes the prediction that accuracy for *this*, *one* and plural numerals will be close to ceiling and that accuracy for *these* will be below chance.

4.2.1. Participants

The aphasic participants and healthy controls who participated in the previous three experiments also participated in Experiment 4.

4.2.2. Stimuli

The stimuli consisted of 25 sentences involving correct and incorrect uses of *this* (36a, b), 25 sentences involving correct and incorrect uses of *these* (37a, b), 25 sentences involving correct and incorrect uses of the singular numeral *one* (38a, b), and 25 sentences involving correct and incorrect

uses of plural numerals like *four* (39a, b). The ratio of grammatical to ungrammatical sentences was 3 to 2 in each condition. To construct these sentences, we selected fourteen verbs and thirteen nouns (as in List 4 of the Appendix), in addition to two demonstratives (*this* and *these*) and four numerals (*one*, *two*, *three* and *four*). All the verbs and nouns were one- or two-syllable high-frequency words, selected from CELEX (Baayen et al., 1993). In all these sentences, the subjects were animate nouns and the objects were inanimate nouns therefore all the sentences were semantically non-reversible.

(36) *this*

- a. The man chased this car.
- b. The man chased *this cars.

(37) *these*

- a. The man chased these cars.
- b. The man chased *these car.

(38) Singular numerals (*one*)

- a. The man chased one car.
- b. The man chased *one cars.

(39) Plural numerals

- a. The man chased four cars.
- b. The man chased *four car.

In addition, ten fillers in this experiment involved dual nouns that have both a mass reading and a count reading (for example, *a turkey* vs. *some turkey* in (40)). Previous studies have demonstrated that aphasic patients cannot distinguish between the mass reading and the count reading of dual nouns in the sentence–picture matching task or in the lexical decision task (Taler, Jarema, & Saumier, 2004). The dual nouns in these fillers were preceded by determiners or quantifiers that trigger either the mass reading or the count reading. Half of the fillers were grammatical and the other half were ungrammatical.

(40) Fillers

- a. They ate a turkey.
- b. They killed *some turkey.

4.2.3. Procedures

Before the experiment, patients were familiarized with the nouns and the verbs used in the experiment. Stimuli were presented using Superlab 4 in the same way as in Experiment 3. Moreover, they were presented with six practice items, three of them read by the experimenter and another three displayed by Superlab 4. The stimuli were pseudo-randomized and were the same across participants.

4.2.4. Results

Accuracy data computed over both grammatical and ungrammatical sentences are shown in Table 10 and Fig. 5. As in the previous three experiments, all the accuracy data were transformed before they were entered into a mixed design ANOVA, with the four conditions as the within subject factor and the two groups of participants (patients and controls) as the between subject factor. There was a significant main effect of test condition, $F(3, 54) = 24.53$, $p < 0.001$, a significant main effect of group, $F(1, 18) = 289.34$, $p < 0.001$, and a significant interaction effect, $F(3, 54) = 18.97$, $p < 0.001$. Pairwise comparisons of the patients's accuracy data indicated that accuracy for demonstratives was significantly lower than that for numerals, $t(1, 9) = 5.28$, $p = 0.001$. Accuracy for *this* was significantly higher than that for *these*, $t(1, 9) = 8.36$, $p < 0.001$.

Table 10
Aphasic patients' individual accuracies in Experiment 4.

	this	these	Sg	Pl
DSG	92	88	92	92
EAS	92	76	92	96
EJ	96	72	96	96
JN	92	76	96	88
JP	92	72	92	88
JY	100	84	92	96
KC	92	72	92	92
MD	92	72	96	92
MK	92	76	96	96
OC	92	84	92	92
Mean	93.2	77.2	93.6	92.8

Additionally, we carried out an ANOVA of the transformed accuracy data of the patients, with grammaticality as the within-subject factor and the four conditions tested in this experiment as the between-subject factor. Except a significant effect of test condition ($F(3, 36) = 29.92, p < 0.001$), we did not find any significant effect of grammaticality ($F(1, 36) = 1.86, p = 0.181$), nor a significant interaction effect ($F(3, 36) = 0.479, p = 0.699$). This means that patients were not significantly more accurate on grammatical stimuli than on ungrammatical stimuli.

4.3. Interim summary and discussion

Experiment 3 and Experiment 4 tested aphasic and control participants' ability to judge the grammaticality of functional morphemes in clauses and nominal phrases. Patients had low response accuracy for those functional morphemes that involve inflection, i.e. *had* and *these*, but they had high response accuracy for those that do not involve inflection, i.e. *have*, complementizers, *this* and

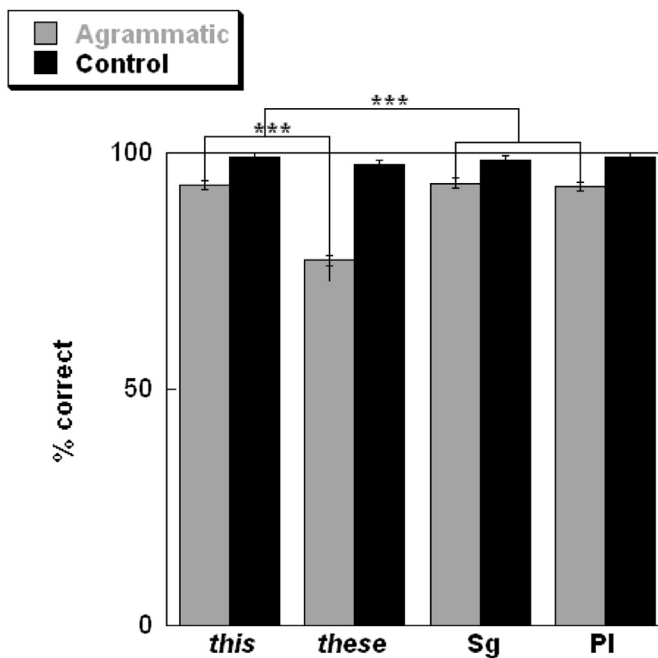


Fig. 5. Mean response accuracy in nominal phrases by condition, Experiment 4. Sg = the singular numeral, Pl = plural numerals. Error bars represent standard errors (SE).

numerals. These results can be better captured by the DMH, which predicts that patients are impaired on functional morphemes that involve inflection, instead of the TPH.

5. General discussions and conclusion

In this study, we tested two hypotheses concerning agrammatic aphasic individuals' impairment of functional morphemes in both nominal phrases and clauses in English. The Tree Pruning Hypothesis (TPH) predicts that those functional morphemes that reside in a higher functional projection within the hierarchical syntactic structure will be more likely to be impaired than those in a lower functional projection. On the other hand, the Distributed Morphology Hypothesis (DMH) predicts that words that involve inflection are more likely to be impaired than those that do not. Previous studies examining deficits in inflectional morphology and function words have investigated these phenomena in clauses only. Our study compared aphasic participants' impairment of inflectional morphemes and function words between nominal phrases and clauses because nominal phrases provide a testing ground for further teasing apart these two hypotheses. On one hand, nominal phrases and clauses in English are structurally parallel to each other and on the other hand, functional morphemes in nominal phrases exhibit different inflection patterns from clauses. Therefore, the two hypotheses predict different impairment patterns in nominal phrases as compared to those in clauses. The results of the experiments in our study reported similar impairment patterns between clauses and nominal phrases among aphasic individuals. As far as clauses are concerned, both the functional morphemes in the CP node (i.e. complementizers) and the morpheme *have*, which is located in TP, were preserved, but the morpheme *had*, which is also in TP, was impaired. In the case of nominal phrases, only the plural demonstrative (i.e. *these*) was impaired but other elements (i.e. the singular demonstrative *this* and numerals) were not impaired. In other words, in both clauses and nominal phrases, only those functional morphemes that involve inflection were impaired. This finding does not support the TPH, which predicts that the functional morphemes located in higher syntactic nodes (e.g. CP and DP) should be more likely to be impaired than those located in lower syntactic nodes (e.g. TP and NumP). Rather, the results of our experiments are more in line with the DMH, which predicts that patients have difficulty in converting phonological features into morphemes.

Building on the assumption in theoretical linguistics that nominal phrases and clauses show strong structural parallelisms, this study reveals that aphasic speakers have similar impairment patterns on functional morphology in clauses and nominal phrases. To our knowledge, only a few studies in the aphasia literature have examined impairment patterns across clausal and nominal domains (Rausch, Burchert, & De Bleser, 2005, 2007; Roeper, Ramos, Seymour, & Abdul-Karim, 2001). Interestingly, the results of these studies support our findings. For example, Rausch et al. (2005, 2007) found parallel impairments in both clauses and nominal phrases among aphasic patients. They reported that agrammatic individuals had difficulty with non-canonical word orders in clauses and nominal phrases, which arose in both production and comprehension tasks. In one study, Rausch et al. (2005) tested aphasic production of the following constructions in German:

- (41) a. Maria beschreibt Peter
Mary describes Peter
b. *Maria Peter beschreibt
Mary Peter describes
c. dass Maria Peter beschreibt
that Mary Peter describes
d. *... dass Maria beschreibt Peter
that Mary describes Peter
- (42) a. [_{PrePN} Marias] [_N Beschreibung]
Mary's description
b. * [_N Beschreibung] [_{PostPN} Marias]
description Mary's
c. die_{Det} [_N Beschreibung] [_{PostPN} Marias]
the description Mary's
d. *die_{Det} [_{PrePN} Marias] [_N Beschreibung]
the Mary's description.

In matrix clauses, finite verbs are in the second position, following a constituent occupying the first position (41a–b), but in embedded clauses, finite verbs are at the end of the clause (41c–d). According to Rausch et al. (2005), the second position of finite verbs in matrix clauses is derived through movement. In nominal phrases, while the proper name obligatorily moves to the prenominal position when the determiner is absent (42a–b), it has to stay in the postnominal position in the presence of a determiner (42c–d). Their production experiment indicated that aphasic had difficulty producing (41a) and (42a), but not (41c) and (42c).

In another study, Rausch et al. (2007) tested aphasic individuals' comprehension of the following constructions:

(43) a. Verbal active

[_{CP} Der Junge_{Agent} verhaftet Herrn Müller_{Patient}]
 the boy_{Agent} detains Mister Miller_{Patient}
 'The boy is detaining Mister Miller.'

b. Verbal passive

[_{CP} Herr Müller_{Patient} wird von dem Jungen_{Agent} verhaftet]
 Mister Miller_{Patient} is by the boy_{Agent} detained.
 'Mister Miller is being detained by the boy.'

c. Nominal 'active'

[_{DP} Peters_{Agent} Verhaftung des Mannes_{Patient}]
 Peter's_{Agent} detention the man's_{Patient}
 '...Peter's detention of the man'

d. Nominal 'passive'

[_{DP} Herrn Müllers_{Patient} Verhaftung durch den Jungen_{Agent}]
 Mister Miller's_{Patient} detention by the boy_{Agent}
 '...Mister Miller's detention by the boy'

The construction in (43a) was an active sentence, which had the canonical agent-verb-patient order. The construction in (43b) was the passive counterpart of (43a), and therefore involved a non-canonical word order. In a similar way, the construction in (43c) had the agent-nominalized verb-patient word order, and the construction in (43d) was the passive counterpart of (43c) and involved a non-canonical word order. Their study found that agrammatic patients had more difficulty comprehending constructions involving non-canonical word orders ((43b) and (43d)) than they did comprehending constructions involving canonical word orders ((43a) and (43c)). In a word, the studies by Rausch et al. (2005, 2007) indicated parallel impairment of non-canonical word orders in both clauses and nominal phrases. The present study, which compares agrammatic patients' impairment patterns between clauses and nominal phrases, indicates that agrammatic individuals' morphological impairments manifest similarly in clauses and nominal phrases. These findings shed light on linguistic debates regarding structural parallelisms between clauses and nominal phrases, providing further evidence supporting this parallel.

One of our findings that require further discussion is that not all elements in TP were equally impaired. That is, our results showed that although both *have* and *had* are in TP, *had* was impaired but *have* was not. This finding goes against the hypotheses proposed in some previous studies, which predict that all functional morphemes associated with tense will be impaired. For example, Wenzlaff and Clahsen (2004, 2005), based on the finding that German agrammatic speakers were impaired in tense marking in production and grammaticality judgment tasks, propose that tense features are especially prone to underspecification in agrammatism. Another explanation is that interpretable features (i.e. tense) are more likely to be impaired than uninterpretable features (agreement) (Burchert et al., 2005; Nanousi et al., 2006). A third hypothesis is that the process of diacritic encoding and retrieval (DER) is impaired among agrammatic patients, therefore, patients have difficulty in encoding tense features (+PAST or +PRESENT) in appropriate inflected verb forms and retrieving them (Faroqi-Shah & Dickey, 2009; Faroqi-Shah & Thompson, 2007). However, all the three accounts predict that tense markings will be impaired across the board, which was not borne out in our study. Instead, our study shows that patients had difficulty with *had* but not with *have*. This result can be captured by the DMH, which claims that patients have difficulty implementing morphological rules. Meanwhile, the

more severe impairment of *had* than *have* is consistent with a result reported in previous studies (Bastiaanse, 2008; Bastiaanse et al., 2011; Duman & Bastiaanse, 2009; Lee et al., 2008) that agrammatic speakers had difficulty with past tense forms. Bastiaanse (2008) and Bastiaanse et al. (2011) claimed that reference to the past involves establishing a link between the speech time and the event time, which operates on discourse, rather than on narrow syntax only (Avrutin, 2006). The results of the experiments in this study indicate that patients had more difficulty with *had* than with *have* in both sentence completion and grammaticality judgment tasks. These results are consistent with the explanation in Bastiaanse (2008) and Bastiaanse et al. (2011).

Moreover, the results of our experiments indicate that in terms of response accuracy, our aphasic participants evinced similar performance patterns in both sentence completion and grammaticality judgment tasks. The aphasic participants had very low response accuracy for the stimuli with inflection, but high response accuracy for those stimuli without. This result is consistent with the claim that functional impairments in agrammatic patients reflect a general syntactic impairment, which is not modality-specific (Clahsen & Ali, 2009; Faroqi-Shah & Dickey, 2009; Nanousi et al., 2006; Varlokosta et al., 2006; Wenzlaff & Clahsen, 2004, 2005).

As a final point of discussion, we briefly address the neural substrate of morpho-syntactic processing. The basic finding of this study is that our aphasic patients evinced difficulty with functional morphemes involving inflection, suggesting perhaps that regions of the brain damaged in our patients are necessary for morpho-syntactic/inflectional processing. Because of the heterogeneity of lesions in our patients as well as limitations regarding lesion-deficit correlation studies, however, it is not possible to determine which of the damaged regions are required for this purpose. Furthermore, it is interesting to note that neuroimaging research examining morpho-syntactic processing has resulted in mixed findings. Some studies have shown left inferior frontal activation (i.e. Brodmann's areas (BA) 44 and 45) for affixation as well as complex syntactic computation (Grodzinsky, 2000a; Hagoort, 2005; Indefrey, Hagoort, Herzog, Seitz, & Brown, 2001; Sahin, Pinker, Cash, Schomer, & Halgren, 2009; Tyler, Bright, Fletcher, & Stamatakis, 2004; Ullman et al., 2005; also see Ullman, 2001; for review), whereas, others have found more distributed activation, involving not only frontal regions, but also posterior perisylvian tissue (Friederici, Meyer, & von Cramon, 2000; Kielar, Milman, Bonakdarpour, & Thompson, 2011; Thompson, Bonakdarpour, & Fix, 2010; Thompson, den Ouden, Bonakdarpour, Garibaldi, & Parrish, 2010, and many others). In addition, the neurocomputation of regularly versus irregularly inflected forms has been debated, with some espousing that regular inflection processes (for verb tense) engages frontal regions, whereas, irregular inflection involves the posterior temporal region of the brain (Beretta et al., 2003; Dhond, Marinkovic, Dale, Witzel, & Halgren, 2003; Jaeger et al., 1996; Ullman et al., 2005). Interestingly, in the present experiments, our participants showed impaired performance of irregular forms (e.g., *had* and *these*) and these same participants also showed impairment on regular verb inflection (as tested by the NAVI). Hence, the neural mechanisms of morpho-syntactic processing remain unclear.

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Appendix. Lists of verbs and nouns in the experiments

1. List of verbs and nouns used in Experiment 1

Verbs ($n = 16$)	Nouns ($n = 22$)
bite	bat
chase	bell
cover	book
cut	box

(continued)

Verbs (<i>n</i> = 16)	Nouns (<i>n</i> = 22)
fix	broom
follow	cake
hug	car
kick	desk
kiss	door
pat	drum
paint	flag
pull	kite
save	lamp
watch	lock
weigh	nail
wrap	pen
	ring
	sock
	spoon
	shirt
	train
	truck

2. List of verbs and nouns used in Experiment 2

Verbs (<i>n</i> = 15)	Nouns (<i>n</i> = 20)
bite	bell
chase	book
cover	box
cut	broom
fix	cake
follow	car
hug	desk
kick	door
kiss	drum
paint	flag
pull	key
see	kite
watch	lock
weigh	nail
wrap	ring
	shirt
	skirt
	spoon
	train
	truck

3. List of verbs and nouns used in Experiment 3

Verbs (<i>n</i> = 15)	Nouns (<i>n</i> = 15)
bite	baby
chase	book
cover	box
cut	car
fix	cat
follow	desk
hug	door
kiss	girl
kick	kite
paint	lamp
pull	mountain
save	movie
watch	plate
weigh	shirt
wrap	truck

4. List of verbs and nouns used in Experiment 4

Verbs (<i>n</i> = 14)	Nouns (<i>n</i> = 13)
chase	bat
cover	box
cut	cake
fix	car
follow	child
hug	desk
kiss	door
kick	flag
paint	kite
pull	lock
save	nail
watch	ring
weigh	shirt
wrap	

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