HHS Public Access
Author manuscript
Aphasiology. Author manuscript; available in PMC 2017 January 01.

Published in final edited form as:
Aphasiology. 2016 ; 30(7): 815–840. doi:10.1080/02687038.2015.1111995.

Assessing Syntactic Deficits in Chinese Broca's aphasia using the *Northwestern Assessment of Verbs and Sentences*-Chinese (NAVS-C)

Honglei Wang[a,*] and **Cynthia K. Thompson**[b,c,d]

[a] College of Foreign Languages, Beihang University, Beijing, China

[b] Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

[c] Department of Neurology, Northwestern University, Feinberg School of Medicine, Chicago, IL, USA

[d] Cognitive Neurology and Alzheimer's Disease Center, Northwestern University, Feinberg School of Medicine, Chicago, IL, USA

Abstract

Background—English-speaking patients with Broca's aphasia and agrammatism evince difficulty with complex grammatical structures, including verbs and sentences. A few studies have found similar patterns among Chinese-speaking patients with broca's aphasia, despite structural differences between these two languages. However, no studies have explicitly examined verb properties, including the number and optionality of arguments (participant roles) selected by the verb, and only a few studies have examined sentence deficits among Chinese patients. In addition, there are no test batteries presently available to assess syntactically important properties of verbs and sentences in Chinese patients.

Aims—This study used a Chinese version of the *Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson, 2011), originally developed for English speakers with aphasia, to examine the verb and sentence deficit patterns among Chinese speakers with aphasia. As in the original NAVS, the Chinese version (NAVS-C) assessed verbs by the number and optionality of arguments as well as sentence canonicity, in the both production and comprehension.

Methods and Procedures—Fifteen Chinese patients with Broca's aphasia and fifteen age-matched healthy normal controls participated in this study. All NAVS-C tests were administered, in which participants were asked either to produce or identify verbs and sentences coinciding with action pictures.

Outcomes & results—Despite grammatical differences between Chinese and English, the impairment caused by structural complexity of verbs and sentences was replicated in Chinese-

* Corresponding author. The present address: College of Foreign Languages, Beihang University, No. 37 Xueyuan Road, Haidian District, Beijing, 100191, China. Tel.: +86 82313889; fax: +86 82315605. hongleiwang@buaa.edu.cn (Honglei Wang). Cynthia K. Thompson: ckthom@northwestern.edu

This is an Accepted Manuscript of an article published by Taylor & Francis Group in Aphasiology on November 16, 2015, available online: http://www.tandfonline.com/10.1080/02687038.2015.1111995

speaking patients using the NAVS-C. Verbs with more arguments were significantly more impaired than those with fewer arguments and verbs with optional arguments were significantly more impaired than those with obligatory arguments. One deviation from English-speaking patients, however, is that the Chinese-speaking patients exhibited greater difficulty with subject relative clauses than with object relative clauses because the former, rather than the latter, involve non-canonical order in Chinese. Similar to English-speaking patients, Chinese patients exhibited more difficulty with object extracted wh-questions than with subject extracted wh-questions. Suggesting that wh-movement in Logical Form may also cause processing difficulty. Moreover, Chinese-speaking patients exhibited similar performance in both production and comprehension, indicating the deficits in both modalities.

Conclusions—The number and optionality of verb arguments as well as canonicity of the Agent-Theme order in sentences impacts Chinese-speaking individuals with aphasia as it does in the case of English-speaking patients. These findings indicate that the NAVS-C is a useful tool for detailing deficit patterns associated with syntactic processing in patients with aphasia cross-linguistically.

Keywords

Syntactic complexity; verb argument structure; NAVS; Chinese aphasia; aphasia assessment

Introduction

It has been observed cross-linguistically that patients with nonfluent Broca's aphasia (with agrammatism in particular) experience difficulty with verbs and complex sentence structures in production and/or comprehension (Bastiaanse & van Zonneveld, 2005; Caramazza & Zurif, 1976; Friedmann, 2000; Schwartz, Saffran, & Marin, 1980; Thompson & Bastiaanse, 2012). One pattern noted across languages is that verb production is influenced by the number of arguments (or participant roles) encoded by the verb and their optionality (i.e., whether or not these arguments are required in the syntax). Across studies, research has shown that verbs with a greater number of arguments are more difficult than verbs with fewer arguments in naming and other production tasks (Dragoy & Bastiaanse, 2010; Kim & Thompson, 2000, 2004; Luzzatti, Mondini, & Semenza, 2012; Thompson, Lange, Schneider, & Shapiro, 1997; Thompson, Shapiro, Li, & Schendel, 1995). For example, Thompson and colleagues found that three-argument (e.g., *give* in (1a)) and two-argument verbs (e.g., *follow* in (1b)) are more difficult for patients than one-argument verbs (e.g., *laugh* in (1c)).

(1) **a.** Three-argument verb:

The artist [AGENT] gave the painting [THEME] to the museum [GOAL].

b. Two-argument verb:

The collie [AGENT] followed the skunk [THEME].

c. One-argument verb:

The actress [AGENT] laughed.

(Cho-Reyes & Thompson, 2012: 2)

Research also has shown that verbs with optional arguments (such as *deliver* in (2a, b)) are more difficult than those with obligatory arguments (i.e., arguments that must be present in the syntax for grammaticality) (such as *put* in (2c, d)) (Shapiro, Gordon, Hack, & Killackey, 1993; Shapiro & Levine, 1990; Shapiro, Nagel, & Levine, 1993).

(2) **a.** Optional three-argument verb with two arguments realized:

The postman delivered the package.

b. Optional three-argument verb with three arguments realized:

The postman delivered the package to the school.

c. Obligatory three-argument verb with three arguments realized:

The boyscout put the matches in his pocket.

d. Obligatory three-argument verbs with two arguments realized:

*The boyscout put the matches.

(Cho-Reyes & Thompson, 2012: 3)

Another common pattern seen in English-speaking patients with agrammatic aphasia is difficulty with sentences that deviate from their canonical (Subject-Verb-Object (SVS)) word order, which corresponds to the Agent-Theme order. Non-canonical sentences involve the reversed order, as in English passives (3a), object relative clause structures (3b), and object extracted wh-questions (3c):

(3) **a.** The boy_i was kissed t_i by the girl.

b. I saw the boy_i who the girl kissed t_i.

c. Who_i is the woman chasing t_i?

In all three sentence types, the object is moved across the subject, resulting in sentences that deviate from the canonical Agent-Theme order (see Shapiro (1996) for detail). Notably, several studies have shown that these sentences are particularly difficult to produce and comprehend in individuals with agrammatic aphasia (Caplan, 2012; Caramazza & Zurif, 1976; Cho-Reyes & Thompson, 2012; Faroqi-Shah & Thompson, 2003; Grodzinsky, 1986, 1989, 1990; Rochon, Laird, Bose, & Scofield, 2005; Schwartz, Saffran, Fink, Myers, & Martin, 1994; Thompson, Tait, Ballard, & Fix, 1999).

Verb and sentence impairments also have been reported in Chinese patients with aphasia. Typologically, Chinese, which includes both Mandarin and Cantonese as dialects, belongs to the Sino-Tibetan language family. The basic word order in Chinese is Subject-Verb-Object (SVO), as it is in English (Clark, 2011; Li, 1990; Menn, 2000; Su, Lee, & Chung, 2007; Sun & Givón, 1985). However, in contrast to English and other European languages, Chinese does not mark tense or subject-verb agreement via verb inflection (Li & Thompson, 1981) and therefore a verb in the bare form (such as *pao* 'run') may correspond either with the infinitive form 'to run' or the finite form with specific tense information inerrable in sentence contexts. Several studies have shown that patients with nonfluent, Broca's aphasia evince impaired production of verbs in contrast to nouns (Bates, Chen, Tzeng, Li, & Opie, 1991; Chen & Bates, 1998; Packard, 1993), however, the affects of verb argument structure on production have been little studied, even though a well-established observation in traditional Chinese grammar is that verbs can be classified according to the number of arguments they encode, as shown in (4) (Li & Thompson, 1981; Shen & Zheng, 1996; Yuan, 2010; Zhou, 2010).

(4) **a.** One-argument verb:

Zhangsan pao le[1]

Zhangsan run away Perf

'Zhangsan ran away.'

b. Two-argument verb:

Zhangsan kan le chang dianying

Zhangsan watch Perf Cl movie

'Zhangsan watched a movie.'

c. Three-argument verb:

Zhangsan gei Lisi yi ben shu

Zhangsan give Lisi one Cl book

'Zhangsan gave Lisi a book.'

Only one case study in the Chinese aphasia literature (Zhou, 2007), to our knowledge, has examined verbs by argument structure, showing results similar to English-speaking patients with aphasia – verbs with a greater number of encoded arguments are more difficult than verbs with fewer arguments, as indicated by lower response accuracy in both naming and comprehension tasks.

In addition, some verbs in Chinese select for optional arguments as do English verbs, as in (5) although this variable has not been studied in Chinese aphasia, to our knowledge.

(5) **a.** Zhangsan zai zhui

Zhangsan Prog chase

'Zhangsan is chasing (someone or something)'

b. Zhangsan zai zhui qiche

Zhangsan Prog chase car

'Zhangsan is chasing a car.'

Meanwhile, this phenomenon co-occurs with some relatively non-productive syntactic patterns in Chinese, where verbs may be followed by apparently non-plausible arguments

[1]Abbreviations used in this paper are as follows: Cl = classifier; DE = the linker between the relative clause and the modified noun; Pass = passive marker; Perf = perfective marker; Prog = progres sive marker.

((6a)) (Lin, 2001; Li, 2014), or where the subject or object may be legally omitted ((6b) and (6c)) (Huang, 1989, 1991):

(6) **a.** Zhangsan si le fuqin

Zhangsan die Perf father

Literal gloss: 'Zhangsan died his father'

Actual interpretation: 'Zhangsan's father died.'

b. Zhangsan shuo hen xihuan Lisi

Zhangsan say very like Lisi

'Zhangsan said that Zhangsan liked Lisi very much.'

c. Zhangsan kanjian le.

Zhangsan see Perf

'Zhangsan has seen (someone or something).'

With regard to complex sentence processing in Chinese aphasia, few studies in the literature have addressed this, with most studies finding that passives (7b), which cause more processing difficulty for Chinese patients than active sentence structures (7a), as in English patients (Law & Leung, 1998, 2000; Su, Lee, & Chung, 2007; but see Su & Law (1993) and Yang & Cao (1997)). The reason for differences in ability to comprehend and/or produce these structures has been attributed to movement during syntactic derivation, required by passive but not active sentences, which results in a non-canonical order of thematic roles.

(7) **a.** Actives:

Jat go naamzai zeo jat go leozai

one Cl boy chase one Cl girl

'A boy is chasing a girl.'

b. Passives:

Naamzai$_i$ bei [leozai zeo __$_i$]

boy Pass girl chase

'A boy is being chased by a girl.'

(Cantonese examples in Law & Leung (1998: 54-55))

A few studies have also examined processing of subject and object relative clauses in both healthy individuals (Gibson & Wu, 2013; Hsiao & Gibson, 2003; Qiao, Shen, & Forster, 2011) and patients with aphasia whose native language is Chinese (Law, 2000; Law & Leung, 1998, 2000; Su & Law, 1993; Su, Lee, & Chung, 2007; Zhou, Zheng, Shu, & Yang, 2010). In contrast to studies in English, results have shown that subject relative clauses (8a) are more difficult to process, and are impaired more severely than object relative clauses

(8b). The widely acknowledged explanation is that Chinese patients rely on the Agent-Theme linear order for mapping thematic roles onto argument positions (Schwartz, Saffran, Fink, Myers, & Martin, 1994; Law, 2000; Su, Lee, & Chung, 2007). In subject relative clauses in Chinese, the Agent-Theme linear order is reversed and therefore non-canonical.

(8) **a.** Subject relative clauses:

[t_i zhui mao] de gou_i hen da

chase cat DE dog very big

'The dog_i that e_i is chasing the cat is very big.'

b. Object relative clauses:

[mao zhui t_i] de gou_i hen xiao

cat chase DE dog very small

'The dog_i that the cat is chasing e_i is very small.'

Moreover, no studies to our knowledge have tested subject and object extracted wh-questions as in (9a, 9b).

(9) **a.** Shui jiu baba

who save father

'Who is saving the father?'

b. Baba jiu shui

father save who

'Who is the father saving?'

Given that wh-words in Chinese do not move in the surface structure, it remains an open question whether the dissociation between subject extracted wh-questions and object extracted wh-questions can be found in Chinese patients, as well. If we assume a syntactic analysis that wh-words in Chinese move to the sentence initial position at Logical Form[2] (Huang, 1982; Huang et al., 2009), then it is reasonable to predict that object wh-questions will be more difficult than subject wh-questions because the former involve such movement, leading to non-canonical word order. Although this prediction has not been tested among Chinese-speaking individuals with aphasia, the processing difficulty with phonetically non-discernable movement at Logical Form has been noted among patients with aphasia in other languages, for example, among Hebrew- and Arabic-speaking speakers with agrammatism (Friedmann, 2002). Moreover, more difficulty with object extracted compared to subject extracted wh-questions has been reported among both children who are learning Mandarin as their first language (Fahn, 2003) and Cantonese-speaking children with language specific impairment (Wong, Leonard, Fletcher, & Stokes, 2004). Given these findings, the Chinese version of the NAVS included subject and object extracted wh-questions in the Sentence

[2]In the generative syntax literature, the derivation of syntactic structures goes through several levels of representation, one of which is Logical Form, which specifies the interpretive structure of sentences (Chomsky, 1981; May, 1985).

Production Priming Test (SPPT) and the Sentence Comprehension Test (SCT) in order to achieve cross-linguistic consistency. Based on the analysis that in object extracted wh-questions, the object moves across the subject at Logical Form for interpretation, we consider this type of question to be non-canonical and subject extracted wh-questions to be canonical, as in English.

The purpose of the present study was to examine verb and sentence deficit patterns in Chinese-speaking individuals with non-fluent, Broca's aphasia to determine patterns of agrammatic performance. Thompson and colleagues developed the *Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson 2011) to test for such deficits in English-speaking people with agrammatic aphasia (Cho-Reyes & Thompson, 2012), The NAVS includes tests for (1) verb naming (i.e., the Verb Naming Test, VNT), controlled for the number and optionality of verb arguments, (2) verb comprehension (i.e., the Verb Comprehension Test, VCT), using the same items tested in the VNT, (3) argument structure production (i.e., the Argument Structure Production Test, ASPT), examining production of active sentences with verb varying in argument structure, and (4) comprehension and production of canonical and noncanonical sentences (i.e., the Sentence Comprehension Test (SCT) and Sentence Production Test (SPT), respectively). Using this test, Cho-Reyes and Thompson (2012) found distinct deficit patterns in agrammatic compared to anomic patients and healthy normal controls. The agrammatic group performed poorly on tasks involving non-canonical sentences and verbs with a greater number of arguments (participant roles); whereas, the anomic group performed poorly only on the most complex verbs and sentence structures, with no argument structure production hierarchy and no consistent effect of sentential canonicity. These findings indicated that the NAVS is useful for detailing verb and sentence deficits in people with agrammatic aphasia. Therefore, a secondary purpose of the present study was to develop an adaptation of the NAVS in Chinese to determine the utility of this measure for evaluating agrammatic deficit patterns in Chinese-speaking patients.

Notably, measures available for testing Chinese aphasia are limited to general-purpose batteries, including the Chinese version of the *Western Aphasia Battery* (WAB; Gao, 1993, 1996; Kertesz, 1982), the Chinese version of the *Boston Diagnostic Aphasia Examination* (BDAE; Goodglass & Kaplan, 1983; Tseng, 1993), the Chinese Rehabilitation Research Center Standard Aphasia Examination (Zhang, Ji, & Li, 2005) and the Chinese version of the *Boston Naming Test* (BNT; Borod, Goodglass, & Kaplan, 1980; Tsang, 2000). Notably, these tests fail to provide a precise picture of the syntactic deficits in this population, in that the verbs included are not classified and compared in terms of the number and optimality of argument structure and the canonical/non-canonical contrast is not specifically addressed. Moreover, the stimuli included are not controlled for frequency, despite its strong influence on patients' language processing (Menn & Duffield, 2013). The same problems also exist for a more recently developed test battery (the *Chinese Agrammatism Battery*, CAB; Zhao, Li, Mao, & Feng, 2002), which does not consider linguistic distinctions among verbs and sentences, nor is it based on impairment patterns identified in Chinese patients.

Given the lack of assessment tools in Chinese available to elucidate verb and sentence deficits, the present study adapted the original English version of the NAVS (after Thompson, 2011) to examine these abilities in Chinese-speaking individuals with aphasia.

Because of similar deficits patterns noted across studies with English and Chinese patients with aphasia, we anticipated the following performance patterns: First, because both languages contain one-, two- and three-argument verbs and verbs in both languages may take optional arguments, we predicted that patients' impairment of verbs with more arguments and more argument configurations would be indexed by lower scores on the VNT, VCT and ASPT in the Chinese NAVS (NAVS-C). Secondly, since it has been reported that Chinese patients are more impaired on passive than active sentences, we expected this pattern to emerge on the SPPT and SCT of the NAVS-C. Thirdly, because of linguistic differences between subject and object relative clause structures in Chinese and English, with subject relatives more complex than object relatives in Chinese, we predicted lower accuracy scores on subject, compared to object, relatives – the opposite of the pattern seen in English-speaking patients. Finally, because object extracted wh-questions in Chinese are also considered to be non-canonical, as they are in English (although linguistic descriptions of the two structures differ slightly across language), we expected poorer performance by Chinese patients for these structures, compared to subject extracted wh-questions, as in English.

METHOD

Participants

A total of 30 individuals, including 15 patients with aphasia and 15 healthy individuals, participated in this study. The two groups were matched for age ($M = 59$, range: 47-67 for patients; $M = 56$, range: 43-70 for healthy normal controls) ($Z = -.977$, $p = .329$, Mann-Whitney U Test) and education. All participants were monolingual native speakers of Mandarin, with preserved reading abilities for single words and short sentences. All patients suffered a thrombo-embolic stroke in the left hemisphere, an average of 3 years prior to participating in the study (range: 1–6 years). No participants reported history of neurological, psychiatric, or speech-language disorders prior to the stroke. All but one was right-handed and demonstrated visual and hearing acuity within normal limits. Patients were diagnosed as Broca's aphasia, using the Mandarin version of the *Western Aphasia Battery* (WAB; Gao, 1993, 1996; Kertesz, 1982)[3]. All patients' WAB aphasia quotients (AQs) ranged from 58 to 86.6 ($M = 74.6$). Collectively, the recorded narratives of the tested patients revealed several characteristics of agrammatism: production of more nouns than verbs, omission or underuse of function words, and reduced production of grammatical sentences (Packard, 1993). They also showed reduced speech rate and utterance length, as seen in English agrammatism (Thompson, Cho, Wieneke, Weintraub, & Mesulam, 2012). In addition, a pilot test developed to examine patients' comprehension of complex syntactic structures revealed asyntactic comprehension such that passives were comprehended less accurately actives.

[3]In most of the literature on Chinese aphasia, agrammatism and Broca's aphasia are used interchangeably (e.g. Law & Leung, 1998, 2000; Su, Lee, & Chung, 2007) and no systematic assessments have been developed to delineate agrammatic language deficits in Chine se patients.

Stimuli

Verb Naming Test (VNT)—All tests in the Chinese version of the NAVS (NAVS-C) included the same number of stimuli as the original NAVS. The target stimuli in the VNT included 22 verbs, 5 one-argument, 10 two-argument (5 obligatory two-argument and 5 optional two-argument), and 7 three-argument verbs (2 obligatory three-argument and 5 optional three-argument). All were one-syllable high frequency verbs according to the Chinese word frequency database established in Cai and Brysbaert (2010). The $\log_{10}$ word frequencies, compared across verb types, were not significantly different using the Mann-Whitney U Test given the different numbers of verbs across the three verb categories: one-versus two-argument (M = 3.8 vs. 3.71; Z = −.735, p = .462); three-argument verbs (M =3.39) were not significantly different from one-argument verbs (Z = −.731, p = .465), nor from two-argument verbs (Z = −.293, p = .770)[4]. In addition, all one- and two-argument verbs were unergative verbs, identified according to Huang (2007), where both one- and two-argument verbs were classified along the dimension of unergativity-unaccusativity. Black and white line drawings of the action as depicted for the verb were prepared for all stimuli. In order to match for visual complexity, the drawings of one- and two-argument verbs also included additional objects as necessary. All picture stimuli were normed with ten healthy native speakers of Mandarin and elicited the target verbs at a rate of 100% before the picture stimuli were used to test both healthy normal controls and patients with aphasia.

Verb Comprehension Test (VCT)—The target verbs for the VCT included the same 22 items used in the VNT. Visual displays for the VCT included the target verb and three distractors: one was selected from the target stimulus set and the other two were not. These monosyllabic items included 5 one-argument verbs, 10 two-argument verbs and 7 three-argument verbs. Distractor verbs were matched for the $\log_{10}$ word frequencies with the corresponding target verbs (one-argument verbs, t = 1.630, p = .142; two-argument verbs, t = .165, p = .871; three-argument verbs, t = .717, p = .487). A pilot test with another ten healthy normal controls indicated that they were able to achieve 99.6% accuracy producing the expected target verbs, using these stimuli.

Argument Structure Production Test (ASPT)—16 animate and 13 inanimate nouns were combined with the target verbs used for the VNT to test verb argument production. These selected nouns were equated for the $\log_{10}$ word frequency across the three grammatical functions: Agent M = 3.66, Theme M = 3.58, Goal M = 3.62; χ^2 (2) = .690, p = .708, Kruskal Wallis Test. Each verb was tested in all possible argument structure configurations, resulting in 32 target sentences. In order to offset word retrieval difficulty, we printed on stimulus cards the Chinese characters that stand for the names of actions and objects/people. Given that tense or subject-verb agreement is not marked on finite verbs in Chinese, the names of actions were in the bare form of verbs. Participants were expected to produce the correct verb as well as all its arguments in the correct order.

[4]Although the age-of-acquisition is known to affect word processing among aphasic speakers (Hirsh & Ellis, 1994; Morrison, Ellis, & Quinlan, 1992), this variable was not controlled in the present study because these data are not available in the Chinese language. Studies are limited to those detailing acquisition of verb usage by sentence type, e.g., in the case of the three-argument verb *gei* 'give', children first acquire the one-argument usage, then the two-argument usage and ultimately three-argument usage by the age of two (Li, 2004; Zhou, 2011; Zou, 2012). We appreciate an anonymous reviewer's comment on age-of-acquisition, which points out a need for such norms in Chinese.

Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT)—Both the SPPT and the SCT tested six sentence types (with five sentences for each type), including the following structures: actives, passives, subject relative clauses (SR), object relative clauses (OR), subject-extracted wh-questions (SWQ) and object-extracted wh-questions (OWQ). All target sentences were semantically reversible with pairs of animate nouns used to create the stimuli, so either noun within a pair could alternate between the Agent and the Theme. In this way, the nouns functioning as the Agent and the nouns functioning as the Theme were matched for the $\log_{10}$ word frequency. The same set of sentence-picture pairs was used for the SCT. We did not include distractors in the SCT as all the stimulus sentences across five sentence types in the SCT were randomized.

Procedures and scoring

Participants were tested by the same examiner on all the tests in the following order: VNT, VCT, ASPT, SPPT, and SCT. All the stimuli, including words and pictures, were printed on white cards and the examiner noted participants' responses on an answer sheet. Total administration time for all five tests was approximately 40 minutes and the examiner provided no response-contingent feedback.

When administering the VNT, the examiner presented a picture and asked the participants to name the action depicted in the picture within 10 seconds. For the VCT, the examiner presented an image containing four actions and asked the participants to point to the action that the examiner named. Five seconds were allotted for participants to respond and examiner repetition of the target action was provided on request. For the ASPT, participants were asked to produce a sentence using the words provided in the picture within a 10-second time constraint.

The tests for sentence production and comprehension used reversible action pictures. For the SPPT, the examiner modeled the target sentence structure for one picture in the pair and the participant was asked to produce the same sentence structure for the other picture within 15 seconds. The SCT used a sentence-picture matching task in which the examiner read aloud the target sentence and asked the participants to point to the corresponding picture within 10 seconds. For both the SPPT and SCT, examiner repetition of the prime or target sentence, respectively, was provided upon the participants' request.

Scoring criteria—For the VCT and the SCT, correct identification of the target picture within the allotted time was counted as a correct response. Spoken responses produced on the VNT, ASPT and SPPT were transcribed verbatim. For all production tests self-corrections were accepted, with the final response produced within the time limit scored.

For the VNT, responses were scored as correct only if both the phonemes and tonal contour of the target verb were produced correctly. In addition, semantically related verbs falling within same argument structure class were considered correct responses. Phonemic and/or tonal substitutions leading to a non-character/word in Chinese were considered phonological errors (Packard, 1993) (e.g., *kiu* with a flat tone, which does not exist in Chinese, for *jiu* with a flat tone) ('pinch').

Additional criteria were also adopted for counting correct responses in the ASPT and the SPPT. For the ASPT, responses were scored as correct if both the target verb and the word order of Agent-Verb-Goal-Theme were produced. Although argument drop is grammatical in Chinese, we counted patients' responses with missing arguments as incorrect because all arguments required in the sentence stimuli were depicted in the pictures, making argument drop impossible. Moreover, the healthy normal controls tested did not produce responses that contained argument drop on the ASPT.

For the SPPT, the following criteria were used for correct responses. For correct passive sentences, all three essential elements (Agent noun, Theme noun and the passive marker *bei*) were required to be produced and the Agent noun was required to follow the marker *bei*. Correct subject relative clauses required the Verb-Theme-*de*-Agent word order and correct object relative clauses required the Agent-Verb-*de*-Theme word order.

In order to control for scoring reliability, both the examiner and an independent rater scored all responses. Point-to-point agreement between the examiner and the rater ranged from 93% to 100%, with the overall agreement of 96.3%.

RESULTS

The healthy normal controls performed well on all five tests, demonstrating no significant differences between any two tests, as summarized in Table 2 and Table 3.

Results for the patients are presented in the figures below.

Verb naming and comprehension by verb argument structure

Figures 5a and 5b show the mean percent accuracy scores for production and comprehension of verbs, respectively. Levene's test of homogeneity of variance was not violated ($p = .456$), therefore a 3 (verb type) by 2 (modality) ANOVA was performed. Results revealed a significant main effect of verb type, $F(2, 38) = 11.701$, $p < .001$, $\eta^2 = .42$, but no significant main effect of modality, $F(1, 38) = .182$, $p = .672$, $\eta^2 = .003$, or interaction effect, $F(2, 38) = .060$, $p = .942$, $\eta^2 = .007$. Comparing accuracy scores by verb type (i.e. one-, two- and three-argument verbs), using the Mann-Whitney U Test, showed no significant difference between production of one- and two-argument verbs (76% vs. 69%; $Z = 1.255$, $p = .209$, $r = .008$), but significant differences between one- and three- argument verbs (76% vs. 59%; $Z = 2.826$, $p = .005$, $r = .26$) and between two- and three-argument verbs ($Z = 2.212$, $p = .027$, $r = .22$) were found. For verb comprehension, no significant differences between one- and two- argument verbs (75% vs. 67%; $Z = 1.581$, $p = .114$, $r = .003$) or between two- and three-argument verbs ($Z = 1.811$, $p = .070$, $r = .024$) were found, but the difference between one- and three-argument verbs was significant (75% vs. 59%; $Z = 2.302$, $p = .021$, $r = .023$).

Because patients produced three-argument verbs more poorly than the other verb types on the VNT, an error analysis was performed for these verbs (see Table 4). One noticeable error was verb omission, substituted by production of a noun depicted in the target pictures ($n = 12$, 27.9% of all errors). Moreover, patients often replaced three-argument verbs with verbs that can take fewer arguments, e.g., production of *na* 'hold in hand', which is a two-argument verb, for *song* 'send', the target three-argument verb.

Verb naming and comprehension by optionality of arguments

To analyze verb production by the optionality of arguments, we regrouped the target items on VNT into those with obligatory arguments (one-, two- and three-argument) and those with optional arguments (two- and three-argument verbs). Results revealed a significant difference between production of obligatory and optional verbs, $Z = 2.423$, $p = .015$, $r = .025$, with accuracy of verbs with obligatory arguments higher ($M = 72\%$ correct) than those with optional arguments ($M = 62\%$ correct). A similar pattern was found on the VCT: comprehension of optional verbs was significantly better ($M = 71\%$) than comprehension of obligatory verbs ($M = 61\%$), $Z = 2.361$, $p = .018$, $r = .027$).

Argument structure production

The mean percent accuracy for production of arguments in sentences is provided in Figure 6. As the homogeneity of variance was not violated ($p = .32$), a one-way ANOVA analysis revealed a significant effect of verb argument structure, $F(2, 29) = 34.134$, $p < .001$, $\eta^2 = .39$. There was no significant difference between accuracy of arguments for one-argument and two-argument verbs (79% vs. 73%; $p = 0.084$, $r = .006$), but a significant difference between one- and three-argument verbs (79% vs. 57%; $p < .001$, $r = .21$) and two- and three-argument verbs ($p = 0.021$, $r = .19$) was found.

Analyses of argument structure errors produced for three-argument items showed a high rate of argument omissions (omitted Agents: $n = 18$, 23.6% of all errors; omitted Themes: $n = 11$, 14.4% of all errors; omitted Goals: $n = 15$, 19.7% of all errors). Role reversal errors also were seen ($n = 22$, 28.9% of all errors) as in (10a) for target sentences such as in (10b):

(10) **a.** Qizi jiu zhangfu

wife save husband

'The wife is saving the husband.'

b. Zhangfu jiu qizi

husband save wife

'The husband is saving the wife.'

Argument structure by optionality of arguments

To test the effect of optionality on verb production, we regrouped the verbs in the ASPT as obligatory (one-, two- and three-argument) versus optional (two- and three-argument) verbs. The comparison between these two groups indicated a significant difference, $Z = 2.348$, $p = .019$, $r = .22$, with the accuracy of obligatory verbs ($M = 73\%$) significantly higher than that of optional verbs ($M = 65\%$).

Sentence production and comprehension

Table 7a shows accuracy scores for production and comprehension of both canonical (active, SWQ and OR) and non-canonical (passive, OWQ and SR) sentences. Given that the assumption of homogeneity of variance was not violated, $p = .398$, we performed a 2 (canonicity) by 2 (modalities) ANOVA. The analysis revealed a significant main effect of canonicity $F(1, 56) = 64.869$, $p < .001$, $\eta^2 = .38$, but no significant main effect of modality $F(1, 56) = 1.584$, $p = .213$, $\eta^2 = .009$, or interaction of sentence type and modality, $F(1, 56) = .063$, $p = .802$, $\eta^2 = .006$. When we compared the accuracy scores for the SPPT and the SCT, a paired t-test was used. In both modalities, non-canonical sentences were significantly more impaired than canonical sentences: production, $t(1, 14) = 7.432$, $p < .001$, $d = .19$; comprehension, $t(1, 14) = 6.546$, $p < .001$, $d = .20$.

Production by sentence type

Figure 7a provides the accuracy for sentence production by sentence type on the SPPT. An ANOVA indicated a significant effect of sentence type on the accuracy, $F(5, 24) = 19.312$, $p < .001$, $\eta^2 = .44$. Follow up pairwise comparisons revealed several significant differences. In terms of accuracy, non-canonical sentences were produced significantly more poorly than their canonical counterparts: passives significantly lower than actives, $t(1, 4) = 6.532$, $p = .003$, $d = .22$; OWQs significantly lower than SWQs, $t(1, 4) = 3.138$, $p = .035$, $d = .23$; SRs significantly lower than ORs, $t(1, 4) = 9$, $p = .001$, $d = .24$. Additionally, SRs were significantly more impaired than actives ($t(1, 4) = 12.649$, $p < .001$, $d = .195$), SWQs ($t(1, 4) = 6.5$, $p = .003$, $d = .201$) and OWQs ($t(1, 4) = 3.163$, $p = .003$, $d = .199$), but not passives ($t(1, 4) = 1.372$, $p = .242$, $d = .006$). However, ORs and OWQs were significantly more impaired than actives, $t(1, 4) = 5.88$, $p = .004$, $d = .21$, $t(1, 4) = 8.66$, $p < .001$, $d = .22$, respectively

Table 8 summarizes the error types that patients made for non-canonical sentences on the SPPT. One noticeable error was substitution of canonical for non-canonical sentences. For example, patients produced actives as in (11b) instead of passives as in (11a) ($n = 18$, 31% of all errors). Similarly, SWQs substitutions for OWQs ($n = 22$, 38.6% of all errors) and OR substitutions for SRs ($n = 22$, 35.5% of all errors) were found. A high percentage was role reversal errors also was noted, e.g., production of sentences as in (11c) for the passive target (11a) ($n = 18$, 31% of all errors). Role reversals also were found for OWQs ($n = 20$, 35.1% of all errors) and SRs ($n = 18$, 29% of all errors). A note should be added that the difference between canonical structure error and role reversal error arises from whether the truth condition of the produced sentence is the same as or different from the scenario depicted in the picture. For example, given a picture where a boy is feeding a girl, if patients produced (11b) instead of (11a), then (11b) is counted as a canonical structure error. If patients produced (11c) instead of (11a), then (11c) was counted as a role reversal error.

(11) **a.** Nanhai bei nühai wei

boy Pass girl feed

‘The boy is fed by the girl.’

b. Nühai wei nanhai

girl feed boy

'The girl is feeding the boy.'

c. Nühai bei nanhai wei

girl Pass boy feed

'The girl is fed by the boy.'

Comprehension by sentence type

Figure 7b illustrates the accuracy for sentence comprehension on the SCT. ANOVA indicated a significant effect of sentence type on accuracy, $F(5, 24) = 17.424$, $p < .001$, $\eta^2 = .398$. Pairwise comparisons further revealed that comprehension of non-canonical sentences was significantly lower than that of canonical sentences. In addition, passive comprehension scores were significantly lower than actives ($t(1, 4) = 13.880$, $p < .001$, $d = .23$), OWQs scores were lower than SWQs ($t(1, 4) = 3.207$, $p = .033$, $d = .197$), and SRs scores were significantly lower than ORs ($t(1, 4) = 4$, $p = .016$, $d = .212$) (see Table 7a). Additionally, SRs had the lowest accuracy scores among all the non-canonical sentences.

DISCUSSION

This study adapted the English version of the *Northwestern Assessment of Verbs and Sentences* (NAVS; Cho-Reyes & Thompson, 2012; Thompson, 2011) in order to quantitatively assess Chinese-speaking patients' deficits with verbs and sentences. Results showed that the Chinese NAVS (NAVS-C) detected Chinese-speaking patients' syntactic deficits, with performance consistent with impairment patterns noted in previous studies of Chinese aphasia. The NAVS-C also examined forms previously untested in Chinese aphasia, i.e., object and subject wh-questions, with results following deficit patterns seen in English agrammatic aphasia. One advantage of the NAVS-C is that it allows analysis of both comprehension and production of verbs and sentences in the same test battery and uses the same verbs and sentence types across modalities. In addition, the NAVS-C important linguistic variables, which have not been controlled in previous studies (Law & Leung, 1998, 2000; Su & Law, 1993; Su, Lee, & Chung, 2007; Zhou, 2007) or in currently available Chinese tests for aphasia (e.g. Gao,1993, 1996; Tseng, 1993; Zhang, Ji, & Li, 2005; Zhao et al., 2002).

In both English and in Chinese, verbs can be categorized based on their argument structure properties, including the number of arguments entailed within the verb's representation and obligatory/optional specification of arguments in the syntax. In addition, sentences in both English and Chinese may follow either a canonical (SVO in both languages) or noncanonical order, with the later more linguistically complex in both languages. Thus we were able to adapt the NAVS-C to test for the influence of verb argument structure and sentence canonicity. We were, however, unable to control for age-of-acquisition for the verbs tested, another variable known to affect production and comprehension (Hirsh & Ellis, 1994; Morrison, Ellis, & Quinlan, 1992), because such acquisition data are not available in Chinese. Further research is needed to develop verb acquisition norms in Chinese and to evaluate the impact of age-of-acquisition in Chinese speakers with aphasia.

Performance patterns of the Chinese patients derived from administration of the NAVS-C were similar to those seen in English speaking speakers with agrammatic aphasia. The Chinese patients tested evinced verb deficits associated with both the number (one, two and three arguments) and type (obligatory and optional) of arguments, with more difficulty noted for verbs with a greater number of argument structure entries and verbs with optional arguments. This finding is similar to that reported in Cho-Reyes and Thompson (2012) for the original NAVS and further attests to the effectiveness of the NAVS for detecting verb deficits among patients. One difference, however, is that the Chinese patients evinced deficits in both verb production and comprehension, whereas, the agrammatic patients tested by Cho-Reyes and Thompson (2012) showed relatively spared verb comprehension. Mixed findings with regard to verb comprehension abilities in English-speaking individuals with aphasia, however, have been reported in other studies, with some showing impaired verb comprehension (see, for example, Kim & Thompson, 2000, 2004; Marshall, Pring, & Chiat, 1998; Miceli, Silveri, Nocentini, & Caramazza, 1988; Miceli, Silveri, Villa, & Caramazza, 1984). The differences in performance found for patients using the English and Chinese versions of the NAVS are, therefore, not likely attributable to cross-linguistic difference between Chinese and English grammars. Notably, the present study is the first to our knowledge to find comprehension deficits in aphasia based on verb argument structure properties, while controlling for important variables, such as verb frequency, obligatory/optional specification of arguments, which have not been controlled in previous studies (Zhou, 2007).

The NAVS-C also revealed sentence deficits similar to those seen in English speakers with aphasia using the original NAVS as well as other measures, indicating that patients in both Chinese and English have difficulty processing sentences with noncanonical thematic role order. Furthermore, parallel deficits in comprehension and production were found based on sentence canonicity, in line with numerous studies with agrammatic patients across languages (Caramazza & Zurif, 1976; Cho-Reyes & Thompson, 2012; Law & Leung, 2000; Rausch, Burchert, & De Bleser, 2005, 2007; Roeper, Ramos, Seymour, & Abdul-Karim, 2001; Schwartz, Saffran, Fink, Myers, & Martin, 1994; Wang, Yoshida, & Thompson, 2014). The Chinese-speaking patients showed deficits for passive, compared to simple active, sentences as do English-speaking patients. They also showed greater difficulty with subject relative clauses compared to object relative clauses. Although the opposite pattern is seen in English patients, with object relative clauses more difficult than subject relative clauses, linguistic analysis of two structures indicates differences between Chinese and English. Subject relative clauses, but not object relative clauses in Chinese, involve a non-canonical order in which the Agent-Theme (canonical) linear order is reversed, as in object relative clauses in the English language. Hence, poorer performance on subject relative clauses was predicted. Finally, object extracted, compared to subject extracted, wh-questions also posed difficulty for Chinese participants with aphasia, which is similar to the deficit pattern reported in Cho-Reyes and Thompson (2012). This result supports the analysis of wh-questions in Chinese, which locates the movement of wh-words at Logical Form, although they are phonetically non-discernable. Finally, in sentence production tasks involving noncanonical Agent-Theme ordering, Chinese patients made frequent role reversal errors, as do English speakers with aphasia (Cho & Thompson, 2010; Cho-Reyes & Thompson, 2012; Faroqi-Shah & Thompson, 2003).

In conclusion, findings from this study indicate that the Chinese version of the NAVS (NAVS-C) yields results similar to those derived from the English version for individuals with Broca's aphasia. Therefore, we suggest that the NAVS-C may be used clinically to determine agrammatic deficit patterns associated with verbs and sentences in both languages and to guide treatment for these impairments. In addition, the test may serve to be useful for detailing aphasic language patterns in neurolinguistic research studies. In particular, future research on langauge impairment patterns in Chinese-speaking patients may include their scores on the NAVS-C, in order to present more precise linguistic profiles and to allow cross-linguistic comparisons of their grammatical deficits.

Acknowledgements

This work was funded by the following grants: the Humanities and Social Sciences Foundation of Ministry of China under Grant 15YJC740079; the Beijing Social Science Foundation under Grant 14WYC045; the Central University Fundamental Research Foundation of Beihang University under Grants 296505, 401262 and YWF-15-WYXY-014.

References

Bastiaanse R, van Zonneveld R. Sentence production with verbs of alternating transitivity in agrammatic Broca's aphasia. Journal of Neurolinguistics. 2005; 18:57–66.

Bates E, Chen S, Tzeng O, Li P, Opie M. The noun-verb problem in Chinese aphasia. Brain and Language. 1991; 41:203–233. [PubMed: 1718531]

Borod JC, Goodglass H, Kaplan E. Normative data on the Boston Diagnostic Aphasia Examination, Parietal Lobe Battery, and the Boston Naming Test. Journal of Clinical Neuropsychology. 1980; 2:209–215.

Cai Q, Brysbaert M. SUBTLEX-CH: Chinese word and character frequencies based on film subtitles. PLOS ONE. 2010; 5:1–8.

Caplan, D. Resource reduction accounts of syntactically based comprehension disorders.. In: Thompson, CK.; Bastiaanse, R., editors. Perspectives on Agrammatism. Psychology Press; New York: 2012. p. 33-59.

Caramazza A, Zurif EB. Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. Brain and Language. 1976; 3:572–582. [PubMed: 974731]

Chen S, Bates E. The dissociation between nouns and verbs in Broca's and Wernicke's aphasia: Findings from Chinese. Aphasiology. 1998; 12:5–36.

Cho S, Thompson CK. What goes wrong during passive sentence production in agrammatic aphasia: An eyetracking study. Aphasiology. 2010; 24:1576–1592. [PubMed: 21188294]

Chomsky, N. Lectures on Government and Binding. Foris; Dordrecht: 1981.

Cho-Reyes S, Thompson CK. Verb and sentence production and comprehension in aphasia: Northwestern Assessment of Verbs and Sentences (NAVS). Aphasiology. 2012; 26:1250–1277. [PubMed: 26379358]

Clark DG. Sentence comprehension in aphasia. Language and Linguistics Compass. 2011; 5:718–730.

Dragoy O, Bastiaanse R. Verb production and word order in Russian agrammatic speakers. Aphasiology. 2010; 24:28–55.

Fahn R-LS. Chinese-speaking children's production of wh-questions. Concentric: Studies in English Literature and Linguistics. 2003; 29:82–117.

Faroqi-Shah Y, Thompson CK. Effect of lexical cues on the production of active and passive sentences in Broca's and Wernicke's aphasia. Brain and Language. 2003; 85:409–426. [PubMed: 12744953]

Friedmann N. Agrammatic comprehension of OVS and OSV structures in Hebrew. Behavioral and Brain Sciences. 2000; 23:33–34.

Friedmann N. Question production in agrammatism: The Tree Pruning Hypothesis. Brain and Language. 2002; 80:160–187. [PubMed: 11827442]

Friedmann, N.; Haddad, M. On the comprehension and production of sentences with syntactic movement in Palestinian Arabic speakers with hearing impairment.. In: Most, T.; Ringwald, D., editors. Topics in Rehabilitation and Education of Children with Hearing Impairment. Mofet; Tel Aviv: 2014. p. 295-351.

Friedmann, N.; Novogrodsky, R.; Szterman, R.; Preminger, O. Resumptive pronouns as a last resort when movement is impaired: Relative clauses in hearing impairment.. In: Armon-Lotem, S.; Rothstein, S.; Danon, G., editors. Generative approaches to Hebrew Linguistics. John Benjamins; Amsterdam: 2008. p. 267-290.

Gao, S. Shiyuzheng [Aphasia]. Peking Union Medical College and Peking Union Medical College; Beijing: 1993.

Gao S. Clinical diagnosis of aphasia in Chinese. Stroke and Nervous Diseases. 1996; 3:57–59.

Gibson E, Wu H-HI. Processing Chinese relative clauses in context. Language and Cognitive Processes. 2013; 28:125–155.

Goodglass, H.; Kaplan, E. Boston Diagnostic Aphasia Examination. Lee and Febiger; Philadelphia: 1983.

Grodzinsky Y. Language deficits and the theory of syntax. Brain and Language. 1986; 27:135–159. [PubMed: 3947938]

Grodzinsky Y. Agrammatic comprehension of relative clauses. Brain and Language. 1989; 37:480–499. [PubMed: 2478254]

Grodzinsky, Y. Theoretical Perspectives on Language Deficits. MIT Press; Cambridge, Mass: 1990.

Hirsh, Katherine W.; Ellis, Andrew W. Age of acquisition and lexical processing in Aphasia: A case study. Cognitive Neuropsychology. 1994; 11:435–458.

Hsiao F, Gibson E. Processing relative clauses in Chinese. Cognition. 2003; 90:3–27. [PubMed: 14597268]

Huang, CTJ. Logical Relations in Chinese and the Theory of Grammar. (Unpublished doctoral dissertation). MIT; Cambridge, Mass: 1982.

Huang, CTJ. Pro-drop in Chinese: A generalized control theory.. In: Jaeggli, O.; Safir, K., editors. The Null Subject Parameter. Kluwer Academic Publishers; Boston: 1989. p. 185-214.

Huang, C-TJ. Remarks on the status of the null object.. In: Freidin, R., editor. Principles and Parameters in Comparative Grammar. MIT Press; Cambridge, Mass: 1991. p. 56-76.

Huang C-TJ. Thematic structures of verbs in Chinese and their syntactic projections. Linguistic Sciences. 2007; 6:3–21.

Huang, C-TJ.; Li, Y-HA.; Li, Y. The Syntax of Chinese. Cambridge University Press; Cambridge, MA: 2009.

Kertesz A. Western Aphasia Battery. New York Grune and Stratton. 1982

Kim M, Thompson CK. Patterns of comprehension and production of nouns and verbs in agrammatism: Implications for lexical organization. Brain and Language. 2000; 74:1–25. [PubMed: 10924214]

Kim M, Thompson CK. Verb deficits in Alzheimer's disease and agrammatism: Implications for lexical organization. Brain and Language. 2004; 88:1–20. [PubMed: 14698726]

Law S-P. Structural Prominence Hypothesis and Chinese aphasic sentence comprehension. Brain and Language. 2000; 74:260–268. [PubMed: 10950918]

Law S-P, Leung M-T. Sentence comprehension in Cantonese Chinese aphasic patients Aphasiology. 1998; 12:49–63.

Law S-P, Leung M-T. Sentence processing deficits in two Cantonese aphasic patients. Brain and Language. 2000; 72:310–342. [PubMed: 10764521]

Li, Y. Ertong yuyande fazhan [The Development of Child Language]. Central Normal University Press; Wuhan: 2004.

Li, CN.; Thompson, SA. Mandarin Chinese: A Functional Reference Grammar. University of California Press; Berkeley and Los Angeles: 1981.

Li, Y-HA. Order and Constituency in Mandarin Chinese. Kluwer Academic; Dordrecht/Boston/London: 1990.

Li Y-HA. Thematic hierarchy and derivational economy. Language and Linguistics. 2014; 15:295–339.

Lin, T-HJ. Light Verb Syntax and the Theory of Phrase Structure. University of California; Irvine: 2001. (Unpublish doctoral dissertation)

Luzzatti, C.; Mondini, S.; Semenza, C. Lexical impairment in agrammatism.. In: Thompson, CK.; Bastiaanse, R., editors. Perspectives on Agrammatism. Psychology Press; New York: 2012. p. 80-108.

Marshall J, Pring T, Chiat S. Verb retrieval and sentence production in aphasia. Brain and Language. 1998; 63:159–183. [PubMed: 9654430]

May, R. Logical Form: Its Structure and Derivation. MIT Press; Cambridge, MA: 1985.

Menn L. It's time to face a simple question: Why is canonical form simple? Brain and Language. 2000; 71:157–159. [PubMed: 10716834]

Menn L, Duffield CJ. Aphasias and theories of linguistic representation: Representing frequency, hierarchy, constructions, and sequential structure. Wiley Interdisciplinary Reviews: Cognitive Science. 2013; 4:651–663. [PubMed: 26304270]

Miceli G, Silveri MC, Nocentini U, Caramazza A. Patterns of dissociation in comprehension and production of nouns and verbs. Aphasiology. 1988; 2:351–358.

Miceli G, Silveri MC, Villa G, Caramazza A. On the basis for the agrammatic's difficulty in producing main verbs. Cortex. 1984; 20:207–220. [PubMed: 6204813]

Morrison CM, Ellis AW, Quinlan PT. Age of acquisition, not word frequency, affects object naming, not object recognition. Memory & Cognition. 1992; 20:705–714. [PubMed: 1435273]

Packard, JL. A Linguistic Investigation of Aphasic Chinese Speech. Springer; 1993.

Qiao X, Shen L, Forster K. Relative clause processing in Mandarin: Evidence from the maze task. Language and Cognitive Processes. 2011; 27:611–630.

Rausch P, Burchert F, De Bleser R. Parallels in the breakdown of CP and DP-internal movement processes in agrammatism: A preliminary case study. Brain and Language. 2005; 95:129–130.

Rausch P, Burchert F, De Bleser R. Comprehension of canonical and non-canonical structures within and across the verbal and nominal syntax domains in agrammatism. Brain and Language. 2007; 103:82–83.

Rochon E, Laird L, Bose A, Scofield J. Mapping therapy for sentence production impairments in nonfluent aphasia. Neuropsychological Rehabilitation. 2005; 15:1–36. [PubMed: 16353851]

Roeper T, Ramos E, Seymour H, Abdul-Karim L. Language disorders as a window on Universal Grammar: An abstract theory of agreement for IP, DP, and V-PP. Brain and Language. 2001; 77:378–397. [PubMed: 11386704]

Schwartz MF, Saffran EM, Fink RB, Myers JL, Martin N. Mapping therapy: A treatment programme for agrammatism. Aphasiology. 1994; 8:19–54.

Schwartz MF, Saffran EM, Marin OSM. The word order problem in agrammatism: I. Comprehension. Brain and Language. 1980; 10:249–262. [PubMed: 7407546]

Shapiro LP, Gordon B, Hack N, Killackey J. Verb-argument structure processing in complex sentences in Broca's and Wernicke's aphasia. Brain and Language. 1993; 45:423–447. [PubMed: 8269333]

Shapiro LP, Levine BA. Verb processing during sentence comprehension in aphasia. Brain and Language. 1990; 38:21–47. [PubMed: 2302544]

Shapiro LP, Nagel HN, Levine BA. Preferences for a verb's complements and their use in sentence processing. Journal of Memory and Language. 1993; 32:96–114.

Shapiro LP. Sentence Processing. ASHA Special Interest Division (Adult Language Disorders). Newsletter. 1996; 6:7–13.

Shen, Y.; Zheng, D. Xiandai hanyu peijia yufa yanjiu [The Studies of Valency Grammar of Modern Chinese]. Beijing University Press; Beijing: 1996.

Su, YC.; Law, S-P. A study of the syntactic comprehension of a Chinese agrammatic patient.. Paper presented at the International Conference on Chinese Linguistics 2; Paris. June; 1993.

Su Y-C, Lee S, Chung Y. Asyntactic thematic role assignment by Mandarin aphasics: A test of the Trace-Deletion Hypothesis and the Double Dependency Hypothesis. Brain and Language. 2007; 101:1–18. [PubMed: 17250884]

Sun C, Givón T. On the so-called SOV word order in Chinese: A quantified text study and its implications. Language. 1985; 61:329–351.

Thompson, CK. Northwestern Assessment of Verbs and Sentences (NAVS). Northwestern University; Evanston: 2011.

Thompson, CK.; Bastiaanse, R. Introduction to agrammatism.. In: Thompson, CK.; Bastiaanse, R., editors. Perspectives on Agrammatism. Psychology Press; New York: 2012. p. 1-16.

Thompson CK, Cho S, Wieneke C, Weintraub S, Mesulam M-M. Dissociation between fluency and agrammatism in Primary Progressive Aphasia. Aphasiology. 2012; 26:20–43. [PubMed: 22199417]

Thompson CK, Lange KL, Schneider SL, Shapiro LP. Agrammatic and non-brain-damaged subjects' verb and verb argument structure production. Aphasiology. 1997; 11:473–490.

Thompson CK, Shapiro LP, Li L, Schendel L. Analysis of verbs and verb-argument structure: A method for quantification of aphasic language production. Clinical Aphasiology. 1995; 23:121–140.

Thompson CK, Shapiro LP, Tait ME, Jacobs B, Schneider S, Ballard K. A system for the linguistic analysis of agrammatic language production. Brain and Language. 1995; 51:124–127.

Thompson CK, Tait ME, Ballard KJ, Fix SC. Agrammatic aphasic subjects' comprehension of subject and object extracted wh questions. Brain and Language. 1999; 67:169–187. [PubMed: 10210629]

Tsang, HL. Confrontation naming abilities of the young, the elderly, and people with Aphasia. University of Hong Kong; Hong Kong, China: 2000. (Unpublished thesis)

Tseng OJ-L. A Chinese version of the Boston Diagnostic Aphasia Examination. 1993 Unpublished manuscript.

Wang H, Yoshida M, Thompson CK. Parallel functional category deficits in clauses and nominal phrases: The case of English agrammatism. Journal of Neurolinguistics. 2014; 27:75–102. [PubMed: 26379370]

Wong AM-Y, Leonard LB, Fletcher P, Stokes SF. Questions without movement: A study of cantonese-speaking children with and without Specific Language Impairment. Journal of Speech, Language, and Hearing Research. 2004; 47:1440–1453.

Yang Y, Cao M. Hanyu pizhixia shiyuhuanzhe zhudongjushi yu beidongjushi lijie shengcheng de biaojiao yanjiu [A study comparing active and passives among Chinese patients with subcortical aphasia in comprehension and production tasks]. Zhongguo yuwen [Chinese Philology]. 1997; 4:282–288.

Yiu EML. Linguistic assessment of Chinese-speaking aphasics: Development of a Cantonese aphasia battery. Journal of Neurolinguistics. 1992; 7:379–424.

Yuan, Y. Hanyu peijia yufa yanjiu [The Studies of Valency Grammar of Chinese]. The Commercial Press; Beijing: 2010.

Zhang Q, Ji S, Li S. Reliability and validity of the Chinese Rehabilitation Research Center Standard Aphasia Examination. Chinese Journal of Rehabilitation Theory and Practice. 2005; 11:703–705.

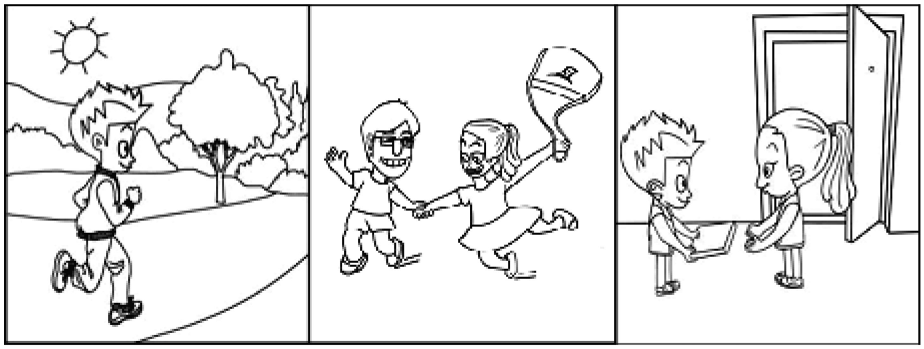
Zhao L, Li C, Mao S, Feng X. Chinese agrammatism battery and its standardization. Stroke and Nervous Diseases. 2002; 9:296–298.

Zhou, G. Xiandai hanyu peijia yufa yanjiu [The Studies of Valency Grammar of Modern Chinese]. Higher Education Press; Beijing: 2011.

Zhou T. Dongci peijiade liangxiaoying yu zhixiaoying: Laizi shiyuzhengde yanjiu [The quantity effect and quality effect of verb valency: Evidence from aphasic studies]. Yuyan wenzi yingyong [Applied Linguistics]. 2007; 1:102–110.

Zhou T, Zheng W, Shu H, Yang Y. Hanyu bingyu congju jiagong youshilun: Laizi shiyuzheng yanjiu de zhengju [The processing superiority of object relative clauses in Chinese: Evidence from the study of aphasic patients]. Yuyan kexue [Linguistic Science]. 2010; 46:225–243.

Zou L. Putonghua zaoqi ertong geiziju xide ge'anyanjiu [The case study of the acquisition of the Mandarin gei ‘give’ construction by early children]. Shijie hanyu jiaoxue [Chinese Teaching in the World]. 2012; 26:560–573.



(a) (b) (c)

Figure 1.

Sample stimuli for the Verb Naming Test (VNT) by verb type. (a) one-argument verb (target verb: 跑 'run'); (b) two-argument verb (target verb: 拉 'pull'); (c) three-argument verb (target verb: 给 'give')

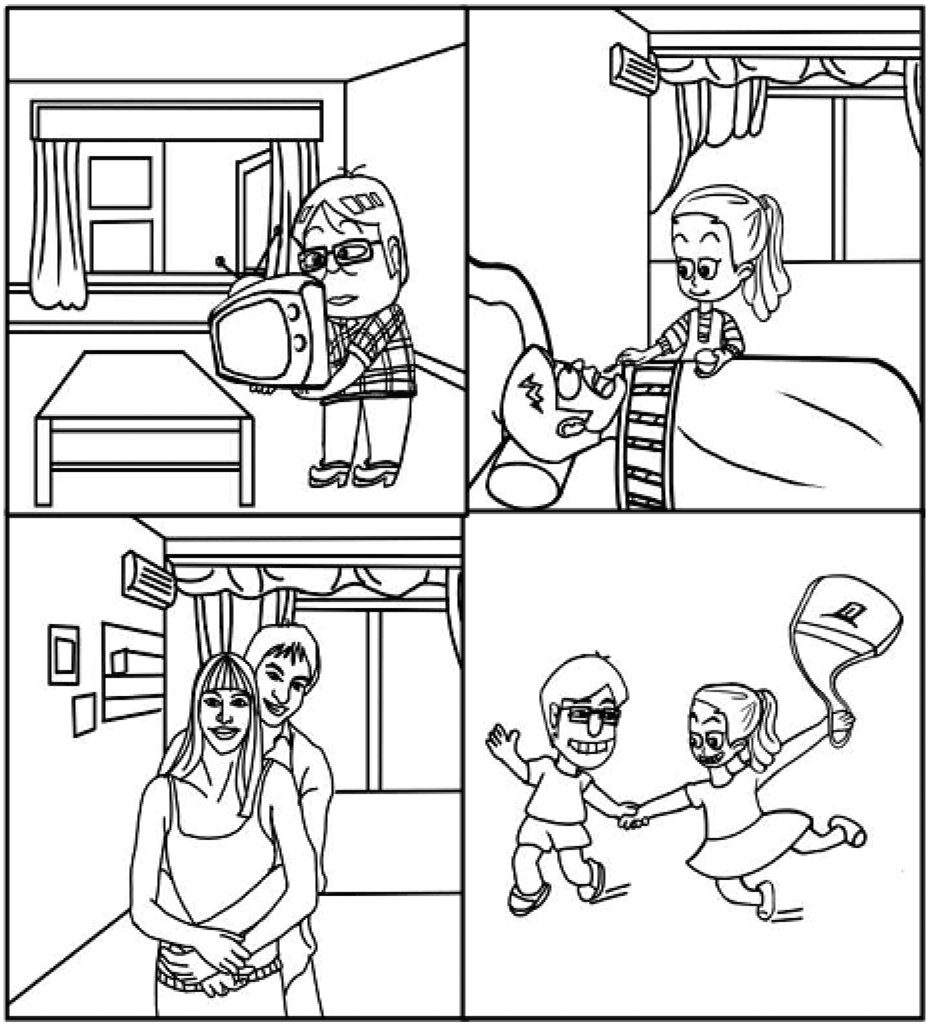
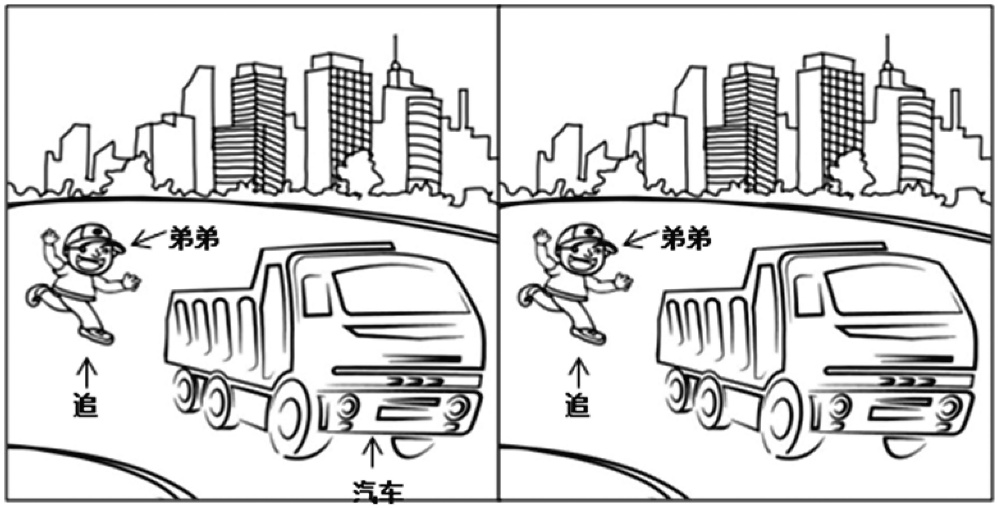


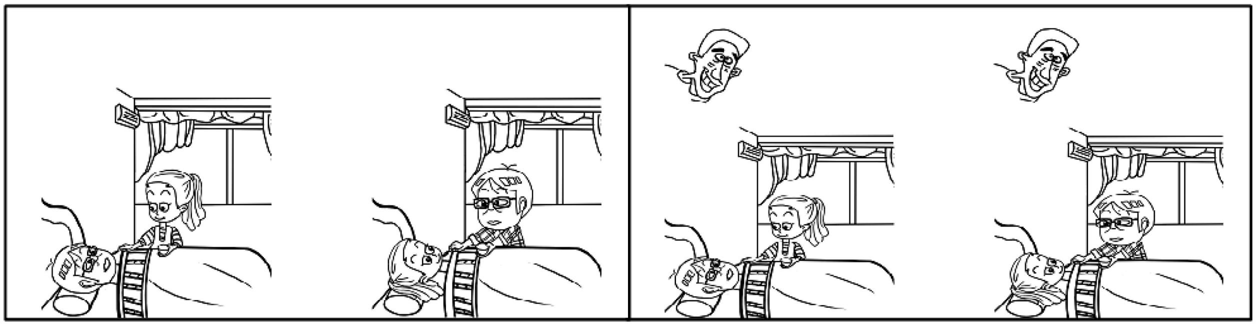
Figure 2.
Sample stimuli for the Verb Comprehension Test (VCT) (from top left to bottom right, same verb distractor: 搬‘move’; different verb distractors: 抱‘hug’ and 喂‘feed’; target: 拉 ‘pull’).



(a) (b)

Figure 3.

Sample stimuli for the Argument Structure Production Test (ASPT). (3a) optional two-argument verb with two arguments (target: 弟弟追汽车‘The younger brother is chasing the car.’); (3b) optional two-argument verb with one argument (target: 弟弟追‘The younger brother is chasing.’)

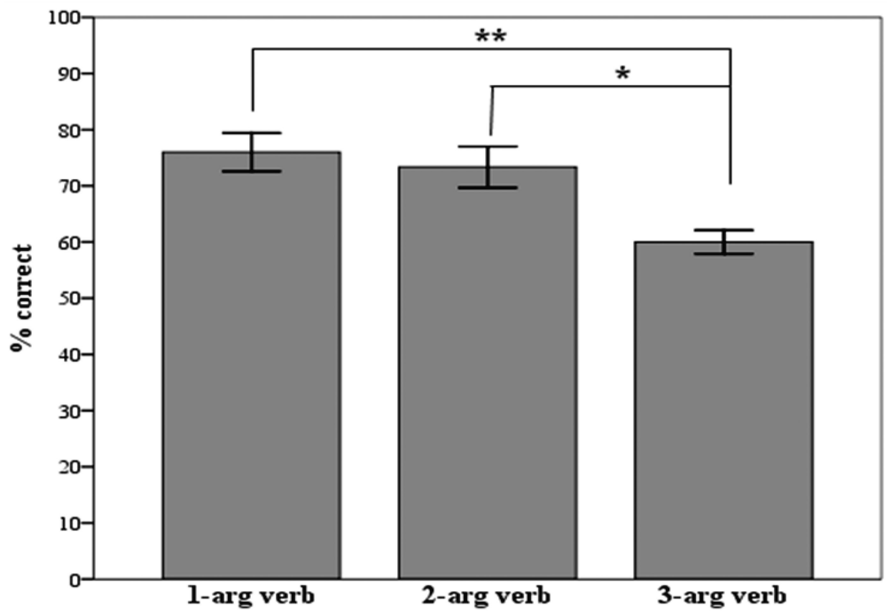


(a) (b)

Figure 4.

Sample stimuli for the Sentence Production Priming Test (SPPT) and the Sentence Comprehension Test (SCT). (a) Sample stimulus for testing actives, passives, subject extracted wh-questions and object extracted wh-questions (SWQ target: 谁喂女孩 'Who is feeding the girl?'; OWQ target: 男孩喂谁 'Who is the boy feeding?'); (b) Sample stimulus for testing subject relative clauses and object relative clauses (SR target: 张三看见喂女孩的男孩 'Zhangsan saw the boy who is feeding the girl.'; OR target: 张三看见男孩喂的女孩 'Zhangsan saw the girl who the boy is feeding.')

(a)



(b)

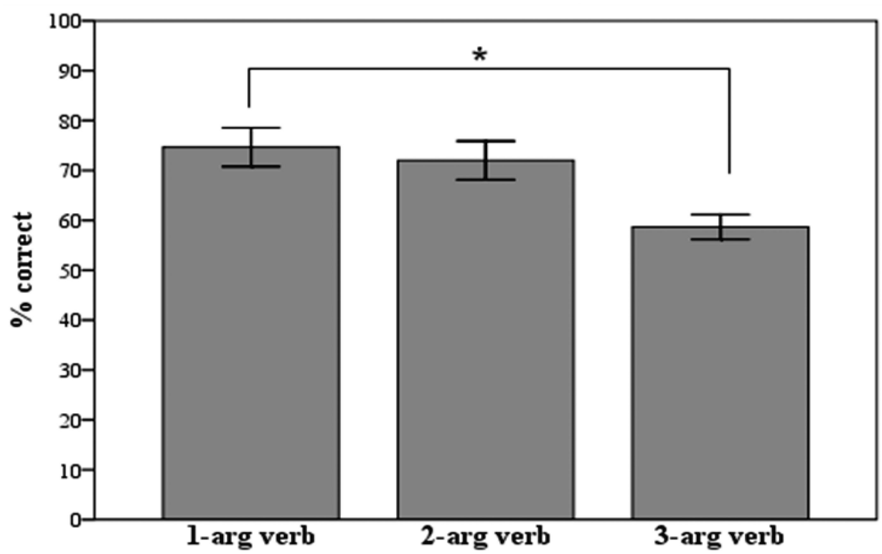


Figure 5.

Mean percentage of correct verbs by type (1-, 2- and 3- argument) for patients (*** $p < .001$, ** $p < .01$, * $p < .05$). (a) Verb Naming Test (VNT) scores, (b) Verb Comprehension Test (VCT) scores.

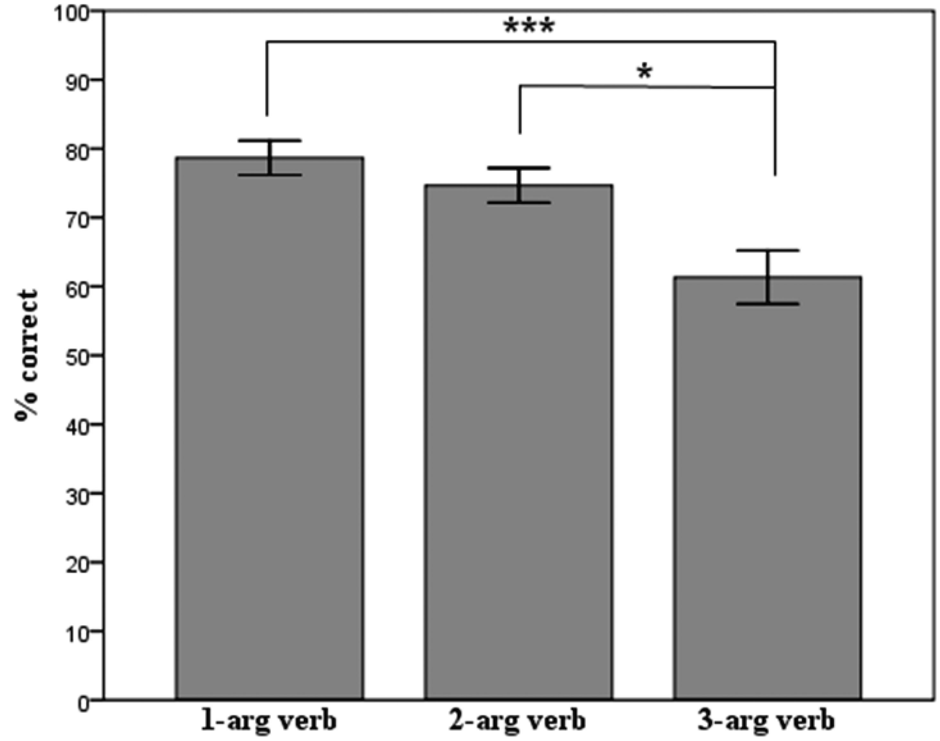
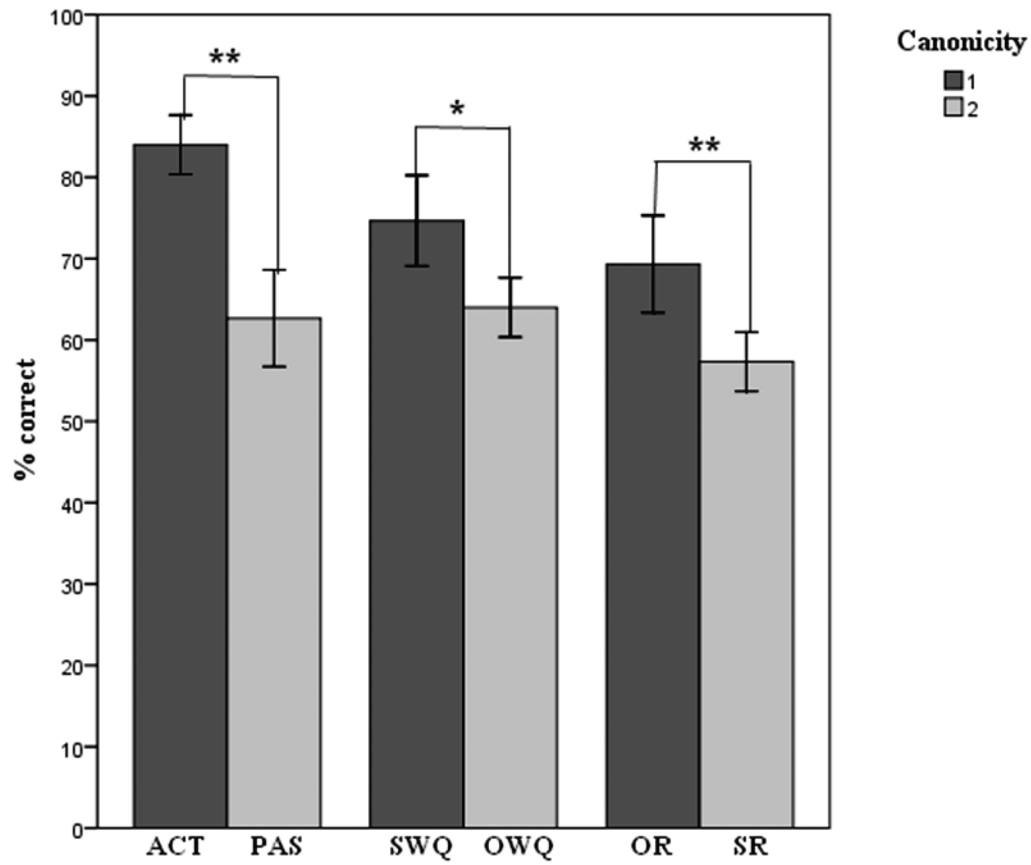


Figure 6.

Mean percentage of correct verbs by type (1-, 2- and 3-argument) for patients in the ASPT (*** $p < .001$, ** $p < .01$, * $p < .05$).

(a)



Canonicity
1
2
% correct
100
90
80
70
60
50
40
30
20
10
0
**
*
**
ACT
PAS
SWQ
OWQ
OR
SR

(b)

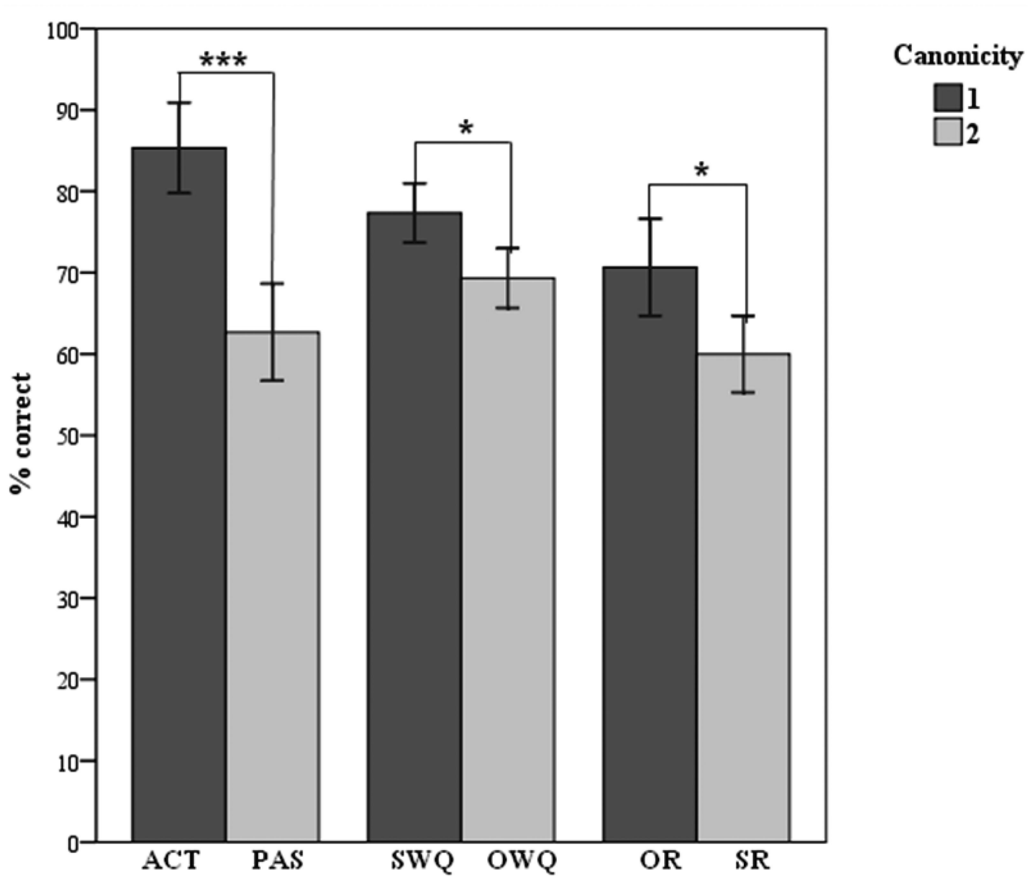


Figure 7.

Mean percentage of correct sentences by type for patients. (a) Sentence Production Priming Test (SPPT) scores; (b) Sentence Comprehension test (SCT) scores. Act = active, PAS = passive, SWQ = subject extracted wh-question, OWQ = object extracted wh-question, SR = subject relative clause, OR = object relative clause. (*** $p < .001$, ** $p < .01$, * $p < .05$).

Table 1

Patients' demographic information (a) and narrative data (b)

a. General information of the tested patients

Subject	*Age*	*Gender*	*Handedness*	*Years post-onset*	*Education*	*AQ*	*Etiology*
1	55	M	R	4	College	86.6	Left CVA
2	52	M	R	3	College	84	Left CVA
3	65	M	R	2	High school	72.1	Left CVA
4	61	M	R	1	High school	58	Left CVA
5	67	F	R	5	College	60.5	Left CVA
6	61	M	R	6	College	72.5	Left CVA
7	59	F	R	2	Middle school	70	Left CVA
8	68	M	R	3	Middle school	74.6	Left CVA
9	59	M	R	4	Middle school	80.5	Left CVA
10	61	M	R	2	Middle school	81.5	Left CVA
11	62	M	L	2	Middle school	67.2	Left CVA
12	47	F	R	2	Middle school	72.5	Left CVA
13	51	F	R	3	College	77.5	Left CVA
14	56	M	R	2	Middle school	76.5	Left MCA
15	60	M	R	4	Middle school	84.6	Left CVA

b. Characteristics of patients' narratives

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**AM**
MLU-W	6.2	4.1	3.2	5.1	3.2	6.3	3.8	4.2	5.6	6.3	3.2	2.6	3.9	4.1	2.1	10.2
%Grammatically Correct Sentences	26.7	29.3	34.5	27.3	38.7	43.2	23.1	34.5	30.4	28.3	50.5	42.1	16.7	21.4	32.3	93.4
%Verb with Correct Argument Structure	32.3	33.4	10.2	32.1	19.4	22.3	20.3	13.5	24.5	35.6	32.1	21.4	22.4	30.2	28.3	90.1
Open: Closed	3.2	1.4	2.1	1.1	1.2	1.6	2.3	2.2	2.4	3.1	2.5	2.6	3.1	2.2	1.5	0.9
Noun: Verb	2.1	1.3	0.9	0.8	1.2	1.4	1.5	2.2	0.9	1.3	1.7	1.2	1.2	1.1	1.3	1.1

CVA = cerebral vascular accident; AQ = Aphasia Quotient.

AM = the average scores from fifteen age-matched health normal controls (from Thompson, Shapiro, Tait, Jacob, Schneider, & Ballard (1995)); MLU-W = mean length of utterance in word; Open: Closed = ratio of open- to closed-class words; Nouns: Verbs = ratio of nouns to verbs.

Table 2

Mean (and SD) percentage of correct verbs for healthy normal controls in the Verb Naming Test (VNT), the Verb Comprehension Test (VCT) and the Argument Structure Production Test (ASPT)

	VNT	VCT	ASPT
One-argument verbs	100%	100%	100%
Two-argument verbs	100%	100%	99.7% (0.01)
Three-argument verbs	100%	100%	99.3% (0.02)

Author Manuscript

Author Manuscript

Author Manuscript

Table 3

Mean (and SD) percentage of correct verbs for healthy normal controls in the Sentence Production Priming Test (SPPT) and the Sentence Comprehension Test (SCT)

	Canonical			**Non-canonical**		
	Active	**SWQ**	**OR**	**Passive**	**OWQ**	**SR**
SPPT	100%	99.7% (0.01)	98.9% (0.04)	99.4% (0.01)	99.1% (0.01)	98.1% (0.03)
SCT	100%	100%	99.2% (0.03)	99.3% (0.01)	100%	98.8% (0.03)

Table 4

Number of three-argument verb errors, by type, on the Verb Naming Test (VNT) for each participant

Error type	*Verb substitution*			*Noun substitution*	*Phonological error*	*No response*	Total per patient
Patient	*1-arg*	*2-arg*	*3-arg*				
1	1	0	0	0	1	0	**2**
2	0	0	0	0	0	0	**0**
3	2	2	1	0	0	0	**5**
4	1	1	0	2	0	0	**4**
5	0		1	0	0	1	**2**
6	1	1	0	2	0	0	**4**
7	0	0	1	1	0	0	**2**
8	0	0	0	0	1	0	**1**
9	0	1	1	0	0	0	**2**
10	1	0	0	1	0	1	**3**
11	0	0	0	1	1	1	**3**
12	0	0	0	0	1	1	**2**
13	2	1	0	2	0	0	**5**
14	1	1	1	1	0	0	**4**
15	1	1	1	2	0	0	**5**
Total per error type	**10**	**8**	**6**	**12**	**4**	**4**	**44**

Table 5

Percentage of correct verbs and sentences by optionality of arguments on three tests of the NAVS-C, by participant

	Verb Naming Test (VNT)		Verb Comprehension Test (VCT)		Argument Structure Priming Test (ASPT)	
	Obligatory	**Optional**	**Obligatory**	**Optional**	**Obligatory**	**Optional**
1	83	70	83	60	75	70
2	83	70	83	50	83	65
3	67	60	75	70	58	80
4	83	70	75	70	75	65
5	50	70	58	70	67	45
6	75	50	67	60	92	55
7	75	50	67	50	58	50
8	67	60	58	50	75	90
9	75	70	75	40	58	65
10	83	60	58	60	58	70
11	83	70	67	70	92	65
12	58	70	67	70	67	65
13	58	60	67	50	83	55
14	83	50	92	80	58	70
15	58	60	75	60	83	70
Mean (SD)	**72 (11)**	**62(8)***	**71(9)**	**61(11)***	**73(12)**	**65(11)***

*significant difference ($p < .05$) between obligatory and optional verbs.

Table 6

Number of errors, by type, on three-argument verb sentences on the Argument Structure Priming Test (ASPT)

Error type	***Missing argument***			***Role reversal***	***Incorrect verb***	***Non-sentence***	***Total***
Patient	***Agent***	***Theme***	***Goal***				
1	1	0	1	1	1	0	**4**
2	1	0	1	1	0	1	**4**
3	0	0	1	0	1	1	**3**
4	3	2	0	2	1	0	**8**
5	3	4	2	1	0	0	**10**
6	0	1	0	1	0	1	**3**
7	2	0	2	2	0	0	**6**
8	0	0	1	1	0	0	**2**
9	2	1	2	1	0	0	**6**
10	0	1	1	1	0	1	**4**
11	1	1	1	2	0	1	**6**
12	2	0	1	3	0	0	**6**
13	2	1	1	2	0	0	**6**
14	0	0	0	2	1	0	**3**
15	1	0	1	2	0	1	**5**
Total	**18**	**11**	**15**	**22**	**4**	**6**	**76**

Table 7

Mean percentage (and SD) correct (a) and individual participant data (b) on the Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT)

a. A comparison by canonicity and sentence type

	By canonicity		*By sentence type*					
			Canonical			*Non-canonical*		
	C	*NC*	*A*	*SWQ*	*OR*	*P*	*OWQ*	*SR*
SPPT	76(8)	61(5)[a]	84(4)	75(6)	69(6)[b,1]	63(6)[b,1]	64(4)[b,1,2]	57(4)[b,1,2,3,5]
SCT	77(8)	64(6)[a]	85 (6)	77(4)[b,1]	70(6)[b,1,2]	63(6)[b,1,2]	69(4)[b,1,2,4]	60(5)[b,1,2,3,5]

b. Individual scores for the fifteen patients

Test	Sentence type		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean
SPPT	**C**	**A**	80	60	100	100	100	60	80	80	100	80	80	60	100	100	80	**84(15)**
		SWQ	60	100	80	60	100	80	80	80	40	100	100	80	60	60	40	**75(20)**
		OR	80	60	80	80	20	80	60	80	60	80	40	80	80	80	80	**69(18)**
	NC	**P**	80	80	60	40	40	60	60	60	60	80	60	40	80	40	100	**63(18)**
		OWQ	80	60	80	40	80	40	80	60	60	80	40	80	60	80	40	**64(17)**
		SR	40	80	40	60	80	40	80	40	60	40	60	80	40	60	60	**57(17)**
SCT	**C**	**A**	80	80	80	100	100	100	60	80	100	80	100	60	80	100	80	**85(14)**
		SWQ	60	80	60	60	80	80	80	100	40	100	80	80	80	100	80	**77(17)**
		OR	60	60	80	80	40	80	40	80	40	80	60	100	100	100	60	**71(21)**
	NC	**P**	60	40	80	60	60	60	80	60	40	80	40	60	80	60	80	**63(14)**
		OWQ	60	80	80	60	60	40	80	60	80	80	80	60	80	80	60	**69(13)**
		SR	60	80	40	60	80	20	80	40	60	40	60	80	60	80	60	**60(18)**

C = canonical; NC = non-canonical; A= active; P = passive; SWQ = subject extracted wh-question; OWQ = object extracted wh-question; SR = subject relative clause; OR = object relative clause; Under the heading of 'by canonicity', the superscript "a" indicates significant difference between canonical and non-canonical forms ($p < 0.05$). Under the heading of 'by sentence type', the superscript "b" indicates significant difference between a structure as compared with others ($p < 0.05$). Superscript numbers indicate significant difference between a structure as compared to active[1], SWQ[2], OR[3], passive[4], OWQ[5], SR[6] at the level of $p < .05$.

Table 8

Patients' number (percentage) of error types for non-canonical sentences on the Sentence Production Priming Test (SPPT)

	Passive	**Object-extracted wh-question**	**Subject relative clause**
Canonical structure error	18 (31%)	22 (38.6%)	22 (35.5%)
Role reversal error	18 (31%)	20 (35.1%)	18 (29%)
Non-sentence	9 (15.5%)	2 (3.5%)	8 (12.9%)
No response	10 (17.2%)	9 (15.8%)	9 (14.5%)
Other	3 (5.2%)	4 (7%)	5 (8%)
Total	58 (100%)	57 (100%)	62 (100%)