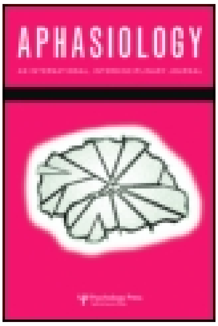

Aphasiology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/paph20

Verb and sentence production and comprehension in aphasia: Northwestern Assessment of Verbs and Sentences (NAVS)

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Version of record first published: 03 Jul 2012

APHASIOLOGY, 2012, i*First*, 1–28

Psychology Press
Taylor & Francis Group

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Background: Verbs and sentences are often impaired in individuals with aphasia, and differential impairment patterns are associated with different types of aphasia. With currently available test batteries, however, it is challenging to provide a comprehensive profile of aphasic language impairments because they do not examine syntactically important properties of verbs and sentences.
Aims: This study presents data derived from the *Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson, 2011), a new test battery designed to examine syntactic deficits in aphasia. The NAVS includes tests for verb naming and comprehension, and production of verb argument structure in simple active sentences, with each examining the effects of the number and optionality of arguments. The NAVS also tests production and comprehension of canonical and non-canonical sentences.
Methods & Procedures: A total of 59 aphasic participants (35 agrammatic and 24 anomic) were tested using a set of action pictures. Participants produced verbs or sentences for the production subtests and identified pictures corresponding to auditorily provided verbs or sentences for the comprehension subtests.
Outcomes & Results: The agrammatic group, compared to the anomic group, performed significantly more poorly on all subtests except verb comprehension, and for both groups comprehension was less impaired than production. On verb naming and argument structure production tests both groups exhibited difficulty with three-argument verbs, affected by the number and optionality of arguments. However, production of sentences using three-argument verbs was more impaired in the agrammatic, compared to the anomic, group. On sentence production and comprehension tests, the agrammatic group showed impairments in all types of non-canonical sentences, whereas the anomic group exhibited difficulty primarily with the most difficult, object relative, structures.
Conclusions: Results show that verb and sentence deficits seen in individuals with agrammatic aphasia are largely influenced by syntactic complexity; however, individuals with anomic aphasia appear to exhibit these impairments only for the most complex

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This study was supported by the NIH grant RO1DC01948 (C.K. Thompson). The authors thank Drs JungWon (Janet) Choy, Michael Walsh Dickey, Stephen Fix, Beverly Jacobs, Mikyong Kim, Kelly L. Lange, Miseon Lee, Lisa Milman, Lewis P. Shapiro, and Sandra L. Schneider, and Sarah Dove BS, Kyla Garibaldi BS, Ted Jenkins BS, and Janet O'Connor MA for their assistance with test development and data collection and analysis.

http://www.psypress.com/aphasiology http://dx.doi.org/10.1080/02687038.2012.693584

forms of verbs and sentences. The present data indicate that the NAVS is useful for characterising verb and sentence deficits in people with aphasia.

Keywords: Verb; Sentence; Production; Comprehension; Agrammatic aphasia; Anomic aphasia.

Verb and/or sentence comprehension and production deficits are commonly seen in individuals with aphasia. For instance, those with both nonfluent and fluent aphasia may show deficits in verb naming, although this pattern is most often seen in individuals with Broca's aphasia with concomitant agrammatism (Basso, Razzano, Faglioni, & Zanobio, 1990; Bastiaanse & Jonkers, 1998; Berndt, Mitchum, Haendiges, & Sandson, 1997; Chen & Bates, 1998; Kambanaros, 2010; Kim & Thompson, 2000, 2004; Kohn, Lorch, & Pearson, 1989; Luzzatti et al., 2002; Miceli, Silveri, Villa, & Caramazza, 1984; Williams & Canter, 1987; Zingeser & Berndt, 1990). In addition, verb comprehension may be impaired in some patients (Jonkers & Bastiaanse, 2006; McCarthy & Warrington, 1985; Miceli, Silveri, Nocentini, & Caramazza, 1988; but see Berndt, Mitchum, et al., 1997; Kim & Thompson, 2000; Marshall, Pring, & Chiat, 1998). Because verbs play an important role in sentence production and comprehension, namely that without a verb a sentence cannot be grammatical, testing for verb production and comprehension is important for understanding aphasic sentence deficits (see Berndt, Haendiges, Mitchum, & Sandson, 1997). Some studies also show that treatment focused on verb production deficits results in improved sentence production (Marshall et al., 1998; Schneider & Thompson, 2003; Thompson, Riley, den Ouden, Meltzer-Asscher, & Lukic, 2012). Hence detailing verb (and sentence) deficits is important for understanding recovery.

Research also indicates that not all verbs impose the same degree of difficulty for aphasic speakers. That is, verbs with a greater number of arguments, or participant roles, often are more difficult to produce than those with fewer (De Bleser & Kauschke, 2003; Dragoy & Bastiaanse, 2010; Kiss, 2000; Luzzatti et al., 2002; Thompson, Lange, Schneider, & Shapiro, 1997; Thompson, Shapiro, Li, & Schendel, 1995). Using picture-naming tasks, Thompson and colleagues found that for agrammatic aphasic speakers three- and two-argument verbs (see 1a and 1b, respectively) are more difficult than one-argument verbs (1c) both in naming and sentence production tasks (Kim & Thompson, 2000; Thompson, Lange, et al., 1997). In addition, in a recent study that included anomic aphasic speakers, both agrammatic and anomic aphasic participants evinced greater difficulty with transitive (i.e., three- and two-argument) compared to intransitive (one-argument) verbs (Thompson, Lukic, King, Mesulam, & Weintraub, 2012). The NAVS tests production and comprehension of verbs with one, two, and three arguments in both verb production and comprehension tasks. In addition, when participants are presented with verbs of each type, the ability to generate verb arguments associated with them is tested in an argument structure production test.

(1) a. <u>The artist</u> [AGENT] *gave* <u>the painting</u> [THME] <u>to the museum</u> [GOAL]. (three-argument verb)
b. <u>The collie</u> [AGENT] *followed* <u>the skunk</u> [THEME]. (two-argument verb)
c. <u>The actress</u> [AGENT] *laughed*. (one-argument verb)

The type of argument that verbs select has also been shown to influence production. For example, within the class of one-argument verbs, unaccusative verbs such as *bloom* (2a) are more difficult for agrammatic individuals to name and to produce in sentences than unergative verbs such as *smile* (2b) (Bastiaanse & van Zonneveld, 2005; Lee & Thompson, 2004; Thompson, 2003; Thompson & Lee, 2009). Luzzatti et al. (2002) also showed that both Wernicke's and anomic aphasic individuals showed greater impairments in naming unaccusative, compared to unergative or two-argument transitive verbs, indicating sensitivity to the thematic role of arguments (also see McAllister, Bachrach, Waters, Michaud, & Caplan, 2009). This effect putatively manifests because the subject noun in (2a) is a theme, whereas that in (2b) is an agent. Further, syntactic descriptions of (2) indicate that syntactic movement (i.e., A movement) is involved in unaccusatives, but not in unergatives (Burzio, 1986) and unaccusatives involve internal causation (Levin & Rappaport Hovav, 1995). The NAVS controls for these distinctions, in that all one-argument verbs included in the test are unergatives, hence production and/or comprehension ability is not confounded by including computationally difficult unaccusative verbs (McKoon & MacFarland, 2002).

(2) a. The flower [THEME] bloomed t_i. (unaccusative verb)
b. The dancer [AGENT] smiled. (unergative verb)

Lastly the obligatory versus optional status of verb arguments may also contribute to verb deficits in aphasia. That is, some verbs require that the arguments entailed in their lexical representation be overtly present in the syntax (i.e., obligatory arguments), whereas other verbs allow some arguments to be omitted (i.e., they are optional). For example, the verb *deliver* is an optional three-argument verb, which can be used in sentences with two or three arguments as in (3a) and (3b), respectively. The verb *put*, however, can only be legally used in a three-argument context, as in (3c), but not in a two-argument context, as in (3d).

(3) a. The postman *delivered* the package. (optional three-argument verb with two argument realised)
b. The postman *delivered* the package to the school. (optional three-argument verb with three arguments realised)
c. The boyscout *put* the matches in his pocket. (obligatory three-argument verb with three arguments)
d. *The boyscout *put* the matches. (obligatory three-argument verb with two arguments)

Studies with healthy listeners suggest that optional compared to obligatory verbs are more complex. Using a cross modal lexical decision paradigm Shapiro and colleagues showed greater reaction times for the former compared to the latter, when encountered in sentences (Shapiro & Levine, 1990; Shapiro, Zurif, & Grimshaw, 1987), suggesting that, when a particular verb is activated during sentence processing, all possible argument structure configurations associated with the verb are also activated, and because the former entail a greater number of theta grids (e.g., possible argument structure configurations) greater processing resources are required for them. This pattern has also been shown for individuals with Broca's, but not Wernicke's, aphasia (Shapiro, Gordon, Hack, & Killackey, 1993; Shapiro & Levine, 1990). In addition, poorer sentence production accuracy has been noted when optional verbs are embedded in sentences (Thompson, Lange, et al., 1997), although verb naming is not always affected by this property (see, e.g., Kim & Thompson, 2000). However, aphasic speakers' ability to name obligatory versus optional verbs has not been extensively studied. The NAVS provides for a direct examination of this effect by including both verbs with obligatory arguments and those with optional ones.

Sentence comprehension and production deficits also are common in individuals with acquired aphasia, with studies showing that sentences with a non-canonical word order, such as passives and object relative clauses, presenting more difficulty than those with a canonical order (e.g., Subject, Verb, Object [SVO] in English). Whereas canonical sentences display this SVO order (e.g., *The dog chased the cat*.), in non-canonical structures the object is moved across the verb and the subject and surfaces in the clause-initial position via syntactic operations—A and A' movement (i.e., NP- and Wh-movement)—for passive (4a) and object relative (4b) structures, respectively (Chomsky, 1981, 1986, 1995).

(4) a. *The boy* was kissed *t* by the girl. (passive, A or NP-movement)
    b. I saw the boy *who* the girl kissed *t*. (object relative clause, A' or Wh-movement)

This difficulty with non-canonical sentences, particularly for semantically reversible sentences, has been well documented in agrammatic individuals for both production (Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003; Rochon, Laird, Bose, & Scofield, 2005; Schwartz, Saffran, Fink, Myers, & Martin, 1994) and comprehension (Berndt, Mitchum, & Haendiges, 1996; Caplan & Futter, 1986; Caramazza & Zurif, 1976; Schwartz, Saffran, & Marin, 1980; Thompson, Tait, Ballard, & Fix, 1999). In addition some studies suggest that production and/or comprehension of non-canonical sentences are impaired in fluent aphasic individuals (Bastiaanse & Edwards, 2004; Butterworth & Howard, 1987; Caramazza & Zurif, 1976; Edwards, 2000; Edwards & Bastiaanse, 1998; Faroqi-Shah & Thompson, 2003; Martin & Blossom-Stach, 1986).

Importantly, treatment studies suggest that the type of syntactic movement (i.e., NP- vs Wh-movement) is an important factor to consider for aphasic individuals with sentence deficits. In a series of studies Thompson and colleagues showed that training sentences with Wh-movement (e.g., object relative structures) does not influence production or comprehension of sentences with NP-movement, such as passives, although generalisation across sentences with similar movement operations is commonly seen (e.g., from object relative structures to object wh-question forms) (Ballard & Thompson, 1999; Dickey & Thompson, 2007; Jacobs & Thompson, 2000; Thompson, Choy, Holland, & Cole, 2010; Thompson, den Ouden, Bonakdarpour, Garibaldi, & Parrish, 2010; Thompson & Shapiro, 2005; Thompson, Shapiro, et al., 1997; Thompson, Shapiro, Kiran, & Sobecks, 2003). The NAVS tests sentences associated with both types of syntactic operations, NP-movement (i.e., passives) and Wh-movement (i.e., object wh-questions and object relative clauses) in both production and comprehension tasks.

In summary, verb and sentence deficits are prevalent in individuals with aphasia. Therefore tests for these deficits are needed in order to understand their language impairment and for treatment planning. However, test batteries for aphasia—for example, the *Western Aphasia Battery* (WAB; Kertesz, 1982), the *Boston Diagnostic Aphasia Examination* (BDAE; Goodglass, Kaplan, & Barresi, 2001), and the *Comprehensive Aphasia Test* (CAT; Swinburn, Porter, & Howard, 2004)—do not address the aforementioned important properties of verbs and sentences. Although an action (verb) naming test is included in some tests (i.e., the BDAE and the CAT), the verbs tested are not controlled for their argument structure properties and/or they include verbs of only one type for testing. In addition, these aphasia batteries do not include tests for verb comprehension nor do they examine canonical and non-canonical sentence production and comprehension. Both the WAB and the BDAE examine sentence production in narrative speech only, and sentences tested for comprehension include simple yes/no questions and imperative sentences. However, the CAT does test comprehension (but not production) of canonical and non-canical sentences, only NP-movement structures (i.e., passives) are tested; Wh- movement structures (e.g., object relatives) are not.

A few specialised tests for examining verb and/or sentence deficits in aphasia have been published and, at least to some extent, these tests have controlled for the aforementioned variables that affect language processing. *An Object and Action Naming Battery* (OANB; Druks & Masterson, 2000) tests verbs controlled for argument structure, examining production (but not comprehension) of one-, two-, and three-argument verbs matched for frequency, age of acquisition, and imageability. However, the one-argument verbs include both unergative and unaccusative verbs, and the optionality of verb arguments is not tested. The *Verb and Sentence Test* (VAST; Bastiaanse, Edwards, & Rispens, 2002) controls verbs for transitivity and hence includes one- and two-, but not three-argument verbs. One advantage of the VAST, however, is that both verb naming and comprehension are tested. Further, the VAST examines sentence production and comprehension using both canonical and non-canonical forms, however different sentence types are tested in the two modalities (i.e., wh-questions for production; subject and object cleft sentences for comprehension). A few tests have been developed explicitly for examining sentence deficits in aphasia, and include both NP- and Wh-movement sentences, i.e., the *Philadelphia Comprehension Battery for Aphasia* (PCBA; Saffran, Schwartz, Linebarger, Martin, & Bochetto, unpublished) and the *Subject-relative*, *Object-relative*, *Active*, *Passive* (SOAP) *syntactic battery* (Love & Oster, 2002). However, the verbs are not controlled for argument structure and sentence production is not tested with these measures. (See Table 1 for a summary of tests which assess verb production and/or comprehension, verb argument structure production, and sentence production and/or comprehension.)

The *Northwestern Assessment of Verbs and Sentences* (NAVS) (Thompson, 2011) was designed to provide a comprehensive assessment of production and comprehension of verbs and sentences. The NAVS consists of five subtests: the Verb Naming Test

TABLE 1
Summary of tests for examining verbs, verb argument structure and/or sentences in aphasia

	Verb			*Sentence*	
	Naming	*Comprehension*	*Argument Structure*	*Production*	*Comprehension*
WAB				√	√
BDAE	√			√	√
CAT	√				√
PCBA		√			√
SOAP					√
OANB	√				
VAST	√	√		√	√

WAB = Western Aphasia Battery; BDAE = Boston Diagnostic Aphasia Examination;
CAT = Comprehensive Aphasia Test; PCBA = Philadelphia Comprehension Battery for Aphasia; SOAP = Subject-relative, Object-relative, Active, Passive syntactic battery; OANB = Object and Action Naming Battery; VAST = Verb and Sentence Test.

(VNT), the Verb Comprehension Test (VCT), the Argument Structure Production Test (ASPT), the Sentence Production Priming Test (SPPT), and the Sentence Comprehension Test (SCT). Verb argument structure and optionality effects are examined in three verb types (i.e., one-, two-, and three-argument verbs) as singletons (i.e., in the VNT and VCT) and in a sentence context (i.e., in the ASPT). Production and comprehension of sentences by canonicity and sentence type are examined in the SPPT and SCT, respectively, using six sentence types (i.e., canonical: active, subject extracted wh-question (SWQ), and subject relative clause (SR); non-canonical: passive, object extracted wh-question (OWQ), and object relative clause (OR)). In order to allow for direct comparisons between modalities the same stimuli were used to assess both production and comprehension. The purpose of this paper is to examine verb and sentence deficits by verb argument structure, canonicity, and syntactic sentence types in both production and comprehension modalities in individuals with agrammatic and anomic aphasia, and to discuss the utility of this test for delineating verb and sentence deficits in people with aphasia.

METHOD

Participants

A total of 59 individuals with aphasia—35 agrammatic (21 males, 14 females) and 24 anomic (15 males, 9 females)—participated in the study and were recruited from the participant pool of the Aphasia and Neurolinguistics Research Laboratory at Northwestern University. The two groups were matched for age ($M = 55$, range: 33–71 for the agrammatic group; $M = 59$, range: 45–79 for the anomic group) ($Z = -1.212$, $p = .225$, Mann-Whitney U Test) and education ($M = 16$, range: 12–20 for the agrammatic group; $M = 16$, range: 12–20 for the anomic group) ($Z = -1.270$, $p = .204$, Mann-Whitney U Test). All were monolingual native speakers of English except for one participant who was premorbidly a Spanish–English bilingual. Although his first language was Spanish, English had been his primary language since the age of 4 and it was preserved to a greater extent than Spanish post-stroke. All participants suffered a thromboembolic stroke in the left hemisphere, with an average of 6 years post-stroke (range: 1–19) for the agrammatic group and 5 years post-stroke (range: 1–25) for the anomic group ($Z = -.812$, $p = .416$, Mann-Whitney U Test). None had history of neurological, psychiatric, speech-language, or learning disorders prior to their stroke. All but one were right-handed and demonstrated visual and hearing acuity within normal limits.

Participants were classified by aphasia type, primarily using the *Western Aphasia Battery* (WAB; Kertesz, 1982). However, spontaneous speech production patterns were used to confirm each participant's diagnosis. The agrammatic participants all showed a deficit profile consistent with Broca's aphasia with WAB aphasia quotients (AQs) ranging from 51.4 to 87.2 ($M = 73.9$) and fluency scores ranging from 1 to 5 ($M = 4.4$). In spontaneous speech samples they showed effortful and dysfluent production, marked by production of short (largely ungrammatical) sentences and deletion/substitution of grammatical morphemes. The anomic participants' WAB AQs ranged from 69.4 to 93.7 ($M = 87.5$) and fluency scores ranged from 6 to 9 ($M = 8.1$). Their speech was marked by preserved prosody and relatively preserved syntax and grammatical morphology with mild-to-moderate word retrieval difficulties. WAB AQs were significantly higher for the anomic compared to the agrammatic group ($Z = -5.655$, $p < .001$, Mann-Whitney *U* Test), largely driven by fluency scores, required to be higher for a diagnosis of anomic aphasia based on qualitative analysis of their production patterns ($Z = -6.692$, $p < .001$, Mann-Whitney *U* Test). Auditory comprehension scores for the anomic group ranged from 8 to 10 ($M = 9.4$), whereas for the agrammatic group scores ranged from 5.5 to 10 ($M = 8.4$) ($Z = -3.275$, $p = .001$, Mann-Whitney *U* Test), and repetition scores ranged from 7.1 to 10 ($M = 8.8$) for the anomic group and from 3.4 to 10 ($M = 7.7$) for the agrammatic group ($Z = -2.819$, $p = .005$, Mann-Whitney *U* Test). We note that these distinctions are in keeping with qualitative differences between the two groups: a diagnosis of Broca's aphasia with agrammatism is associated with sentence comprehension deficits and, in addition, is often accompanied by repetition difficulties associated with concomitant motor speech impairments that are not seen in anomic aphasia. However, naming scores for the agrammatic participants ($M = 8$, range = 4.2–10) were not significantly different from those for the anomic participants ($M = 8.6$, range = 4.3–9.9) ($Z = -1.954$, $p = .051$, Mann-Whitney *U* Test). A summary of WAB scores is provided in Table 2.

A total of 26 age-matched healthy control participants (age $M = 62$, range = 50–74; education $M = 16$, range = 13–20) were also recruited from the subject pools of the Aphasia and Neurolinguistics Research Laboratory and the Cognitive Neurology and Alzheimer's Disease Center (CNADC) at Northwestern University. All were monolingual native speakers of English with normal or corrected-to-normal vision and hearing. None presented with a history of neurological, psychiatric, speech-language, or learning disorders prior to the study. The study was approved by the Institutional Review Board at Northwestern University, and informed consent was obtained from all participants.

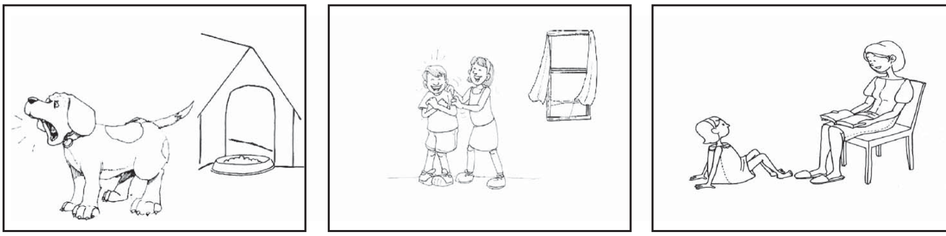
Stimuli

Verb Naming Test (VNT). Target stimuli included 22 verbs, 5 one-argument, 10 two-argument (5 obligatory and 5 optional), and 7 three-argument (2 obligatory and 5 optional) verbs. One- and two-argument verbs were equated for the $\log_{10}$ lemma frequency from the CELEX (Baayen, Piepenbrock, & van Rijn, 1993) ($M = 1.46$ vs 1.58; $Z = -.490$, $p = .624$, Mann-Whitney *U* Test). However, three-argument verbs ($M = 2.40$) were more frequent than both one- and two-argument verbs ($Z = -2.196$, $p = .030$; $Z = -2.342$, $p = .019$, Mann-Whitney *U* Test) (see Appendix A). Verbs were selected for their argument structure properties based on the Brandeis Verb Lexicon (Grimshaw & Jackendoff, 1981) as well as linguistic tests (see Appendix B). For each verb a black and white line drawing of the action was prepared on a 8.5 × 11-inch card. In order to match the visual complexity of drawings for three-argument verbs,

TABLE 2
Mean scores (*SD*) for the Western Aphasia Battery

	AQ	*F*	*AC*	*R*	*N*
Agr	73.9 (8.9)*	4.4 (0.9)*	8.4 (1.2)*	7.7 (1.5)*	8.0 (1.4)
An	87.5 (5.2)	8.1 (1.3)	9.4 (0.5)	8.8 (0.9)	8.6 (1.3)

Agr = agrammatic; An = anomic; AQ = Aphasia Quotient; F = Fluency; AC = Auditory Comprehension; R = Repetition; N = Naming. * indicates at least $p < .05$.



(a) (b) (c)

Figure 1. Sample stimuli for the Verb Naming Test (VNT) by verb type. (a) one-argument verb (target verb: *bark*); (b) two-argument verb (target verb: *tickle*); (c) three-argument verb (target verb: *read*).

drawings for one- and two-argument verbs included additional elements as necessary (e.g., two-argument verbs were depicted with a locative object). All picture stimuli were normed with 10 native speakers of English, and elicited the target verbs at a rate of 95%. Sample pictures for each verb type are provided in Figure 1(a), (b), and (c).

Verb Comprehension Test (VCT). Target verbs for the VCT were the same as for the VNT, with visual displays for each item depicting the target and three distractors, one of the same verb type as the target (selected from the target stimulus set) and two others with different argument structures selected from 24 additional verbs (8 one-argument, 11 two-argument, and 5 three-argument verbs). Distractor verbs were matched for the $\log_{10}$ lemma frequency with corresponding target verbs (one-argument verb $M = 1.64$, $Z = -.294$, $p = .768$; two-argument verb $M = 1.72$, $Z = -.634$, $p = .526$; three-argument verb $M = 1.99$, $Z = -.731$, $p = .465$) (see Appendix A for a complete stimuli list of the VCT). Target verbs and distractors for each were presented in black and white drawings on 8.5×11-inch cards with one picture placed in each of the four corners (see Figure 2). The position of the target verb picture was counterbalanced across stimuli. Ten unimpaired native speakers of English were able to identify all target verbs without difficulty.

Argument Structure Production Test (ASPT). For the ASPT, 9 animate and 13 inanimate nouns were combined with the verbs used for the VNT. Each verb was tested in all of its argument structure contexts, resulting in 32 target sentences. For example, the optional two-argument verb *wash* was tested with all of its arguments (e.g., in an agent and theme context) and once with the agent only (because the theme argument is optional) (see Appendix C). Selected nouns were equated for the $\log_{10}$ lemma frequency (agent $M = 2.43$, theme $M = 1.98$, goal $M = 2.47$; $\chi^2(2, n = 35) = 4.089$, $p = .129$, Kruskal-Wallis Test). The picture stimuli used for the VNT were modified for the ASPT, with arrows added to denote objects or people representing arguments of the verb. Additionally, elements added to control for visual complexity in the VNT and VCT stimuli were removed. The names of the action and the objects/people were also written on the pictures, to offset word retrieval difficulty. However, participants were required to produce the correct verb as well as all of its arguments in the correct order. Sample pictures for eliciting an optional two-argument verb with all of its arguments and the obligatory argument only are shown in Figure 3 (a) and (b), respectively.

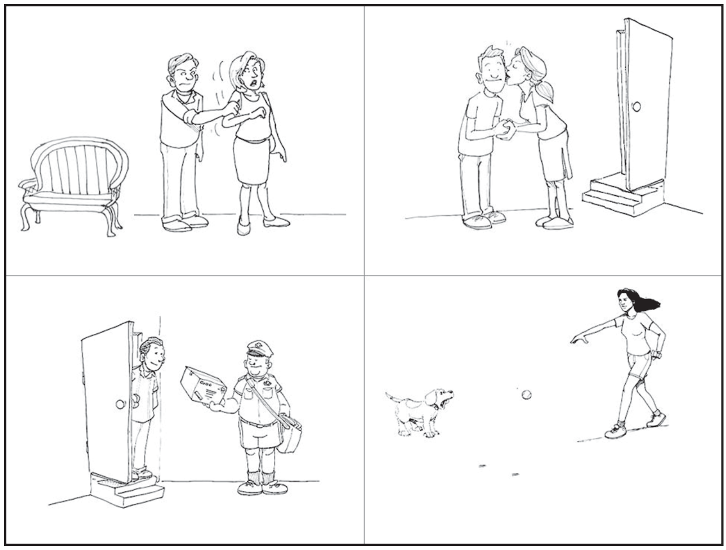


Figure 2. Sample stimuli for the Verb Comprehension Test (VCT) (from top left to bottom right, different verb distractor: *grab* and *kiss*; target: *deliver*; same verb distractor: *throw*).

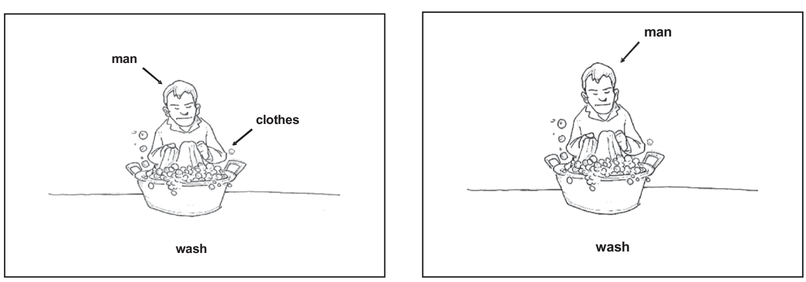


Figure 3. Sample stimuli for the Argument Structure Production Test (ASPT). (3a) optional two-argument verb with two arguments (target: *The man is washing the clothes*); (3b) optional two-argument verb with one argument (target: *The man is washing*).

Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT). The SPPT elicited production of six sentence types ($n = 5$ for each type) in 5 (a)–(f), with three canonical sentence structures—i.e., active (5a), subject-extracted wh-question (SWQ) (5c), and subject relative clause (SR) (5e)—and their non-canonical counterparts—i.e., passives (5b), object-extracted wh-question (OWQ) (5d), and object relative clause (OR) (5f). For each target sentence its semantically reversed counterpart was used as a prime. All sentences contained animate nouns matched for the $\log_{10}$ lemma frequency (agent $M = 2.56$ vs theme $M = 2.51$; $Z = -.218$, $p = .827$, Mann-Whitney U Test), and two-argument verbs of high frequency ($M = 1.97$).

(5) a. The dog is chasing the cat. (prime: The cat is chasing the dog.)
b. The cat is chased by the dog. (prime: The dog is chased by the cat.)
c. Who is chasing the cat? (prime: Who is chasing the dog?)
d. Who is the dog chasing? (prime: Who is the cat chasing?)

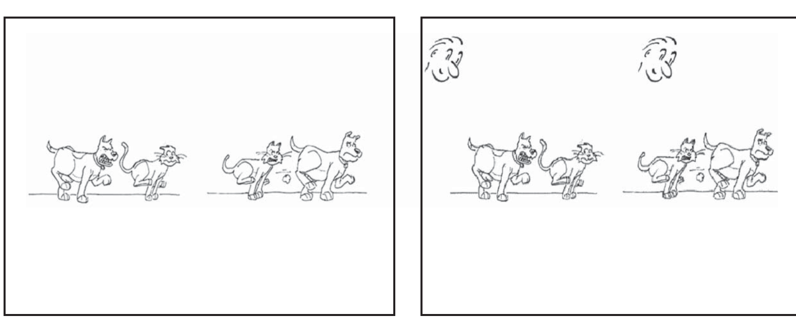
e. Pete saw the dog who is chasing the cat. (prime: Pete saw the cat who is chasing the dog.)
f. Pete saw the cat who the dog is chasing. (prime: Pete saw the dog who the cat is chasing).

For each prime–target pair corresponding black and white line drawings were prepared, one depicting the prime event on the left of the card and the other depicting a semantically reversed version, i.e., the target event, on the right of the card (see Figure 4a). For relative clauses a man was shown, looking over the transitive action, i.e., *Pete* (see Figure 4b). The location of event participants in the pictures was counterbalanced across pictures. For the SCT the same picture pairs used for the SPPT were utilised; all were normed by 10 native speakers of English and elicited target sentences at a rate of 95%. A complete list of sentences tested in the SPPT and SCT is provided in Appendix D.

During the course of stimulus development, sentence stimuli for the SPPT and SCT were examined for length and order effects. Long (10-item) and short (5-item) versions were created, with sentence types presented in blocks or in random order and the two versions administered on two separate occasions separated by at least 3 days and not more than 2 weeks. The order of presentation of the two versions was counterbalanced across participants. Analysis of the two versions revealed that scores derived for the long and short versions were related, indicating no difference between the two, $\chi^2(28, n = 21) = 66.949$, $p < .001$, Chi-square tests of independence). In addition, scores from the block versus random order versions were related to one another: block first: $\chi^2(12, n = 12) = 36.000$, $p < .001$; random first: $\chi^2(20, n = 24) = 57.600$, $p < .001$, Chi-square tests of independence). The final SPPT and SCT therefore included items blocked by sentence type, with five items of each type.

Procedures

Participants were seated in front of an examiner in a quiet room with the NAVS subtests administered in the following order: VNT, VCT, ASPT, SPPT, and SCT. For the VNT the examiner presented an action picture and asked participants to name the



(a) (b)

Figure 4. Sample stimuli for the Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT). (a) Sample stimulus for testing actives, passives, and subject and object extracted wh-questions (SWQ target: *Who is chasing the dog*?; OWQ target: *Who is the cat chasing*?); (4) Sample stimulus for testing subject and object relative clauses (SR target: *Pete saw the cat who was chasing the dog*; OR target: *Pete saw the dog who the cat was chasing*).

action in each picture. Participants were given 10 seconds to respond. For the VCT the examiner presented an image with four actions and named one (the target) for participants to identify by pointing; 5 seconds were given for each response. For the ASPT the examiner provided a stimulus item and requested that participants make a sentence using the action word and all things marked with arrows. Participants were allowed 10 seconds to respond. Prior to each subtest two practice trials preceded test items.

For the SPPT the examiner presented a prime–target picture pair and identified the event participants in each. For example, for the target sentence *The cat is chasing the dog* the examiner explained, "*Here are two pictures, both showing a dog and a cat. The action in these pictures is chase*". Then the examiner produced the prime sentence while pointing to the event on the left, "*For this picture, I could say: the dog is chasing the cat*" and prompted participants' production by saying, "*For this picture, you could say* . . . " while pointing to the event on the right. Participants were given 15 seconds to respond. For the SCT the examiner read aloud the target sentence, and participants were asked to point to the picture corresponding to the sentence (sentence–picture matching). Participants were given 10 seconds to respond. Sentences were repeated once on request. On both SPPT and SCT three practice trials preceded presentation of each subtest.

Scoring

For the VCT and SCT correct identification of the picture corresponding with the auditory stimulus were recorded and tallied for each item. For the VNT, ASPT, and SPPT all responses were transcribed verbatim, including fillers (e.g., uh, um) and self-corrections. When there were self-corrections the final response produced within the allotted response time was scored for accuracy. For the VNT production of the target verb in any morphological form (*wash*, *washes*, is/was *washing* for the verb *wash*) was accepted. In addition, semantic substitutions with verbs in the same argument structure class (e.g., *clean* for *wash*) and phonemic paraphasias containing at least 50% of the phonemes for the target word (e.g., /*kining*/ or /*klining*/ for *cleaning*) were scored as correct.

For the ASPT responses were scored as correct if the target verb and all required verb arguments in the picture were produced in the correct order. For three-argument verbs either the NP-V-NP-NP or NP-V-NP-PP structure was accepted (e.g., *the boy is giving the woman the gift* or *the boy is giving the gift to the woman*). For the NP-V-NP-PP structure, however, the correct preposition needed to precede the goal of the verb (e.g., *to the woman*). Target nouns in any form (e.g., *a boy*, *the boy* for the target *boy*) and semantic substitutions for nouns (e.g., *lady* for *woman* and *guy* for *man*) were accepted.

For the SPPT additional criteria were applied to score passive and relative clause structures. For correct passive sentences at least two out of three morphological indicators of passive voice needed to be present (i.e., an auxiliary, participle morpheme *ed*, and the preposition *by*) and thematic roles needed to be correctly assigned. For relative clauses, grammatically correct reduced relatives were accepted in which both/either the relative pronoun (i.e., *who* or *that*) and/or the auxiliary were omitted (e.g., for the target SR *Pete saw the cat who is chasing the dog*, *Pete saw the cat that is chasing the dog, Pete saw the cat chasing the dog*, and *Pete saw the cat is chasing the dog* were accepted; and for the target OR *Pete saw the boy who the girl is kissing*, *Pete saw the boy that the girl is kissing* and *Pete saw the boy the girl kissing* were accepted).

In addition, variation of verb forms as well as phonological paraphasias and semantic substitutions were accepted for target nouns.

Reliability

A total of 30% of the testing sessions were scored by an independent rater. Point-to-point agreement between the primary examiner and the independent rater's scores ranged from 97% to 100%, with overall agreement of 99.8%.

Data analysis

Mean percent correct production and comprehension of verbs and sentences were calculated for each participant group by verb or sentence type. These accuracy data were analysed using mixed-design ANOVAs, with group as a between-participants variable and verb/sentence type (and optionality/modality) as within-participant variables. Within-group comparisons were performed using one-way ANOVAs followed by post-hoc analyses using the Bonferroni correction, unless otherwise specified. Between-group comparisons were performed using the Mann-Whitney *U* Test with corrected *p* values for multiple comparisons, as calculated by .05/number of comparisons.

RESULTS

Healthy volunteers

The healthy control participants performed well on all subtests with no statistically significant differences between verb and sentence type on any subtest. For the VNT mean percentage correct production of one-, two-, and three-argument verbs were 100%, 99.23% ($SD = 2.77$), and 99.45% ($SD = 2.86$), respectively, $F(2, 50) = 1.230$, $p = .301$, whereas all three verb types were 100% correct for the VCT. For the ASPT mean percentage correct production of verbs and verb arguments were 100%, 100%, and 98.08% ($SD = 6.03$) for one-, two-, and three-argument verbs, respectively, $F(2, 50) = 2.744$, $p = .074$. Similarly, on the SPPT mean percentage correct production of actives, SWQs, passives, and OWQs were all 100%, whereas that of SRs and ORs was 98.46% ($SD = 5.54$) and 99.23% ($SD = 4$), respectively, $F(5, 125) = 1.423$, $p = .221$. For the SCT mean percentage correct comprehension of actives, SWQs, SRs, and OWQs were 100%, whereas that of passives and ORs was 99.23% ($SD = 4$) and 98.46% ($SD = 5.54$), respectively, $F(5, 125) = 1.423$, $p = .221$. For both production and comprehension no significant differences were found between canonical and non-canonical sentences, SPPT: $t(25) = -.570$, $p = .574$; SCT: $t(25) = 1.806$, $p = .083$. Due to the ceiling effect on all subtests, the control group was not included in subsequent statistical analyses of the aphasic participants' data.

Aphasic groups

Verb naming and comprehension by verb argument structure. Figures 5 (a) and (b) show the mean percent correct production and comprehension of verbs, respectively, by type (the number of arguments) for the agrammatic and anomic groups. A 2 (group) × 3 (verb type) × 2 (modality) ANOVA revealed significant main effects of verb type, $F(2, 114) = 26.352$, $p < .001$, with three-argument verbs more difficult compared to two- and one-argument verbs ($ps < .001$), and modality, $F(1, 57) = 76.311$, $p < .001$, with verb naming more impaired than comprehension. The agrammatic group produced fewer correct responses than the anomic group, but this difference did not reach statistical significance, $F(1, 57) = 3.712$, $p = .059$. Significant two-way interactions were found between group and modality, $F(1, 57) = 5.327$, $p = .025$, and between verb type and modality, $F(2, 114) = 19.530$, $p < .001$. However, there was no significant interaction between group and verb type, $F(2, 114) = 2.059$, $p = .132$. A marginally significant three-way interaction was also found, $F(2, 114) = 3.041$, $p = .052$, which we followed with a 2 (group) × 3 (verb type) ANOVA for each modality. For naming there were main effects of group, $F(1, 57) = 4.658$, $p = .035$, and verb type, $F(2, 114) = 25.270$, $p < .001$, whereas for comprehension there was a main effect of verb type, $F(2, 114) = 5.544$, $p = .005$, but not group, $F(2, 57) = .024$, $p = .878$. These results indicated that the agrammatic, compared to the anomic, group's poorer performance could be attributed to production, rather than comprehension, differences. Despite the lack of significant two-way interactions for both modalities, one-way ANOVAs were performed for each group and modality in order to examine within group verb type effects. For the agrammatic group, there was a significant effect of verb type for naming, $F(2, 102) = 12.624$, $p < .001$, but not comprehension, $F(2, 102) = 2.481$, $p = .089$. The same pattern was found for the anomic group—naming: $F(2, 69) = 4.000$, $p = .023$; comprehension: $F(2, 69) = 1.616$, $p = .206$. Post hoc analyses for the agrammatic group indicated that naming of three-argument verbs (66%) was more difficult than that of two- (84%; $p = .001$) and one-argument verbs (89%; $p < .001$), whereas for the anomic group a significant difference was found only between three- and one-argument verbs (81% vs 93%; $p = .025$). No between-group comparisons were significant (see Figure 5a).

Table 3 summarises error analysis of three-argument verbs on the VNT by participant group. Although both groups showed greater difficulty with naming three-argument verbs, their error patterns were different. The agrammatic group often produced nouns for three-argument verbs (e.g., *present* for *give*) ($n = 25$, 30% of all errors), whereas noun substitutions were not commonly seen in the anomic group ($n = 5$). Verb substitution errors were the most common error type for both groups. Notably, the agrammatic group often substituted less-complex verbs, i.e., one- or two-argument verbs (e.g., *walk*, *catch* for *throw*) for three-argument verbs ($n = 38$), and less often substituted three-argument verbs (e.g., *write* for *send*) ($n = 14$), whereas the anomic participants substituted three-argument verbs as frequently as less-complex verbs ($n = 10$ vs 13).

Verb naming by optionality of arguments. In order to examine the effect of optionality of arguments on verb naming, the verbs were regrouped as obligatory (one-, two-, and three-argument) versus optional (two- and three- argument) verbs, as in Table 4. A two-way ANOVA indicated a main effect of group, $F(1, 57) = 4.582$, $p = .037$, but not optionality, $F(1, 57) = .198$, $p = .658$. Although the interaction between group and optionality was not significant, $F(1, 57) = 3.198$, $p = .079$, paired t-tests were performed to examine the optionality effect within group. Neither group showed significant differences between obligatory and optional verbs—agrammatic: 81% vs 77%, $t(34) = 1.715$, $p = .095$; anomic: 86% vs 89%, $t(23) = -.900$, $p = .337$—at a corrected significance level of $p < .013$ (.05/4). In addition, no between-group differences were found for either obligatory ($Z = -1.101$, $p = .271$) or optional ($Z = -2.212$, $p = .027$) verb naming (see Table 4).

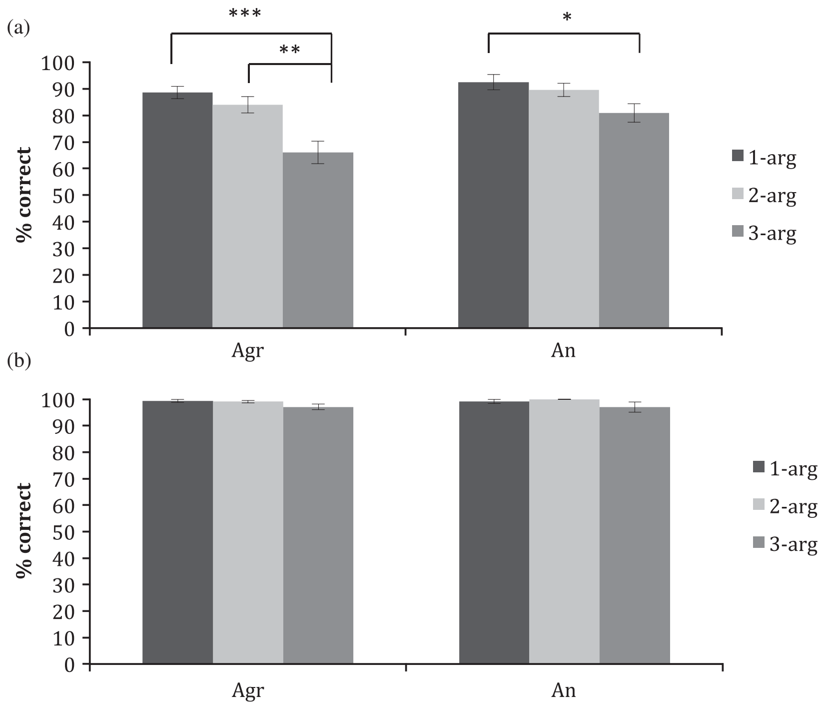


Figure 5. Mean percentage of correct verbs by type (one, two, and three arguments) for agrammatic and anomic participants (*** $p < .001$, ** $p < .01$, * $p < .05$). (a) Verb Naming Test (VNT) scores, (b) Verb Comprehension Test (VCT) scores. Agr = agrammatic; An = anomic.

TABLE 3
Number (percentage) of error types for three-argument verbs on the VNT

Error type	*Agr*	*An*
Noun substitution	25 (30%)	5 (16%)
Verb substitution	52 (62%)	23 (72%)
1-arg	13	2
2-arg	25	11
3-arg	14	10
Adjective/Adverb substitution	1 (1%)	1 (3%)
No response	6 (7%)	3 (9%)
Total	84 (100%)	32 (100%)

Agr = agrammatic; An = anomic.

Argument structure production. Mean percentage correct production of sentences by the number of arguments is shown in Figure 6. A 2 (group) × 3 (verb type) ANOVA again showed main effects of group, $F(1, 56) = 13.965$, $p < .001$, and verb type, $F(2, 112) = 36.705$, $p < .001$. The interaction between group and verb type was also significant, $F(2, 112) = 10.565$, $p < .001$. One-way ANOVAs for both groups revealed significant effects of verb type—agrammatic: $F(2, 104) = 23.515$, $p < .001$; anomic: $F(2, 66) = 12.741$, $p < .001$—and follow-up pairwise comparisons indicated that producing sentences with three-argument verbs compared to the other two verb types

TABLE 4
Mean (and *SD*) percentage of correct verbs and sentences by optionality of arguments for each participant group

	VNT		*ASPT*	
	Ob	*Op*	*Ob*	*Op*
Agr	81 (17)	77 (20)	87 (15)*	84 (16)*
An	86 (14)	89 (12)	97 (5)	95 (6)

Agr = agrammatic; An = anomic; Ob = obligatory verbs; Op = optional verbs. * indicates $p < .013$ for between-group comparisons.

was more difficult for both agrammatic (71%, 91%, and 97% for three-, two-, and one-argument verbs, respectively; *p*s < .001) and anomic groups (92% vs 98%, three- vs two-argument verbs: $p = .003$; 92% vs 100%, three- vs one-argument verbs: $p < .001$). Between-group comparisons, however, indicated significant differences between the agrammatic and anomic groups: at a corrected significance level of $p < .017$ (.05/3), the agrammatic compared to anomic speakers showed significantly greater difficulty producing sentences with three-argument verbs ($Z = -3.950$, $p < .001$), but not with the other verb types (see Figure 6).

Error analysis of sentences with three-argument verbs on the ASPT by participant group is provided in Table 5. Although both groups produced errors, the agrammatic participants produced over five times as many as the anomic participants (121 vs 22). Qualitative differences in the types of errors produced were also noted. Whereas the agrammatic group produced a total of 31 argument structure errors (26% of all errors), with goal arguments frequently omitted, the anomic participants produced only three errors of this type. Further, although both groups produced preposition errors, the agrammatic group produced over four times as many such errors, consisting of substitutions, omissions, and additions (e.g., *the woman is giving the gift for the boy; the woman is giving the gift the boy; the woman is giving to the gift to*

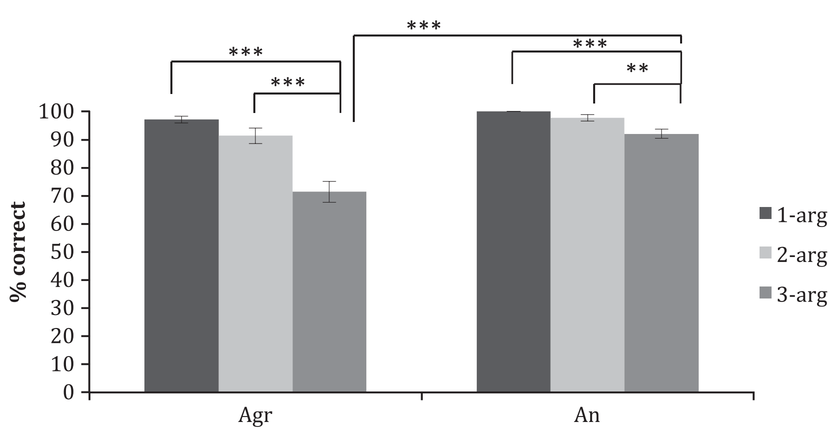


Figure 6. Mean percent correct production of sentences with one-, two-, and three-argument verbs on the Argument Structure Production Test (ASPT) for agrammatic and anomic participants (*** $p < .001$, ** $p < .01$). Agr = agrammatic; An = anomic.

TABLE 5
Number (percentage) of error types for sentences with three-argument verbs on the ASPT

Error type	*Agr*	*An*
Missing argument	31 (25.6%)	3 (13.6%)
Agent	5	0
Theme	8	3
Goal	18	0
Preposition error	65 (53.7%)	16 (72.7%)
Substitution	48	15
Omission	10	0
Addition	7	1
Incorrect verb	8 (6.6%)	3 (13.6%)
Role reversal	8 (6.6%)	0 (0%)
Non-sentence	9 (7.4%)	0 (0%)
Total	121 (100%)	22 (100%)

Agr = agrammatic; An = anomic.

the boy). Conversely, the anomic participants produced primarily substitution errors. Furthermore the agrammatic, but not the anomic, participants produced role reversal errors and non-sentences (i.e., word strings with no verb).

Argument structure by optionality of arguments. Data from the ASPT were also analysed for the optionality of arguments. Once again verbs were regrouped as obligatory (one-, two-, and three-argument) versus optional (two- and three-argument) verbs, as in Table 4. A two-way ANOVA revealed main effects of group, $F(1, 56) = 13.191$, $p = .001$, and optionality, $F(1, 56) = 4.863$, $p = .032$, indicating greater impairments in the agrammatic group, compared to the anomic group, and greater difficulty with optional compared to obligatory verbs. There was no interaction between group and optionality, $F(1, 56) = 2.767$, $p = .803$. Follow-up comparisons using paired t tests, however, indicated that within each participant group there were no significant differences between producing sentences with obligatory and optional verbs at a corrected significance level of $p < .013$ (.05/4): agrammatic: 87% vs 84%, $t(34) = 1.656$, $p = .107$; anomic: 97% vs 95%, $t(22) = 1.981$, $p = .060$. Nonetheless, group comparisons revealed that the agrammatic group, compared to the anomic group, performed significantly more poorly on sentences with both obligatory ($Z = -3.539$, $p < .001$) and optional verbs ($Z = -3.530$, $p < .001$) (see Table 4).

Verb and verb argument structure patterns derived by eliminating low AQ agrammatic participants. Because we included participants in the agrammatic group with lower WAB AQ scores than those in the anomic groups (see Participants section), we performed additional analyses eliminating nine agrammatic individuals with AQ scores below 69.4 (the lowest AQ score for participants in the anomic group) (total agrammatic participants = 26 vs 35). This resulted in more closely matched AQs, however, because of fluency scores, significant between-groups differences remained (AQ: agrammatic = 78.2, anomic = 87.5; $p < .05$). Notably, however, the results were very similar to those derived from analysis of the entire group. For the VNT, VCT, and ASPT all main effects and interaction effects (using ANOVAs as described above) remained unchanged for significance. Between-group comparisons also remained unchanged, with significant effects found only for three-argument verbs. Once again the agrammatic group showed significantly poorer production of sentences with three-argument verbs compared to the anomic group. Within-group analyses with the revised agrammatic group, however, resulted in a significant optionality effect on the ASPT, which was not found for the entire group. The agrammatic group showed significantly greater difficulty producing sentences with optional verbs ($M = 87\%$, $SD = 13$) compared to obligatory verbs ($M = 92\%$, $SD = 11$) $t(25) = 2.805$, $p = .010$, using a corrected significance level of $p < .013$ (.05/4). All other within-group analyses remained the same.

Sentence production and comprehension. Table 6 provides the mean percent correct production and comprehension of canonical (i.e., active, SWQ, and SR) and non-canonical (i.e., passive, OWQ, and OR) sentences for each participant group. A 2 (group) × 2 (canonicity) × 2 (modality) ANOVA indicated significant main effects for all three factors: the agrammatic group performed significantly more poorly than the anomic group, $F(1, 54) = 21.101$, $p < .001$), non-canonical compared to canonical sentences were more difficult, $F(1, 54) = 62.669$, $p < .001$, and sentence production was more difficult than comprehension, $F(1, 54) = 24.271$, $p < .001$). There were also significant two-way interactions between group and canonicity, $F(1, 54) = 5.695$, $p = .021$, and modality and canonicity, $F(1, 54) = 25.528$, $p < .001$, suggesting a greater canonicity effect in the agrammatic, compared to the anomic, group and greater impairments for production compared to comprehension. Within-group analyses by canonicity for each modality indicated that both production and comprehension of non-canonical sentences were significantly more impaired than canonical sentences for both agrammatic—production: $t(34) = 7.822$, $p < .001$; comprehension: $t(33) = 3.915$, $p < .001$—and anomic—production: $t(23) = 7.089$, $p < .001$; comprehension: $t(21) = 3.315$, $p = .003$—groups. However, between-group comparisons, with a corrected significance level of $p < .013$ (.05/4), indicated that the agrammatic, compared to the anomic, group performed significantly more poorly in production of non-canonical

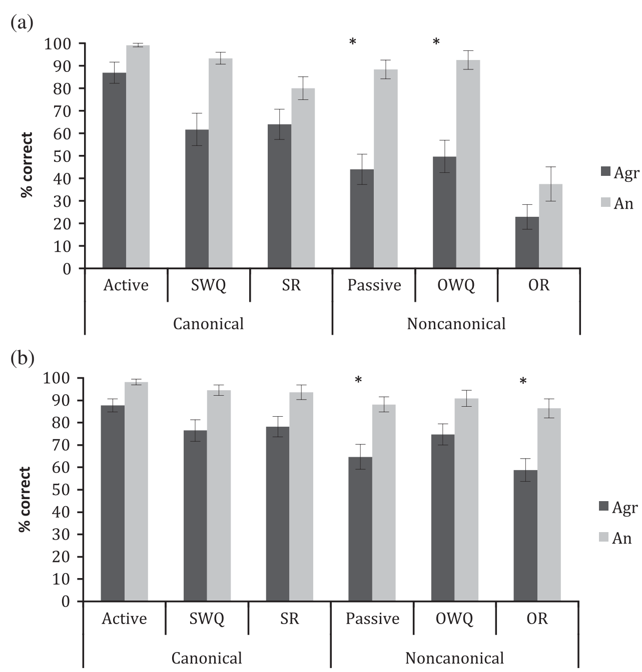
TABLE 6
Mean (*SD*) percentage of correct sentence production and comprehension by canonicity and sentence type for each participant group

		By Canonicity		*By Sentence Type*					
				Canonical			*Non-canonical*		
		C	*NC*	*Active*	*SWQ*	*SR*	*Passive*	*OWQ*	*OR*
SPPT	Agr	72 (30)	$39^{a,0}$ (32)	87 (28)	62 (42)	64 (40)	$44^{b,1}$ (40)	$50^{b,1}$ (43)	$23^{1,2,3}$ (33)
	An	91 (11)	73^{0} (17)	99 (4)	93 (13)	80 (25)	88 (20)	93 (20)	$38^{1,2,3,4,5}$ (37)
SCT	Agr	81^{a} (19)	$66^{a,0}$ (25)	88 (17)	76 (28)	78 (27)	$65^{b,1}$ (32)	75 (28)	$59^{b,1}$ (30)
	An	95 (9)	88^{0} (10)	98 (6)	95 (11)	94 (16)	88 (16)	91 (17)	86 (20)

SPPT = Sentence Production Priming Test; SCT = Sentence Comprehension Test; Agr = agrammatic; An = anomic; C = canonical sentences; NC = non-canonical sentences; SWQ = subject extracted wh-question; OWQ = object extracted wh-question; SR = subject relative clause; OR = object relative clause. By canonicity, ^{a} indicates $p < .013$ for between-group comparisons and ^{0} indicates $p < .01$ for within-group comparisons. By sentence type, ^{b} indicates $p < .0042$ for between-group comparisons, and each superscript number indicates significantly greater difficulty with a particular structure compared to active^{1}, SWQ^{2}, SR^{3}, passive^{4}, and OWQ^{5} at least $p < .05$ within each group.

sentences (agrammatic: 39% vs anomic: 73%; Z = −4.020, $p < .001$) and comprehension of both canonical (agrammatic: 81% vs anomic: 95%; Z = −3.120, $p = .002$) and non-canonical sentences (agrammatic: 66% vs anomic: 88%; Z = −3.515, $p < .001$) (see Table 6).

Production by sentence type. Mean percent correct production of sentences by type is shown in Figure 7 (a). In order to detail differences driven by sentence type, a 2 (group) × 6 (sentence type) ANOVA was performed. Significant main effects for both group, $F(1, 57) = 18.062$, $p < .001$, and sentence type, $F(5, 285) = 41.849$, $p < .001$, as well as a significant interaction between group and sentence type were found, $F(5, 285) = 5.101$, $p < .001$. A one-way ANOVA for the agrammatic group indicated a significant effect of sentence type, $F(5, 204) = 11.254$, $p < .001$. Follow-up pairwise comparisons revealed that production of passives and OWQs were more impaired than actives ($p < .001$, $p = .001$, respectively). In addition, production of ORs was significantly more impaired than that of all canonical sentence types (ps $< .001$), but not passives ($p = .314$). The difference between ORs and OWQs was marginally significant ($p = .052$). Similarly, for the anomic group, a significant effect for sentence type was found, $F(5, 138) = 24.288$, $p < .001$. Follow-up pairwise comparisons indicated that production of ORs was more impaired than all other sentence



Note: SWQ = subject extracted wh-question; SR = subject relative clause; OWQ = object extracted wh-question; OR = object relative clause; Agr = agrammatic; An = Anomic

Figure 7. Mean percentage of correct sentences by type for agrammatic and anomic participants (* $p < .0042$). (a) Sentence Production Priming Test (SPPT) scores; (b) Sentence Comprehension Test (SCT) scores. SWQ = subject extracted wh-question; SR = subject relative clause; OWQ = object extracted wh-question; OR = object relative clause; Agr = agrammatic; An = Anomic.

types ($ps < .001$). Finally, between-groups analyses, using a corrected significance level of $p < .0042$ (.05/12), revealed that the agrammatic, compared to the anomic, group showed significantly poorer production of passive sentences (44% vs 88%; $Z = -4.139$, $p < .001$) and OWQs (50% vs 93%; $Z = -4.093$, $p < .001$), but no differences were noted for the other sentence types. This suggests that the group difference stemmed mainly from agrammatic participants' difficulty producing non-canonical sentences (see Table 6 and Figure 7a).

Table 7 provides error analysis for production of ORs by participant groups. Although production accuracy of ORs was not significantly different between the agrammatic and anomic groups, error types produced by the two groups were qualitatively different. Both participant groups frequently produced sentence structure errors ($n = 48$ for each group), providing a correct description of target pictures using a sentence structure other than a target OR. Notably, the agrammatic group mainly produced canonical sentence substitutions, i.e., actives and SRs for target ORs (e.g., *the dog is chasing the cat*; *Pete saw the dog who is chasing the cat* for the target *Pete saw the cat who the dog is chasing*), ($n = 35$ out of 48), whereas the anomic group produced non-canonical sentences, i.e., passivised relatives (e.g., *Pete saw the cat who is being chased by the dog*) ($n = 31$ out of 48). Although the agrammatic group also produced 13 passivised relatives, this error type was only seen from three (of 35) participants. Furthermore, the agrammatic participants made substantial role reversal errors, once again using actives and SRs (e.g., *the cat is chasing the dog*; *Pete saw the cat who is chasing the dog* for the target *Pete saw the cat who the dog is chasing*) ($n = 55$, 43% of the total errors); however, role reversals were less frequent for the anomic participants ($n = 18$, 24% of the total errors).

Comprehension by sentence type. Figure 7 (b) shows the mean percentage of correct comprehension by sentence type. A 2 (group) × 6 (sentence type) ANOVA revealed main effects of group, $F(1, 54) = 18.342$, $p < .001$, and sentence type, $F(5, 270) = 7.997$, $p < .001$, however, there was no interaction between group and sentence type,

TABLE 7
Number (percentage) of error types for object relative (OR) sentences on the SPPT

Error type		*Agr*	*An*
Sentence structure error		48 (37.2%)	48 (64%)
Canonical	Active	14	1
	SR	21	16
Non-canonical	Passivised relative	13	31
Role reversal error		55 (42.6%)	18 (24%)
Canonical	Active	12	0
	SR	31	8
Non-canonical	Passivised relative	0	2
	OR	12	8
Other		20 (15.5%)	8 (11%)
Lexical error		4 (3.1%)	1 (1%)
Non-sentence		1 (0.8%)	0 (0%)
No response		1 (0.8%)	0 (0%)
	Total	129 (100%)	75 (100%)

SR = subject relative clause; OR = object relative clause; Agr = agrammatic; An = anomic.

$F(5, 270) = 1.401$, $p = .224$. Nonetheless, one-way ANOVA for the agrammatic group indicated a significant effect of sentence type, $F(5, 198) = 4.777$, $p < .001$. Follow-up pairwise comparisons revealed that comprehension of both passives and ORs were significantly more impaired than actives ($p = .010$, $p < .001$, respectively). In addition, performance for ORs was poorer than SRs (although this was only marginally significant ($p = .057$)). For the anomic group, however, comprehension of all sentence types was relatively unimpaired, with no significant sentence type effects found, $F(5, 126) = 1.866$, $p = .105$. In addition, between-group analyses, with a significance level of $p < .0042$ (.05/12), indicated that the agrammatic participants evinced greater comprehension difficulty than the anomic participants for both passives (65% vs 88%; $Z = -2.848$, $p = .004$) and ORs (59% vs 86%; $Z = -3.453$, $p = .001$), once again indicating agrammatic speaker's impairments associated with non-canonical sentences (see Table 6 and Figure 7b).

Sentence deficit patterns derived by eliminating low AQ agrammatic participants. Analyses also were undertaken examining sentence production and comprehension patterns derived from the NAVS including only agrammatic participants with AQs of 69.4 or above ($n = 26$). Results showed no differences in significance levels for main effects or interaction effects derived from the original and revised data sets. Between-group analyses, however, using the revised data set, showed no significant differences between groups for canonical sentence comprehension (with both participant groups demonstrating similar ability to comprehend these forms), or for comprehension of passive sentences. However, comprehension of ORs remained (marginally) significant: $p < .005$ versus $p < .0042$ (corrected level for multiple comparisons).

DISCUSSION

This study examined production and comprehension of verbs and sentences in individuals with agrammatic and anomic aphasia, using the *Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson, 2011). The Verb Naming Test (VNT) and Verb Comprehension Test (VCT) investigated verbs by number (one, two, and three) and optionality (obligatory vs optional) of arguments using verbs as singletons, whereas the Argument Structure Production Test (ASPT) examined the same verbs in sentence contexts, allowing examination of the effects of argument number and optionality on sentence production. The Sentence Production Priming Test (SPPT) and Sentence Comprehension Test (SCT) examined the effects of canonicity and syntactic sentence type (i.e., those associated with NP- and Wh-movement). Overall, results showed that the agrammatic participants performed significantly more poorly than the anomic participants on all subtests with the exception of the VCT, with both participant groups performing relatively well on this measure (97% or above on each verb type). These performance patterns were not surprising given that the NAVS was designed to evaluate syntactic aspects of verbs and sentences, which are more vulnerable in agrammatic aphasia. Regardless of aphasia type, production of both verbs and sentences was significantly more impaired than comprehension across tests of the NAVS (VNT vs VCT, SPPT vs SCT), consistent with deficit patterns in agrammatic and anomic aphasia (Berndt, Mitchum, et al., 1997; Goodglass et al., 2001; Kambanaros & van Steenbrugge, 2006; Kim & Thomson, 2000; Marshall et al., 1998).

In keeping with the results of previous studies examining verbs by argument structure and optionality, the present study showed that verbs with more complex lexical entries resulted in greater difficulty for both verb naming and sentence production. Results from the VNT and ASPT indicated that the agrammatic group showed greater impairments for three-, compared to one- and two-, argument verbs on both tests, consistent with previous studies (De Bleser & Kauschke, 2003; Dragoy & Bastiaanse, 2010; Kim & Thompson, 2000; Thompson, Lange, et al., 1997). Interestingly, the anomic participants also evinced more difficulty for three-argument verbs on the VNT and the ASPT, although the agrammatic group showed significantly poorer performance than anomic group on the ASPT and the anomic group showed this effect on the VNT only for three-argument compared to one-argument verbs. Nevertheless, we undertook error analyses for three-argument verbs, which revealed qualitative differences between groups in the types of errors produced for these complex verbs, suggesting different underlying sources of verb naming and sentence production impairment. The substantial use of nouns and substitution of less complex verbs (i.e., one- and two-argument verbs) for three-argument verbs on the VNT seen in the agrammatic participants indicates difficulty accessing verbs with complex argument structure entries. Conversely our anomic participants frequently substituted non-target three-argument verbs for target three-argument verbs, suggesting that access to verbs with complex argument structure is more readily available compared to agrammatic individuals. In addition, the agrammatic speakers evinced a large number of argument omissions (primarily goal arguments), a pattern that was not prevalent for the anomic participants. These data suggest that agrammatic, but not anomic, aphasic speakers evince grammatical encoding deficits, which affects phrase structure building for verbs with complex argument structure. These findings, however, highlight the fact that, although verb and verb argument structure deficits have most frequently been associated with agrammatic speakers, individuals with anomic aphasia also may exhibit impairments associated with verbs. Notably, other research with anomic aphasic individuals has also reported sensitivity to the number and type of verb arguments for some patients in this group (Luzzatti et al., 2002; Thompson et al., 2012). However, the present data point to putatively different sources of such impairments for the two participant groups.

Analyses of obligatory versus optional verbs on the VNT and ASPT, using the original data set, indicated that neither participant group showed significant differences between the two verb types in verb naming or sentence production tasks. Notably, however, exclusion of nine agrammatic participants with lower WAB AQ scores (< 69.4) resulted in a significant optionality effect on the ASPT, with the remaining 26 agrammatic participants showing significantly greater difficulty with optional compared to obligatory verbs in sentence production. Inspection of the original data set showed that nine lower-performing agrammatic participants, excluded from the revised data set, performed poorly on obligatory three-argument verbs, which decreased overall scores for obligatory verbs. Consistent with previous studies (Kim & Thompson, 2000; Thompson, Lange et al., 1997), these findings suggest that agrammatic individuals are affected by the optionality of verb arguments when constructing sentences more so than when naming as verbs as singletons. No optionality effect seen in our anomic participants for verb naming or sentence production is not surprising given that their production impairments are not likely related to grammatical encoding. Because optional verbs entail greater argument structure (i.e., theta-grid) density, these verbs require greater computational resources compare to obligatory verbs.

Turning to the results from the SPPT and SCT, non-canonical sentences were more difficult for both agrammatic and anomic participants compared to canonical sentences for both production and comprehension, a finding largely in line with previous studies (production: Caplan & Hanna, 1998; Faroqi-Shah & Thompson, 2003; Rochon et al., 2005; Schwartz et al., 1994; comprehension: Berndt et al., 1996; Caplan & Futter, 1986; Caramazza & Zurif, 1976; Schwartz et al., 1980; Thompson et al., 1999). Analyses by sentence type on the SPPT and the SCT further revealed particular difficulty with non-canonical structures for the agrammatic participants, with both production and comprehension of passives and object wh-questions significantly impaired (compared to actives). Furthermore, for object relatives (the most syntactically complex form tested) production was significantly more difficult than any of the canonical forms (actives, subject wh-questions, and subject relatives) and comprehension of this structure was more impaired than that of subject relatives (although this effects was only marginally significant) but not the other canonical forms. The greater deficit in production (and comprehension) of object relatives compared to subject relatives suggests that agrammatic individuals' impairments are associated with syntactic complexity, rather than general factors such as sentence length. In addition, the greater production difficulty with object relatives compared to object wh-questions, but not passives, indicates relative impairments in more compared to less complex structures within sentences with similar syntactic properties (Wh- movement), supporting the syntactic hierarchy proposed in treatment studies (e.g., Thompson, Ballard, & Shapiro, 1998; Thompson et al., 2003; Thompson & Shapiro, 2005, 2007).

Unlike agrammatic participants, our anomic participants performed relatively well on both canonical and non-canonical sentences in production and comprehension (with the exception of production of object relatives). Furthermore, significant group differences between the agrammatic and anomic participants were found only for non-canonical sentence types. These findings, taken together, suggest that agrammatic individuals' sentence deficits in both production and comprehension are associated with syntactic properties of sentences; however, for anomic individuals such deficits appear to be evident only when producing the most complex sentences. Error analysis of object relative sentences derived from the SPPT further reveals qualitatively different deficit patterns for the agrammatic and anomic groups. The agrammatic group often produced both sentence structure and role reversal errors. Notably, erred sentence structures consisted of simple actives with omission of the main clause (*Pete saw*) or subject relative structures (the canonical form of the object relatives tested). Together with a high incidence of role reversal errors, the present data suggest that agrammatic individuals evince particular difficulty mapping arguments onto non-canonical syntactic positions, consistent with a grammatical encoding deficit. On the contrary, the anomic participants' errors consisted primarily of production of non-target (albeit grammatical and often complex) sentence structures, e.g., passivised relative clauses, which arguably are syntactically more complex than object relatives. The predominant use of complex sentence structures as well as a low rate of role reversals is indicative of relatively preserved syntactic abilities in anomic individuals.

One potential issue relative to the findings of the present study concerns differences in WAB AQ scores between the agrammatic and anomic groups. Although AQ differences between participant groups was largely driven by fluency scores (which necessarily differ for the two groups), it is possible that our results reflect the fact that some participants in the agrammatic group presented with more severe aphasia compared to those in the anomic group. Notably, however, a complete reanalysis of the data, eliminating agrammatic participants with low AQ scores (see Results section), resulted in identical finding, with the exception of production of optional versus obligatory verbs in sentences as noted above. Therefore the present findings reflect grammatical ability of the two patient groups, rather than overall severity.

In summary, the NAVS is a comprehensive test battery which examines syntactic properties of verbs and sentences in both production and comprehension modalities. Results corroborate those of previous studies, suggesting that individuals with agrammatic aphasia exhibit verb and sentence impairments, which are affected by linguistic complexity. Furthermore, these results show that individuals with anomic aphasia, despite relatively preserved syntactic abilities, are impaired with the most complex forms of verbs and sentences. The present findings, from a large number of aphasic participants, indicate that the NAVS is useful for capturing these deficit patterns, which is important both clinically for differential diagnosis and treatment planning and theoretically to inform psycholinguistic models of language processing.

Manuscript received 19 January 2012
Manuscript accepted 7 May 2012
First published online 3 July 2012

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APPENDIX A

Target verbs used in the Verb Naming Test (VNT) and Verb Comprehension Test (VCT) and distractor verbs included in the VCT

Trial no.	*Verb type*	*Target*	*Same type*	*Different Type*	*Distractor*
1	Ob1	Bark	Laugh	Dig	Chase
2	Ob1	Laugh	Howl	Kiss	Grab
3	Ob1	Swim	Bark	Spill	Show
4	Ob1	Crawl	Swim	Dig	Eat
5	Ob1	Howl	Crawl	Spill	Chase
6	Ob2	Cut	Tickle	Sit	Hang
7	Ob2	Stir	Cut	Sit	Write
8	Ob2	Pinch	Stir	Dive	Hang
9	Ob2	Shove	Bite	Shiver	Insert
10	Ob2	Tickle	Shove	Sleep	Pant
11	Op2	Drive	Watch	Build	Show
12	Op2	Wash	Drive	Dive	Shiver
13	Op2	Watch	Shave	Write	Insert
14	Op2	Bite	Wash	Build	Sleep
15	Op2	Shave	Pinch	Run	Pray
16	Ob3	Put	Give	Eat	Kick
17	Ob3	Give	Put	Yawn	Run
18	Op3	Send	Read	Pull	Save
19	Op3	Read	Send	Sweep	Pray
20	Op3	Deliver	Throw	Kiss	Grab
21	Op3	Pour	Deliver	Pull	Sweep
22	Op3	Throw	Pour	Kick	Save

Ob = obligatory verb; Op = optional verb; 1 = one-argument verb; 2 = two-argument verb; 3 = three-argument verb.

APPENDIX B

Criteria for classification of verbs by argument structure

One-argument verbs choose only one external argument (typically agent), for example *sleep*. They usually cannot be followed by a noun phrase (NP) (e.g., **The bear sleeps the woods*), but can be followed by a prepositional phrase (PP) (e.g., *The bear sleeps in the woods*). Further, they cannot be passivised (e.g., **The bear was slept by* ____).

Two-argument verbs select two arguments, one external and one internal (typically agent and theme), for instance *the boy chased the girl*. They can be passivised (e.g., *The girl was chased by the boy*), but cannot be followed by a PP (e.g., **The boy chased around the garage*).

Three-argument verbs select three arguments, one external and two internal (typically agent, theme, goal), for example *put*, and must meet two of the three following criteria: (1) a goal is obligatory rather than optional (e.g., *John put the movie in the VCR* vs **John put the movie*); (2) part of a verb phrase cannot be substituted with a "do so" phrase (e.g., **John will put the car in the garage and Bill will do so in the parking lot* vs *John will rent the car in Chicago and Bill will do so in New York*); (3) two internal arguments cannot be separated by a PP (e.g., **John will put the car on Tuesday in the garage* vs *John will rent the car on Tuesday in Chicago*).

APPENDIX C

Target sentences used in the Argument Structure Production Test (ASPT)

Trial no.	*Verb type*	*Number of argument*	*Verb stimuli*	*Sentence stimuli*
1	Ob1	1	Bark	The dog is barking.
2	Ob1	1	Crawl	The baby is crawling.
3	Ob1	1	Laugh	The man is laughing.
4	Ob1	1	Swim	The man is swimming.
5	Ob1	1	Howl	The dog is howling.
6	Ob2	2	Tickle	The girl is tickling the boy.
7	Ob2	2	Stir	The woman is stirring the juice.
8	Ob2	2	Pinch	The man is pinching the woman.
9	Ob2	2	Shove	The man is shoving the woman.
10	Ob2	2	Cut	The man is cutting the paper.
11	Op2	2	Wash	The man is washing the clothes.
12	Op2	1	Wash	The man is washing.
13	Op2	2	Drive	The man is driving the car.
14	Op2	1	Drive	The man is driving.
15	Op2	2	Watch	The dog is watching the cat.
16	Op2	1	Watch	The dog is watching.
17	Op2	2	Bite	The dog is biting the cat.
18	Op2	1	Bite	The cat is biting.
19	Op2	2	Shave	The man is shaving the beard.
20	Op2	1	Shave	The man is shaving.
21	Ob3	3	Put	The man is putting the box on the shelf.
22	Ob3	3	Give	The woman is giving the gift to the boy.
23	Op3	3	Send	The man is sending the letter to the woman.
24	Op3	2	Send	The man is sending the letter.
25	Op3	3	Deliver	The postman is delivering the package to the man.
26	Op3	2	Deliver	The postman is delivering the package.
27	Op3	3	Throw	The girl is throwing the ball to the dog.
28	Op3	2	Throw	The woman is throwing the ball.
29	Op3	3	Read	The woman is reading the book to the girl.
30	Op3	2	Read	The woman is reading a book.
31	Op3	3	Pour	The man is pouring the water for the boy.
32	Op3	2	Pour	The man is pouring the water.

Ob = obligatory verb; Op = optional verb; 1 = one-argument verb; 2 = two-argument verb; 3 = three-argument verb.

APPENDIX D

Prime and target sentences in the Sentence Production Priming Test (SPPT) and picture pairs used in the Sentence Comprehension Test (SCT)

Trial no.	*Sentence type*	*Prime sentence*	*Target sentence*
1	A	The boy is pulling the girl.	The girl is pulling the boy.
2	A	The dog is chasing the cat.	The cat is chasing the dog.
3	A	The man is saving the woman.	The woman is saving the man.
4	A	The dog is watching the cat.	The cat is watching the dog.
5	A	The woman is kissing the man.	The man is kissing the woman.
6	P	The cat is chased by the dog.	The dog is chased by the cat.
7	P	The girl is pulled by the boy.	The boy is pulled by the girl.
8	P	The man is kissed by the woman.	The woman is kissed by the man.
9	P	The cat is watched by the dog.	The dog is watched by the cat.
10	P	The woman is saved by the man.	The man is saved by the woman.
11	SWQ	Who is kissing the man?	Who is kissing the woman?
12	SWQ	Who is chasing the cat?	Who is chasing the dog?
13	SWQ	Who is saving the woman?	Who is saving the man?
14	SWQ	Who is pulling the girl?	Who is pulling the boy?
15	SWQ	Who is watching the cat?	Who is watching the dog?
16	OWQ	Who is the woman kissing?	Who is the man kissing?
17	OWQ	Who is the dog watching?	Who is the cat watching?
18	OWQ	Who is the man saving?	Who is the woman saving?
19	OWQ	Who is the dog chasing?	Who is the cat chasing?
20	OWQ	Who is the boy pulling?	Who is the girl pulling?
21	SR	Pete saw the man who is saving the woman.	Pete saw the woman who is saving the man.
22	SR	Pete saw the dog who is watching the cat.	Pete saw the cat who is watching the dog.
23	SR	Pete saw the boy who is pulling the girl.	Pete saw the girl who is pulling the boy.
24	SR	Pete saw the woman who is kissing the man.	Pete saw the man who is kissing the woman.
25	SR	Pete saw the dog who is chasing the cat.	Pete saw the cat who is chasing the dog.
26	OR	Pete saw the girl who the boy is pulling.	Pete saw the boy who the girl is pulling.
27	OR	Pete saw the woman who the man is saving.	Pete saw the man who the woman is saving.
28	OR	Pete saw the cat who the dog is watching.	Pete saw the dog who the cat is watching.
29	OR	Pete saw the cat who the dog is chasing.	Pete saw the dog who the cat is chasing.
30	OR	Pete saw the man who the woman is kissing.	Pete saw the woman who the man is kissing.

A = active; P = passive; SWQ = subject extracted wh-question; OWQ = object extracted wh-question; SR = subject relative clause; OR = object relative clause.