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Verb and noun deficits in stroke-induced and primary progressive aphasia: The Northwestern Naming Battery¹

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Abstract

Background—Word class naming deficits are commonly seen in aphasia resulting from stroke (StrAph) and primary progressive aphasia (PPA), with differential production of nouns (objects) and verbs (actions) found based on StrAph type or PPA variant for some individuals. Studies to date, however, have not compared word class naming (or comprehension) ability in the two aphasic disorders. In addition, there are no available measures for testing word class deficits, which control for important psycholinguistic variables across language domains. This study examined noun and verb production and comprehension in individuals with StrAph and PPA using a new test, the *Northwestern Naming Battery* (NNB; Thompson & Weintraub, experimental version), developed explicitly for this purpose. In addition, we tested verb type effects, based on verb argument structure characteristics, which also is addressed by the NNB.

Method—Fifty-two participants with StrAph (33 agrammatic, Broca's (StrAg); 19 anomic (StrAn)) and 28 PPA (10 agrammatic (PPA-G); 14 logopenic (PPA-L); 4 semantic (PPA-S)) were included in the study. Nouns and verbs were tested in the Confrontation Naming and Auditory Comprehension subtests of the NNB, with scores used to compute noun to verb ratios as well as performance by verb type. Performance patterns within and across StrAph and PPA groups were then examined. The external validity of the NNB also was tested by comparing (a) NNB Noun Naming scores to the *Boston Naming Test* (BNT; Kaplan, Goodglass, & Weintraub, 1983) and *Western Aphasia Battery* (WAB-R, Kertesz, 2007) Noun Naming subtest scores, (b) NNB Verb Naming scores to the *Boston Diagnostic Aphasia Examination* (BDAE; Goodglass, Kaplan & Barresi, 2001) Action Naming score (for StrAph participants only), and (c) NNB Comprehension subtest scores to WAB-R Auditory Comprehension subtest scores.

Outcomes and Results—Both agrammatic (StrAg and PPA-G) groups showed significantly greater difficulty producing verbs compared to nouns, but no comprehension impairment for either word class. Whereas, three of the four PPA-S participants showed poorer noun compared to verb

¹On behalf of the authors of the paper I wish to offer congratulations to Dr. Robert C. Marshall (Bob) for his outstanding career. His many contributions, as a researcher and a clinician, have greatly impacted the profession as well as the lives of people with aphasia. I also extend heartfelt gratitude to him for his influence on my own career. It was under his supervision, as a fellow at the Portland VA Medical Center, where I was first introduced to people with aphasia. Intrigued by their language impairment patterns resulting from brain damage, coupled with Bob's commitment and dedication to research, solidified my interest in research focused on understanding breakdown and recovery patterns in aphasia. Cynthia K. Thompson.

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production, as well as comprehension. However, neither the StrAn or PPA-L participants showed significant differences between the two word classes in production or comprehension. In addition, similar to the agrammatic participants, the StrAn participants showed a significant transitivity effect, producing intransitive (one-argument) verbs with greater accuracy than transitive (two- and three-argument) verbs. However, no transitivity effects were found for the PPA-L or PPA-S participants. There were significant correlations between NNB scores and all external validation measures.

Conclusions—These data indicate that the NNB is sensitive to word class deficits in stroke and neurodegenerative aphasia. This is important both clinically for treatment planning and theoretically to inform both psycholinguistic and neural models of language processing.

Keywords

primary progressive aphasia (PPA); word class deficits; naming deficit patterns; verb argument structure production

Introduction

Naming, one of the most basic of language functions, is known to be disrupted in individuals with aphasia caused by stroke (StrAph) (McCarthy & Warrington, 1985; Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1990 and many others), in which an acute vascular event disrupts cortical and/or subcortical networks associated with language processing in a distribution dictated by the cerebral vasculature. Naming impairments also have been identified in patients with primary progressive aphasia (PPA), a clinical dementia syndrome in which neurodegenerative disease slowly and progressively disrupts the language regions of the brain, resulting in a gradual, and initially isolated, decline in language function (Mesulam, 1982, 2001, 2003). Notably, neurodegenerative disease affects only particular groups and layers of cells, leaving others relatively intact. Hence, affected regions of the brain can remain active during language task performance (Sonty et al., 2003). Nevertheless, both StrAph and PPA are associated with necrosed or atrophied tissue in the left hemisphere language network (Damasio & Damasio, 2000; Damasio, Grabowski, Tranel, Hichwa & Damasio, 1996; Gorno-Tempini et al., 2004; Kertesz, 1977; Mesulam et al., 2009b; Vanier & Caplan, 1990). However, because of differences in the underlying pathophysiology of brain damage, it is possible that naming deficits in the two populations may manifest differently.

Developing an accurate profile of naming deficit patterns associated with aphasia types or variants in the two populations is important both clinically and theoretically. Effective language rehabilitation requires a complete detailing of patient strengths and weaknesses. Moreover, understanding how brain damage disrupts normal language processing contributes to both psycholinguistic and neural models of language processing. This paper describes a study comparing production and comprehension of nouns and verbs in the two types of patients using a new test, the *Northwestern Naming Battery*, designed for this purpose.

Research across languages has shown that StrAph can selectively impair production of nouns and verbs, with nonfluent, agrammatic aphasic (i.e., StrAg) speakers often showing more difficulty producing verbs compared to nouns, and fluent, anomia aphasic individuals (StrAn) exhibiting the opposite pattern (Bates, Chen, Tzeng, Li, & Opie, 1991; Berndt, Mitchum, Haendiges, & Sandson, 1997; Chen & Bates, 1998; Kim & Thompson, 2000, 2004; Luzzatti, Raggi, Zonca, Pistarini, Contardi, & Pina, 2002; Miceli et al., 1984; Zingeser & Berndt, 1990). However, some studies also have shown verb deficits in individuals with fluent aphasia (see Williams & Canter, 1987; Kohn, Lorch, & Pearson, 1989; Hillis &

Caramazza, 1991; Berndt, Mitchum, Haendiges, & Sandson, 1997). For example, in a large study of 58 StrAph patients, Luzzatti et al. (2002) found verb (greater than noun) deficits in five of six agrammatic speakers and in two (of 13) with anomia (see Luzzatti, Mondini, & Semenza, in press, for review). Noun-verb dissociations also have been shown in patients with “nonfluent” and “fluent” PPA. As in the majority of StrAph individuals, those with nonfluent patterns show greater verb, compared to noun, naming deficits and patients with fluent PPA profiles show greater noun naming impairments (Bak & Hodges, 2003; Hillis, Oh, & Ken, 2004; Hillis et al., 2006). Some studies show that, in addition to naming deficits, some StrAph individuals also demonstrate selectively impaired comprehension of nouns or verbs (see, for example, Miceli, Silveri, Nocentini, & Caramazza, 1988), although most show spared single word comprehension of both word classes. To our knowledge word class comprehension impairments have not been investigated in PPA.

Classifying individuals with PPA as either nonfluent or fluent has recently been challenged because the classifications Progressive Nonfluent Aphasia (PNFA) or Semantic Dementia (SD) do not distinguish between fluency and grammatical ability (see Thompson et al., 2011). That is, some individuals with PPA show nonfluent speech and poor grammatical ability and others show nonfluent speech, with a relative sparing of grammaticality. The need to account for this latter pattern was emphasized by Gorno-Tempini and colleagues (2004) who used the term “logopenic” to characterize a nonfluent and non-semantic presentation. Mesulam and colleagues (2008, 2009b) further proposed a tripartite nomenclature, devoid of reference to fluency, including agrammatic (PPA-G), logopenic (PPA-L), and semantic (PPA-S) to refer to three PPA subtypes. The PPA-G variant is characterized by reduced ability to produce grammatical sentences, but relatively well-preserved single-word comprehension, accompanied by motor speech deficits in some patients; PPA-L is associated with preserved production of grammatical sentences and single-word comprehension, but frequent word-finding pauses and occasionally poor complex sentence comprehension; and PPA-S is associated with good ability to produce (and comprehend) grammatical sentences, but naming and single-word comprehension are severely impaired. PPA-S is sometimes also referred to as Semantic Dementia in which semantic memory impairments affect object recognition and knowledge (Adlam et al., 2006). Most recently, these diagnostic categories have been endorsed and elaborated upon by an international consensus group (Gorno-Tempini et al., 2011). Because the neuroanatomic atrophy patterns differ for the three groups (Gorno-Tempini et al., 2004; Mesulam et al., 2009a; Sapolsky et al., 2010) it is likely that noun and verb comprehension and production may fractionate in different ways across groups. Therefore, in the present study, we classified individuals with PPA based on these three variants.

In addition to dissociations among different grammatical variables, StrAg speakers also show verb production deficits that are influenced by event or verb argument structure. Every verb selects for specific verb arguments, which are assigned thematic roles such as agent, theme, and goal. Intransitive verbs such as *run* select for only an agent, whereas, two-argument, transitive verbs such as *fix* select for an agent and a theme. Other verbs such as *give* and *send* select for three arguments – an agent, a theme, and a goal. Research has shown that StrAph speakers, particularly those with agrammatism, evince greater difficulty producing verbs requiring a greater number of arguments (Dragoy & Bastiaanse, 2009; De Bleser & Kauschke, 2003; Kim & Thompson, 2000, 2004; Luzzatti et al., 2002; Thompson, Lange, Schneider, & Shapiro, 1997; Thompson, Shapiro, Li, & Schendel, 1995). Thus, one-argument verbs are easier to produce than two- or three-argument verbs. Similarly, two-argument verbs are easier to produce than three-argument verbs.

The effects of argument structure on verb production have not been systematically investigated in PPA aside from one study in which it was shown that verb argument structure is violated in the narrative speech of PPA-G but not in that of PPA-L or PPA-S individuals (Thompson et al., 2011). However, it can be hypothesized that PPA-G patients may show patterns similar to those seen in StrAg, particularly if the source of naming deficits is similar in the two participant groups. Although the mechanisms underlying noun-verb dissociations and verb argument structure effects are not completely clear, some suggest that verb and verb argument structure deficits in StrAg aphasia are associated with sentence level impairments, relevant to phrase structure building and/or overarching syntactic deficits (Friedmann, 2005; Friedmann, Wenkert-Olenik & Gill, 2000; Lee & Thompson, 2004; Thompson, Bonakdarpour & Fix, 2010). As pointed out above PPA-G, but not other variants of PPA, evince difficulty producing grammatical sentences. In addition, a recent study examining morphosyntactic performance patterns in patients with PPA-G and PPA-L (as well as StrAph types), Thompson et al. (in press) found noncanonical (versus canonical) sentence deficits (in both comprehension and production conditions) for PPA-G, as seen in StrAg. In addition, the PPA-G participants showed verb inflection deficits, also similar to those found in StrAg.

Several published tests are available for assessing word class deficits. None, however, adequately examine both production and comprehension of nouns and verbs. Tests such as the *Boston Naming Test* (BNT; Kaplan, Goodglass, & Weintraub, 1983), *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2007), *Boston Diagnostic Aphasia Examination* (BDAE; Goodglass, Kaplan and Barresi, 2001) and *Psycholinguistic Assessment of Language Processing in Aphasia* (PALPA; Kay, Lesser & Coltheart, 1992) focus predominantly on assessing production and comprehension of nouns, but not verbs. In contrast, the *Verb and Sentence Test* (VAST; Bastiaanse, Edwards & Rispens, 2002) assesses production and comprehension of verbs, but not nouns and the *Boston Assessment of Severe Aphasia* (BASA; Helm-Estabrooks, Ramsberger, Morgain, & Nicholas, 1989) and *An Object and Action Naming Battery* (OANB; Druks & Masterson, 2000) assess noun and verb production, but not comprehension. The VAST, BASA and OANB also do not test for argument structure effects. Given these limitations, clinicians currently rely on the results of multiple tests to develop profiles of word class deficits.

The *Northwestern Naming Battery* (NNB; Thompson & Weintraub, experimental version) was designed to provide a comprehensive assessment of noun and verb production and comprehension in individuals with language impairments induced by stroke and progressive neurological disease. With regard to PPA, the NNB may also be useful for addressing the relation between clinical symptoms and brain pathology, for example, PPA-G seems to correlate with tauopathy forms of frontotemporal lobar degeneration (FTLD) at post mortem brain examination², PPA-L with Alzheimer disease neuropathology, and PPA-S with FTLD-ubiquitinopathy on post mortem autopsy (Mesulam & Weintraub, 2008; Hodges & Patterson, 2007). In addition, tracking how naming deficits change over time in PPA will help to address questions about PPA diagnostic variants. Inspired by cognitive neuropsychological models of lexical processing (e.g., Kay, Lesser & Coltheart, 1992), the NNB is comprised of seven subtests examining Auditory Discrimination, Non-word Repetition, Auditory Lexical Decision, Confrontation Naming, Auditory Comprehension, Semantic Associates, and Word Repetition. Performance across subtests can be used to identify the source of naming deficits. In the present study, the Confrontation Naming and Auditory Comprehension subtests of the NNB were analyzed to evaluate noun and verb production and comprehension in individuals with StrAph and PPA. In addition, we

²Tauopathies are a class of neurodegenerative diseases associated with the pathological aggregation of tau protein in the human brain.

examined verb argument structure effects. These subtests use pictured objects (nouns) from different semantic categories and actions (verbs) with one-, two-, and three-arguments. In order to establish the validity of the NNB, we also compared NNB production and comprehension scores to those derived from administration of published standardized tests. These included comparisons between NNB Noun Naming and WAB-R Noun Naming subtest scores and between NNB Noun Naming and BNT scores for both StrAph and PPA participants. NNB Auditory Comprehension and WAB-R Auditory Comprehension subtest scores also were compared for these participant groups. Finally, BDAE Action Naming subtest scores were compared to NNB Verb Naming scores for the StrAph participants only.

Method

Participants

Fifty-two StrAph (33 StrAg; 19 StrAn), 28 PPA (10 PPA-G, 14 PPA-L and four PPA-S), and 28 healthy volunteers, recruited from the subject pools of the Aphasia and Neurolinguistics Research Laboratory in Evanston, IL and the PPA Program of the Cognitive Neurology and Alzheimer's Disease Center (CNADC) in Chicago, IL, participated in the study. Healthy controls were excluded from participation if they reported a history of neurological, psychological, or speech, language and/or learning deficits. Many of the controls had also undergone neuropsychological and neurological examinations as part of their participation in the CNADC Clinical Core. Three PPA, five StrAph, and three healthy control participants were left-handed; all others were right-handed. All were native, monolingual English speakers, with normal or corrected-to-normal hearing and vision (i.e., all passed hearing and vision screenings), matched across groups for education, with no significant differences between the groups ($F(2, 105) = 0.36, p = .700$). Participants ranged in age from 35 to 95 years, with a mean age of 57.21 ($SD = 10.6$) for StrAph, 63.75 ($SD = 7.7$) for PPA, and 63.25 ($SD = 6.3$) for healthy controls. The StrAph group was younger than the PPA participants (StrAph: $t(78) = -2.87, p = .005$), and the StrAph participants were younger than the controls ($t(77.26) = -3.20, p = .002$) (see Table 1). All participants provided informed consent, and Institutional Review Board at Northwestern University approved the study.

With the exception of 1 participant who had a right-hemisphere cerebrovascular accident (CVA), all of the StrAph participants suffered left-hemisphere strokes, at least 6 months prior to the study. Fluency ratings and aphasia quotients (AQ) obtained from the *Western Aphasia Battery-Revised* (WAB-R; Kertesz, 2007) and other clinical tests were used to determine aphasia type (see Tables 2 and 3). Mean fluency ratings and AQs for the StrAg participants were 4.15 (range = 1 to 5) and 72.03 (range = 40.2 to 87.2), respectively. Mean fluency ratings and AQs for the StrAn participants were 7.58 (range = 6 to 9) and 81.94 (range = 59.2 to 95.0)³, respectively. Noun naming ability, tested using the *Boston Naming Test* (BNT, Goodglass, Kaplan, & Weintraub, 1983) showed scores ranging from 5 to 59 (total possible = 60) ($M = 38.57$) for the StrAg participants and from 7 to 49 ($M = 34.73$) for the StrAn participants, indicating noun naming deficits ranging from mild to severe for both groups. Verb naming ability was tested with the Action Naming subtest from the *Boston Diagnostic Aphasia Examination* (BDAE, Goodglass, Kaplan & Barresi, 2001), and scores ranged from 0 to 12 (total possible = 12) ($M = 8.08$) for the StrAg patients and from 2 to 12 ($M = 9.31$) for the StrAn participants. Diagnoses of StrAg and StrAn were based on the aforementioned test scores as well as participants' spontaneous verbal output on WAB-R picture description. StrAg participants' speech was non-fluent, telegraphic, and agrammatic,

³WAB AQs for StrAn-5 and StrAn-14 exceeded the "cut-off" score for aphasia (i.e., 93.8) as did a subset of "recovered" aphasic individuals ($n=21$) described by Kertesz (2007), who demonstrated word-finding difficulty or paraphasic errors, justifying a clinical diagnosis of aphasia. However, because of their high scores, these participants were not included in the WAB standardization sample.

whereas the StrAn participants presented with fluent, grammatical speech, with reduced semantic content and circumlocutory output. Comprehension was relatively preserved in both groups, with WAB auditory comprehension scores (based on performance on yes/no questions, auditory word recognition, and sequential commands) ranging from 5.8 to 10 (total possible = 10) ($M = 8.54$) for the StrAg patients and from 6.9 to 10 ($M = 9.04$) for the StrAn participants). Repetition was preserved in the StrAn group but variable in the StrAg group.

The diagnosis of PPA (Mesulam 2001, 2003; Gorno-Tempini et al., 2011) was based on neurological examination, clinical presentation, language and neuropsychological testing, and magnetic resonance imaging, with none of the participants showing evidence of stroke or other neurological disorder. All presented with at least a two-year history of progressive language deficits in the face of spared performance in other cognitive domains. WAB-R (Kertesz, 2007) fluency scores ranged from 4 to 10 and WAB-AQs ranged from 49.6 to 97.2⁴. All PPA participants reported naming and word-retrieval deficits in conversational speech, with performance on the WAB-R naming subtest and BNT ranging from very mildly impaired (in some cases scores were within normal limits) to severely impaired (from 2 to 59 on the BNT) (see Table 4). Some, but not all, also presented with impaired auditory comprehension, with scores on the WAB-R Auditory Comprehension subtest ranging from 6.1 to 10. Diagnosis of PPA-G, PPA-L or PPA-S was based on overall clinical impression as well as performance on quantitative measures of fluency, grammar, and single word auditory comprehension according to an algorithm described by (Mesulam et al., 2009b).

Materials and Conditions

Thirty-two items from the NNB's Confrontation Naming subtest designated for testing noun to verb ratios were used, including 16 objects (from the categories of animals, fruits/vegetables, tools, and clothing) for testing noun production and 16 actions for testing verb production. Six of the verbs were intransitive one-argument verbs, whereas, the remainder were transitive (six two-argument verbs and four three-argument verbs). Single word comprehension was tested using 22 items (10 nouns and 12 verbs) from the Auditory Comprehension subtest of the NNB. The verb set included four intransitive and eight transitive items (four two-argument and four three-argument verbs). Criteria for determining verb type were based on classification of verbs by argument structure in Thompson et al. (2007). Picture stimuli (black and white line drawings) were developed for each noun (object) and verb (action) and checked for naming reliability with 10 undergraduate and graduate students from Northwestern University. See Appendix 1 for a complete list of stimuli and Figures 1A and 1B for sample stimuli used to test naming and comprehension, respectively.

Stimulus sets were matched for the $\log_{10}$ lemma frequency of occurrence per million using the CELEX Database (Baayen, Piepenbrock, van Rijn, 1995), with no significant differences between production and comprehension items (Production: $t(30) = -1.731$, $p = .094$; Comprehension: $t(20) = -2.057$, $p = .053$), and no differences between nouns ($t(24) = 0.340$, $p = .737$) or verbs ($t(26) = -0.250$, $p = .804$) in the two modalities. In addition, the sets were matched for the number of phonemes, with no significant differences between production and comprehension items (Production: $t(20) = 1.49$, $p = .151$; Comprehension: t

⁴PPA-L6 and PPA-L12 evinced WAB AQ scores of 97.2 and 97.1, respectively, exceeding the "cut-off" for aphasia. The WAB, however, was standardized on individuals with aphasia resulting from stroke, not PPA. Notably, PPA participants often present with mild impairments, at least in initial stages. In addition, these PPA patients were part of a large-scale longitudinal study and were retested on follow-up visits occurring after completion of the present study. PPA-L12 evinced scores on follow-up visits 2 and 3 of 90.3 and 81.3, respectively (within the AQ range of aphasia for StrAp); PPA-L6 scored 94.3 on visit 2 (this patient has not yet undergone visit 3 testing, however, we anticipate further language decline for this patient as well). Also see footnote (1) above.

(20) = 1.211, $p = .240$). Verb stimuli also were checked for frequency, orthographic neighborhood effects, and phonological neighborhood effects (Davis, 2005), with no significant differences found between one-, two- and three-argument verbs for any of these variables (Mann-Whitney test; see Table 5). However, significant differences were found for frequency between one- and three-argument verbs, with the latter significantly more frequent than the former ($M = 2.7$ for three-argument verbs and $M = 1.3$ for one-argument verbs). The noun stimuli also were not matched with verb stimuli for imageability (according to the MRC psycholinguistic database; Wilson, 1988). The extent to which imageability accounts for word class production deficits reported in the literature is unclear. For example, Bird et al. (2002) suggested that differences between nouns and verbs is consequence of imageability; however, Luzzatti et al. (2002) found that continuous lexical variables, including imageability (as well as age of acquisition, length, and frequency) did not account for word class deficits in aphasic speakers.

Procedures

Participants were tested by researchers in the Aphasia and Neurolinguistics Research Laboratory located in Evanston, IL, and the Cognitive Neurology and Alzheimer's Disease Center (CNADC) in Chicago, IL. Noun and verb naming were tested separately in one session, with the order of presentation counterbalanced across participants. Participants were instructed to name the object or action depicted, and no feedback was provided. Responses were scored as correct if they were recognizable verbal productions of target items. Self-corrections occurring within 10 sec were accepted and, because we were interested in lexical knowledge, rather than naming errors resulting from phonological processes, phonological, but not semantic, paraphasias also were considered correct. For verb naming, all forms were scored as correct (e.g., for the verb 'sweep', *sweep*, *sweeps*, *sweeping*, or *swept* were accepted).

To examine auditory comprehension, participants were presented with a stimulus card containing 10 noun or 10 verb pictures and asked to point to the target item named by the examiner. Responses, including self-corrections, were scored as correct if made within 10 seconds. Each item could be repeated once upon request. A different stimulus card with choices represented in different locations was presented for each test item so that participants would be less likely to arrive at their responses by process-of-elimination.

Thirty percent of the testing sessions were scored for inter-rater reliability by an independent observer situated in the testing room. Agreement between the two raters was 95% for both confrontation naming and auditory comprehension.

To examine the validity of the NNB, Noun Naming subtest scores were compared to the BNT and WAB-R, Noun Naming subtest scores, and Verb Naming subtest scores were compared to the BDAE, Action Naming subtest. NNB Auditory Comprehension scores were compared to WAB-R Auditory Comprehension subtest scores. For all comparisons, a Pearson's Product-Moment Correlation test was performed (Pearson, 1956).

Data Analysis

Percentage correct production and comprehension of nouns and verbs was calculated separately for each participant group and differences between groups and conditions were analyzed using repeated measures analyses of variance (ANOVAs) and Tukey *post-hoc* tests. An alpha level of $p < .05$ was set for these statistical tests. Because of the small number of PPA-S participants, their data were analyzed individually using chi-square.

Results

Word Class Effects

Scores for percent correct production and comprehension of nouns and verbs for the StrAph (StrAg and StrAn), PPA (PPA-G and PPA-L) and healthy control participants are shown in Table 6. Statistical analysis of these data (i.e., between groups production and comprehension scores for nouns and verbs) revealed a significant main effect for group ($F(2, 78) = 10.87, p < .001$), with control participants outperforming both StrAph ($p = .000$) and PPA ($p = .009$) participants⁵. Because the control participants performed at ceiling across all conditions, they were excluded from further analyses.

Comprehension—Analysis of the data for the StrAph and PPA groups indicated that both groups performed well on comprehension of both nouns and verbs, with no main effects for group (StrAph: $F(1, 27) = 1.59, p = .218$; PPA: $F(1, 22) = 0.147, p = .705$) or word class (StrAph: $F(1, 27) = 0.12, p = .729$; PPA: $F(1, 22) = 2.62, p = .120$), and no interaction effects (StrAph: $F(1, 27) = 0.49, p = .488$; PPA: $F(1, 22) = 0.001, p = .978$). There also was no effect of severity as measured by WAB AQ. That is, the same significance levels were found when WAB AQ was entered into the analysis as a covariate.

Production—Analysis of the production data also revealed no main effects for group for either the StrAph ($F(1, 50) = 0.00, p = .998$) or PPA ($F(1, 22) = 0.01, p = .908$) participants. However, a significant effect for word class was found for the PPA participants ($F(1, 22) = 13.14, p < .001$), indicating better performance for nouns compared to verbs, but this effect was not found for the StrAph participants ($F(1, 50) = 3.16, p = .082$). A significant interaction effect between condition and group was found for both clinical groups (StrAph: $F(1, 50) = 5.73, p = .020$; PPA: $F(1, 22) = 7.39, p = .013$), with post-hoc analyses indicating that the agrammatic participants, both StrAg and PPA-G, produced nouns more accurately than verbs (StrAg: $t(32) = 4.22, p = .000$; PPA-G: $t(9) = 4.29, p = .002$); whereas, the StrAn participants and PPA-L groups showed no significant differences between word classes (StrAn: $t(18) = -0.31, p = .763$; PPA-L: $t(13) = 0.687, p = .504$) (see Figure 2).

Argument Structure Effects

The percentage correct naming and comprehension scores for verbs by argument structure type (i.e., one-argument, two-argument, and three-argument) are shown in Table 7 for all aphasic groups (StrAph, PPA). Analyses of comprehension by verb argument structure revealed no effect of group ($F(1,51) = 0.008, p = .927$) or verb type⁶ ($F(2,80) = 1.122, p = .319$) and no interaction effect ($F(2,102) = 0.171, p = .843$). Similarly, when these data were analyzed separately by clinical disease group, (i.e., StrAph groups: StrAg, StrAn and PPA subtypes: PPA-G, PPA-L) there were no significant group effects (StrAph: $F(1,27) = 0.823, p = .372$; PPA: $F(1, 22) = 0.043, p = .838$) or verb type effects (StrAph: $F(2,54) = 0.328, p = .721$; PPA¹: $F(1,25) = 0.829, p = .386$) and no significant interactions were found (StrAph: $F(2,54) = 0.33, p = .721$; PPA: $F(2,44) = 1.581, p = .217$).

⁵In a separate analysis we used age as a covariate and found similar results: a significant main effect for group ($F(2, 77) = 11.01, p < .001$), with control participants outperforming both StrAph ($p = .000$) and PPA ($p = .011$) participants.

⁶The F value was adjusted for lack of sphericity using Greenhouse-Geisser constant.

¹On behalf of the authors of the paper I wish to offer congratulations to Dr. Robert C. Marshall (Bob) for his outstanding career. His many contributions, as a researcher and a clinician, have greatly impacted the profession as well as the lives of people with aphasia. I also extend heartfelt gratitude to him for his influence on my own career. It was under his supervision, as a fellow at the Portland VA Medical Center, where I was first introduced to people with aphasia. Intrigued by their language impairment patterns resulting from brain damage, coupled with Bob's commitment and dedication to research, solidified my interest in research focused on understanding breakdown and recovery patterns in aphasia. Cynthia K. Thompson.

Analysis of production by verb type by groups within each disease category (i.e., StrAph: StrAg, StrAn; PPA: PPA-G, PPA-L) showed significant main effects for verb type (StrAph groups: $F(2, 100) = 12.87, p < .001$; PPA subtypes: $F(2, 44) = 12.87, p < .001$). However, there was no main effects for group within each disease category (StrAph groups: $F(1, 50) = 0.61, p = .436$; PPA subtypes: $F(1, 22) = 0.76, p = .392$) and no group by verb type interaction effects (StrAph groups: $F(2, 100) = 0.95, p = .391$; PPA subtypes: $F(2, 44) = 3.208, p = .050$). However, post-hoc analyses showed that both StrAph and PPA groups performed more accurately on one-argument verbs compared to two- and three-argument verbs (StrAph: 1-argument > 2-argument ($p < .001$), 1-argument > 3-argument ($p = .044$); PPA: 1-argument > 2-argument ($p < .001$), 1-argument > 3-argument ($p = .020$)). Additionally, both groups performed better on three-argument verbs compared to two-argument verbs (StrAph: 3-argument > 2-argument ($p = .005$); PPA: 3-argument > 2-argument ($p = .021$)).

Further analyses showed that both agrammatic groups (StrAg and PPA-G) as well as the PPA-L group produced one-argument verbs significantly more accurately than two- or three-argument verbs (StrAg: 1-argument > 2-argument ($p < .001$), 1-argument > 3-argument ($p = .010$); PPA-G: 1-argument > 2-argument ($p = .029$), 1-argument > 3-argument ($p = .042$); PPA-L: 1-argument > 2-argument ($p < .001$), 1-argument > 3-argument ($p = .046$)); however, the StrAn group showed no significant differences between production of one- and two-argument verbs or between one- and three-argument verbs (StrAn: 1-argument vs. 2-argument ($p = .326$), 1-argument vs. 3-argument ($p = .112$)). Interestingly, all four participant groups showed significantly more accurate production of three- compared to two-argument verbs (3-argument > 2-argument: StrAg ($p < .001$), StrAn ($p = .003$), PPA-G ($p = .026$), PPA-L ($p = .002$)).

Transitivity Effects—Because of the aforementioned argument structure effects, we further analyzed the verb production data for transitivity, combining two- and three-argument verbs, which select for a direct object, and comparing them to intransitive, one-argument verb production. A two groups (StrAph and PPA participants) $\times$ two verb types (intransitive, transitive) repeated measures ANOVA revealed no main effect for group ($F(1, 74) = 0.586, p = .446$) and no group by verb type interaction ($F(1, 74) = 0.343, p = .560$), however, a significant main effect for verb type was found ($F(1, 74) = 27.65, p < .001$), with post hoc analysis indicating that intransitive verbs were produced more accurately than transitive. Separate analysis examining the StrAph participants by aphasia type (StrAg, StrAn) showed similar results, with a significant main effect for verb type ($F(1, 50) = 16.77, p < .001$), no main group effect ($F(1, 50) = 1.04, p = .312$) and no interaction ($F(1, 50) = 0.76, p = .389$). This same pattern was found when we examined for severity effects, using WAB AQ as a covariate. Follow-up planned comparisons using t-tests indicated that for both the StrAg and StrAn groups intransitive verbs were produced significantly more accurately than transitive verbs (StrAg: $t(32) = 2.86, p = .007$; StrAn: $t(18) = 2.82, p = .011$). Similar analysis of the PPA data by aphasia type (PPA-G, PPA-L) again showed a significant main effect for verb type ($F(1, 22) = 18.76, p < .001$), with intransitive verbs produced more accurately than transitive verbs. No significant main effect of group ($F(1, 22) = 0.401, p = .533$) or group by verb type interaction effect ($F(1, 22) = 3.74, p = .066$) was found. These same patterns were found using WAB AQ as a covariate. Follow up t-tests comparing intransitive to transitive verb production, however, showed a significant difference for the PPA-G ($t(9) = 3.79, p = .004$), but not for the PPA-L subgroup ($t(13) = 1.97, p = .070$), with intransitive verbs produced, once again, significantly more accurately than transitive verbs (see Figure 3).

Performance Patterns for the Semantic PPA (PPA-S) Participants—The naming and comprehension data for the PPA-S participants are shown in Table 8 and Figure 4. Due

to the small number of PPA-S participants (i.e., $n = 4$) we analyzed these data separately for each participant using a chi-square test of independence. All demonstrated better accuracy for production of verbs compared to nouns – a pattern that was significant for three of the four PPA-S participants (PPA-S1 ($\chi^2(1, N = 1) = 10.66, p < .001$; PPA-S3 ($\chi^2(1, N = 1) = 8.96, p = .003$; PPA-S4 ($\chi^2(1, N = 1) = 12.70, p < .001$), but not for PPA-S2 ($\chi^2(1, N = 1) = 3.31, p = .07$). Similarly, three of the four PPA-S participants (PPA-S1, PPA-S3, and PPA-S4) exhibited better comprehension of verbs than nouns, however, this difference was significant only for PPA-S1 (PPA-S1: $\chi^2(1, N = 1) = 12.69, p < .001$; PPA-S3: $\chi^2(1, N = 1) = 1.56, p = .21$; PPA-S4: ($\chi^2(1, N = 1) = 0.63, p = .43$) and PPA-S2 showed comprehension of both word classes at 100% accuracy. Fisher Exact Tests produced analogous results. Finally, no significant differences were observed for analyses by verb argument structure or transitivity in either production or comprehension conditions for any of the PPA-S patients.

External validity of the NNB

Significant positive correlations between NNB Confrontation Naming (both nouns and verbs) and scores derived from the WAB Naming subtest were found (StrAph: $r = .798, p = .01$; PPA: $r = .875, p = .01$). Further, NNB Noun Naming scores were positively and significantly correlated with BNT scores for both participant groups (StrAph: $r = .874, p = .01$; PPA: $r = .870, p = .01$). Comparing NNB verb naming scores to scores on the Action Naming subtest of the BDAE also showed a significant positive correlation for the stroke aphasic participants (StrAph: $r = .757, p = .01$). Finally, scores on the Auditory Comprehension subtest of the NNB correlated positively with those derived from the Auditory Comprehension subtest of the WAB for both groups (StrAph: $r = .520, p = .01$; PPA: $r = .705, p = .01$).

Discussion

This study was designed to assess noun and verb comprehension and production in individuals with stroke-induced aphasia and those with primary progressive aphasia (PPA), using the *Northwestern Naming Battery* (NNB), a new measure of single word processing. Findings from this study indicate that the NNB is sensitive to word class deficits in aphasia resulting from either cerebrovascular or neurodegenerative disease.

In keeping with previously reported findings, the present study showed that comprehension of nouns and verbs is relatively spared in stroke-induced agrammatic and anomic aphasia. This pattern also was found in the agrammatic and logopenic PPA participant groups. Conversely, three of the four semantic participants evinced impaired comprehension of both word classes, indicating that word comprehension deficits, that are common in semantic PPA, affect both objects and actions. A novel finding of the present research, however, is that for the semantic PPA participants' noun comprehension was significantly more impaired than their verb comprehension. We note that future studies with a larger cohort of patients with the semantic variant of PPA are needed to validate this latter finding.

With regard to naming, verb (compared to noun) production deficits were found for both agrammatic participant groups, stroke and PPA, indicating that verb production is particularly vulnerable in agrammatism, regardless of neuropathology, and that this vulnerability can be quantified using the NNB. In contrast, individuals with stroke-induced anomic aphasia as well as those with logopenic PPA showed no significant differences in production of nouns and verbs. Interestingly, the semantic PPA group showed yet another pattern: noun naming was more impaired than verb naming, indicating that objects are more impaired than actions in both comprehension and production domains.

These results support those derived from previous studies of stroke-induced aphasia. That is, nonfluent stroke-induced aphasic individuals, with concomitant agrammatism characterized by difficulty producing grammatical sentences (and comprehension of noncanonical forms), often evince greater difficulty producing verbs as compared to nouns, but this pattern is not often seen in individuals with stroke-induced fluent aphasia, particularly those with anomic aphasia whose sentence production is typically devoid of grammatical errors, which characterized the fluent stroke participants in our study (Bates et al., 1991; Miceli et al., 1984; Zingeser & Berndt, 1990). The present data also support (in part) previous studies of noun and verb naming in PPA. That is, studies examining word class deficits in PPA have found greater verb naming deficits in “nonfluent” PPA and greater noun naming deficits in “fluent” PPA (Bak & Hodges, 2003; Hillis et al., 2004, 2006). However, recent research shows that the nonfluent-fluent distinction used to classify stroke aphasia does not adequately differentiate PPA subtypes. That is, both agrammatic and logopenic PPA speakers may present with nonfluent production patterns (e.g., reduced words per minute and/or mean length of utterance as compared to normal), whereas, semantic PPA and some logopenic PPA patients show fluent output. Importantly, however, agrammatic PPA is associated with grammatical production deficits in narrative speech, which are not prevalent in logopenic or semantic variants of PPA (Thompson et al., 2011; also see Thompson, Ballard, Tait, Weintraub, & Mesulam, 1997). In addition, agrammatic, but not logopenic PPA patients, show impaired comprehension and production of syntactically complex sentences as well as verb inflection deficits (Thompson et al., in press). The present data show that verb production also is compromised in agrammatic PPA. On the contrary, the semantic variant is associated with noun naming deficiencies (3 out of 4 participants showed this pattern in the present study), but these deficiencies are generally not significant in agrammatic (or logopenic) patients. In the present study we distinguished between agrammatic, logopenic, and semantic PPA using both clinical and quantitative methods for subtyping (Mesulam et al., 2009b). The present results, thus, show interesting linkages between grammatical impairments, marked by verb production deficits, and semantic impairments, associated with noun production (and comprehension) deficits.

With respect to verb argument structure effects, the NNB revealed that all participant groups, except for those with the semantic variant of PPA, showed significantly better ability to produce intransitive, one-argument verbs, than two- or three-argument verbs. In addition, follow up transitivity analyses showed a transitivity effect for three of the participant groups. That is, for both the agrammatic and anomic stroke aphasic individuals and the agrammatic PPAs, intransitive (one-argument) verbs were produced accurately more often than transitive (two-argument verbs and three-argument verbs). This finding of greater verb production difficulty for verbs with greater argument structure density was expected only for the agrammatic groups, based on the idea that difficulty producing verb argument structure is associated with agrammatic phrase structure building impairments. It is possible, however, that other factors (e.g. imageability) may have influenced production of one-argument verbs for the stroke-induced anomic participants, which can be addressed in future research. However, it is of interest to note that a significant transitivity effect was not found for the logopenic PPA group or for any of the semantic PPA patients in the present study, which may turn out to be diagnostically salient for subtyping PPA. However, a larger sample of logopenic and semantic PPA patients is needed to confirm those effects. In any case, the NNB is capable of revealing verb argument structure deficits, which is not possible using any other test available for examining naming in neurologically impaired individuals with language deficits.

In addition, both agrammatic groups (stroke and PPA) showed better production of three- compared to two-argument verbs. According to the argument structure complexity hypothesis (ASCH, Thompson, 2003), greater difficulty is expected with three-argument as

compared to one-argument or two-argument verbs. It is possible, however, that the present findings resulted from inclusion of optional three-argument verbs among the stimulus items (because there are few obligatory three-argument verbs in the English language). The effects of verb argument structure optionality on production and comprehension has not been well studied and conflicting results have derived from the few published studies examining this effect (Shapiro & Levine, 1990; Shapiro, Zurif, & Grimshaw, 1987; Kim & Thompson, 2000; Thompson et al., 1997). Hence, this property of verbs should be addressed in future studies. In addition, we included a smaller number of three-argument compared to one- and two-argument verbs in our test set, reducing power. Furthermore, the three-argument verbs included in the NNB had significantly higher frequency of occurrence than the other verb types in the test, which may have influenced production accuracy (although this variable did not overshadowed verb argument structure effects found in previous studies examining verbs by type (see Kim & Thompson, 2000, 2004)). Nevertheless, further research is needed to examine verb naming deficits in aphasia (both stroke and PPA) associated with complex argument structure entries. However, based on the present data, the NNB will be revised, collapsing two- and three-argument verbs into a single transitive verb category.

Scores derived from the NNB were highly correlated with several standardized aphasia tests. These findings support the validity of the NNB as a useful instrument for assessing word class deficits. The NNB departs from other tools available in that it tests both comprehension and production of both nouns (objects) and verbs (actions), which is not accomplished by any other currently available test. Thus, clinicians can confidently use the NNB to assess both comprehension and production of both word classes using a single measure. In addition, although not reported in this paper, the NNB contains subtests for evaluating other aspects of lexical semantic processing, based on cognitive neuropsychological models of lexical processing. Thus, administration of the NNB also provides a mechanism for detailing the source of naming deficits, which may lead to potentially effective intervention strategies for improving naming ability.

The NNB may also prove to be useful for detailing the decline of naming ability in individuals with PPA as the disease progresses, providing information relative to the relation between word class knowledge and brain pathology. A particularly perplexing question in the study of PPA is the fate of different PPA variants over time. Are those with the logopenic variant truly different from those with other PPA variants or do some participants in this group develop agrammatic symptoms and others semantic or mixed deficit patterns over time? Indeed, the nature of the language deficit appears to predict underlying neuropathology, with agrammatism associated with post mortem brain autopsy findings of tauopathy, logopenic PPA predicting typical Alzheimer disease neuropathology, and the semantic variant most often associated with TDP-43 proteinopathy⁷ (Knibb, Xuereb, Patterson, & Hodges, 2006; Mesulam et al., 2008). Because presently there are no gold-standard biomarkers for neurodegenerative diseases causing dementia, clinicians must rely on clinical patterns to distinguish among them. Data derived from the NNB, therefore, may be useful for characterizing PPA deficits as they progress. In addition, word class deficit patterns revealed by administration of the NNB may be useful for planning treatment and/or compensatory intervention strategies as naming abilities change over time.

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⁷TDP-43 proteinopathy refers to the neuropathology underlying major forms of sporadic and familial frontotemporal lobar degeneration and motor neuron disease

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Appendix 1. Noun and Verb Stimuli

Nouns Tested for Confrontation Naming and Auditory Comprehension

Nouns				Nouns			
Production (n=16)	FRQ	LENGTH-P	IMG	Comprehension (n=10)	FRQ	LENGTH-P	IMG
CAT	1.63	3	617	TIE	1.56	2	551
SUIT	1.80	3	536	SNAKE	1.19	4	627
TIE	1.56	2	551	CORN	1.41	3	580
APPLE	1.27	3	637	BELT	1.35	4	585
BELT	1.35	4	585	MOUSE/RAT	0.96	3	615
ELEPHANT	1.13	7	616	GLOVE	0.75	4	596
CORN	1.41	3	580	ONION	1.02	5	617
SNAKE	1.19	4	627	HAMMER	1.13	5	668
GLOVE	0.75	4	596	PEPPER	0.89	5	587
MOUSE/RAT	0.96	3	615	SCISSORS	0.73	5	609
SOCK	0.60	3	553				
ONION	1.02	5	617				
HAMMER	1.13	5	668				
PEPPER	0.89	5	587				
BROOM	0.87	4	595				
SCISSORS	0.73	5	609				
MEAN	1.14	3.9	599	MEAN	1.10	4.0	604

Note: FRQ = log10 lemma frequency of occurrence per million, LENGTH-P = number of phonemes, IMG= imageability

Verbs Tested for Confrontation Naming and Auditory Comprehension

Verbs				Verbs			
Production (n=16)	FRQ	LENGTH-P	IMG	Comprehension (n=12)	FRQ	LENGTH-P	IMG
WRITE ***	2.11	3	548	WRITE ***	2.11	3	548
READ ***	2.48	3	499	READ ***	2.48	3	499
PULL **	1.83	3	348	THROW ***	1.69	3	477
THROW ***	1.69	3	477	CLIMB **	1.56	4	485
CRY *	1.70	3	478	POUR ***	1.41	3	495
CLIMB **	1.56	4	485	JUMP *	1.45	4	506
POUR ***	1.41	3	495	SWEEP **	1.19	4	547
JUMP *	1.45	4	506	SWIM *	1.40	4	627
SWEEP **	1.19	4	547	STIR/MIX **	1.26	4	475
SWIM *	1.40	4	627	CRAWL *	0.95	4	475
STIR/MIX **	1.26	4	475	SPILL **	0.72	4	n/a
CRAWL *	0.95	4	475	PRAY *	1.21	3	502
SPILL **	0.72	4	n/a				
BARK *	1.00	3	540				
PRAY *	1.21	3	502				

Verbs				Verbs			
Production (n=16)	FRQ	LENGTH-P	IMG	Comprehension (n=12)	FRQ	LENGTH-P	IMG
ZIP**	0.53	3	n/a				
MEAN	1.41	3.4	500	MEAN	1.453	3.6	512

Note:

* = 1-argument verbs,

** = 2-argument verbs,

*** = 3-argument verbs, n/a = no entry in CELEX, FRQ = log₁₀ lemma frequency of occurrence per million, LENGTH-P = number of phonemes, IMG= imageability

Figure 1A.

Figure 1B.

Figure 1.

Figure 1A. Picture stimuli used to test production of the noun *corn* and the verb *sweep*.

Figure 1B. Stimuli used to test comprehension of the noun *corn* and the verb *sweep*.

Figure 2. Production of nouns and verbs for stroke aphasia (StrAph) (top graph) and primary progressive aphasia (PPA) participant groups (lower graph).

Figure 3. Production of intransitive and transitive verbs by stroke aphasia (StrA) and primary progressive aphasia (PPA) participant groups.

Figure 4. Mean percent correct production and comprehension of nouns and verbs for participants with the semantic variant of primary progressive aphasia (PPA-S).

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Table 1

Demographic data for study participants

Participant Group	Total N	Males	Age (Mean) (Range)	Months Post Stroke/Duration of Dementia (Mean) (Range)	Education Years (Mean) (Range)	Right-Handed (N)
Stroke Aphasia (StrAph)						
Agrammatic Str-Ag	33	21	55 (35–81)	67 (7–237)	16 (12–20)	29
Anomic – StrAn	19	11	61 (45–79)	61 (6–336)	16 (12–20)	18
Primary Progressive Aphasia (PPA)						
Agrammatic – PPA-G	10	4	64 (52–72)	42 (18–60)	16 (12–20)	9
Logopenic – PPA-L	14	9	66 (48–81)	53 (24–114)	16 (12–20)	12
Semantic – PPA-S	4	1	57 (53–63)	49 (36–66)	15 (12–18)	4
Controls	28	12	63 (51–75)	N/A	16 (11–20)	25

Table 2

Language scores for agrammatic stroke aphasic (StrAg) participants

	WAB-AQ (100)	BNT (60)	BDAE-AN (12)
StrAg -1	75.2	32	10
StrAg -2	73.8	41	11
StrAg -3	67.2	28	6
StrAg -4	72.2	32	8
StrAg -5	40.2	15	3
StrAg -6	77.6	49	10
StrAg -7	87.2	59	12
StrAg -8	68.2	9	6
StrAg -9	51.4	5	0
StrAg -10	78.2	45	8
StrAg -11	73.6	45	n/a
StrAg -12	69.2	39	6
StrAg -13	59.2	52	n/a
StrAg -14	66.0	29	6
StrAg -15	54.3	7	8
StrAg -16	87.0	50	n/a
StrAg -17	69.4	42	10
StrAg -18	83.2	56	n/a
StrAg -19	80.8	58	12
StrAg -20	74.6	n/a	n/a
StrAg -21	69.2	43	n/a
StrAg -22	71.9	37	10
StrAg -23	69.2	36	5
StrAg -24	80.0	55	9
StrAg -25	75.8	48	10
StrAg -26	77.0	n/a	n/a
StrAg -27	66.0	5	5
StrAg -28	74.6	n/a	7
StrAg -29	82.7	51	12
StrAg -30	85.4	55	n/a
StrAg -31	75.8	48	9
StrAg -32	74.2	50	10
StrAg -33	66.8	36	9
MEAN	72.03	38.57	8.08
SD	10.08	16.22	2.94

Note: WAB=Western Aphasia Battery (AQ=Aphasia Quotient), BNT=Boston Naming Test, BDAE=Boston Diagnostic Aphasia Exam (AN=Action Naming), and n/a = not applicable

Table 3

Language scores for anomic stroke aphasic (StrAn) participants

	WAB-AQ (100)	BNT (60)	BDAE-AN (12)
StrAn-1	89.8	49	11
StrAn-2	85.0	12	7
StrAn-3	79.6	7	8
StrAn-4	83.6	47	11
StrAn-5	94.8	55	12
StrAn-6	92.4	50	11
StrAn-7	65.0	25	n/a
StrAn-8	93.6	49	12
StrAn-9	88	26	11
StrAn-10	91.0	49	10
StrAn-11	84.6	56	12
StrAn-12	70.6	29	n/a
StrAn-13	64.2	n/a	2
StrAn-14	95.0	n/a	7
StrAn-15	78.8	n/a	n/a
StrAn-16	83.5	32	10
StrAn-17	68.8	13	7
StrAn-18	59.2	22	6
StrAn-19	89.4	n/a	12
MEAN	81.07	34.73	9.31
SD	11.24	16.88	2.87

Note. WAB=Western Aphasia Battery (AQ=Aphasia Quotient), BNT=Boston Naming Test, BDAE=Boston Diagnostic Aphasia Exam (AN=Action Naming), and n/a = not applicable

Table 4

Language scores for participants with Primary Progressive Aphasia (PPA)

	WAB-AQ (100)	BNT (60)
PPA-G1	49.6	12
PPA-G2	82.3	59
PPA-G3	79.9	49
PPA-G4	78.8	46
PPA-G5	80.4	59
PPA-G6	75.3	53
PPA-G7	80.6	44
PPA-G8	73.9	27
PPA-G9	87.6	56
PPA-G10	85	56
MEAN	77.34	46.10
SD	10.56	15.34
PPA-L1	92	59
PPA-L2	90.5	52
PPA-L3	86.9	54
PPA-L4	78.6	50
PPA-L5	90.4	21
PPA-L6	97.2	53
PPA-L7	93.2	59
PPA-L8	83.2	59
PPA-L9	85.6	56
PPA-L10	88.8	34
PPA-L11	81.8	25
PPA-L12	97.1	58
PPA-L13	93	54
PPA-L14	73.4	5
MEAN	87.98	45.64
SD	6.90	17.25
PPA-S1	67.8	2
PPA-S2	88.2	14
PPA-S3	65.9	4
PPA-S4	83.2	6
MEAN	76.28	6.50
SD	11.10	5.26

Note: PPA-G1 – PPA-G10 = agrammatic; PPA-L1 – PPA-L14 = logopenic; PPA-S1 – PPA-S4 = semantic; WAB=Western Aphasia Battery (AQ=Aphasia Quotient), and BNT=Boston Naming Test.

Table 5

Frequency and neighborhood effects for verbs by argument structure

Verbs	Frequency	Orthographic Neighborhood Effects	Phonological Neighborhood Effects
1-argument vs. 2-argument	U = 16 <i>p</i> = .749	U = 14.5 <i>p</i> = .568	U = 14.5 <i>p</i> = .927
1-argument vs. 3-argument	U = 3 <i>p</i> = .055	U = 11 <i>p</i> = .829	U = 8.5 <i>p</i> = .451
2-argument vs. 3-argument	U = 3 <i>p</i> = .055	U = 11 <i>p</i> = .830	U = 3 <i>p</i> = .085

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Table 6

Mean percentage correct (standard deviations) noun and verb naming and comprehension for the stroke aphasic (StrAph) and primary progressive aphasic (PPA) groups

Group	Naming		Comprehension	
	Nouns M(SD)	Verbs M(SD)	Nouns M(SD)	Verbs M(SD)
Stroke Aphasia (StrAph)				
Agrammatic	87.69 (19.79)	78.78 (20.13)	93.68 (10.12)	95.17 (6.98)
Anomic	82.57 (21.2)	83.88 (17.09)	98.00 (4.22)	97.50 (5.62)
Primary Progressive Aphasia (PPA)				
Agrammatic	95.00 (11.71)	79.38 (18.17)	100.0 (0.00)	96.67 (8.05)
Logopenic	89.29 (26.68)	87.05 (22.12)	99.29 (2.67)	95.83 (10.71)
Healthy Controls	99.87 (0.89)	99.74 (1.23)	100.0 (0.00)	100.0 (0.00)

Table 7

Mean percentage correct (standard deviations) naming and comprehension by verb type for stroke aphasic (StrAph) and primary progressive aphasic (PPA) groups

Group	Verb Naming		Verb Comprehension					
	One-Argument (Intransitive) M (SD)	Two-Arg M (SD)	Three-Arg M (SD)	Transitive M (SD)	One-Argument (Intransitive) M (SD)	Two-Arg M (SD)	Three-Arg M (SD)	Transitive M (SD)
Stroke Aphasia								
StrAg	85.86 (20.88)	69.19 (25.38)	82.57 (26.13)	75.88 (23.03)	94.74 (13.38)	96.05 (12.54)	94.74 (10.47)	95.39 (7.46)
StrAn	93.86 (9.95)	75.44 (25.68)	81.58 (29.86)	78.51 (25.2)	100.00 (0.00)	97.5 (7.91)	95.00 (29.86)	96.25 (8.44)
Primary-Progressive Aphasia								
PPA-G	95.00 (8.05)	63.33 (30.22)	80.00 (22.97)	71.67 (24.52)	97.50 (7.91)	95.00 (10.54)	97.50 (7.91)	96.25 (13.67)
PPA-L	92.86 (22.37)	82.14 (25.07)	85.71 (25.40)	83.92 (23.96)	98.21 (6.68)	98.21 (6.68)	91.07 (23.22)	94.64 (13.62)
Healthy Controls	100.0 (0.00)	99.32 (3.33)	100.0 (0.00)	99.66 (1.66)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)	100.0 (0.00)

Table 8

Mean percentage correct noun and verb naming and comprehension for patients with the semantic variant of primary progressive aphasia (PPA-S)

	Naming					Comprehension						
	Nouns	Verbs	One-Argument (Intransitive)	Two-Arg	Three-Arg	Transitive	Nouns	Verbs	One-Argument (Intransitive)	Two-Arg	Three-Arg	Transitive
PPA-S1	0.00	50.00	50.00	33.33	75.00	54.17	0.00	83.33	100.00	50.00	100.00	75
PPA-S2	81.25	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100
PPA-S3	0.00	43.75	33.33	16.67	100.00	58.33	40.00	66.67	100.00	25.00	75.00	50
PPA-S4	25.00	87.50	100.00	66.67	100.00	83.33	80.00	91.67	100.00	100.00	75.00	87.5
Mean	26.56	70.31	70.83	54.17	93.75	73.96	55.00	85.42	100.00	68.75	87.50	78.13
SD	38.32	27.66	34.36	36.96	12.50	21.62	44.35	14.23	0.00	37.50	14.43	21.35

Note. Arg = argument; SD = standard deviation.