Introduction

Individuals with stroke-induced agrammatic aphasia (StrAg) exhibit impaired comprehension and production, particularly for semantically reversible constructions with noncanonical word order (Caramazza & Zurif, 1976; Grodzinsky, 2000), whereas those with anomic aphasia (StrAn) show relatively preserved syntactic abilities (Goodglass & Kaplan, 2001). Language deficits have also been reported for individuals with primary progressive aphasia (PPA), an impairment caused by a neurodegenerative disease (Mesulam, 1982, 2007). Among three variants of PPA (agrammatic [PPA-G]; logopenic [PPA-L]; semantic [PPA-S]), PPA-G has been associated with syntactic deficits whereas the other two variants of PPA do not show marked syntactic difficulty (e.g., Thompson et al., 1997; Weintraub et al., 2009; Wilson et al., 2010). Despite differences in underlying pathophysiology between StrAph and PPA, both are generally associated with compromised tissue in the left frontal region, and StrAn and PPA-L typically result from left temporo-parietal region infarct or atrophy, respectively (Damasio & Damasio, 2000; Kertesz, 1977; Mesulam et al., 2009). The purpose of the current study was to the compare syntactic abilities of aphasic participants with different etiologies (StrAph vs. PPA) and language profiles (agrammatic svs. non-agrammatic), using the Sentence Comprehension Test (SCT) and the Sentence Production Priming Test (SPPT) from *the Northwestern Assessment of Verbs and Sentences* (NAVS; Thompson, experimental version).

Method

Participants

Twenty six StrAg (age: 35-71, post-onset: 1-17 years), 20 StrAn (age: 38-79, post-onset: 1-25 years), 15 PPA-G (age: 52-79, symptom duration: 0.5-5 years) and 17 PPA-L (age: 48-76, symptom duration: 2-10 years) individuals participated in the study. Although the PPA participants in general were older than the StrAph participants (p = .001), there was no significant difference between the StrAg and StrAn groups ($p > .1$) and between the PPA-G and PPA-L groups ($p > .1$). The StrAph participants' aphasia resulted from a thrombo-embolic stroke in the left hemisphere, whereas the PPA participants did not show evidence of stroke or other neurological disorder. All participants were tested using the Western Aphasia Battery (Kertesz, 1982), with Aphasia Quotients (AQs) ranging from 51.4 to 87.2 for the StrAg group, from 69.4 to 96.8 for the StrAn group, from 41.8 to 95.2 for the PPA-G group, and 74.4 to 97.2 for the PPA-L group. All were native, monolingual English speakers, well-educated, and demonstrated good visual and hearing acuity.

Materials and Condition

For the SCT, 30 sentences were coupled with 30 pairs of corresponding pictures, depicting the target (e.g., *the dog is chasing the cat*) and its semantically reversed counterparts (e.g., *the cat is chasing the dog*). All sentences were semantically reversible and included two animate nouns and a transitive verb with the exception of relative clause structures, which included an additional main clause. The nouns used for as agents and themes in each sentence were matched for the $\log_{10}$ lemma frequency (mean = 2.605 vs. 2. 466), and the verbs were highly frequent (mean = 1.965) based on CELEX norms (Baayen, Piepenbrock, & van Rijn, 1993). Six sentence types were tested: three canonical (i.e., active (1a), subject-extracted wh-question (SWQ) (1c), and subject relative clause (SR) (1e)) and three noncanonical (i.e., passives (1b), object-extracted wh-question (OWQ) (1d), and object relative clause (OR) (1f)). On experimental trials, participants listened to a sentence and were asked to point to the picture corresponding to the sentence.

For the SPPT, the same sentence and picture stimuli were used. On each experimental trial, the examiner modeled the target sentence structure, describing the picture on the participant's left. Then, the participant was asked to produce a sentence 'just like it' for the picture on the right. Target sentence types were tested in blocks, with five exemplars of each type presented consecutively.

(1) a. The dog is chasing the cat. (Active)
b. The cat is chased by the dog. (Passive)
c. Who is chasing the cat? (SWQ)
d. Who is the dog chasing? (OWQ)
e. Pete saw the dog who is chasing the cat. (SR)
f. Pete saw the cat who the dog is chasing. (OR)

Results

The StrAph participants in general showed greater difficulty in production compared to comprehension, and in noncanonical compared to canonical sentences (*p*'s < .001). The StrAg group performed significantly more poorly than the StrAn group in comprehension of both canonical (M = 84% vs. 94%) and noncanonical (M = 66% vs. 87%) sentences and production of noncaonical sentences (M = 46% vs. 73%) (*p*'s < .05). The same patterns were also found for the PPA participants, with modality and canonicity effects in general (*p*'s < .01). That is, the PPA-G compared to PPA-L group showed greater difficulty comprehending canonical (M = 87% vs. 97%) and noncanonical (M = 75% vs. 90%) sentences and producing noncanonical sentences (M = 52% vs. 86%) (*p*'s < .05). Between the two agrammatic groups, StrAg and PPA-G, no significant differences were found on any of the comparisons (*p*'s > .1).

Further analyses of individual sentence types also revealed group differences in both modalities. In comprehension, the StrAg, compared to StrAn, group showed greater difficulty with all types of noncanonical sentences (i.e., passives, OWQs, ORs) as well as simple canonical actives (*p*'s < .05) (see Figure 1). In production, this group difference was shown only for noncaonical sentences, i.e., passives and OWQs (*p*'s < .05) (see Figure 2). The PPA-G, compared to PPA-L, group performed significantly more poorly in comprehension of SWQs and passives (*p*'s < .05), and this difference approached signifcance for ORs (*p* = .057) (see Figure 3). In production, differences between the PPA-G and PPA-L groups were found only for noncanonical sentences, i.e., passives, OWQs, and ORs (*p*'s < .05) (see Figure 4). No significant differences were found for the comparisons between the StrAg and PPA-G groups (*p*'s > .1).

Discussion

Considerable similarities were found between StrAph and PPA participants. In both groups, individuals with agrammatic deficits were significantly more impaired in comprehension and production of noncanonical sentences than participants of the anomic or logopenic type. One interesting finding is that the agrammatic participants showed significantly poorer canonical sentence comprehension (i.e., actives for StrAg patients; SWQs for PPA-G patients) than the anomic and logopenic participants. However, their comprehension of canonical sentences was significantly higher than that of noncanonical sentences. These findings indicate that the NAVS can be used to characterize sentence comprehension and production deficits in stroke-induced and primary progressive aphasia, which is important both clinically for differential diagnosis and theoretically to inform psycholinguistic models of language processing.

Reference

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). The CELEX Lexical Database (Release1). Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Caramazza, A., & Zurif, E. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, *3*, 572-582.

Damasio, A. & Damasio, H. (2000). Aphasia and the neural basis of language. In: *Principles of behavioral and cognitive neurology*, Mesulam. M. (ed.), pp 294–315. Oxford, UK: Oxford University Press.

Goodglass, H. & Kaplan, E. (2001). *Assessment of aphasia and related disorders*, 3rd edition. New York: Lea and Febiger.

Grodzinsky, Y. (2000). The neurology of syntax: Language use without Broca's area. *Behavioral and Brain Sciences*, *23*, 1-71.

Mesulam, M.-M. (1982). Slowly progressive aphasia without generalized dementia. *Annals of Neurology*, *11*(6), 592-598.

Mesulam, M.-M. (2007). Primary progressive aphasia: A 25-year retrospective. *Alzheimer Disease and Associated Disorders*, *21*(4), S8-S11.

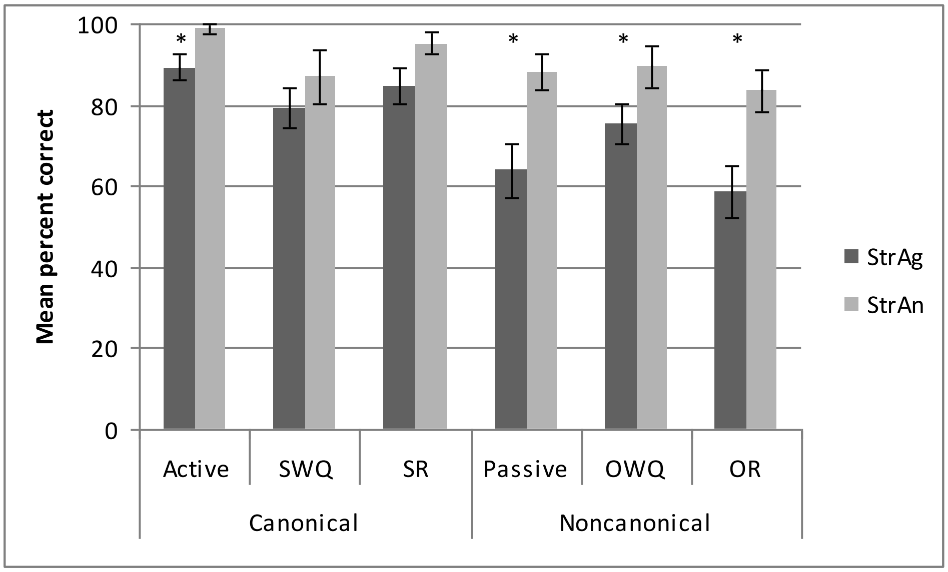
Mesulam, M.-M., Wieneke, C., Rogalski, E., Cobia, D., Thompson, C.K., & Weintraub, S. (2009b). Quantitative template for subtyping primary progressive aphasia. *Archives of Neurology*, *66*(12), 1545-1551.

Thompson, C.K., Ballard, K.J., Tait, M.E., Weintraub, S., & Mesulam, M.-M. (1997). Patterns of language decline in nonfluent primary progressive aphasia. *Aphasiology*, *11*, 297-321.

Weintraub, S., Mesulam, M-M., Wieneke, C., Rademaker, A., Rogalski, E.J., & Thompson, C.K. (2009). The Northwestern Anagram Test: measuring sentence production in primary progressive aphasia. *American Journal of Alzheimer's Disease and Other Dementias 24*(5), 408-416.

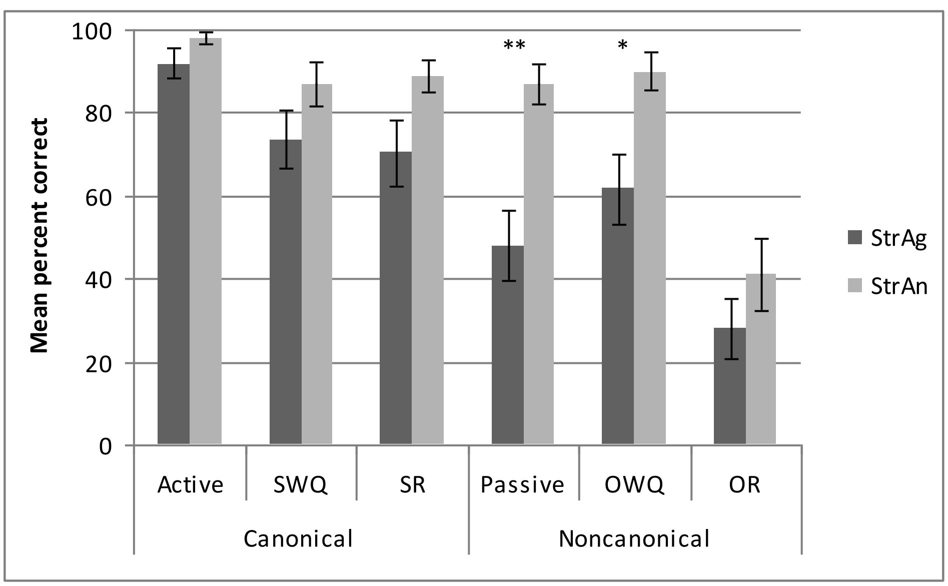
Wilson, S., Henry, M., Besbris, M., Ogar, J., Dronkers, N., Jarrold, W., et al. (2010). Connected speech production in three variants of primary progressive aphasia. *Brain*, *133*, 2069-2088.

Figure 1. Mean percent correct comprehension by sentence type for StrAg and StrAn participants



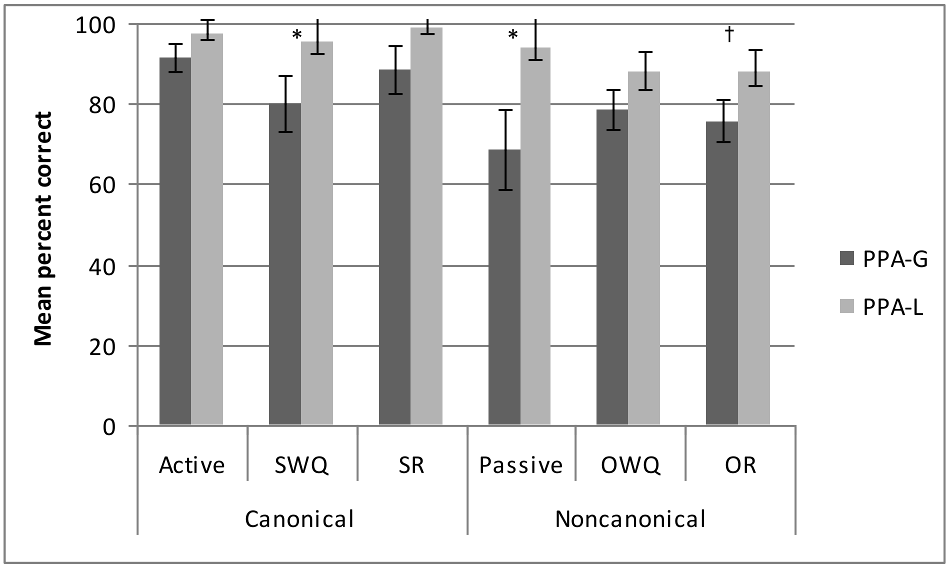
* p < .05, Mann-Whitney *U* Test, two-tailed.

Figure 2. Mean percent correct production by sentence type for StrAg and StrAn participants



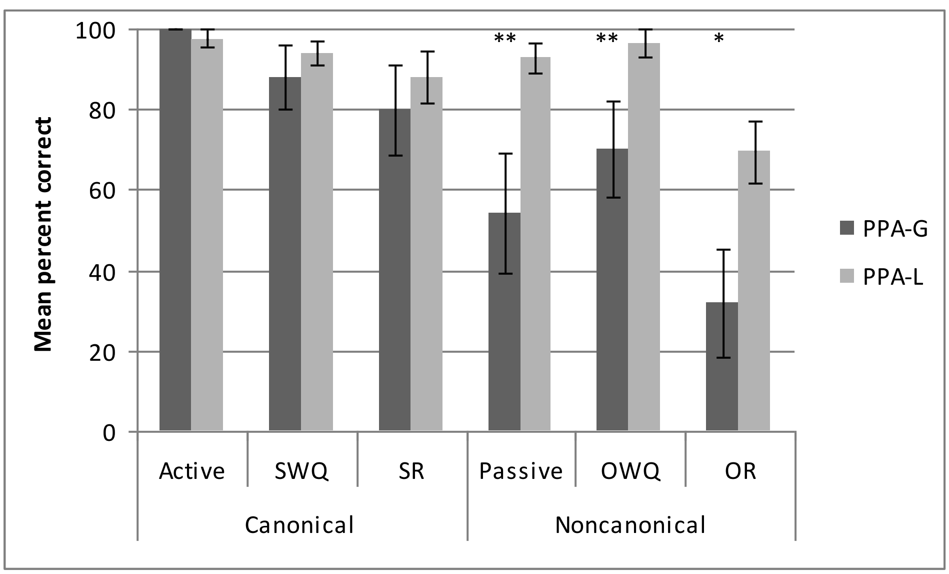
* p < .05, ** p < .01, Mann-Whitney *U* Test, two-tailed.

Figure 3. Mean percent correct comprehension by sentence type for PPA-G and PPA-L participants



* p < .05, † p = .057, Mann-Whitney *U* Test, two-tailed.

Figure 4. Mean percent correct production by sentence type for PPA-G and PPA-L participants



* p < .05, ** p < .01, Mann-Whitney *U* Test, two-tailed.