The primary outcome measures for aphasia treatment investigations targeting anomia typically include naming accuracy of trained and untrained words. Recently, several treatment investigations have also included error analyses that closely look at the way in which word retrieval breaks down pre-treatment vs. post-treatment (Gordon, 2007; Kendall, Pompon, Brookshire, Minkina, & Bislick, 2013; Kiran & Johnson, 2008, Kiran & Thompson, 2003). In one such analysis, Kendall et al. (2013) investigated treatment-induced changes in aphasic naming errors following a phonomotor treatment for anomia. The study was rooted in an interactive two-stage model of word retrieval, in which world retrieval is initiated with activation of semantic representations, allowing for access of the word's lemma (which holds grammatical properties), while phonological representations are accessed in the second stage (Dell, 1986). In the analyses of confrontation naming errors in ten people with aphasia, several trends were noted immediately following treatment: a decrease in the proportion of omissions on trained words, and an increase in the proportion of mixed (phonologically and semantically related) errors on untrained words. These results suggested that treatment led to more precise activation of nodes supporting word retrieval.

The present study sought to replicate this error proportion analysis in a larger group of participants and expand the analysis to explore changes in raw numbers of errors. The following research questions were asked both for trained and untrained words:

Preliminary research question

1) Is there a significant difference between picture naming *accuracy* pre-treatment vs. immediately post-treatment, and pre-treatment vs. three months post-treatment?

Main research questions

2) Is there a significant difference in *raw numbers of various error types* made during picture naming pre-treatment vs. immediately post-treatment, and pre-treatment vs. three months post-treatment?
3) Is there a significant difference in *error type proportions* (the number of each error type divided by the total errors made) observed during picture naming pre-treatment vs. immediately post-treatment, and pre-treatment vs. three months post-treatment?

Method

Participants included 24 individuals with chronic aphasia, acquired as a result of a left CVA, who were part of a larger treatment study looking at the effects of phonomotor treatment on word retrieval (Table 1). Inclusionary criteria included demonstration of aphasia, as measured by the Western Aphasia Battery (WAB; Kertesz, 1982), and word retrieval impairments, as measured by the Boston Naming Test (BNT; Kaplan, Goodglass, Weintraub, & Segal, 1983). Phonological processing was assessed with the Standardized Assessment of Phonology in Aphasia (SAPA; Kendall et al., 2010). Though several participants did not meet the standard cut-offs for impairments on the WAB and BNT, these participants demonstrated difficulty with phonological processing (as observed during the SAPA) and anomia in conversational speech (as judged by a certified speech-language pathologist). Participants with severe apraxia of speech were excluded, as determined by a certified speech-language pathologist's perceptual assessment of the following: slowed rate, distortions, distorted substitutions, and prosodic abnormalities.

Treatment stimuli consisted of all English phonemes in isolation and in combination with one another, 72 phonotactically legal nonwords, and 39 real words. All words and nonwords were one or two syllables in length, and were of low phonotactic probability and high neighborhood density. Participants received 60 hours of treatment by a certified speech-language pathologist. The therapy focused on phonemes in isolation and phoneme sequences, and was delivered in a multimodal manner (tasks included oral motor movement awareness, production, auditory perception, and grapheme to phoneme correspondence), and progressed from simpler to more complex sound combinations. For detailed treatment procedures, see Kendall et al. (2013).

The outcome measure for whole word accuracy was confrontation naming of pictures representing trained and untrained real words. Responses were audio-recorded, and final responses were coded as correct or incorrect by one of seven raters. All incorrect responses were coded as one of the following error types: semantic, phonological, unrelated, mixed, omission, and neologism. To assess accuracy, paired-samples *t*-tests comparing confrontation naming accuracy pre-treatment vs. immediately post-treatment and pre-treatment vs. three months post-treatment were conducted. To assess error profiles, paired-samples *t*-tests compared the raw number of each error type pre-treatment vs. immediately post-treatment and pre-treatment vs. three months post-treatment, and error type proportions (proportion of each error type relative to total number of errors made) pre-treatment vs. immediately post-treatment and pre-treatment vs. three months post-treatment. Due to low numbers of unrelated, mixed, and neologistic errors, they were excluded from further analyses.

Results

Whole word accuracy

Results of paired-samples *t*-tests comparing percent naming accuracy on trained items showed statistically significant improvements in naming accuracy when comparing pre-treatment and immediate post-treatment probes ($p < .001$) and pre-treatment and three months post-treatment probes ($p < .001$). Results of paired-samples *t*-tests comparing percent naming accuracy on untrained items showed statistically significant improvements in naming accuracy when comparing pre-treatment and immediate post-treatment probes ($p = .020$) and pre-treatment and three month post-treatment probes ($p = .004$).

Error analyses

Raw number of errors. For each group of *t*-tests (semantic, phonologic, omissions), α was set at .0125 to correct for multiple comparisons. For trained words, a significant decrease in errors was evident immediately post-treatment for semantic errors ($p < .001$) and omissions ($p < .001$). Additionally, there was a trend towards a decrease in phonological errors on trained words immediately post-treatment as compared to pre-treatment ($p = .016$). Three months post-treatment results showed a significant decrease in phonological errors ($p = .010$), semantic-related errors ($p < .001$), and omissions ($p = .003$) as compared to pre-treatment. For untrained items, several trends emerged: a decrease in semantic-related errors three months post-treatment ($p = .045$) and a decrease in omissions immediately post-treatment ($p = .024$) and three months post-treatment ($p = .070$) (Figures 1 and 2).

Error proportions. Trends towards a decrease in proportion of omission errors on trained items were noted immediately post-treatment ($p = .065$) and three months post-treatment ($p = .044$). A trend towards a decrease in proportion of omission errors on untrained items was noted three months post-treatment ($p = .059$) (Figures 3 and 4).

Discussion

As a whole, the results of this study suggest that phonomotor treatment led to a shift in linguistic processing in which the word retrieval network was holistically altered as a result of phonomotor treatment. This claim is supported by both the whole word accuracy and error analysis results. First, the improvements on both trained and untrained items immediately and three months post-treatment suggest that intensive phonomotor therapy targeting phonological representations can lead to the strengthening of the entire word retrieval network (i.e., lemma and semantic representations in addition to phonological representations). With regard to the error analysis results, the reduction in raw numbers of all types of errors on trained items suggests increased efficiency throughout the whole word retrieval network, and supports the claim that sound-based treatment can induce changes at all levels of word retrieval. The trends in the decrease in the number of omissions and semantic errors in untrained items further support this claim. Additionally, the error proportion analysis demonstrated trends towards a decrease in the proportion of omissions and, therefore, a joint increase in the proportion of errors with a relationship to the target (semantic and phonological errors) on both trained and untrained items, demonstrating that our multimodal phonomotor treatment program facilitated access to both phonologic and semantic representations.

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Table 1

Participant Characteristics

Participant	Age (yrs)	Gender	Education level (yrs)	Duration post onset (mo)	WAB (AQ) (out of 100)	BNT (out of 60)	SAPA (number correct out of 151)
1	49	M	16	21	87.5	37	96
2	26	M	16	45	94.2	57	128
3	48	M	13	16	94.6	52	131
4	27	M	13	17	51.1	44	74
5	67	F	14	162	84.5	36	94
6	53	M	19	81	63.9	13	64
7	64	M	20	52	76.3	9	80
8	57	F	14	38	52.6	5	61
9	47	F	16	11	84.6	50	123
10	62	M	15	29	96.1	57	115
11	74	F	18	8	91.3	51	105
12	30	F	14	14	50.8	5	50
13	57	M	16	24	82.0	31	102
14	72	M	18	211	69.8	34	76
15	67	M	16	104	81.1	56	103
16	68	M	23	14	92.0	57	109
17	33	F	15	31	78.2	31	65
18	70	M	16	10	94.7	43	114
19	45	F	12	14	85.2	22	124
20	78	M	13	41	90.2	46	105
21	61	F	16	15	95.0	50	110
22	67	M	15	20	86.6	18	124
23	61	F	18	155	92.0	32	109
24	51	F	13	22	74.3	41	96
AVG	**55.6**	**N/A**	**15.8**	**48.1**	**81.2**	**36.5**	**98.3**
SD	**15.1**	**N/A**	**2.6**	**55.1**	**14.2**	**16.9**	**23.2**

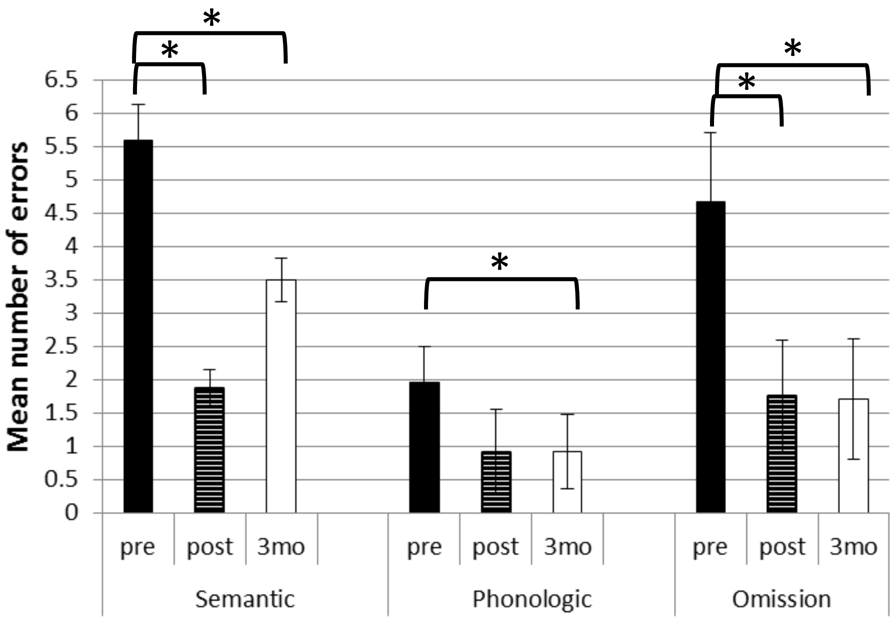

Figure 1. Mean raw numbers of error type for trained stimuli. Statistically significant differences are shown with a bracket and asterisk. Standard errors are represented by the error bars attached to each column.

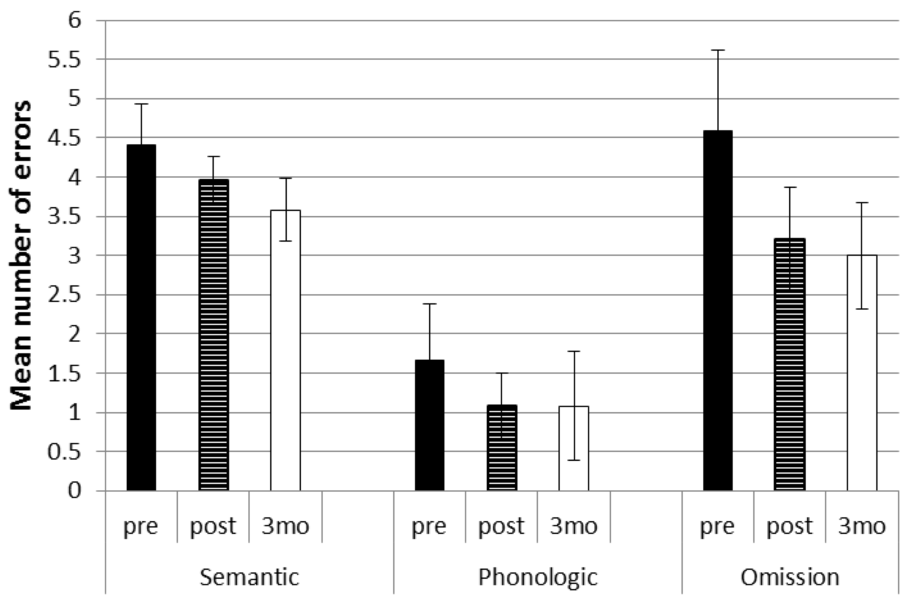

Figure 2. Mean raw numbers of error type for untrained stimuli. Standard errors are represented by the error bars attached to each column.

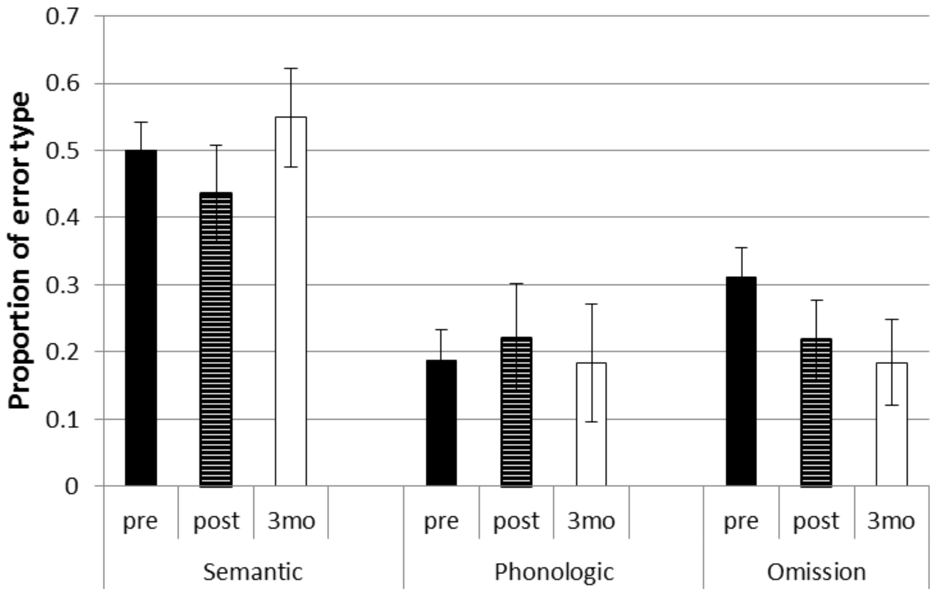

Figure 3. Proportion of error type for trained stimuli. Standard errors are represented by the error bars attached to each column.

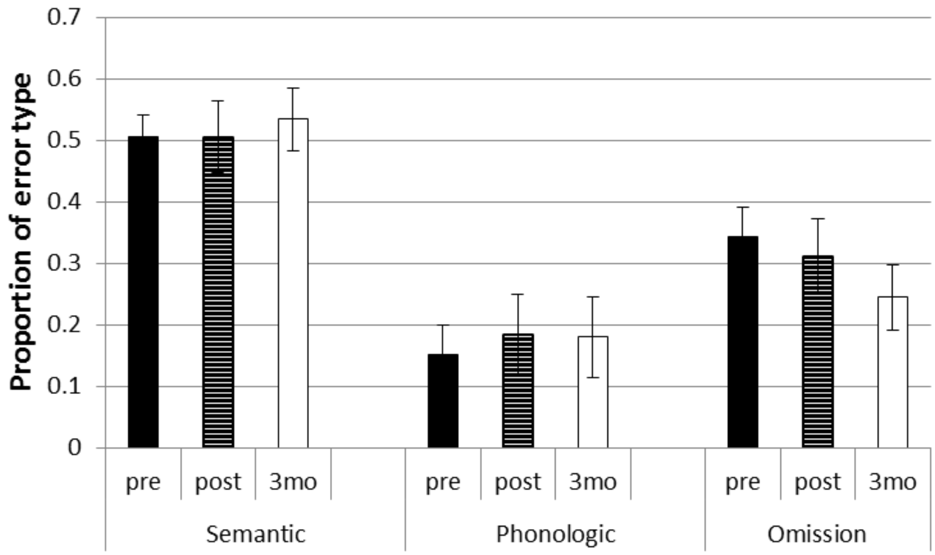

Figure 4. Proportion of error type for untrained stimuli. Standard errors are represented by the error bars attached to each column.