Introduction

Individuals with aphasia often have a number of concomitant cognitive impairments which may adversely affect their language abilities. Researchers have identified attention control as one factor contributing to language performance in this population (Murray, Holland, Beeson, 1998). One therapeutic intervention shown to positively affect attention control, including inhibitory processes, in healthy aging and disordered populations is physical fitness training (e.g., Colcombe & Kramer, 2003). Accordingly, the purpose of the current study was to identify improvements in cognitive and language behavior following physical fitness training in persons with chronic aphasia.

Literature Review

Aphasia research examining the effect of cognitive therapy on language outcomes has yielded primarily positive results. Helms-Estabrook and Albert (2004) employed a variety of non-linguistic attention training tasks with participants with aphasia. Post-treatment testing revealed significant improvements in both language and cognitive measures. Coehlo (2005) applied an attention training program to treat a reading impairment associated with mild aphasia. The participant demonstrated improved reading comprehension on probes, formal reading measures, and an improved WAB-AQ score. Clinical trials have also demonstrated enhanced speech/language therapy outcomes when combined with low doses of dextroamphetamine, a medication traditionally used to treat ADHD (e.g., Stefanatos, Gershkoff, Joe, & Ieuji, 2006).

There has been increasing focus on the influence of physical fitness on cognitive abilities in older adults, and its role in reducing the risk of age-associated diseases. Findings generally indicate an inverse relationship between fitness and cognitive decline (e.g., Colcombe, et al., 2004). Colcombe and Kramer (2003) conducted a meta-analysis into the benefits of exercise on cognition and found that across eighteen intervention studies, executive control processes including planning, scheduling, working memory, inhibitory processes, and multi-tasking benefitted most from physical fitness. Using neuroimaging techniques, Colcombe and colleagues (2004) further found that aerobic exercise was associated with increased activity in the frontal and parietal regions commonly associated with attentional control.

Despite the positive cognitive outcomes identified in exercise studies with the healthy aging population, no research has followed this line with the chronic aphasia population or relatedly, examined possible linguistic benefits of exercise. Thus, it is not known if aphasic individuals would also demonstrate cognitive or linguistic improvements from exercise and improved physical fitness. Because exercise positively affects cognitive functioning in non-brain-damaged adults and cognitive treatment positively affects linguistic functioning in individuals with aphasia, we hypothesized that providing physical fitness training to individuals with aphasia would be associated with improvements in both their cognitive and language abilities, particularly those related to attentional control.

Methods

The study employed a controlled single subject experimental design with four participants with chronic aphasia of varying type and severity (Table 1). The duration of the protocol for each participant was approximately 6 months (Figure 1). All participants were receiving speech therapy, and continued to receive their previously established therapy regimen (with no alterations) throughout the study. All participants began with the exercise condition due to constraints on availability of campus exercise facilities and equipment; additional participants, are being recruited to receive the reverse treatment order.

Formal assessment measures included: (a) *Western Aphasia Battery* to determine aphasia type and severity, (b) *Delis-Kaplan Trail Making Test* to assess cognitive flexibility, (c) *Flanker Task* to assess inhibition and switching, (d) *Communication Effectiveness Inventory* (CETI) to evaluate functional communication, and (e) *Geriatric Depression Scale* to identify level of emotional satisfaction. Participants completed written and spoken discourse tasks, and the Senior Fitness Test. Language probes consisting of five generative naming tasks, a grammaticality judgment task, and picture identification task were administered at each assessment period (Figure 1).

Exercise sessions consisted of 30-minutes of light aerobic exercise on a recumbent bike under supervision of a personal trainer. Each session concluded with a language probe consisting of two generative naming tasks, a grammaticality judgment task, and picture identification task.

Conversation partner sessions were also 30-minutes each and served as a placebo condition in that they matched in format the type of natural conversation that occurred with the personal trainer during exercise sessions. Conversations were not directed; researchers developed lists of topics that were of known interest to each participant based on topics commonly discussed during the exercise sessions. Common topics of discussion included current events, hobbies, travel, and family.

Results

To date, four participants have completed the entire program with the exception of the 6-week follow-up session. Preliminary data for Participant 1 have been analyzed (Tables 2-4), and by May, data collection and analysis for the remaining participants will be completed.

For Participant 1, there was overall language improvement across both exercise and conversation conditions in terms of his WAB scores; the improvement following exercise training was double that following the conversation condition (Table 2). Participant 1's family member's ratings on the CETI suggested some improvements in his daily communication skills, particularly following exercise training. For example, his median rating more than doubled following the exercise condition (32 mm to 68 mm), but dropped to 54 following the conversation condition.

On the Flanker task, Participant 1 had increases in response time after both training conditions, with a decrease in errors following only exercise training (Table 2). It appears that at least initially, following the exercise condition, he dedicated more time to responding and his performance improved as a result of the increased response time. Whereas the Flanker is an inhibition task that relies on visual processing of one abstract symbol, the *Trail Making Task* involves processing and organizing letters and numbers. In all instances except for visual scanning, Participant 1 could not complete this task within the 150 second limit. Following exercise training, however, he did increase the quantity of items sequenced on all three sequencing tasks, indicating an increased speed of processing. Following the conversation condition, an increase was observed for only the number sequencing task. Participant 1's performance decreased in the most difficult task, which required sequencing while alternating between numbers and letters.

Probe tasks were equivocal, as performance was mixed across the various tasks. A clear improvement was observed on the grammaticality judgment task following the exercise condition, but with a subsequent decrease. There was a slow, steady increase in performance on most generative naming tasks, but a decrease in performance on one. Participant 1 maintained a high level of accuracy on picture identification.

Written discourse dramatically improved both in terms of length and use of complete sentences following the exercise condition, with nominal change following conversation (Table 3). Although his lexical diversity and density decreased over time, this was expected considering his initial sample consisted of only 8 words and was limited to naming prominent objects in the picture. His oral discourse samples (Table 4) decreased in length, but showed increases in lexical diversity as evidenced by a higher TTR.

Discussion

These preliminary findings suggest that the addition of exercise training to traditional aphasia therapy can produce improvements in both language and cognition, exceeding those of a placebo, conversation stimulation condition. This study extends the current positive research on exercise and cognition to include individuals with brain damage and chronic aphasia. It is the first to demonstrate that exercise positively affects language. Although we cannot ascertain from this study the degree of linguistic improvement that is a direct result of exercise versus improved cognition, it illuminates a area for future research.

Table 1

Participant	1	2	3	4
Gender	Male	Male	Female	Female
Age	72	59	56	58
Education	PhD	BA	MSW	High School
Aphasia				
Type	Anomic	Anomic	Broca's	Anomic
Quotient	67	78.8	28.2	76.8
Time post Onset	3 years	4 years 2 months	2 years 7 months	6 years
Concomitant Deficits	Apraxia R Hemiparesis R Hemianopsia Mild memory impairment Alexia without agraphia	Mild oral apraxia Memory Problem solving Attention Hyperverbosity	Apraxia R Hemiparesis Memory impairment	Dysarthria R Hemiparesis

Table 2

Test	**Pre-testing**	**Between**	**Post-testing**
WAB	67	75.4	78.8
Flanker 1	(Max 5000 ms)	(Max 5000 ms)	(Max 5000 ms)
Congruent – time	1527.8 ms.	2132.8 ms.	3422.7 ms.
Congruent – error	0	0	3
Incongruent – time	1683.6 ms.	2260.9 ms.	3055.6 ms.
Incongruent - error	2	1	2
Flanker 2	(Max 5000 ms)	(Max 5000 ms)	(Max 5000 ms)
Congruent – time	1370.2 ms.	2194.1 ms.	4806 ms.
Congruent – error	0	0	6
Incongruent – time	1794.5 ms.	1766.6 ms.	4514 ms.
Incongruent - error	2	0	8

Trail Making Task – time	(Max 150 sec)	(Max 150)	(Max 150)
Visual Scanning	150 sec.	112 sec.	140 sec.
Number sequencing	150 sec.	150 sec.	150 sec.
Letter sequencing	150 sec.	150 sec.	150 sec.
Number-letter switching	150 sec.	150 sec.	150 sec.
Trail Making Task			
Percent completed			
Visual Scanning	23/24 = 96%	24/24 = 100%	24/24 = 100%
Number sequencing	1/15 = 7%	3/15 = 20%	5/15 = 33%
Letter sequencing	2/15 = 13%	4/15 = 27%	4/15 = 27%
Number-letter switching	4/31 = 13%	6/31 = 20%	4/31 = 13%
CETI			
Range	0 – 86	6 – 92	1 – 90
Mean	30.9	56.2	49.65
Median	32	68	54
Probe Measures			
Action fluency			
- average # across 3 trials	5.6	6	9.33
Letter Fluency			
T - average # across 3 trials	5	3	4.3
Letter Fluency:			
P - average # across 3 trials	3	6	7.33
Category Fluency			
Vegetable - average	.66	1.33	1
Category Fluency			
Fruit - average	2	2	2.33
Picture ID	87%	87%	82%
Grammaticality judgment	52%	60%	53%

Table 3
Written Discourse Analysis

Analysis	**Pre-testing**	**Between**	**Post-testing**
Word count	8	42	49
TTR[1]	8/8: 1	18/42: 43%	24/49: 49%
Lexical density[2]	7/8: 88%	24/42: 57%	26/49: 53%
Complete sentences[3]	1	7	6
Paraphasias	0	1	0

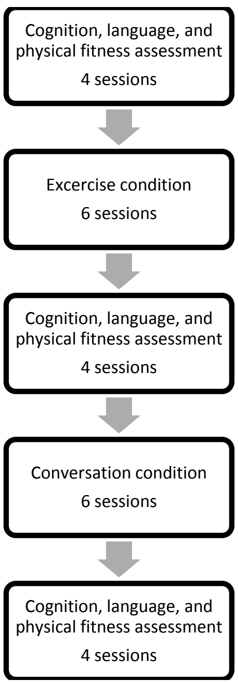
1 = Type Token Ratio
2 = Nouns, verbs, adjectives & adverbs
3 = As compared to lists of words. SV or SVO minimally; may be missing articles/determiners

Table 4
Oral Discourse Analysis

Analysis	Pre-testing	Between	Post-testing
Word count[1,2]	121	53	47
False starts, reformulations, repeats	10	4	4
Total Morpheme Count[3]	139	57	56
TTR[4]	59/121: 49%	30/53: 57%	12/47: 26%
Lexical density[5]	48/121: 40%	18/53: 34%	26/47: 55%

1 = Excludes fillers such as *uh*, *um*, false starts, reformulations, or repetitions unless the repetition is for emphasis.
2 = Contractions counted as two words
3 = Excludes fillers such as *uh*, *um*, false starts, reformulations, or repetitions unless the repetition is for emphasis
4 = Type token ratio
5= Text without fillers, false starts, reformulations and repetitions. Nouns, verbs, adjectives & adverbs

Figure 1



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