Introduction

The aphasia literature has clearly established that treatments for aphasia are effective, particularly when therapy begins during the acute post-stroke recovery period and when provided in an intensive fashion [1-5]. Despite evidence to support the efficacy of aphasia treatments, only a few studies have examined service utilization [6-8], reimbursement [9-10], cost [11], or cost-effectiveness [12]. In 1996, Boysen and Wertz [12] asked, "What is a Word Worth?" They analyzed five aphasia group efficacy studies. Based on $28 per hour, they estimated that therapy cost between $1,344 per patient for inefficacious treatment to $7,392 for efficacious treatment. Using 15% PICA overall change as the effect size in two Veterans Administration cooperative studies, and assuming 15% overhead, the estimated personnel costs ranged from $206 to $567 for each percentile change (per patient).

Unfortunately, subsequent studies related to the economics of aphasia treatments have been sparse and to some degree limited by aphasia studies that contain poorly defined variables (e.g. type of therapeutic interventions, frequency, duration, and extreme variability in intensity of interventions) necessary for realistic examinations [13-14]. However, the current climate in healthcare nationwide suggests that regardless of the issues related to aphasia treatment methodologies, whether randomized group designs, quasi-experimental designs, or single subject experimental designs (SSE), aphasiologists are now required to be attentive not only to the *cost* and the *effectiveness* of aphasia treatment, but also to the *cost effectiveness* of the treatments they provide [15].

Purpose

The purpose of this study was to examine SSE therapeutic interventions for aphasia presented at the *Clinical Aphasiology Conference* (CAC) to determine their cost effectiveness. The specific aims of this preliminary investigation were to determine the cost, the cost effectiveness, and the marginal benefit of additional treatment sessions. We report an examination of the *cost* and *cost-effectiveness* of therapeutic interventions for aphasia completed using SSE designs and reported in papers previous presented at CAC conferences. We selected studies completed with SSE designs because they are ideally suited to address methodological concerns associated with the study of the costs and cost-effectiveness of aphasia treatments [16].

Methods and Procedures

We previewed *The Aphasiology Archive* 1974-2006 (University of Pittsburgh, 2006) [17] and identified the empirical studies of aphasia treatment using SSE methodology. Inclusion criteria were: 1) poststroke aphasia, 2) single subject experimental treatment, and 3) English speakers only. Exclusion criteria were: 1) non-stroke etiologies, 2) interventions emphasizing treatment of apraxia of speech, 3) interventions using a predetermined rather than criterion-based number of treatment sessions, and studies using hybrid SSE methodologies.

Demographic and diagnostic characteristics, the number of treatment sessions, and baseline and outcome proficiency levels of each treated behavior were extracted from

each qualified study. The *cost-effectiveness* of the interventions was determined using a multivariate regression. We used a multi-level mixed-effect design with separate random effects for the intervention and the subject, thereby controlling for unmeasured differences between the interventions and subjects. See **Table 1** for operational definitions relevant to this analysis.

We measured *cost-effectiveness* in two ways:

1) by calculating the average treatment effect or increase in the target treatment variable while ignoring the number of sessions.

2) by calculating a quadratic treatment effect that allows the effect of each additional session to change over time. The quadratic treatment effect was measured by using the coefficient on the number of treatment sessions and the number of treatment sessions squared.

Two specifications were used for each model: 1) moderate or severe aphasia at baseline, and 2) patient characteristics. We report the effect of treatment under both specifications.

Results

The results from 96 observations; aphasia interventions completed on individual subjects as reported in studies using SSE designs We report baseline demographics: (age, education, gender, baseline aphasia severity, and aphasia chronicity in Table 2. Race/ethnicity, handedness, stroke number, stroke type, or post-treatment performance on standardized aphasia measures are not reported due to missing data.

The average number of treatment sessions completed was approximately 10 for each aphasia intervention. The performance proficiency for the target variables (interventions) before treatment averaged about 23%; after treatment, about 67%. **Table 3** summarizes proficiency levels before and after treatment, and the number of treatment sessions completed to achieve the proficiency level. For this analysis, a per session treatment cost of $35.53 was used. This figure was based upon rates obtained from the Bureau of Labor Statistics [18-19] (**Table 1**). Given an average number of sessions of 10.563 (**see Table 3**), and a *per session cost* of $35.53, the cost of a 45% point increase in a single treated target behavior was: 10.563*35.53=$375.30. This yields a cost effectiveness ratio of 8.34: ($375.30/45=8.34), i.e., it costs $8.34 for each 1% increase in the target behavior.

To determine whether the treatment effect was larger during the first several sessions, and whether the beneficial effect of each additional session diminishes as the number of treatments increase, we analyzed the marginal effectiveness of additional treatment sessions. Specification 1 controlled for pre-treatment aphasia severity; Specification 2 controlled for patient characteristics.

The results in **Table 4** are interpreted as follows:

(1) Since the number of sessions (6.128) is positive, we can infer that the sessions are effective.

(2) However, since the coefficient associated with the squared term is negative (-0.161), we imply that the effectiveness of each session declines as the number of sessions increases. Based on these values, it can be shown that *maximum effectiveness occurs by 19 sessions*.

To estimate cost-effectiveness ratios of groups of 5 sessions up to 20 sessions, we applied the quadratic result in **Table 4**. The first 5 sessions yielded an improvement of 18.53 percentage points; the next 5 sessions, an improvement of 10.46 percentage points; and the next 5, an additional 2.38 points (**See Table 5**). The final 5 sessions did not yield an improvement and actually may have had a negative effect. The right column (**Table 5)** shows the CE ratio; a calculation of the cost of five sessions divided by the percentage improvement associated with the five sessions. The CE ratio for the first five sessions is 9.59. The CE ratio increased from 9.59 to 16.99, and finally, to 74.60. Thus, it is seven times more expensive to facilitate a 1% change in performance in sessions 11 to 15, as compared to sessions 1-5.

Discussion

These findings show that treatments rendered in an SSE format yield improvement in the proficiency of target behaviors. Aphasia therapy 'works,' but is it cost-effective? Our data suggest that aphasia interventions, on average, are cost effective up to 19 sessions. After that point, the cost effectiveness ratio increases substantially as marginal benefit declines. To our knowledge, no previous study has analyzed the cost effectiveness of aphasia treatment that used SSE methodology. Despite the obvious appeal of SSE designs for demonstrating accountability, aphasiologists should be attentive not only to the effectiveness of SSE aphasia treatment, but also to its cost effectiveness. Further investigations are needed to fully understand the value (effectiveness, cost effectiveness, and marginal benefit) of different types of interventions for different types of patients to help assure that aphasiologists select patients appropriately, match specific treatments to specific aphasia profiles, and use scarce healthcare dollars responsibly.

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Table 1. Operational definitions for this study.

Observation: Each treatment (intervention) for each separate target behavior.

Outcome (dependent variable): The difference between pre-treatment and post-treatment performance proficiency, each calculated as the *average of the lowest and highest datapoints* in the relevant phase.

Cost: The average professional cost was $35.53 per hour (Bureau of Labor Statistics, 2005, 2006).

Cost effectiveness (CE) ratio: The cost per unit of effectiveness, in this case, a 1% change.

Marginal effect: The effect of one additional unit of treatment, derived by comparing the amount of change across sessions using the quadratic equation described in the paper.

Table 2. Sample characteristics for individuals with aphasia who engaged in single subject experimental treatments.

Variable	**Sample Characteristics**	**Standard Deviation**
Age (years)	55.30	15.35
Male (percentage)	78.72	0.410
Education (years)	13.03	3.178
High school education (percentage)	48.96	0.501
Chronicity (months post onset)	47.49	51.520
Western Aphasia Battery (aphasia quotient)	84.38	0.364
Porch Index of Communicative Abilities (overall percentile)	26.04	0.440
Boston Diagnostic Aphasia Examination (overall severity)	5.21	0.223
Baseline moderate aphasia (percentage)	71.88	0.451
Baseline severe aphasia (percentage)	25.00	0.434

Note: Missing data for gender, race/ethnicity, handedness, stroke number and stroke type precluded analysis.

Table 3. Proficiency levels of target behaviors before and after aphasia treatment for a variety of interventions using single subject experimental methodology

Variable	**Sample Characteristics**	**Standard Deviation**
Proficiency before treatment	23.198	20.268
Proficiency after treatment	68.672	21.172
Number of treatment sessions	10.563	8.142

Table 4. Average effect of treatment on percent change in performance proficiency level

	Specification 1		**Specification 2**	
	Average Effect of Treatment		*Average Effect of Treatment*	
	Effect	S.D.	Effect	S.D.
Treatment	45.474	2.186	45.652	2.510
	Quadratic Effect of An Additional Session		*Quadratic Effect of An Additional Session*	
	Effect	S.D.	Effect	S.D.
Number of sessions	6.128	0.485	5.900	0.537
Number of sessions squared	-0.161	0.018	-0.156	0.019

Specification 1: Controls for baseline moderate and severe aphasia
Specification 2: Controls for baseline moderate and severe aphasia plus indicator variables for male, high school education, chronicity, and baseline aphasia severity (WAB, PICA or BDAE)

Table 5. Cost effectiveness ratios by number of treatment sessions in single subject experimental aphasia interventions

Increasing Number of Sessions (Treatments)	**Improvement in Score (percentage points)**	**CE Ratio**
From 1 to 5	18.53	$9.59
From 6 to 10	10.46	$16.99
From 11 to 15	2.38	$74.60
From 16 to 20	-5.69	N/A

Note: The right column reflects the increasing cost for each 1% change in proficiency.