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OUTCOME IMPROVEMENTS IN PERSONS WITH CHRONIC GLOBAL APHASIA FOLLOWING THE USE OF A SPEECH-GENERATING DEVICE

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SUMMARY

Background Advanced computer-based interventions have demonstrated effectiveness in aphasia rehabilitation even in the chronic stage, and outcome studies using standardised assessment instruments reveal previously unstudied patterns of improvement and associated improvement magnitudes. Here we analyze persons with chronic global aphasia.

Material/Methods: Twenty subjects were assessed at intake and at discharge, at the impairment and functional communication levels, using standardized assessment instruments. During intervention, the subjects used a speech-generating device, therapeutically and communicatively, in the clinic and at home. Matched t-tests were used to measure the significance of overall improvements after intervention; and WAB assignments to same or different aphasia diagnostic category at discharge established subject subgroups, with one-way ANOVA employed to measure the significance of differences.

Results: Mean subject time post-onset was 2.7 years, and mean duration of intervention was 20.6 weeks. Following intervention, the subject means improved significantly on 3 of 5 impairment-level items, and on 15 of 17 functional-level items. Eight of the 20 subjects (40%) were recategorized to Broca's aphasia at discharge, while the others significantly improved within global aphasia. Overall, the Gl:Br subgroup scored significantly higher – among other items – in Auditory Verbal Comprehension, and at discharge in "having a spontaneous conversation". By contrast, the Gl:Gl subgroup improved much more during intervention than the Gl:Br subgroup in "getting someone's attention" and "communicating anything (including 'yes' or 'no') without words".

Conclusions: Advanced computer-based interventions can improve mean rehabilitation outcomes in chronic global aphasia at the impairment and functional communication levels. Some may be reassigned to Broca's aphasia, while others improve greatly in basic functional communication tasks that improve quality of life.

Key words: Severe Brain Injury Rehabilitation, Computerized Treatment

INTRODUCTION

Towards the end of his landmark study of the aphasias in wounded Soviet soldiers following WW II, Alexander Luria devotes several pages to a simple iconographic system for aphasia rehabilitation (Luria 1947). He reports benefits – including improved grammaticality and extended phrase length – in persons with expressive aphasia following use of this system. Though the improvements were modest, Luria's report is nonetheless significant. It first suggested, over six decades ago, that the use of augmentative and alternative communication (AAC) tools, materials, and methods can result in improvements in the natural speech-language communication of persons with aphasia.

Subsequently and independently, a team headed by Gardner and Zurif at the Boston Aphasia Research Center probed the use of an iconographic AAC system to support and expand communicative transactions in global aphasia. Test subjects treated with the low-technology Visual Communication (ViC) system showed modest but distinct communicative benefits, and the researchers concluded that – even in global aphasia – key linguistic capabilities may remain intact and potentially available for further rehabilitative exploitation (Gardner et al. 1976). Their research thus further advanced our understanding of AAC and aphasia, while also opening new areas for exploration.

When affordable personal computers with graphic user interfaces became available in the 1980s, the US Department of Veterans Affairs, though its Rehabilitation Research and Development Service, funded work to research the potential of implementing a visual communication system in this new medium for the rehabilitation of persons with aphasia. Initially, studies focused on replicating ViC research to establish that persons with aphasia could learn to operate the systems and use them to improve communication in tasks such as following commands, answering simple questions, and expressing basic emotions (Steele et al. 1987; Weinrich et al. 1989a; Weinrich et al. 1989b; Steele et al. 1989). Subsequently, attention shifted to identifying and analyzing new application areas for the evolving technologies (Weinrich & Steele 1988; Steele et al. 1992; Steele 1995).

Over the past decade and a half, researchers have devoted increasing energies to understanding the uses and quantifying the benefits of computer-based AAC systems employing graphic user interfaces in persons with aphasia (Dean 1987; Enderby 1987; Crerar et al. 1996; Katz 2001; Katz 2008). Various devices, including commercially offered devices by Lingraphica®, Dynavox®, and others, have been investigated by researchers in a variety of settings, including community-based clinical treatment programs and academic research settings (Aftonomos et al. 1997; Katz & Brown 2004; Koul et al. 2005; Koul & Corwin 2003; Corwin & Koul 2003; Koul & Harding 1998; Steele et al. 2003). The interest and activity has only grown since 2001, when Medicare and other insurers in the United States began reimbursing for the provision of speech-generating devices (SGDs) prescribed for use by individuals with aphasia.

At the same time, medical and aphasia rehabilitation researchers in academic and clinical settings continue developing new ways of using the standardized assessment instruments, refining methodologies for conducting research, and broadening our understanding of responses to therapy in a variety of aphasia types and severities (Ellwood 1988; Nicholas et al. 1993; Basso et al. 1996; Connolly et al. 1999; Carlomagno et al. 2001; Ansaldo et al. 2004; Sarno et al. 2005; Bakheit et al. 2005; Nolfe et al. 2006; Laska et al. 2007).

All these various and wide-ranging research efforts have contributed to progress, both individually and synergistically. In retrospect, we can see that the rehabilitation benefits from the marriage of iconographic AAC approaches with advanced computer technology have significantly exceeded initial expectations, which for various reasons were modest. For example, it has been positively confirmed that practice and use of computer-based iconographic AAC systems can produce improvements in the natural speech-language communication of persons with aphasia (Weinrich et al. 1995); research is delineating the improvement profiles – following SGD use – that are characteristic of persons in the various diagnostic categories of aphasia (Aftonomos et al. 1997; Aftonomos et al. 1999; Aftonomos et al. 2001); and outcome studies suggest that these improvements overall are age-independent (Steele et al. 2003).

Despite progress to date, however, research in these areas is still at an early stage. Much needs to be done to establish scopes, mean magnitudes, and ranges of improvements for persons in each of the various aphasia diagnostic categories. This needs to be done, moreover, at each of the three WHO disease classification levels individually, i.e., [1] impairment, [2] participation restriction (affecting functional communication), and [3] activity limitation (affecting role assumption and quality of life) (WHO 1980; WHO 2001). It is furthermore desirable to employ data from standardized, valid and reliable assessment instruments in this initiative. There is an opportunity to identify significantly different patterns of improvement within individual aphasia diagnostic categories at intake, to document the changes characteristic of each, and to describe how individuals within those patterns present clinically both at intake and discharge. Detailed analysis of these types and extent are likely to produce findings of both theoretical and practical clinical significance.

The current article represents a step in this undertaking. Here we analyze data from individuals with chronic global aphasia at intake, who became proficient with and used a commercially available icon-based SGD for one to several months, and who were assessed at intake and discharge using one or more standardized assessment instruments developed for persons with aphasia. We characterize these subjects demographically and clinically, quantitatively analyze their changes on each administered item of each assessment instrument, inspect rank orderings of functional communication items before and after use, and then compare and contrast the changes of the sample by subgroups, based on their discharge assignments to aphasia diagnostic categories. It is hoped that the results will prove of value to clinicians who work with persons in chronic aphasia, as well as to researchers who are looking to refine research questions and experimental hypotheses in studying the rehabilitation of persons in chronic aphasia.

METHOD

Subjects

The subjects were adults who had been diagnosed with aphasia and referred to community-based speech therapy programs. Additional criteria for inclusion in this study were: (i) assignment to the diagnostic category of global aphasia through intake administration of the Western Aphasia Battery (WAB, Kertesz 1982); (ii) aphasia chronicity, defined as program enrollment occurring more than 6 months post-onset for each patient; and (iii) administration – at intake and discharge – of both the WAB for speech-language impairment assessment and the Communicative Effectiveness Index or CETI (Lomas et al. 1989) for functional communication assessment. Altogether, 20 patients met the criteria, and they comprise the sample for this study. Table 1 characterizes the study subjects individually.

Table 1. Subjects

Patient	Etiology	Categ.	Gender	Age	YPO	Tx wks	Tx freq	WAB	CETI
1-MG	L-CVA	global	m	63	3.6	14.1	—	X	X
2-BJ	L-CVA	global	m	67	6.6	13.0	—	X	X
3-ER	L-CVA	global	m	71	2.4	20.4	2.9	X	X
4-AN	L-CVA	global	m	44	1.0	10.4	2.2	X	X
5-BT	L-CVA	global	m	73	6.7	21.7	2.2	X	X
6-MK	L-CVA	global	f	70	2.3	27.7	1.9	X	X
7-JM	L-CVA	global	f	63	1.5	15.0	1.9	X	X
8-WD	L-CVA	global	m	68	1.0	26.1	2.1	X	X
9-LW	L-CVA	global	m	64	1.9	22.1	1.7	X	X
10-RJ	L-CVA	global	m	45	3.8	12.4	0.8	X	X
11-DA	L-CVA	global	f	79	1.9	16.3	2.2	X	X
12-HS	L-CVA	global	m	68	1.3	21.3	1.6	X	X
13-JC	L-CVA	global	m	73	0.8	26.4	2.2	X	X
14-JM	L-CVA	global	f	68	9.0	25.0	1.8	X	X
15-MW	L-CVA	global	f	76	0.5	15.4	2.5	X	X
16-WG	L-CVA	global	m	60	0.7	21.4	1.6	X	X
17-RP	L-CVA	global	m	68	4.3	16.9	2.0	X	X
18-JC	L-CVA	global	f	73	1.3	23.0	3.0	X	X
19-CC	L-CVA	global	f	66	0.7	45.9	1.1	X	X
20-MC	L-CVA	global	f	85	3.0	18.3	2.5	X	X

Table 2. Summary of Demographic / Clinical Data

Characteristic	Mean (SD)	Range	No. (%)
Gender			
male			12 (60.0)
female			8 (40.0)
Age (y)	67.2 (9.7)	44–55	20 (100)
Handedness			
right			9 (45.0)
unknown			11 (55.0)
Time post-onset (y)	2.70 (2.35)	0.52–8.97	20 (100)
Etiology			
L–CVA			20 (100)
Intake assessments			
WAB AQ	13.4 (5.2)	4.4–25.3	20 (100)
CETI Overall	30.8 (13.3)	7.6–61.9	20 (100)
Treatment			
frequency (sess/wk)	2.0 (0.5)	0.8 – 3.0	20 (100)
duration (wks)	20.6 (7.8)	10.4–45.9	20 (100)
Intake/Discharge Assessments			
impairment level (WAB)			20 (100)
functional level (CETI)			20 (100)

All subjects participated in clinical treatment programs that operated under the supervision of designated Medical Directors to provide speech-therapy services for reimbursement by Medicare and/or other insurance. In accordance with hospital and clinic policies under which these programs operated and with Medicare regulations under which reimbursement was obtained, informed consent was obtained from all subjects. None of the sites acquired imaging data on the subjects. Table 2 provides a summary overview of subjects' demographic and clinical data.

Treatment

All subjects used the Lingraphica® Speech Generating Device (SGD) in the clinic and at home (Aftonomos et al. 1997). In the clinic, they participated twice a week in 1-hour, one-on-one therapy sessions with Speech-Language Pathologists (SLP), who trained the subjects in the use of programmed therapy exercises, and used a formal treatment algorithm to guide decisions regarding exercise types, difficulty levels, and activity progressions. The subjects took their SGDs home and had unrestricted access for assigned "homework," exploration of domains, word repetition, communication composition, practice, rehearsal, and the support of interactive communication with others.

Subject participation continued as long as improvement in natural speech communication could be documented; after that, the subjects were discharged.

Assessment

The subjects were assessed at intake and discharge using the language subtests of the WAB and the 16 items of the CETI. Both are standardized, valid and reliable assessment instruments providing quantitative scores at complementary levels of the WHO taxonomy of illness: the WAB assessing the impairment level, and the CETI assessing functional communication. Administrations were done in the standard ways, without the SGD present, in order to assess natural, unaided speech-language communication. The WAB was administered by the treating Speech-Language Pathologist in the clinic, and the CETI ratings were completed by someone close to the subject – most often a spouse or other family member, occasionally a unrelated caregiver – who was familiar with the communicative style of the subject before the onset of aphasia. The resulting scores comprise valid, reliable quantitative data on 22 assessed items (WAB – 5, CETI – 17), from a sample of 20 subjects, at both intake and discharge.

Data Analysis

Raw data were entered into the Data Desk® application for statistical and exploratory data analysis (James 1998; Tukey 1977). We first investigated within-subject changes, to compare the performance of individuals before and after program participation. To investigate change over time, we calculated the existence, magnitude, and direction of the difference of means before and after program participation, and then established the statistical significance of those differences, using matched t-tests (Student's test). This yields a before/after comparison on each of the 5 assessed items of the WAB, and on each of the 17 assessed items of the CETI. The paired t–tests thus scrutinize 22 independent and orthogonal items: independence is clear prima facie for the items of the WAB, and it was established through factor analysis during construction of the CETI (Lomas et al. 1989). This approach yields rich outcome detail at two complementary levels, i.e., impairment and functional communication.

We then partitioned our sample into two subgroups, based on assignment to aphasia diagnostic category at discharge, and analyzed how they compared at intake, during participation, and at discharge. Thus, for each subgroup at each time, means and standard deviations were calculated, the existence, magnitude, and performance levels of subgroups calculated, and one-way analyses of variance (ANOVA) were used to calculate the statistical significance of the difference of the means.

In all cases, the level for rejection of the null hypothesis was set at $p < .05$ (Hatch & Farhady 1982).

RESULTS

Overall: At the impairment level (see Table 3), matched t-tests show that the overall sample of 20 subjects improved significantly in two of the four WAB language subtests (Auditory Verbal Comprehension, Naming) and in the computed Aphasia Quotient (AQ); the remaining two language subtests (Spontaneous Speech, Repetition) showed no significant changes. Of those items showing significant improvements, mean Auditory Verbal Comprehension scores rose from 60.7 at intake to 72.8 at discharge, an improvement of

Table 3. Impairment-level changes after SGD use

Item	n	Initial Mean (SD)	Final Mean (SD)	Diff (SD)	t_{obs}	p
Spontaneous speech	20	2.4 (1.5)	2.8 (2.0)	+ 0.4 (1.5)	+1.22	≤ .237
Auditory Verbal Comprehension	20	60.7 (12.8)	72.8 (19.4)	+12.1* (14.4)	+3.77	≤ .002
Repetition	20	9.2 (14.4)	13.8 (14.3)	+ 4.6 (11.5)	+1.82	≤ .085
Naming	20	4.2 (5.6)	7.5 (8.4)	+ 3.3* (4.6)	+3.07	≤ .007
Aphasia Quotient (AQ)	20	13.4 (5.2)	17.0 (6.1)	+ 3.6* (3.9)	+4.14	≤ .001

*$p < .05$

Table 4. Functional Communication Changes, After SGD Use

CETI Item Nº	n	Initial Mean (SD)	Final Mean (SD)	Diff (SD)	t_{obs}	p
1	20	58.8 (31.4)	71.4 (23.2)	+12.6* (20.1)	+2.79	≤ .02
2	19	30.0 (18.4)	42.6 (23.2)	+12.6* (10.2)	+5.37	≤ .001
3	20	37.8 (22.2)	56.9 (20.5)	+19.1* (11.7)	+7.33	≤ .001
4	20	42.1 (23.3)	59.1 (20.2)	+17.0* (10.3)	+7.38	≤ .001
5	20	51.4 (21.8)	65.8 (19.3)	+14.4* (15.3)	+4.22	≤ .001
6	20	37.2 (29.0)	48.0 (19.4)	+10.8* (15.7)	+3.07	≤ .01
7	20	31.8 (22.5)	41.0 (25.3)	+ 9.2* (8.3)	+4.99	≤ .001
8	20	18.2 (21.2)	31.1 (23.1)	+12.9 (28.2)	+2.04	= .055
9	20	26.5 (18.4)	43.6 (20.7)	+17.1* (17.4)	+4.39	≤ .001
10	20	22.1 (21.8)	33.5 (24.1)	+11.4* (13.8)	+3.71	≤ .01
11	20	43.7 (30.4)	60.7 (24.7)	+16.5* (22.3)	+3.32	≤ .01
12	20	22.2 (25.7)	31.8 (25.8)	+ 9.6* (12.2)	+3.51	≤ .01
13	19	27.7 (26.6)	45.8 (31.8)	+18.1* (17.2)	+4.58	≤ .001
14	19	15.1 (15.1)	18.6 (20.4)	+ 3.5 (11.3)	+1.36	= .19
15	20	15.3 (20.1)	20.1 (20.3)	+ 4.8* (6.8)	+3.15	≤ .01
16	20	11.1 (13.4)	15.9 (15.1)	+ 4.8* (5.7)	+3.74	≤ .01
1–16 Overall	20	30.8 (13.3)	42.8 (14.4)	+12.0* (7.3)	+7.39	≤ .0001

*$p < .05$

+12.1% ($p < .002$); mean Naming scores increased from 4.2 at intake to 7.5 at discharge, an improvement of +3.3% ($p < .007$); and mean AQ scores went from 13.4 at intake to 17.0 at discharge, an improvement of +3.6% ($p < .001$). Quantitatively, all these improvements are of modest magnitude.

At the functional communication level (see Table 4), matched t-tests show that the overall sample of 20 subjects improved significantly in fourteen of the sixteen CETI items rated, as well as in the means of Items 1-16 Overall. Only (i) Item 8 ("Saying the name of someone whose face is in front of him/her") and (ii) Item 14 ("Being part of a conversation when it is fast and there are a number of people involved") showed no significant change. The magnitudes of the significant improvements ranged from + 4.8% (Items 15 & 16) to +19.1% (Item 3). Overall, the means of Items 1-16 for subjects – an indication of functional communication improvement generally in the sample – rose from 30.8 at intake to 42.8 at discharge, an improvement of +12.0% ($p < .0001$).

Table 5 identifies the 16 items assessed by the CETI, and gives rank orders of the subjects' mean scores for these items at intake and discharge.

Table 5. Rank Orders of CETI Items Before/After SGD Use

Rank Orders at:		
Intake	Discharge	CETI Item (number & verbatim phrasing)
1	1	# 1. Getting somebody's attention
2	2	# 5. Indicating that he/she understands what is being said to him/her
3	3	#11. Responding to or communicating anything (including *yes* or *no*) without words
4	4	# 4. Communicating his/her emotions
5	5	# 3. Giving *yes* and *no* answers appropriately
6	6	# 6. Having coffee-time visits and conversations with friends and neighbors (around the bedside or at home)
7	10	# 7. Having a one-to-one conversation with you.
8	9	# 2. Getting involved in groups conversations that are about him/her
9	7	#13. Understanding writing
10	8	# 9. Communicating physical problems such as aches and pains
11	12	#12. Starting a conversation with people who are not close family
12	11	#10. Having a spontaneous conversation (*i.e.,* starting the conversation and/or changing the subject)
13	13	# 8. Saying the name of someone whose face is in front of him/her
14	14	#15. Participating in a conversation with strangers
15	15	#14. Being part of a conversation when it is fast and there are a number of people involved
16	16	#16. Describing or discussing something in depth

'Before ~ After' Spearman Rank Order Correlation Coefficient: $\rho = .9853$

Towards the top of the table are the items with higher numerical ratings, signaling greater communicative success; and towards the bottom are the more challenging items, with lower numerical ratings. At page bottom, we report the calculated Spearman Rank Order Correlation Coefficient for the intake and discharge orderings – ρ = .9853 – indicative of high overall stability of ordering.

By Discharge Groups: The WAB assigns subjects to aphasia diagnostic categories based on the values and patterns of subject scores on their individual language subjects. One criterion for inclusion in this study was WAB assignment at intake to the diagnostic category of global aphasia. Readministration of the WAB to all subjects at discharge showed that 12 of the 20 subjects (60%) continued in the category of global aphasia, while the remaining 8 subjects (40%) were reassigned to the less severe diagnostic category of Broca's aphasia. Using these discharge assignments, we partitioned the overall sample into two subgroups: [i] those whose discharge assignment remained global aphasia (i.e., the Gl:Gl group); and [ii] those whose discharge assignment changed to Broca's aphasia (i.e., the Gl:Br group). Mean scores for each of these subgroups can be computed separately, compared, and tested for statistical significance using analyses of variance (ANOVA). This approach reveals whether the group means differ significantly: (i) at intake; (ii) in improvement, during program participation; and (iii) at discharge.

At the impairment level: At intake (Table 6), one-way ANOVAs of raw data show that WAB mean scores for the Gl:Br group are significantly higher than mean scores for the Gl:Gl group on two language subtests: namely, Auditory Verbal Comprehension and Naming. The mean Auditory Verbal Comprehension score of the Gl:Gl group at intake was 55.2, while that for the Gl:Br group at intake was 68.9. The difference of 13.7, in favor of the Gl:Br group, is significant at the p = .014 level. The mean Naming score for the Gl:Gl group at intake was 1.9, while that for the Gl:Br group was 7.5 – a significant difference of 6.6 (p = .026), again favoring the Gl:Br group.

At discharge (Table 6), the impairment-level picture resembles the intake picture, with the Gl:Br group scoring significantly higher in the mean than the Gl:Gl group on Auditory Verbal Comprehension and Naming; but now the mean differences by group are yet greater than at intake, as are also the associated p values. Of particular note, at discharge the Gl:Br group outscored the Gl:Gl group in Auditory Verbal Comprehension by 31.7 points, and the means are very widely separated (F = 36.50, p << .0001). Over the same period, Gl:Br's advantage in Naming has risen to 8.9 points (p = .016).

One-way ANOVA of improvements during program participation (Table 6) shows that the Gl:Br group improved significantly more than the Gl:Gl group on one language subtest, namely, Auditory Verbal Comprehension. The Gl:Gl group improved their mean scores by +4.9, while the Gl:Br group improved theirs by +22.9; the difference of +18.0* – favoring the Gl:Br group – is significant at the p = .003 level.

Table 6. Impairment-level ANOVAs: Global:Global (12) vs. Global:Broca's (8)

WAB Item	Gl:Gl Means	Gl:Br Means	Diff	*F*-ratio	p
Intake Assessments					
Spontaneous Speech	2.5	2.1	(0.4)	0.31	= .588
Auditory Verbal Comprehension	55.2	68.9	13.7*	7.41	= .014
Repetition	8.3	10.5	2.2	0.11	= .742
Naming	1.9	7.5	5.6*	5.92	= .026
AQ	12.6	14.7	2.1	0.84	= .372
Improvements (Δ) during Participation					
Spontaneous Speech	+0.5	+ 0.2	(0.3)	0.13	= .719
Auditory Verbal Comprehension	+4.9	+22.9	18.0*	11.70	= .003
Repetition	+2.3	+ 8.1	5.8	1.24	= .280
Naming	+2.0	+ 5.3	3.3	2.36	= .142
AQ	+2.3	+ 5.5	3.2	3.45	= .080
Discharge Assessments					
Spontaneous Speech	3.0	2.3	(0.7)	0.43	= .519
Auditory Verbal Comprehension	60.1	91.8	31.7*	36.50	<< .0001
Repetition	10.6	18.6	8.0	1.56	= .229
Naming	3.9	12.8	8.9*	7.08	= .016
AQ	14.9	20.2	5.3	4.26	= .054

*$p < .05$

In functional communication: at intake (Table 7), one-way ANOVA on CETI data shows that mean scores for the Gl:Br group are significantly higher than for the Gl:Gl group on three items, namely #1 ("Getting somebody's attention"), #7 ("Having a one-to-one conversation with you"), and #11 ("Responding to or communicating anything [including yes or no] without words"). Differences on the 13 remaining items are non-significant.

By discharge (Table 7), the Gl:Br group scored significantly higher than the Gl:Gl group on two CETI items, namely #7 ("Having a one-to-one conversation with you") and #10 ("Having a spontaneous conversation [i.e., starting the conversation and/or changing the subject]"). While they continue to score higher on two other items – #1 and #11 – their advantages on these are no longer significant, as they were at intake. For these latter two items, then – as on all remaining items – differences in group means at discharge are not significant.

Table 7. Functional Communication ANOVAs: Global:Global(12) vs. Global:Broca's (8)

CETI Item Nº	GI:GI Means	GI:Br Means	Diff	*F*-ratio	p
Intake Assessments					
1 - re: getting attention	46.3	77.6	31.3*	6.07	= .024
2 - re: group conv. about self	26.3	36.3	10.0	1.31	= .268
3 - re: answering yes/no	33.9	43.6	9.7	0.91	= .352
4 - re: commun. emotions	36.7	50.3	13.6	1.69	= .210
5 - re: indicating understanding	47.3	57.4	10.1	1.02	= .325
6 - re: coffee-time visits	30.5	47.3	16.8	1.66	= .215
7 - re: one-to-one conv.	23.1	44.9	21.8*	5.57	= .030
8 - re: saying person's name	19.8	15.6	-4.2	0.18	= .676
9 - re: comm. phys. problems	23.8	30.8	7.0	0.69	= .418
10 - re: spontaneous conv.	19.3	26.3	7.0	0.48	= .497
11 - re: responding w/o words	30.5	63.4	32.9*	7.53	= .013
12 - re: starting conversations	20.5	24.8	4.3	0.13	= .727
13 - re: understanding writing	29.8	24.3	-5.5	0.18	= .678
14 - re: fast conv., many people	15.4	14.6	-0.8	0.01	= .920
15 - re: conv. with strangers	14.8	16.0	1.2	0.02	= .903
16 - re: in-depth discussions	12.0	9.8	-2.2	0.13	= .724
1–16 Overall	26.9	36.3	9.4	2.78	= .113
Improvements (Δ) during Participation					
1 - re: getting attention	+18.0	+ 4.3	(13.7)	2.44	= .136
2 - re: group conv. about self	+10.4	+16.4	6.0	1.63	= .219
3 - re: answering yes/no	+20.4	+17.2	-3.2	0.37	= .551
4 - re: commun. emotions	+18.3	+15.0	-3.3	0.49	= .494
5 - re: indicating understanding	+15.2	+13.4	-1.8	0.06	= .805
6 - re: coffee-time visits	+13.2	+ 7.2	-6.0	0.67	= .424
7 - re: one-to-one conv.	+ 8.1	+10.9	2.8	0.54	= .473
8 - re: saying person's name	+10.3	+16.9	6.6	0.25	= .621
9 - re: comm. phys. problems	+17.5	+16.3	-1.2	0.02	= .892
10 - re: spontaneous conv.	+ 5.4	+20.3	14.9*	7.66	= .013
11 - re: responding w/o words	+26.0	+ 2.2	(23.8)*	7.29	= .015
12 - re: starting conversations	+ 5.9	+15.0	9.1	2.95	= .103
13 - re: understanding writing	+18.8	+16.8	-2.0	0.05	= .817
14 - re: fast conv., many people	+ 2.6	+ 4.8	2.2	0.15	= .699
15 - re: conv. with strangers	+ 5.5	+ 3.8	-1.7	0.31	= .587
16 - re: in-depth discussions	+ 6.8	+ 1.8	-5.0	4.02	= .060
1–16 Overall	+12.8	+11.3	-1.5	0.27	= .610

One-way ANOVA of improvements during program participation (Table 7) shows that each group has one item of significantly greater improvement than the other. The GI:Br group improved significantly more than the GI:GI group on #10 ("Having a spontaneous conversation [i.e., starting the conversation and/or changing the subject]"). In contrast, the GI:GI group improves significantly more than the GI:Br group on #11 ("Responding to or communicating anything [including yes or no] without words").

Table 7 cont. Functional Communication ANOVAs: Global:Global(12) vs. Global:Broca's (8)

Discharge Assessments					
1 - re: getting attention	64.3	81.9	17.6	3.03	= .099
2 - re: group conv. about self	36.7	52.7	16.0	2.27	= .150
3 - re: answering yes/no	54.3	60.8	6.5	0.46	= .508
4 - re: commun. emotions	55.0	65.3	10.3	1.26	= .277
5 - re: indicating understanding	62.5	70.8	8.3	0.87	= .362
6 - re: coffee-time visits	43.7	54.5	10.8	0.72	= .407
7 - re: one-to-one conv.	31.2	55.8	24.6*	5.62	= .029
8 - re: saying person's name	30.1	32.5	2.4	0.05	= .826
9 - re: comm. phys. problems	41.3	47.1	5.8	0.39	= .539
10 - re: spontaneous conv.	24.7	46.6	21.9*	4.77	= .042
11 - re: responding w/o words	56.5	65.6	9.1	0.64	= .433
12 - re: starting conversations	26.4	39.8	13.4	1.30	= .269
13 - re: understanding writing	48.6	41.1	-7.5	0.24	= .631
14 - re: fast conv., many people	18.0	19.4	1.4	0.02	= .889
15 - re: conv. with strangers	20.3	19.8	-0.5	0.01	= .952
16 - re: in-depth discussions	18.8	11.6	-7.2	0.95	= .342
1–16 Overall	39.7	47.6	7.9	1.49	= .237

$^{*}p < .05$

Group Relationships, Categorized: Table 8 extracts from Tables 5 and 6 those items where significant differences between the Gl:Gl group (n = 12) and the Gl:Br (n = 8) group are documented at one or more points in time, and organizes the findings to highlight endpoint relationships. Three patterns were found: [i] the Gl:Gl group starts at a significant disadvantage with respect to the Gl:Br group, but overcomes that disadvantage over the period of the study; [ii] the Gl:Br group starts with significant advantages over the Gl:Gl group, and holds those advantages stable over the course of the study; and [iii] the Gl:Br group improves in ways and at magnitudes that confer upon it qualitatively new advantages over the Gl:Gl group by the time of discharge.

Inspection shows that – at the impairment level – the two WAB items showing significant group differences (i.e., Auditory Verbal Comprehension, Naming) both favor the Gl:Br group. In contrast, at the functional communication level, there is some balance: in two CETI items (#1, #11), the Gl:Gl group holds the advantage, catching up with the Gl:Br group by discharge and ending up not significantly worse; while in two other CETI items (#7, #10), the Gl:Br group is the favored one, starting out and/or ending up significantly better than the Gl:Gl group.

DISCUSSION

The current findings extend and refine results reported in earlier studies, and open new territory by describing differential improvement patterns by discharge diagnoses that have not previously been closely investigated.

Table 8. Subgroup ANOVA endpoint relationships, categorized

Gl:Gl Group Catches Up with Gl:Br Group		
at Intake	Gl:Gl ∆ Advantage	at Discharge
CETI #1 – Getting somebody's attention		
Gl:Gl significantly worse (*p* = .024)	13.7 ns	Gl:Gl not significantly worse ns
CETI #11 – Responding to or communicating anything (including yes and no) without words		
Gl:Gl significantly worse (*p* = .013)	23.8* (*p* = .015)	Gl:Gl not significantly worse ns
Gl:Br Group Holds On to Initial Significant Advantage		
at Intake	Gl:Br ∆ Advantage	at Discharge
WAB – *Naming*		
Gl:Br significantly better (*p* = .026)	3.3 ns	Gl:Br significantly better (*p* = .016)
CETI #7 – Having a one-to-one conversation with you		
Gl:Br significantly better (p = .030)	2.8 ns	Gl:Br significantly better (p = .029)
Gl:Br Group Improves Qualitatively, via Significant Quantitative Improvements		
at Intake	Gl:Br ∆ Advantage	at Discharge
WAB – Auditory Verbal Comprehension		
Gl:Br significantly better (*p* = .014)	18.0* (*p* = .003)	Gl:Br vastly better (*p* << .0001)
CETI #10 – Having a spontaneous conversation (i.e., starting the conversation and/or changing the subject		
Gl:Br not significantly better ns	14.9* (*p* = .013)	Gl:Br significantly better (p = .042)

This study corroborates earlier findings that persons in the chronic stage of global aphasia may well be candidates for further statistically significant improvements following SGD therapy and use, at both the impairment and functional communication levels. Generally, improvements at the impairment level are modest in magnitude (e.g. single-digit percentages), while improvements in functional communication may be sizable (e.g. double-digit percentages). Regardless of magnitude, however, these improvements can be important practically. For persons with global aphasia, who start from a low base, these gains may represent important steps, contributing out of proportion to their limited magnitude to more effective communication and improved quality of life.

Earlier studies had reported significant impairment-level improvements for persons with chronic global aphasia, and that a sizable minority of persons with chronic global aphasia move to Broca's aphasia following SGD use (Aftonomos et al. 1999), but these reports were confined to the WAB AQ, an overall measure of involvement (Aftonomos et al. 1999; Aftonomos et al. 2001). The current study extends the analysis of this phenomenon, by using data from both the impairment and functional communication levels in comparing the two groups, Gl:Gl and Gl:Br. We report each of the sixteen rated items of the CETI individually, in addition to the overall improvement previously reported.

At the impairment level, data analysis corroborates the received clinical wisdom that chronic global aphasia is refractory, difficult to remediate. Scores on two of the four language subtests (50%) were low at intake and showed no significant improvement by discharge. The overall measure of involvement – the WAB AQ – showed an improvement that, while statistically significant ($p < .001$), is of modest clinical importance at best, registering a mean only in the low single digits (+3.6*).

At the functional communication level, improvements are larger and more consistent. Of the sixteen CETI items rated, fourteen (87.5%) showed improvements that were statistically significant ($p \leq .02$), of which ten (62.5%) were double-digit in magnitude (11.4–19.1). The findings establish that persons with chronic global aphasia may be candidates for widespread noteworthy improvements in functional communication, even in the face of severe, stubborn impairment-level deficits. They also suggest that metalinguistic factors, such as attention, focus, motivation and communicative environment, can play key roles, given the mostly static language assessments during the course of treatment. The question of just which non-linguistic factors are contributing, how, and why, thus emerges as an issue for future research.

Most strikingly, at the impairment level, the Gl:Br group significantly outperforms the Gl:Gl group in Auditory Verbal Comprehension at intake, in improvement, and at discharge, and the advantage grows larger with time. At intake, the Gl:Br group's raw AVC score is 25% larger than the Gl:Gl group's; by discharge, the advantage is 50% larger. It is surprising to find this change among persons in the chronic stage of global aphasia; it is surprising to find it affecting such a large minority (40%) of these cases; and it is very surprising to find over 35 standard deviations separating the means of the two groups by discharge. Clearly in some individuals with global aphasia, AVC holds unrealized potential for substantial improvement; and initial AVC scores may help identify these persons. Future controlled experimental research designs may help us build on this knowledge, to develop clinical tools to improve treatment goal formulation, prognoses, and intervention selection and application.

Perhaps equally important is the finding that not all quantitatively large changes favor the Gl:Br group. On two quite basic items of functional communication – namely, CETI #1: 'Getting somebody's attention', and CETI #11: 'Responding to or communicating anything (including yes or no) without words' – the Gl:Gl group improved during treatment much more than did the Gl:Br group. As a result, by time of discharge the initial significant advantage of the Gl:Br group over the Gl:Gl group is removed. In effect, persons in the Gl:Gl group improve sufficiently to become – by discharge – indistinguishable in these tasks from persons who evolve to Broca's aphasia. This is no small thing, either clinically or functionally: in persons with global aphasia, such changes can contribute in key ways to success in everyday communicative transactions, improving satisfaction and helping to raise quality of life.

Several considerations influenced the selection of data analysis techniques employed in this study. The first consideration was directness: matched t-tests are the simplest and most direct method permitting establishment of magnitude and significance of a sample's change over time, item by item; and one-way ANOVA is analogously the first-order way of comparing and contrasting changes in those assessed items, subgroup by subgroup. Where assessed items are all orthogonal – a prima facie property of the WAB items, and a constructed property of the CETI items – the large number of tests is not a problem per se, and the results comprise a picture of broad and rich detail. A second consideration was maintenance of comparability with previously reported analyses. Earlier publications had employed these statistical tests, but had focused primarily on analyzing data from summary measures, e.g., the WAB AQ, the CETI Overall. The present report supports both direct comparison with previously published analyses, and examination of important details behind those summary results. And finally, a third consideration was to avoid introducing Type II errors by utilizing techniques that overly fragment the initial sample of 20. Partitioning that sample into Gl:Gl and Gl:Br produces subgroups of 12 and 8 respectively, on the edge of acceptability. Further partitioning – say, for examining interaction effects – seems ill advised until sample size is increased.

An important caveat regarding generalization of findings requires mention. The subjects whose data are reported and analyzed here do not constitute a randomly selected sample of persons with chronic global aphasia. Rather, this was a self-selected group of persons in chronic aphasia that chose to participate in a treatment program employing an advanced treatment technology. They are likely not representative generally of persons with chronic global aphasia, in at least two respects: (i) they presumably subjectively felt they were capable of further improvement at time of intake; and (ii) they were not dissuaded by the introduction of an unfamiliar technology. These considerations do not negate the validity or importance of findings reported here, but they do prompt the question of how widespread such outcomes would be among all persons with chronic global aphasia. This is a question that only future research can answer.

We note in addition that the current findings emerge from an outcome study, which is a variety of post-hoc analysis. An inherent limitation of outcome studies is that they do not allow for the attribution of causality – whether to SGD features, to length of use sessions, to engagement in particular activities, or to any other factors. Attribution of causality requires controlled, experimental research designs. Nonetheless, as Ellwood importantly noted in his 1988 Shattuck Lecture (Ellwood 1988), through well conceived, executed and reported outcome studies clinical practitioners may make significant contributions to medical science, in two ways. First, quantitatively superior clinical outcomes may help identify and refine best practices for everyday clinical service delivery; and second, emergent findings in outcome studies may help shape the formulation of questions and selection of the investigative methodologies employed in subsequent controlled, experimental research designs (Ellwood 1988).

CONCLUSIONS

As it stands, this outcome study provides some valuable new insights into the types and magnitudes of improvements that may be found in persons with chronic global aphasia following treatment with an SGD. It corroborates the hypothesis that global aphasia is typically refractory at the impairment level, but that functional communication is often amenable to changes of importance in quality of life. It shows that some persons in chronic global aphasia may improve enough to evolve to severe Broca's aphasia, and that even those who do not nonetheless can improve greatly in basic functional communication. It helps identify issues that may merit future controlled, experimental research, and it suggests fruitful directions for work to improve clinical tools, materials, and methods. Considering that chronic global aphasia is often viewed as unpromising for clinical intervention, the current findings suggest new grounds for engagement and hope.

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