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C-Speak Aphasia Alternative Communication Program for People with Severe Aphasia: Importance of Executive Functioning and Semantic Knowledge

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Abstract

Learning how to use a computer-based communication system can be challenging for people with severe aphasia even if the system is not word-based. This study explored cognitive and linguistic factors relative to how they affected individual patients' ability to communicate expressively using *C-Speak Aphasia*, *(CSA)*, an alternative communication computer program that is primarily picture-based. Ten individuals with severe non-fluent aphasia received at least six months of training with *CSA*. To assess carryover of training, untrained functional communication tasks (i.e., answering autobiographical questions, describing pictures, making telephone calls, describing a short video, and two writing tasks) were repeatedly probed in two conditions: 1) using *CSA* in addition to natural forms of communication, and 2) using only natural forms of communication, e.g., speaking, writing, gesturing, drawing. Four of the ten participants communicated more information on selected probe tasks using *CSA* than they did without the computer. Response to treatment also was examined in relation to baseline measures of non-linguistic executive function skills, pictorial semantic abilities, and auditory comprehension. Only nonlinguistic executive function skills were significantly correlated with treatment response.

Keywords

Aphasia; Alternative and Augmentative Communication (AAC); Executive Functioning; Semantics; Treatment

Introduction

Many individuals with severe aphasia never recover functional verbal and written expression skills. These individuals are unable to communicate even basic social information such as expressing a birthday greeting on the telephone or answering a conversational question about a family member. In these cases, the focus of communication treatment may be redirected from speech and writing to the use of alternative modalities for expression such as drawing or gesturing, or using external communication aids such as a laptop or mini-computer. Advances in technology have resulted in the development of many picture-based communication devices that have been tried in clinical settings with people with severe

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aphasia. New applications for devices such as the iTouch™ and iPad™ are being developed regularly, as are applications for other handheld computers. Given the increasing number of computerized communication options for people with severe aphasia (PWSA), it is surprising that few well-controlled studies of treatment efficacy or outcomes of their use have been published. Such studies would provide information to guide clinicians in selecting viable candidates for alternative communication systems, i.e., those PWSA most likely to use these applications *functionally* to supplement their communication.

Many of the published studies of computerized communication systems are single case reports that highlight the usefulness of a specific alternative approach for a particular individual (Hough & Johnson, 2009; Johnson, Hough, King, Vos, & Jeffs, 2008; McKelvey, Dietz, Hux, Weissling, & Beukelman, 2007.) Unfortunately, there are no single case reports of individuals who are *not* successful at using these devices to benefit their communication; presumably these reports would not be deemed worthy of publishing. Yet, in clinical settings it is not uncommon for clinicians and family members to report that expensive AAC (alternative and augmentative communication) systems purchased for PWSA are not being used, a problem sometimes referred to as the "it's on the shelf" phenomenon. Some clinicians and family members even mistakenly interpret this non-use as the person with aphasia's *refusal* to use an augmentative system, when the difficulty should probably be interpreted as an inability to use the system independently due to a combination of cognitive and language deficits. Independent use of AAC devices is critical for productive functional communication. Beukelman and others (Beukelman, Fager, Ball, & Dietz, 2007; Beukelman, Ball, & Fager, 2008; Lasker & Bedrosian, 2001; Lasker & Garrett, 2006) have classified AAC users with respect to their level of independent use of the AAC modality. Some individuals are classified as dependent users who require the assistance of others, while others are designated as relatively independent. These authors have emphasized the importance of considering the entire communication situation in the "AAC acceptance model" including the milieu, the person, and the technology (Lasker & Bedrosian, 2001; Lasker & Garrett, 2006). Importantly, however, the critical underlying cognitive mechanisms that allow one individual to be an independent AAC user while another individual is unable to become an independent user have not been clearly identified. Consideration of cognitive mechanisms underlying successful use would fall under the category of "the person" in the AAC classification model.

In addition to attention and memory which are basic cognitive requirements for *learning* any new process, the skills that are typically grouped under the domain of "executive functions" are integral to productive functional communication through any mode possible. Among these "executive" skills are planning, initiation and follow through, self control, self monitoring, and self correction. To illustrate, consider the example of a person without aphasia who suddenly finds herself in a foreign country and is unable to comprehend or speak the language of the environment. She would be able to think of and initiate alternative ways to express herself, perhaps by drawing pictures, or pantomiming, or pointing to objects in the immediate area. She would be able to monitor whether her message was being received correctly, and would adjust her output accordingly, perhaps trying a new modality of expression to revise the first communicative attempt. In effect, she would be using her intact executive function skills, including problem solving, monitoring, and cognitive flexibility to find a solution to her communication dilemma. Persons with severe aphasia find themselves in a similar situation in so far as they are unable to comprehend and unable to express themselves via natural language. Some are quite resourceful and turn to a variety of clever ways to get their messages communicated. Others, however, do not figure out alternative ways to communicate on their own; in effect, they are unable to find a solution to their communication dilemma. Even after months of treatment focused specifically on developing and using alternative modalities, many PWSA remain unable to use these means to communicate successfully (Purdy, 2002.)

After years of anecdotal clinical evidence, research suggests that it is additional cognitive deficits in the domain of executive function in conjunction with the language disorder that may be partially responsible for unsuccessful communication in people with aphasia (Fridriksson, Nettles, Davis, Morrow, & Montgomery, 2006; Helm-Estabrooks, 2002; Purdy, 2002; Purdy & Koch, 2006; Van Mourik, Verschaeve, Boon, & Paquier, 1992). Individuals with left hemisphere damage resulting in severe aphasia often show other non-linguistic deficits on neuropsychological testing, deficits that may hinder their ability to become independent users of alternative communication systems in any modality (Alexander, Benson, & Stuss, 1989; Fine et al., 2009; Kertesz, 1988; Murray & Ramage, 2000.)

Only a few studies have focused on the relation between selected executive function skills and response to treatment of communication deficits, but investigators have found that relative preservation of executive functions is important to good response both to language-based treatments (Fillingham, Sage, & Lambon Ralph, 2005; Lambon Ralph, Snell, Fillingham, & Conroy, 2010; Lambon Ralph & Fillingham, 2007) and nonlinguistic communication treatments, (e.g., Purdy, 2002; Purdy & Koch, 2006; van de Sandt-Koenderman et. al, 2007). Individuals with executive function impairments did not spontaneously shift to using alternate modes of communication such as gesturing or pointing to items on a communication board despite having been successfully trained to do so in treatment tasks (Purdy, 2002; Purdy & Koch, 2006).

Most computer-assisted picture-based communication systems organize vocabulary into semantic sets for ease of access; subsequently, relatively intact semantic categorization abilities also would be important to functional use of such systems. Indeed, some researchers (e.g., van de Sandt- Koenderman, Wiegers, Wielaert, Duivenvoorden, & Ribbers, 2007) have stressed the importance of intact semantic abilities for using a computer alternative communication system known as *TouchSpeak*. In 1999, Nicholas found that PWSA who were being considered as candidates for an alternative computer-based communication system generally performed quite well on experimental tasks assessing their ability to make nonverbal semantic category judgments about pictorial material. These observations motivated exploration of the relative importance of both domains of cognition, executive functioning and semantic knowledge, for effectively communicating with a computer device in participants who received training to use *C- Speak Aphasia*.

Computer-based communication systems that are appropriate for people with aphasia must be picture-based rather than text-based because of the difficulties with reading and spelling that are nearly always part of the language disorder of aphasia. One such computer program, *C-Speak Aphasia* (*CSA*) Nicholas & Elliott, 1998), is a picture-based software program that was developed specifically for people with severe non-fluent aphasia. In an earlier report (Nicholas, Sinotte, & Helm-Estabrooks, 2005) the preliminary results from the first series of single-subject analyses indicated that several individuals with severe aphasia demonstrated improved functional communication using *CSA* after a period of treatment. Those who also demonstrated relatively preserved executive function skills learned to use *C-Speak Aphasia* better than those who had deficits in these skills. The purposes of the current study were to investigate if these results could be replicable in a larger sample of individuals and to continue to investigate cognitive factors that may be relevant to response to training with *CSA* and similar alternative communication programs.

The *C-Speak Aphasia* program used in this study is conceptually based on the C-ViC program (Steele, Weinrich, Wertz, & Kleczewska, 1989; Steele, Kleczewska, Carlson, & Weinrich, 1992), that itself was a precursor to *Lingraphica* (Aftonomos, Steele, Appelbaum, & Harris, 2001). Using *C-Speak Aphasia*, patients learn to select icons from semantic-category groups and put them together to create novel messages in the form of statements, commands, and questions. Each message can be spoken aloud by the computer's speech synthesizer by clicking on the message display area. All individual vocabulary items are represented as pictures with the English word written above the picture. There are also specialized screens to assist in social communication activities such as conversing on the telephone, writing, sending e-mail messages, and expressing autobiographical information. *CSA* is operated using the *Speaking Dynamically Pro* application available from the Mayer-Johnson Company, (King Software Development, 1997). A version of *CSA* that can be operated on handheld mini-computers also has been developed by the first author. The handheld version was created using a different software package called Point-to-Pictures Mobile (available at rjcooper.com) but was designed to be as similar as possible to the laptop version. Figure 1 depicts two sample *C-Speak Aphasia* screens with a statement (daughter study school September 5) on the top and a question (Woman go beach?) in the message display area on the bottom.

In the current study it was investigated whether individuals with severely limited verbal output due to aphasia could significantly improve their functional communication skills by using the *C-Speak Aphasia* program as an alternative means of expression. The following hypotheses were tested: 1) some individuals would be able to improve functional communication significantly using the *C-Speak Aphasia* system, 2) measures of executive functioning (EF) would be related to response to *C-Speak Aphasia* training in that participants with preservation of EF would be able to use *C-Speak Aphasia* to improve functional communication better than participants with impaired EF skills, and 3) nonverbal pictorial semantic abilities would be relatively preserved in most participants and thus would not necessarily relate to treatment response. An important aspect of the current study design which distinguishes it from previously published single case studies is that generalization of treatment effects to real-life functional communication contexts was repeatedly measured throughout treatment. Studies that provide evidence with respect to candidacy for and/or treatment efficacy of alternative computer-based communication systems for PWSA are limited. However, these particular investigations have potential to provide insights into mechanisms underlying positive response to treatment and, therefore, aid clinicians in treatment planning and selection of appropriate devices or software programs for each PWSA (Beukelman et al., 2007; Schlosser, 2003; Schlosser, 2003; Schlosser, Koul, & Costello, 2007; van de Sandt-Koenderman, 2004).

Methods

Overview

The study used a multiple baseline design in which 10 individuals served as their own controls. Participants received three baseline assessments and then entered into a treatment program to learn the *C-Speak Aphasia* program. To measure treatment outcomes, the amount of meaningful, relevant information each participant expressed on five functional communication tasks was compared across two conditions (using *CSA*, referred to as "on-computer", and not using it, referred to as "off-computer.") The functional communication tasks were repeatedly probed during a treatment period extending at least six months. Additional details of the testing and treatment protocol are described in the next sections.

Participants

There were 10 participants (3 females), who all were at least 10 months post-onset relative to large left-hemisphere CVAs resulting in severe non-fluent aphasia. All had phrase length in verbal output of less than or equal to one word in spontaneous speech; six participants produced primarily verbal stereotypies when speaking. Participants displayed a range of auditory comprehension abilities, as well as a range of nonverbal cognitive impairments. Aphasia diagnoses ranged from global aphasia to mixed non-fluent aphasia to severe Broca's aphasia, depending on the degree of auditory comprehension impairment. Participant demographic characteristics are presented in Table 1.

Baseline Assessments

Baseline assessments were completed in three areas: 1) standardized testing of language and nonverbal cognitive skills related to visual processing and executive functioning, 2) semantic knowledge tasks, and 3) repeated assessments (three times each) of the five functional communication probe tasks to insure stability of performance prior to initiating the treatment phase.

Standardized testing

Participants were assessed with the full Boston Diagnostic Aphasia Examination, (BDAE-3) (Goodglass, Kaplan, & Barresi, 2000) and five non-linguistic subtests of the Cognitive Linguistic Quick Test (CLQT), (Helm-Estabrooks, 2000): symbol cancellation, symbol trails, design memory, mazes, and design generation. The CLQT symbol cancellation task assesses visual attention, visual scanning, and self-monitoring of performance. Examinees are shown a page of randomly displayed abstract symbols. The targets are distributed three-to-a-quadrant among the foils and the goal is to cross out all targets within the allotted two minutes. Scores are based on the number of correct cancellations minus the number of incorrect cancellations. The CLQT trails task is similar to a standard trails task except that, instead of letters and numbers, alternating geometric shapes of gradually increasing size are used to eliminate difficulties posed by the linguistic nature of the stimuli in a standard trails task. Examinees are first trained to draw a line connecting circles by size from smallest to largest, then to make a trail that alternates between circles and triangles of the same size. The scored task requires examinees to make a trail alternating between six circles and six triangles from the smallest to the largest of each. The time allotment is three minutes and the score is the number of correct connections for a possible score of 10 points. The trails task assesses executive functions required to learn rules, maintain cognitive flexibility, hold multiple rules in mind, and monitor performance. It also relies on visual attention and visuoperceptual abilities. The CLQT design memory task has three items that require examinees to look at two abstract designs for each item for 20 seconds, to hold them in visual memory for a short period, and then point to both of the designs from a vertical array that includes the target designs and four foils. The maximum score is six designs correctly recalled. The CLQT mazes task includes two mazes, a simple one that must be completed within one minute and a more difficult one that is completed within two minutes. Examinees must draw a line through each maze from the starting point to the end point without crossing walls or proceeding up blind allies. The mazes task assesses the executive function of planning and foresight to map out a visual route, and to self-monitor performance. The CLQT design generation task requires examinees to produce unique designs by connecting sets of four dots with four lines. Examiners establish "set" for this task by creating two designs while the examinee observes the procedure. Then the examinee is asked to make as many different designs as possible (without copying the examples) connecting each of the remaining 13 sets of dots using four lines for each design. The score is the number of unique, correct, non-perseverative designs. This task assesses multiple executive functions related to learning rules, self-monitoring, and maintaining cognitive flexibility to avoid perseverating.

For this investigation, scores from three BDAE-3 auditory comprehension subtests (word discrimination, commands, and complex ideational material) were used as the measure of auditory comprehension, and a mean accuracy score was calculated across the three subtests. The CLQT subtests were measured individually and a composite score was calculated by adding the five subtest scores together. Cronbach's alpha indicated an internal consistency of the scores of .81 for the five subtests. These subset scores were subsequently aggregated to a single variable measuring nonverbal cognitive and executive function skills.

Semantic knowledge tasks

Most picture-based augmentative communication devices depend on nonverbal semantic category selection (e.g., foods/clothing/vehicles). Thus, participants were assessed with two semantic knowledge tasks developed previously (Nicholas, 1999) to determine whether participants could select a semantic category for a stimulus presented in two conditions, once as a picture and once as a spoken word. In the first task, called People-Actions-Objects, participants decided whether a given stimulus (e.g. a picture of a firefighter in the pictorial condition, or the spoken word "firefighter" in the auditory condition) represented a person, an action, or an object. Participants saw a choice of two pictured categories on the computer and had to select the category where they would likely find the stimulus item. There were 48 items in each of the two presentation conditions (pictorial, auditory). In a second task, called Subcategories of Objects, they were given a stimulus item (again, either a picture or a spoken word) and had to select the object subcategory (from a set of 4 subcategories pictured on the computer screen) where they would find that item. For example, the participant was shown a picture of grapes and was asked to select the category where they would find that item from the pictured category choices of *fruit, clothing, wild animals,* and *furniture*. There were 64 items in each of the presentation conditions (pictorial and auditory) and 16 different subcategories of objects used overall.

Functional communication tasks were given three times at baseline to insure stability of performance prior to initiating the treatment phase. These same tasks were then used repeatedly throughout the training phase to probe for generalization of treatment effects to functional communication abilities. The five tasks are described later in the "Measuring Response to Treatment" section.

Treatment Program

Each participant received the treatment program for a period of at least six months, usually at the rate of two hour-long sessions per week (see Table 1). There were three training modules: 1) generative language, in which the participant learned how to produce statements, ask questions, and give commands using *CSA* as well as use the personalized "autobiography" screen, 2) communicating on the telephone using *CSA*, and 3) communicating via writing and/or e-mail with the assistance of *CSA*. A training manual guided the clinician through a structured treatment protocol that began with literal dictation of multi-icon messages for which the person with aphasia (PWA) received maximum guidance and extensive feedback. The training progressed gradually to open-ended conversational exchanges for which the PWA received minimal guidance and only normal conversational feedback.

Each participant received the generative language module first. More time was spent in this module because it is here that the PWA learns the organization of most of the vocabulary items in *CSA*. The training emphasized the production of actor-action-object messages, as

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well as how *CSA* can be used to communicate novel information that is unknown to the clinician. For example, as early as the first session, the participant is asked to communicate something about a meal they have eaten prior to the session. In this way, participants are exposed early to the primary function of *CSA*, i.e. to communicate novel information using picture selections.

In the telephone module, the participant learned to use a combination of pre-programmed phrases such as "I'm using the computer to help me speak. Please be patient", that are combined with novel messages using other vocabulary icons. Similarly, in the assisted writing module, participants combine stock phrases (e.g. "Thanks for your letter") with novel vocabulary selections. Messages are then either sent to a printer, converted to text and sent as an e-mail message, or even copied onto paper via hand writing. In all three modules, training progresses from literal dictation to self-initiated utterances with a performance criterion of 80% correct without guidance before initiating the next step. Further details about the steps and procedures used in the three training modules are presented in Appendix A.

Measuring Response to Treatment

Response to treatment could be determined in a variety of ways, including measuring accuracy levels within treatment sessions, determining how quickly a transition is seen from clinician-directed to PWA-initiated expression, and assessing generalization of performance to functional probe tasks. For the purposes of this study, only data for this last measure are included. Generalization of skills learned in treatment was measured by repeatedly probing performance on five tasks designed to reflect a range of real-life functional communication activities. The tasks were 1) responding to a set of seven autobiographical questions, such as "what is your address?", 2) describing a set of five pictures, (e.g. a picture of a woman cutting a cake), 3) describing a one-minute nonverbal video showing a mother and her children performing daily tasks in a kitchen, 4) making two semi-scripted telephone calls in which specific information needed to be exchanged, and 5) writing a birthday card and a grocery list.

At baseline and during each probe session, performance using *C-Speak Aphasia* ("on-computer") was compared to performance without the computer ("off-computer") on each of the five tasks. All modalities of expression were permissible in both conditions, except for using the computer in the "off-computer" condition. That is, an individual who wanted to draw or gesture or otherwise supplement communication was able to use any of these expressive modalities in both conditions. Probe sessions were conducted after every 100 "utterances" of the training procedure, which was approximately once each month. Participants were videotaped while performing the autobiographical questions, picture descriptions, and video scene recounting tasks and were audiotaped for the telephone calls task. Only graphic productions on paper were scored for the writing task. The order of the two probe conditions ("on-computer" and "off-computer") was counterbalanced across individuals and across probe sessions.

On the probe tasks, accuracy scores were obtained by evaluating performance in terms of how many discrete information units the participant was able to express. Performance was noted in terms of modality of expression and credit was given for clear expression of information in any modality that was relevant to the task. Perseverative or unrelated responses received no points. For example, on the picture description task, to describe a photo of a man drinking coffee, the participant could say the word "man", could produce a gesture representing drinking, and click on the picture of coffee on the *CSA* screen for beverages so that the computer's synthesized speech output said "coffee." In this example, the participant would be given three points for expression of three different and relevant bits of information: *man, drink, coffee*. All videotapes and audiotapes were scored by the first or second author or by graduate students trained in the scoring procedures. A subset of the probe assessments (approximately 1/3) was doubly scored by two of the authors to insure inter-rater reliability. Due to variability in participants' schedules and availability to continue with treatment, the overall duration of the treatment program was not uniform across individuals with the number of probe sessions ranging from three to nine probe sessions.

To examine whether performance changed over time within each of the conditions ("on-computer" and "off-computer"), difference scores were calculated for each probe task for each participant. Difference scores were calculated by subtracting the mean score obtained at baseline (across three sessions) from the mean score obtained for all the probe sessions during the treatment phase. Scores close to zero, therefore, would indicate very little change during the treatment phase, while higher scores indicate expression of a greater number of information units in the functional communication tasks over baseline performance. Using these scores it also was possible to calculate effect sizes (ES) for the individual probe tasks. A summary difference score also was calculated by summing the difference scores across all five probe tasks. The participants all received at least six months of treatment and were tested for at least three probe sessions. As the difference scores are based on individual performance across the probe sessions and each participant serves as his/her own control in the design, the variability in number of probe sessions is accounted for in the statistical analyses.

To examine the relationship between response to treatment and baseline measures of language and cognition, the summary difference scores for both "on-computer" and "off-computer" conditions were analyzed with respect to the baseline measures of auditory comprehension from the BDAE-3, performance on the tasks of semantic processing, and performance on the CLQT measures of executive functioning, using a multiple regression analysis.

Results

Baseline Assessments

Auditory Comprehension of Language—Despite similarity in their verbal expression profiles (all participants had severe non-fluent aphasia with phrase lengths of one word or less), performance on the baseline measures of the auditory comprehension subtests of the BDAE-3 indicated that participants' auditory comprehension accuracy scores were quite variable across individuals, ranging from 31% to 90% correct (See Figure 2). Thus, although all participants had severe non-fluent aphasia, some were characterized as having Broca's aphasia and some as having either mixed non-fluent aphasia or global aphasia.

Semantic Processing Tasks—Performance on the two semantic knowledge tasks indicated that the ability to make semantic category selections was relatively preserved across participants. Collapsing the data across the two tasks (the people-actions-objects task and the subcategories of objects task), accuracy rates in the pictorial stimulus condition were above 80% for all participants and were above 70% in the auditory stimulus condition for 9 of the participants. These observations indicate that knowledge of basic semantic categories and the ability to make a reasonable guess about where a particular item might be located in a pictorial semantic hierarchical system are skills that remained relatively preserved in this sample of people with severe aphasia (See Figure 2).

Nonverbal Cognitive Measures (CLQT)—Unlike performance on semantic processing tasks, performance on the CLQT non-linguistic subtests was quite variable (see Table 2.)

Three participants performed at or above normal cut-off on all five subtests, an additional three participants performed at normal cut-off on only one of the five CLQT tasks, and the remaining four participants fell in between. Normal cut-off scores are based on performance of a sample of non-brain-damaged adults grouped by age as reported in the CLQT manual. Individual profiles across all three areas tested, (i.e., auditory comprehension, semantic category selection abilities, and nonverbal cognition) are displayed in Figure 2.

Generalization of Skills to the Functional Communication Probe Tasks

Table 3 displays the difference scores and effect sizes calculated for each participant's performance on the probe tasks. The summary difference scores are displayed in the far right column and also are illustrated graphically in Figure 3. Comparison of the "on-computer" to the "off-computer" summary scores, shows that four participants demonstrated much greater improvements in their "on-computer" condition scores over time (Participants 1, 2, 6 and 9) than in their "off-computer" scores. For these participants, learning how to use *CSA* as an augmentative and alternative communication modality enabled them to communicate significantly more information. Two additional participants showed a moderate improvement in "on-computer" scores compared to "off-computer" (Participants 3 and 5). The remaining four participants either showed no or minimal improvement with treatment (Participants 7 and 10) or showed a similar amount of change both "off" and "on-computer" (Participants 4 and 8.)

Response to the Specific Functional Communication Probe Tasks

Depending upon the functional communication task, notable variability in *CSA* use existed within participants. Even the four "good" responders (Participants 1, 2, 6 and 9) found that using *C-Speak Aphasia* was helpful for some but not all tasks. For example on Task 4, making telephone calls, seven of the 10 participants showed effect sizes of 1.5 or greater in the "on-computer" condition, indicating that for some types of communication acts such as telephoning, *CSA* may be especially useful. When speaking on the telephone, gesturing, drawing and other nonverbal means of expression are obviously not helpful, so having an augmentative device to supplement communication becomes more crucial. Examples of individual participant data on the telephone task for a "good" user on this task (Participant 6) and for a less effective user (Participant 3) are shown in Figure 4. Notably, only one participant benefited by using *C-Speak Aphasia* for the writing tasks. The summed scores for all 5 tasks for each participant across time are presented in Figure 5. Data for each task for each participant are available in Appendix B.

Differences in responses seen in the "on-computer" condition compared to the "off-computer" condition are exemplified in the following responses from one of the good responders (participant 1) to the video retelling task at the probe 4 test time. The short video used in this task has no dialogue and depicts a mother in a kitchen cutting vegetables for a salad; a girl comes in and eats some grapes, then leaves; the girl reenters the room but slips and falls down and the mother gives her a hug; the mother then gives her cookies and a glass of milk; a boy enters carrying a cat which he hands to the girl; the mother gives him cookies and milk. After watching the video, participant 1, in the "off-computer" condition gave five communicative gestures and spoke one relevant word ("two") to relate information about the video. He gestured to represent cutting something, falling, two children, drinking, and eating, resulting in a communication score of 6 information units. In the "on-computer" condition, he produced the following messages spoken by the computer using *CSA*: "Marjorie cook knife cucumber lettuce. Girl eat grapes. Girl fall a little bit. Marjorie eat cookies milk. Girl girl go cat. Boy eat cookies milk." He did not attempt to use other means of expression to augment the *CSA* message. The number of information units in the *CSA* description resulted in a score of 21, as compared to his score of 6 in the “off-computer” condition.

In contrast, one of the participants who showed no benefit from using *CSA* (participant 4) earned nearly identical scores for the video retelling task in both the “on” and “off-computer” conditions at the same testing point (probe 4) as Participant 1. For his “off-computer” description he received 8 points for producing communicative drawings on paper that represented the woman and lettuce (2 points); a girl on the floor (2 points), a woman holding out her arms (2 points), and a girl and a cat (2 points). He perseverated the last drawing of the girl and the cat and received no additional points for those drawings. In the “on-computer” condition he produced the following series of responses:

Computer speech:	“Marj, eat, Marj	(2 points)
Verbal output:	“Yes, but…eat.. eat”	
Computer speech:	“Cook, Marj”	(1 point)
Gesture:	an X with his finger	
Verbal output:	“Boom boom but”	“um um one two three ok, but boom”
Gesture:	falling	(1 point)
Computer speech:	“Wash”	
Drawing:	Cat	(1 point)
Verbal output:	“Yeah OK, my spot, do do do do”	
Drawing:	Girl, Cookie	(2 points)
Verbal output:	“Yes, um, cookies, cookie”	

This combination of responses resulted in a communication score of 7 points in the “on-computer” condition as compared to 8 in the “off-computer” condition. This example illustrates the pattern seen repeatedly for this individual; although he was often able to communicate some information in multiple modalities, the addition of the computer rarely resulted in an augmentation of his communication.

Relation Between Response to Treatment and Baseline Measures of Language, Semantic Processing, and Nonverbal Executive Functions

A series of two multiple regression analyses were conducted with the criterion variables of (a) on-computer difference score and (b) off-computer difference score. The predictors were (a) BDAE mean auditory comprehension score, (b) pictorial semantic categorization score, and (c) CLQT nonverbal subtest composite score. Multi-collinearity was not a concern as indicated by the variance inflation factors (VIF), thus all predictors were retained in the model. Results of the initial multiple regression analyses for both the on-computer difference scores and off-computer difference scores failed to achieve statistical significance.

However, examining the scatter plot of the CLQT composite scores and the on-computer difference scores (see Figure 6), revealed that one individual (Participant 10, arrow pointing on the figure) was an outlier who possibly skewed these results. Therefore, the analysis was recalculated without this individual. Omitting Participant 10, the linear combination of the predictors explained 79.2% of the on-computer difference score variance, $F(3, 8) = 6.36$, $p < .05$. Of the predictor variables, only the CLQT composite score was statistically significant ($\beta = 6.25$, $p < .05$), and was uniquely responsible for 30% of the explained variance (part correlation coefficient =.55). Thus it appears that individuals who perform better on measures of nonverbal cognition tended to have higher difference scores using *C-*

Speak Aphasia compared to their baseline performance on the functional communication tasks overall. Insert Figure 6 here

Discussion

With respect to the first hypothesis, the results indicated that some participants with severe non-fluent aphasia significantly improved communicative performance on the functional communication probe tasks when using the *C-Speak Aphasia* program. Using the computer as an alternative and augmentative communication device, four of the 10 participants were able to communicate substantially more information on selected probe tasks across the treatment phase, and another two participants showed modest improvements. The advantage in communication ability afforded by using the *C-Speak Aphasia* program was most pronounced on the telephone calls task, but also was seen clearly on tasks requiring answers to autobiographical questions, describing pictures, and recounting the events observed in a short video. The variability in performance across individuals is important to emphasize, as not all people with similar baseline profiles of aphasic language impairments responded positively to the *C-Speak Aphasia* treatment, despite receiving an extended period of treatment.

To determine which individuals were more or less likely to become relatively independent users of an alternative and augmentative system such as *C-Speak Aphasia*, a multiple regression was calculated using baseline measures in three areas (auditory comprehension, semantic knowledge, and nonverbal executive functioning) and performance on functional communication outcome measures that were repeatedly probed during treatment. Neither auditory comprehension scores nor scores on the experimental tasks of semantic categorical knowledge were significantly predictive of response to treatment difference scores in the regression model. The results of the analysis, however, supported hypothesis 2, that measures of nonverbal executive functioning alone related to changes observed across time in treatment. The CLQT nonverbal composite score was responsible for a sizable portion of the variance in response to treatment, after outlier Participant 10 was removed. In other words, people with severe aphasia who had relative preservation of some nonverbal cognitive measures of executive functioning were more likely to benefit from the training with *C-Speak Aphasia* and could communicate more content than individuals with impaired nonverbal cognition.

In considering the individual subtests of the CLQT, it was speculated that performance on the design generation task may relate to response to treatment because it requires executive function skills that may be especially important to the use of *CSA* for communication. This task requires the individual to make a series of different designs, each different from the previous one, within a given time period. Several skills are required for optimal performance including creativity in making new designs, remembering the “rules”, and monitoring performance to avoid perseveration, all within a short (3 minute) time frame. Three of the four best responders to treatment performed at the normal cut-off on this measure, and only one of the poor responders (Participant 10) scored at or above the normal cut-off. The other subtests of the CLQT that comprise the composite score used in the analysis also require skills that are likely important to good response to independently use *C-Speak Aphasia* such as relatively good visual attention, visual discrimination and scanning skills, and visual memory. These skills are prerequisite for any picture-based communication system, for the user must be able to accurately scan a visual array of icons in order to select pictures for communicative purposes.

The “outlier” case (Participant 10) within the sample performed at the normal cut-off level on the nonverbal measures yet showed no improvement in functional communication using

CSA after treatment. Thus, while executive function skill as measured by the nonverbal cognitive CLQT subtests appeared to be more relevant to treatment response than semantic categorization abilities or degree of auditory comprehension impairment for *most* participants, other factors may influence response to treatment in a subset of individuals like Participant 10. This participant appeared at first to be an excellent candidate for the program based on his baseline testing. Furthermore his premorbid educational and occupational status (he was a PhD researcher in a medical school) led us to expect he would be highly motivated to use whatever means he could to supplement his communication and compensate for his severe aphasia. Nevertheless, he did not show improvement in functional communication using *CSA* despite learning how to use it in treatment sessions with at least the same speed and facility that others did. On functional communication probe tasks, he often resorted to use of drawing and once he started with that mode, he continued with drawing, failing to switch to other modes that might be more effective. In this respect his performance was at odds with others who did well on formal nonverbal cognitive assessment measures such as design generation. Note that failure to switch communication modes occurred in participants with low nonverbal cognitive scores. In recent work, Purdy and colleagues have targeted this expressive modality switching ability in an attempt to enable PWA to become better users of alternative communication modalities (Purdy & Cocchiola, 2006). It may be that some individuals could benefit from a course of preliminary therapy focused on improving selected executive functions such as cognitive flexibility, prior to direct work on communication. One therapy program that shows promise is the model-based Problem Solving Treatment Program developed by Helm-Estabrooks and Karow, 2010. At the least, these findings suggest that non-linguistic measures of executive functioning should be part of every aphasia assessment when attempting to determine candidacy for certain types of treatment programs. Furthermore these findings may help to explain why some individuals with severe aphasia remain dependent users of AAC systems, relying on the assistance of other communication partners, while other people with equally severe aphasia become independent successful users.

This study investigated two areas of nonverbal cognitive abilities- executive functions related to cognitive flexibility and nonverbal semantic categorization abilities, but there are likely other cognitive skills that may affect a person's ability to effectively learn and use alternative communication modalities. One area that was not addressed in the current study that may be relevant to use of AAC by people with aphasia is the processing of nonverbal events. In order to use AAC to describe events that have occurred or will occur in the future, the user must have an appreciation of events so that they can be "translated" using the pictures or icons of the AAC system. The thematic roles of people and objects in observed events must be well understood in order to subsequently describe what happened via an alternate modality. Most of the time, the assumption is that people with aphasia are processing events they witness in the world in a normal fashion. Studies by Dean, Marshall and colleagues (Dean & Black, 2005; Marshall, Pring, & Chiat, 1993a; Marshall, Chiat, & Pring, 1997), however, provide evidence that some PWA have particular difficulty processing nonverbal events in order to make accurate indications of what was occurring during the event or to predict the end result of the event. Marshall and colleagues (Marshall, Pring, & Chiat, 1993b) created short, 5- to 10-second "role videos" that showed events taking place that were either reversible involving two people (e.g., a woman sitting on a bench who sticks out her leg to trip a man walking by), or nonreversible involving one person (e.g., a man washing a bowl in the sink). No overt language was used in the videos. Some individuals with aphasia who observed these short video depictions of events had difficult fully understanding the event.

In an unpublished study, 32 role videos developed by Marshall and colleagues were used with a group of 30 people with chronic aphasia to assess their ability to select an outcome

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picture after watching the videos (Vaughan, Nicholas, Macaruso & Flynn, 2009). The surprising result was that more than half of the sample (17 of 30) showed impairments on the task, performing at more than two standard deviations below the performance of an age-matched control group without aphasia. Indeed, Marshall (2009) has recently suggested that treatment for some forms of aphasia may require “thinking therapy” to address this deficit found in some, but clearly not all, people with aphasia. Processing of visual nonverbal events in the world also has been associated with specific brain networks in the temporal and occipital lobes (Chatterjee, 2008; Kable, 2004; Kable, Lease, Spellmeyer, & Chatterjee, 2002; Wu, Waller, & Chatterjee, 2007; Wu, Morganti, & Chatterji, 2008), areas which are often affected in people with aphasia.

At least two of the functional communication probe tasks used in the current study (video retell and picture description) rely on this ability to translate an observed event into an alternate means of expression. Therefore, it is expected that individuals who perform poorly on a task like the “role videos” would also be least likely to use a system like *C-Speak Aphasia* to describe events in their lives. Four individuals in the current study also were assessed with the role videos as part of the unpublished study. Two of these were good responders to *C-Speak Aphasia* (Participants 6 and 9) and two were poor responders (Participants 4 and 10). Contrary to what might have been expected, the two poor responders to *CSA* performed within normal limits on the role videos and the two good responders performed in the impaired range. Further investigation will no doubt help to delineate the relative contributions of preservation or impairment of cognitive skills in the areas of executive functioning, nonverbal semantics, and event processing to successful use of alternative communication modalities by people with aphasia.

Conclusions

The results of this study support the hypothesis concerning the relatively greater importance of nonverbal executive functioning over language skills to treatment with an AAC system (*C-Speak Aphasia)* for people with severe nonfluent aphasia. Participants with more intact executive function skills responded better to treatment with *CSA* than participants with relatively greater impairment in these skills. Severity of linguistic auditory comprehension impairment did not correlate with treatment response, nor did performance on tasks of pictorial semantic processing. These results suggest that PWSA with relatively intact executive function skills are more likely to become independent users of programs like *C-Speak Aphasia* for augmenting other communication modes. PWSA with impaired executive function skills may still be able to benefit from an alternative communication system like *CSA*, but they will require more support and are unlikely to master independent use. Although only *CSA* was investigated as the communication system in this study, these results appear relevant to many other currently available picture-based systems for augmentative communication. Thus, it is important to consider a variety of cognitive skills beyond language skills when determining candidacy for these systems.

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Appendix A Treatment Manual for the C-Speak Aphasia (CSA) program (Abridged)

Training Module 1: Generative Language

Clinicians should read the sections called “Before You Start” and “Training Principles” in the C-Speak Aphasia Manual (Nicholas & Elliott, 1998). These principles should be adhered to in completing the following steps in the training procedure.

Note: Boldface words are names of individual C-Speak Aphasia screens

STEPS

1. Introduce “Go” statements using the participant as the actor, “Go” as the action, and a place from the first page of **Places** as the object. Use maximal guidance to prevent the participant from making a wrong move. For example point to the button on the board that the participant should click on. The initial item in the session with a participant named Ed might go as follows:

   “Today you came to the hospital for your treatment, right? I’m going to help you write that message yourself: ‘Ed goes to the hospital’ First, we need to find the picture of you. Come over here to the people category and click on this button (point to the **People** button; Ed clicks on it.) *Good. Now, which one of these is you, Ed?* (If Ed moves the cursor up to Ed on his own, tell him to click on it; if not, point to the correct button and have him move to it and click on it.) *Now, let’s find the picture that means to go somewhere. Come to the actions category here* (point to the **Actions** button; Ed clicks on it) *Which one of these do you think means to go or to travel somewhere?* (If Ed moves to the wrong one, point to the correct one and ask him to click on it.) *OK, now we have ‘Ed go’ down in the message display. Next we need to find hospital. Come into the objects category here* (Point to **Objects** button; Ed clicks on it.) *Look at all these different types of things. You’ll learn these eventually. For now, click on the places subcategory up here* (Point to the **Places** button; Ed clicks on it) *Now, which of these do you think is a hospital?* (Ed moves right to the hospital icon and clicks on it). *Great, now we have the whole message about what you did today, ‘Ed go hospital’ Now, click on your message* (or the speaker button) *and the computer will say it for you* (Point to the message display or the speaker button; Ed clicks on it). *OK, let’s try another one.”*

   Do a few more “Go” statements with the participant as the actor and other places from the first page of **Places** as the locations. After every message is created and spoken aloud by the computer, have the participant click on the eraser button to clear the display.

   Sample Targets: Ed go hospital Ed go school

2. Introduce “Buy” commands using the participant’s spouse or other family member as the actor, “Buy” as the action, something from the **Clothes** board as the object, and “Please” as an obligatory command marker. The initial item at this step might go as follows”

   “Ok, now I’m going to help you write some commands that you might need to tell other people to do. For example, suppose you needed some new socks and you wanted your wife to buy you some. Let’s write, ‘Alice, buy socks please.’ First we

need to find Alice. Where do you think you'd find her? (Ed clicks on the **People** button.) *Good, now which one is your wife, Alice?* (Ed clicks on Alice.) *Good, now we need to find the picture for buy. Remember we usually go to actions next.* (Point to **Actions** button, because Ed seems hesitant where to go.). *This picture up here with the money and the hands means to buy something, like you would do at a store. Click on this* (Ed does.) *Ok, now we need to find the socks. Go into the objects category here.* (Ed clicks on **Objects**.) *Look at all these and see where you think you might find things like socks and other clothing items.* (Ed clicks on **Clothes**.) *That's right. Now which one is socks?* (Ed clicks on socks). *Now, because you are giving your wife an order you should be polite, so I want you to add 'please' to your command. Come up here and click on the please button* (show Ed where please is, he clicks on it.) *Great, make the computer say the whole thing."* (Ed clicks on the message display).

Notice that in this session, there is slightly less direct guidance given and more opportunity for the participant to make decisions about where to click on his or her own. Prevention of errors should still be avoided, but gradually the sessions will move away from the clinician showing the participant where to click towards the participant making those decisions independently.

Sample targets: Alice buy socks please Alice buy shirt please

3. First novel communication. In these early sessions, there should be opportunities provided for the participant to communicate some novel information to the clinician (unknown to the clinician), so that it can be made clear from the start what the ultimate reason for learning C-Speak Aphasia is. Choose several items from the following set in each of the first few sessions of training. The clinician navigates to the screen and asks the participant to select something from the screen. Items can be repeated across sessions:

   - Go to the screen of **Breakfast Foods** (the first food screen accessible from **Objects**) and ask the participant to select the picture of what he or she had for breakfast that morning.
   - Go to the screen of the **Map of the U.S**. (an **Objects** subcategory) and ask the participant to show you which states he or she has visited.
   - Go to the screen of **Sports** (an **Objects** subcategory) and ask the participant to select his or her favorite sport.
   - Go to the **Calendar** screen (an **Objects** subcategory or accessible from **Main**) and ask the participant to select his or her birthday month and date.
   - Go to the **Weather/Seasons** screen (an **Objects** subcategory) and ask the participant to show you his or her favorite season, or what the temperature is like outside.

4. Introduce "Eat" statements with the participant as the actor, "Eat" as the action, and something from the first page of **Food** as the object. The same procedures outlined for the previous sessions should be used.

   Sample targets: Ed eat eggs Ed eat soup

5. Intermix "Buy" commands with "Eat" and "Go" statements. Introduce the clinician as an actor also, to be used in commands and statements.

   Sample targets: Alice buy pants please Ed eat cereal

6. Introduce “Cook” commands and statements. Use foods from the first page of **Food**, and then introduce foods from other pages. The clinician should explain that many categories of items have multiple pages that are accessed by clicking on the “More” button in the upper left corner.

   Sample targets: Alice cook burger please Ed cook ravioli

7. Introduce **Autobiography** screen. At approximately this point in training, introduce all the information on the autobiography screen. This screen needs to be personalized to include the information relevant for the participant prior to training. Click on each of the buttons (that have been personalized prior to training) and demonstrate what each one says. Then ask questions from the following list to elicit responses from the participant that would be appropriate. Return to this screen periodically throughout training whenever a new person is meeting the participant. Make sure the participant learns how to access this screen (from **Main**). (The **Photo Album, Family Tree**, and **Stories** screens are introduced in the Supplementary Lessons later.)

   - Where were you born?
   - What kind of work did you do?
   - Tell me about your family.
   - How many children do you have?
   - What happened to you to give you aphasia?
   - Where did you go to school?
   - How far did you go in school?
   - What sorts of hobbies do you have?

8. Introduce “Drink” statements with beverage objects.

   Sample targets: Alice drink water Ed drink beer

9. Introduce “Go” statements using map locations (From both **USA** and **Foreign Countries**) as objects. Foreign countries can be selected from the map of the world as well as from a **List** of written names, depending on the reading comprehension level of the participant and which countries are needed. Introduce compound actors using participant and spouse.

   Sample targets: Ed go Florida Clinician go Italy

10. Introduce “Go” commands; intermix with “Go” statements as above in number 8. Also use some places from second page of **Places**.

    Sample targets: Alice go airport please Ed Alice go restaurant

11. Continue to introduce more vocabulary items and the notion that many categories have multiple pages of icons. At first use friends or other family members as actors (from second page of **People**), then gradually introduce actions from second page of **Actions**. Introduce other sub-categories of objects such as **Sports, Tools, Transportation, Furniture, Animals, Body Parts**, etc. Introduce compound objects.

    Sample targets: Bill (Ed’s son) go Florida Alice buy car

12. Introduce questions using “Buy” or “Go”. Use the question mark icon in the final position. A sample item might go as follows:

    “OK, now you’re going to learn how to ask questions, to ask for information from another person. Suppose you wanted to know whether your wife had bought the shoes you had asked her to get. You would ask, ‘Alice buy shoes question’. So let’s write that.” (Ed selects the icons for Alice buy shoes.) *Ok, now to make sure Alice knows it’s a question, come click on this question mark here.”* (Clinician points to the question mark; Ed clicks on it). The speech synthesizer will use a questioning intonation in most cases if a question mark is added to the end of the message.

    Sample targets: Alice buy shoes? Alice go bank?

13. Introduce **Calendar** and **Clock** screens accessed from the **Main** screen or from the **Objects** screen. Time concepts such as individual days of the week, months, or specific dates should be included as the final units of the message after the action or object items.

    Sample targets: Alice watch football Monday Alice go mall tomorrow?

14. Introduce “Want” statements and questions; then explain how “Want” can be used in conjunction with a second action. Introduce “Love” plus a second action as well.

    Sample targets: Ed want burger fries Alice want hotdog?

15. Introduce **Modifiers** and **Colors** screens. The **Modifiers** screen is accessed from the **Main** screen. The **Colors** screen is accessed from the **Modifiers** screen or from the **Clothes** screens. In order to maintain the actor-action-object syntax that has been trained, the modifier term should follow the object or action that it is modifying, unlike English syntax. There is also a scale on the modifiers screen for indicating degrees of intensity. The scale items should follow the modifier item as well.

    Sample targets: Bill (Ed’s son) buy house large Alice love drive slow

16. Introduce Numbers from the **Keyboard with Word Prediction and Numbers** screen, accessed from the **Main** screen. The numbers 1–10, 100, 1000, and the dollar sign ($) are available. Begin by asking the participant to select numbers to answer questions such as:

    How old are you?

    What year did you have your stroke?

    Then, introduce numbers used as modifiers and dates. When numbers are used as modifiers they should be placed after the item they are modifying, following the principle in Step 15, (unlike English syntax). Dates may be placed after the action or after the object. When selecting money amounts the dollar sign may be placed after or before the numerical amount.

    Sample targets: Ed watch movies 2 Alice want $100

17. Introduce **Feelings** screen accessed from the **Main** screen. **Feelings** vocabulary items can be used in conjunction with the scale on the left-hand side of the screen to express degrees of feeling. In keeping with the way modifiers are used, the scale items (extreme, very much, moderate, a little bit, and not at all) should be selected after the feeling is selected. These items are used without an action icon since the feeling state itself implies the action, “feel”. A scenario should be given for which

the statement of feeling would be appropriate, e.g. " *Suppose you wanted to tell me that your wife felt sick today, you could write, 'Alice sick very much'.*"

Sample targets: Alice happy extreme Clinician sick moderate

18. Introduce negation. The negation particle, NOT, is available on every **Actions** screen. It should be selected after the action is selected to express certain concepts that do not have their own icons. For example, the concept of dislike or hate, is expressed by "love NOT". Again scenarios should be provided that require the negative particle, such as *"How would you tell me that your son did not go to the movies after all, you could write, 'Bill go not movie theater'*.

    Sample targets: Bill go not movie theater Alice love not lobster

19. Introduce remaining people, actions, and objects vocabulary. People from pages three (**Relatives**) and four should be introduced (**Professionals**) as actors and indirect objects. Actions from pages three through five of actions should be gradually introduced as well. Objects from all sub-categories of objects should be introduced.

    Sample targets: Sister cut grass Alice call nurse please

20. Use C-Speak Aphasia for a variety of functional communication tasks. All vocabulary and types of messages have been trained at this point. The remaining goal in this module is to have the participant use C-Speak Aphasia to communicate novel information that is unknown to the clinician. The following tasks should be used to accomplish this goal:

    - Retelling events. Ask the participant to write C-Speak Aphasia messages to describe activities done the previous day or weekend.
    - Describing pictures. Ask the participant to select a picture from a set provided by the clinician and to describe it so that the clinician would know which one had been selected.
    - Bring in a third person who is unfamiliar with the participant and have the participant engage in conversation using C-Speak Aphasia with that person.
    - Describing favorite movies, TV shows, or books. Ask the participant to think of a favorite movie, book, or show and try to describe it using C-Speak Aphasia vocabulary so that the clinician could guess what it was.
    - Take turns using C-Speak Aphasia to play the "Family Secrets" game. The clinician creates a C-Speak Aphasia message to tell the participant something about a family member, e.g. "Grandfather work train New York 1925", and the participant responds with a C-Speak Aphasia message telling something about his or her grandfather.

Training Module 2: Telephoning

The **Telephone** screen is accessed from the **Main** screen. It should be personalized prior to beginning this module so that all items that include the participant's name, address, and phone number are correct. In addition, the pop-up screen accessed when the user clicks on the "I want to speak with" button should have 4–5 names added of the people that the user is most likely to call. The phone directory screen accessed by clicking on the **Phone #'s** button should also be personalized to include the name, address, and phone numbers of the 4–5 people the participant calls the most. Other names can be added in later. The button marked **Personal phone script** will be addressed later.

STEPS

1. Introduce each of the buttons on the **Telephone** screen. Ask the participant to click on each one that you point to so he or she can hear and/or see what happens when each one is selected. Then ask the participant to find each button that you describe, e.g. "*Which button says 'Hello, this is Ed Bradshaw'?"*, or *"Which button says 'I made a mistake'?"* or *"Which button says, 'I don't understand'?"* Go on to the next step when the participant is consistently locating the correct buttons you request.

2. While you are seated with the participant, ask him or her questions as if you were a conversational partner on the phone to elicit the correct button selections as the responses. Repeat until the participant is able to consistently select the correct buttons without guidance.

Clinician's question	Participants Response
What is your name?	Clicks on "Hello" or "my name is" button
What is your phone number?	Clicks on "my phone number is" button
What is your address?	Clicks on "my address is" button
Why are you using the computer?	Clicks on the button with computer picture
Who would you like to speak to?	Clicks on "I'd like to speak with" button, and selects a person from pop-up screen

3. Simple phone scripts: Making an appointment and Ordering a pizza. Demonstrate the button marked "I'd like to make an appointment". Ask the participant to click on that button and then go to the calendar screen to select a day and time. Practice an entire script that includes this information:

   "Hello, this is ____________"

   "Please don't hang up. I'm using the computer to help me speak on the phone…"

   "I'd like to make an appointment"

   "October 23, 2:00 Please"

   "Thank you"

   "Goodbye"

   Similarly, demonstrate the function of the buttons on the Pizza Ordering screen, and practice having the participant order a pizza and drink using the following or a similar script:

   "Hello, this is_____________"

   "Please don't hang up. I'm using the computer to help me speak on the phone…"

   "I'd like to order a pizza please, large, with mushrooms"

   "I'd like a Pepsi"

   "When will it be ready?"

   "How much will it cost?"

"Thank you"

"Goodbye"

4. Speaker phone use begins. A standard speaker phone should be used. Preferably also use computer speakers placed near the microphone of the speaker phone. Review and practice the basic operations of the speaker phone, including how to place a call and answer a call by pushing the speaker button and not picking up the handset.

5. Participant learns to receive calls. Clinician goes to a neighboring office and places a call to the participant. Participant answers phone and responds to questions of the clinician. The clinician should ask the same questions asked in Step 2 above. Repeat, until participant is able to consistently select correct responses without guidance.

6. Participant learns to place calls. Clinician goes to a neighboring office and participant calls clinician using the two practiced scripts from Step 3. First the clinician pretends to be the receptionist at the doctor's office and the participant makes an appointment. Then, the clinician pretends to be the pizza parlor, and the participant orders the pizza and a drink. Repeat these scripts until the participant is able to complete them without guidance.

7. Participants uses C-Speak Aphasia on the telephone for novel communication. Clinician goes to a neighboring office and engages in simple, short conversation with the participant, who responds using information from telephone screen as well as other C-Speak Aphasia screens, and speaker phone. Make sure that the responses you are eliciting and expecting from the participant are represented within the C-Speak Aphasia system. For example, sample questions to be asked by the clinician are as follows:

Who will you be eating dinner with tonight?

What time did you get up this morning?

Tell me something that you did yesterday.

What is your favorite sport to watch on TV?

What will you do when you get home today?

How will you get home today?

Tell me what you had for breakfast (lunch) today.

8. Participant places a call to clinician and has a task to give specific information over the phone. Participant is told by clinician to give specified information over the phone to the clinician in another office. Clinician then goes to a neighboring office and awaits phone call. The following are sample pieces of information that the participant is asked to relay:

- A list of five food items from the grocery store that the participant asks the clinician to buy. Target messages would be something like this:
- "Hello, this is Ed Bradshaw. Clinician buy tomatoes, lettuce, onions, mustard, chicken please. Thank you. Goodbye.
- A message that the participant is sick and won't be coming to his appointment on Friday.

- "Hello, this is Ed Bradshaw. Ed sick. Ed go not hospital (clinic) Friday. Thank you. Goodbye"
- A message stating the date when and where participant and spouse are going on their vacation.
- "Hello, this is Ed Bradshaw. Alice Ed go California September 15. Goodbye"
- A request that the clinician call the participant's daughter (son) tomorrow.
- "Hello, this is Ed Bradshaw. Clinician call daughter tomorrow please. Thank you. Goodbye."

9. Using personalized C-Speak Aphasia telephone script in the clinic. Talk with the participant and family to find out types of information and questions that would be useful to add to a personalized phone script. Find out which family members and/or friends the participant wants to or needs to talk to most frequently on the phone and what specific information those people are likely to need to get from the participant over the phone. The clinician should edit the script to contain all this information. Then practice using the script with the participant in calls again from a neighboring office, pretending that you are the family member or friend. The personalized phone script has questions on the left-hand side of the screen and answers or responses on the right-hand side. Only a few common social phrases are included in the template. Wherever possible include pictures in addition to text when creating the script for each individual.

When the participant is able to use the script well without guidance, practice using both items from the script and novel messages created in the message display in combination. For example, the participant creates a message ahead of time in the message display, then goes to the script page and selects both social phrases and the message in the message display for speaking over the phone.

10. Using personalized telephone script to place an actual call to family member or friend. The clinician calls the family member or friend ahead of time and explains that the participant will be practicing making telephone calls with the computer. Then, the participant makes the call and uses the script as well as other screens in C-Speak Aphasia to respond to the friend's questions. The clinician is seated beside the participant to offer suggestions and guidance if needed.

11. Participant places a call to a friend who hasn't been told ahead of time about the call and engages in natural conversational interchanges. The clinician is seated beside the participant to offer suggestions and guidance if needed.

12. Participant places a call to clinician from participant's home at a pre-arranged time. Participant and clinician engage in natural conversational interchanges.

Training Module 3: Assisted Writing and e-mailing

STEPS

1. Open up the **Assisted Writing and E-mailing** screen, accessed from **Main**. Before beginning this step, personalize the **Names** pop-up screen that is accessed by clicking on the "Dear" button to include the names of the 4 or 5 people who the participant is most likely to correspond with by writing or e-mailing. Add the participant's name to the message associated with the "Sincerely," and "Love" buttons as well. Then demonstrate to the participant what happens when each of the buttons on the screen is clicked on. The preprogrammed phrases are set up in a standard letter format, with the date at the top, greetings next, and farewells at the bottom. Demonstrate that the message that is being composed can be spoken aloud by clicking on the message display. This may be important for individuals who have poor reading comprehension and relatively better auditory comprehension, since most of the phrases here do not have picture representations. For now, ignore the buttons for **Holiday Greetings**, **Weather**, and **Keyboard with Word Prediction**.

2. Provide the participant with a short sample letter (missive) written on a piece of paper that is to be used as a model. Ask the participant to create the exact same letter on the C-Speak Aphasia screen by clicking on the appropriate buttons. For example, the following letter would be the initial target item: (Note: slashes here mark the boundaries between individual buttons' messages, but they are not part of the written output.)

    Friday, September 15, 2000/

    Dear John,/

    Hello!/I'm using the computer to write this letter.

    Please excuse any mistakes./How are you?/Please write soon./

    Sincerely,

    Ed/

    Do a few more sample letters of this type, providing a written model each time.

3. Explain that the pre-programmed phrases can be used in conjunction with other vocabulary items from C-Speak Aphasia when creating messages. Again provide a written model that uses the pre-programmed phrases, plus a message from other C-Speak Aphasia vocabulary screens. For example,

    Tuesday, September 19, 2000/

    Dear John,/

    Hello!/I'm using the computer to write this letter.

    Please excuse any mistakes./How are you?/

    Ed/go/movie theater/yesterday/

    Please write soon./

    Sincerely, Ed/

    The part of the letter shown here in bold type is created from vocabulary items on other screens. In the message display, both pictures and text will be visible. Demonstrate the functions of the Print button. The Print button is programmed to print the contents of the message display including both pictures and text. It will print the message on whatever printer the computer is attached to. (Note: If text-only messages are desired to be printed out, the clinician needs to copy the "copy text and send to e-mail" button and substitute another word-processor program for the application to be launched rather than the Internet Service Provider.)

    Do a few more letters of this type, using a combination of pre-programmed phrases and other vocabulary providing a written model each time. Ask the participant to print out the messages after each one.

4. Introduce the **Holiday Greetings** and **Weather** screens accessible in the upper left of the **Telephone** screen. The weather screen has already been introduced in Module 1. Ask the participant to use one of the holiday greetings or one of the phrases on the **Weather** screen in the letter he or she is writing. Provide a written model for the first one, and then ask the participant to try to write a letter on his or her own for a few others. Sample targets for the initial letters of this step might look like this:

   Tuesday, September 19, 2000/

   Dear John,/

   Hello!/I'm using the computer to write this letter.

   Please excuse any mistakes./

   Happy Birthday!/Thanks for your letter/

   Love, Ed/

5. Ask the participant to create sample letters such as the following. Do not provide any written models.

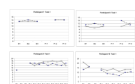
   - Write a letter to a sibling, telling about what events he or she has participated in during the past month.
   - Write a letter to a family member requesting that he or she purchase certain items for the participant
   - Write a letter to the clinician telling about his or her last vacation

6. Introduce sending the letter as e-mail. This step is for those individuals who have personal or family e-mail accounts. If the participant has never used e-mail before, he or she may still be interested in setting up an e-mail account and establishing access to the internet. The exact details of the procedure will be variable depending on what ISP is used. At the present time, we recommend AOL (America Online) for people with aphasia because of the highly pictorial nature of the user interface. However, other ISPs that use icons may be equally as easy to use.

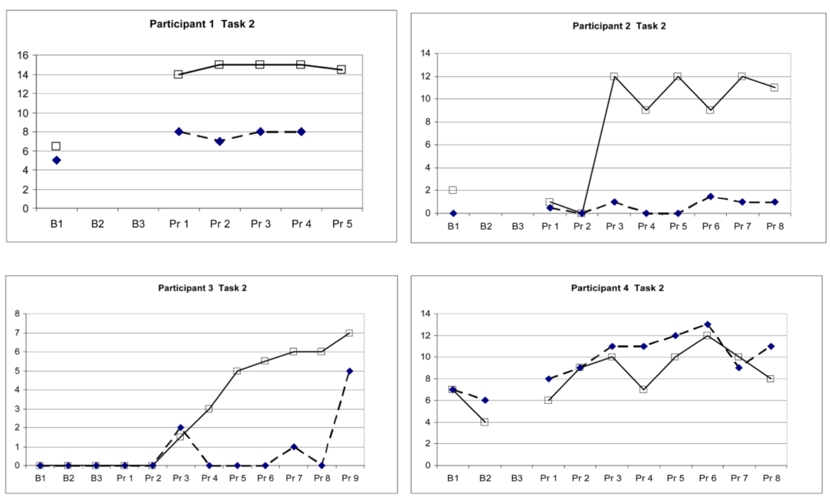
   The basic procedure involves creating the written message in the message display as explained above in Steps 1–4, and then clicking on the "copy text and send to e-mail" button. This button is programmed to copy the text of the message (which gets placed on the computer "clipboard") and then to launch the application of the ISP. Procedures for creating a new message within that application will have to be followed. At a minimum, this usually involves selecting an e-mail address of the person to whom the letter is being sent and clicking on the space where a letter gets created. Then the participant has to use the Edit-Paste function in order to put the C-Speak Aphasia message into the ISP's message space. The C-Speak Aphasia message that was on the "clipboard" will then appear in that space. The participant then clicks on whatever "send" button the ISP provides.

Appendix B Individual participant performance graphs for each of the 5 outcomes tasks

In all graphs the solid line with open square data points is for the On-Computer condition and the dotted line with solid diamond data points is for the Off-Computer condition.



Task 1.
Answering autobiographical questions



Task 2.
Describing pictures

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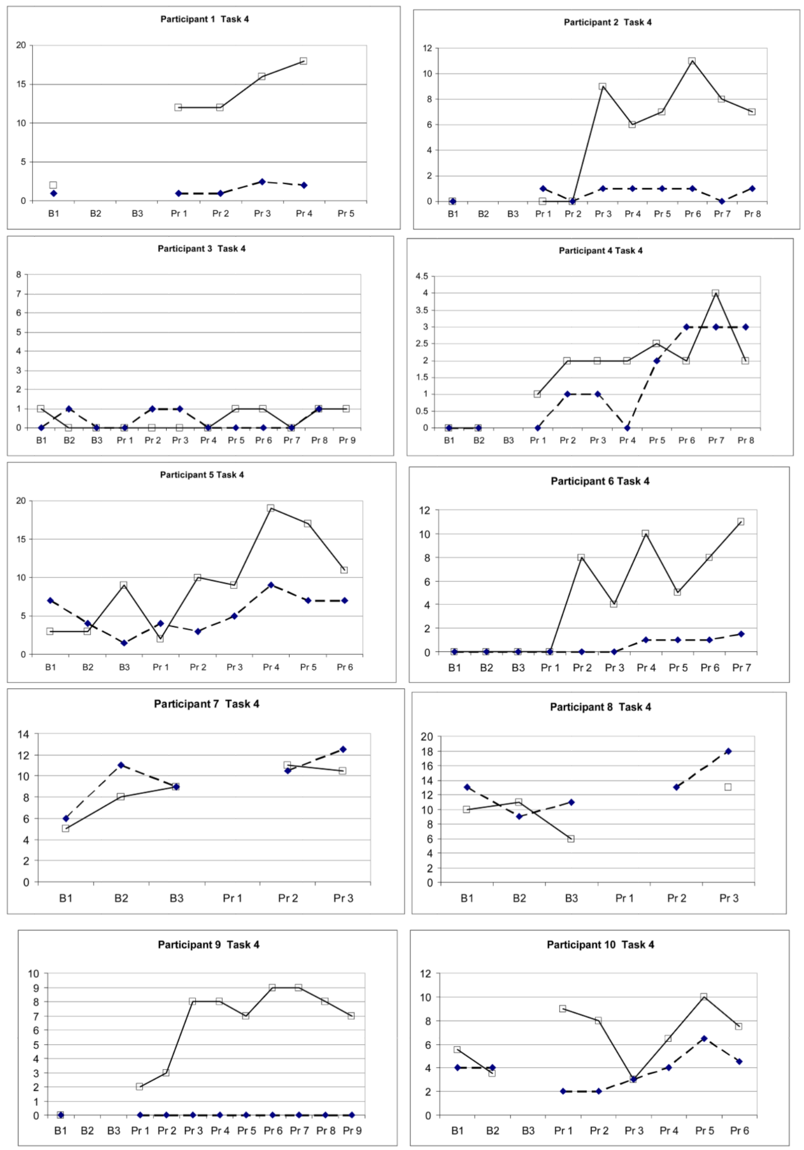
Task 3.
Video Retell



Task 4.
Telephoning

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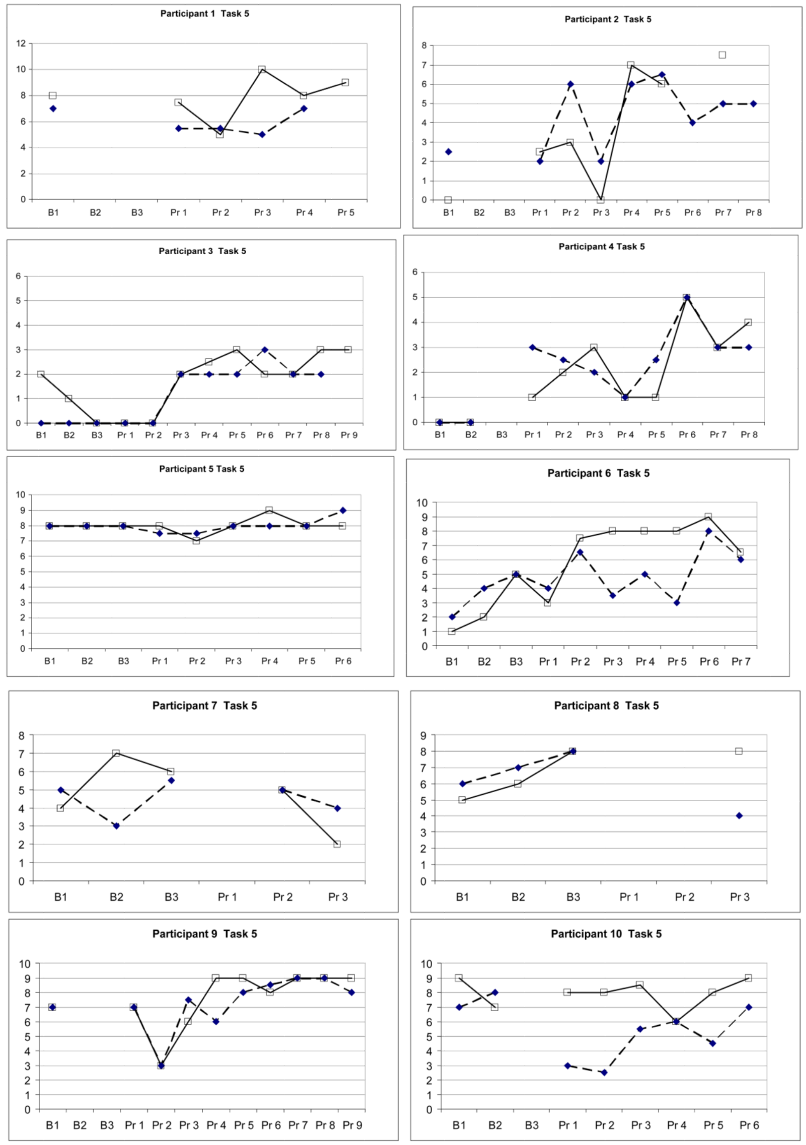

Task 5.
Writing Grocery list and Birthday Card

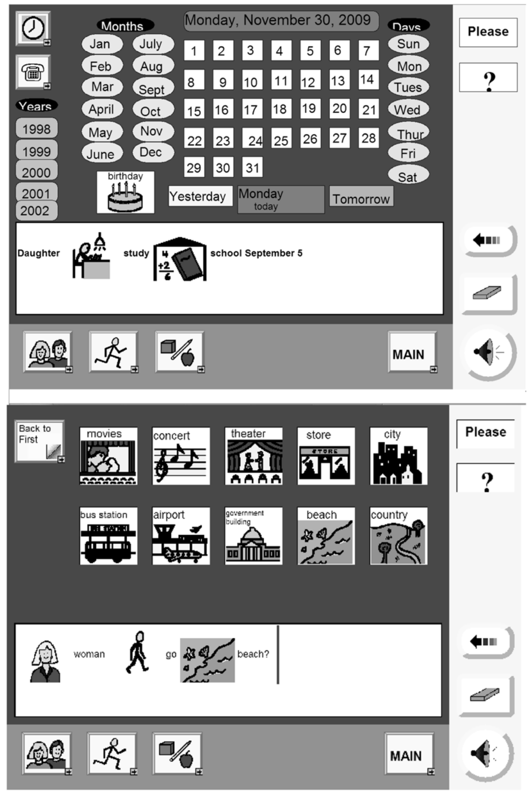

Figure 1.
Two sample *C-Speak Aphasia* screens.

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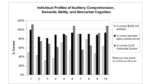

Figure 2.

Profiles of auditory comprehension, semantic ability, and CLQT composite scores. Data are mean accuracy rates for Participants 1–10 from left to right on the graph.

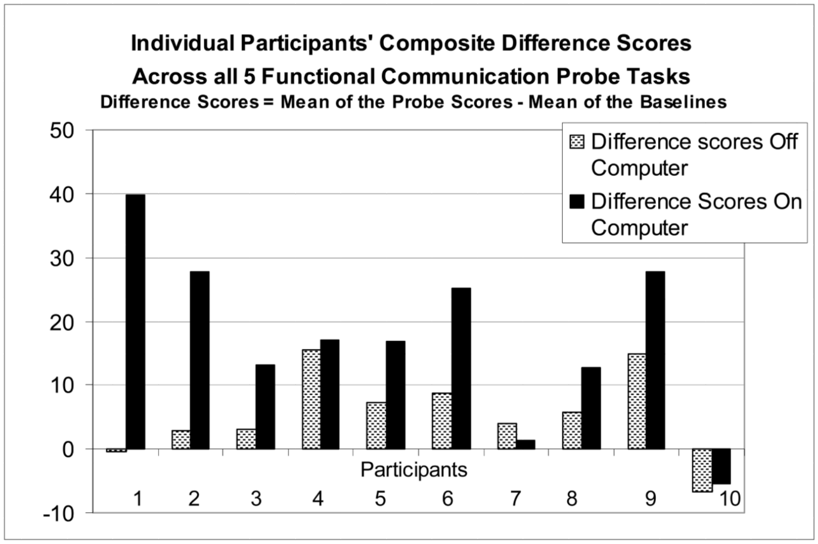

Figure 3.

Individual participants' composite difference scores across all 5 functional communication probe tasks, comparing scores "off-computer" (left bar of each pair) to "on-computer" (right bar).

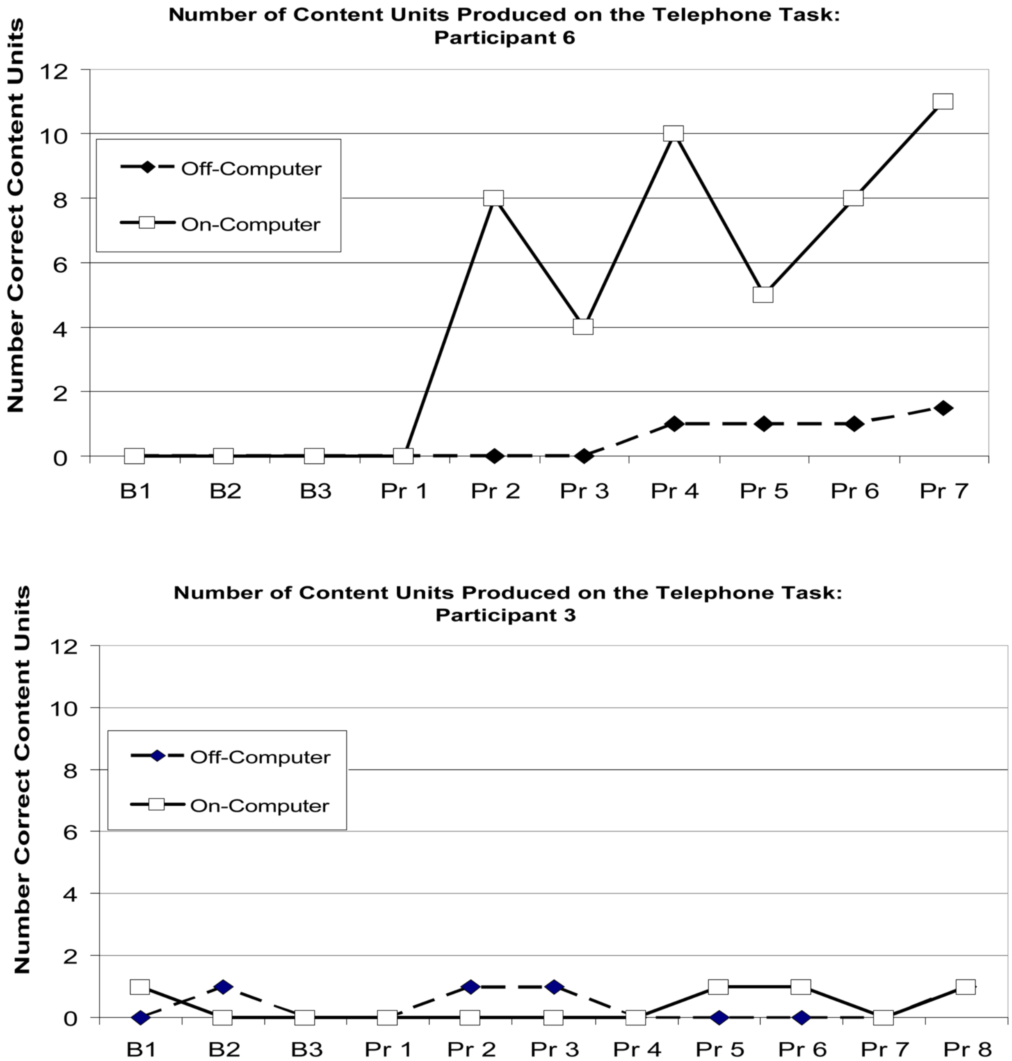

Figure 4.

Sample individual participant data on the telephone task comparing the "off-computer" (dashed, diamonds) to the "on-computer" (solid, squares) in a good user (Participant 6, top) and a less effective user (Participant 3, bottom). B=baselines, Pr=probes

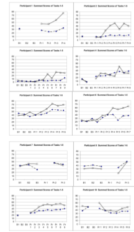

Figure 5.

Summed scores across the 5 outcome tasks for each participant across time. In all graphs the solid line with open square data points is for the On-Computer condition and the dotted line with solid diamond data points is for the Off-Computer condition.

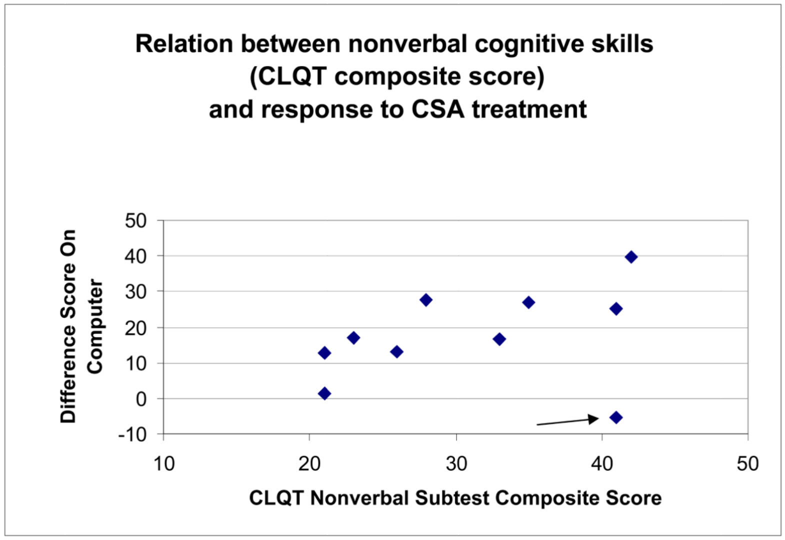

Figure 6.
Graph plotting the difference score “on-computer” (y axis) and CLQT composite score (x axis.) See arrow at the outlier data point (Participant 10).

Table 1

Participant characteristics. CSA= *C-Speak Aphasia*

Participant	Gender	Age	Time post-onset at start of tx.	Duration of CSA tx./no. of probes
S 1	M	27	8 years	9 mos. 5 probes
S 2	F	67	11 mos.	9 mos. 8 probes
S 3	F	53	2 years	17 mos. 9 probes
S 4	M	60	19 mos.	14 mos. 8 probes
S 5	M	51	4 years	15 mos. 6 probes
S 6	M	56	14 mos.	26 mos. 7 probes
S 7	M	55	2 years	7 mos. 3 probes
S 8	M	59	3 years	6 mos. 3 probes
S 9	F	57	10 mos.	38 mos. 9 probes
S 10	M	51	16 mos.	18 mos. 6 probes

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Table 2

Nonverbal cognition scores on the CLQT subtests with reference to normal cut-off scores in parentheses: above or equivalent to the cut-off (+) or below the cutoff (−)

Participant	Symbol Cancellation (11)	Symbol Trails (9)	Mazes (7)	Design Generation (6)	Design Memory (5)	Number of sub-tests > cut-off score	CLQT Composite Score across all 5 subtests
S 1	12 +	10 +	8 +	6 +	6 +	5	42
S 2	11 +	3 −	4 −	6 +	4 −	2	28
S 3	5 −	7 −	5 −	3 −	6 +	1	26
S 4	8 −	3 −	4 −	3 −	5 +	1	23
S 5	11 +	7 −	7 +	3 −	5 +	3	33
S 6	11 +	10 +	7 +	7 +	6 +	5	41
S 7	7 −	1 −	4 −	4 −	5 +	1	21
S 8	3 +	10 +	4 −	4 −	Missing +	3	26
S 9	11 +	8 −	5 −	5 −	6 +	2	35
S 10	12 +	9 +	8 +	7 +	5 +	5	41

Participant 8 was not given the design memory subtest so a modal score of 5 was used for him.

Table 3

Difference scores and effect sizes (in parentheses) for each of the 5 functional communication tasks for each participant. Cohen's d (difference score/s.d. of the baselines) or d_2 (difference score/s.d. of all data (pooled) if variance was 0, either because of only one baseline or baseline scores were all the same.)

Participant	Autobiog. Questions		Picture Descriptions		Video Description*		Telephone Calls		Writing Tasks		Summary Difference Score (Across all 5 tasks)	
	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
S 1	−2.38 (−1.4)	5.60 (2.2)	2.8 (2.1)	8.2 (2.4)	0.0	13.5 (1.7)	.6 (.9)	12.5 (2.0)	−1.3 (−1.3)	−.1 (−.1)	−.3	39.7
S 2	−3.13 (−1.7)	0.13 (0.0)	.6 (1.1)	6.3 (1.2)	2.5 (1.3)	11.0 (1.9)	.75 (1.5)	6.0 (1.4)	2.1 (1.2)	4.3 (1.4)	2.8	27.7
S 3	−.2 (−.6)	4.0 (.7)	.9 (.6)	3.8 (1.3)	.9 (.4)	4.2 (1.2)	0.0 (.1)	.1 (.2)	1.6 (1.4)	.9 (.8)	3.2	13.1
S 4	3.4 (1.5)	5.8 (1.2)	4.0 (5.7)	3.5 (1.7)	4.1 (1.5)	3.1 (.9)	1.6 (1.2)	2.2 (1.9)	2.8 (1.8)	2.5 (1.5)	15.9	17.1
S 5	.8 (.4)	.2 (.1)	2.2 (1.1)	5.8 (1.7)	2.5 (5.0)	4.5 (2.2)	1.7 (.6)	6.3 (1.8)	0.0 (0.0)	0.0 (0.0)	7.2	16.8
S 6	2.0 (.9)	8.8 (5.8)	3.1 (1.8)	1.2 (.4)	1.6 (.5)	4.0 (4.0)	.6 (1.1)	6.6 (1.5)	1.5 (1.0)	4.5 (2.2)	8.8	25.1
S 7	.7 (1.2)	1.0 (1.8)	1.0 (.5)	1.8 (1.6)	−.5 (−.7)	−2.7 (−4.6)	2.8 (1.1)	3.4 (1.6)	0.0 (0.0)	−2.2 (−1.4)	4.0	1.4
S 8	1.2 (2.0)	1.3 (2.3)	2.7 (4.6)	5.7 (4.9)	.5 (.1)	0.0 (0.0)	4.5 (2.3)	4.0 (1.5)	−3.0 (−3.0)	1.7 (1.1)	5.8	12.7
S 9	5.2 (2.8)	6.3 (2.6)	4.0 (1.6)	8.4 (2.0)	5.2 (2.2)	5.6 (2.0)	0.0 (0.0)	6.8 (2.1)	.3 (.2)	.7 (.3)	14.8	27.8
S 10	−5.2 (−2.4)	−5.7 (−1.6)	1.7 (1.4)	1.6 (.7)	−.2 (0.0)	−4.2 (−.8)	−.3 (−.2)	2.8 (1.1)	−2.8 (−3.9)	−.1 (−.1)	−6.8	−5.5

*Because baselines were not available for this task for Subjects 1–4, the first score earned in the "off-computer" condition was used as the mean baseline score for these calculations