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Novel Technology for Treating Individuals with Aphasia and Concomitant Cognitive Deficits

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Abstract

Purpose—This article describes three individuals with aphasia and concomitant cognitive deficits who used state-of-the-art computer software for training conversational scripts.

Method—Participants were assessed before and after 9 weeks of a computer script training program. For each participant, three individualized scripts were developed, recorded on the software, and practiced sequentially at home. Weekly meetings with the speech-language pathologist occurred to monitor practice and assess progress. Baseline and posttreatment scripts were audiotaped, transcribed, and compared to the target scripts for content, grammatical productivity, and rate of production of script-related words. Interviews were conducted at the conclusion of treatment.

Results—There was great variability in improvements across scripts, with two participants improving on two of their three scripts in measures of content, grammatical productivity, and rate of production of script-related words. One participant gained more than 5 points on the Aphasia Quotient of the Western Aphasia Battery. Five positive themes were consistently identified from exit interviews: increased verbal communication, improvements in other modalities and situations, communication changes noticed by others, increased confidence, and satisfaction with the software.

Conclusion—Computer-based script training potentially may be an effective intervention for persons with chronic aphasia and concomitant cognitive deficits.

Keywords

aphasia; cognitive deficits; computer treatment; rehabilitation; script training

Several studies have established that people with aphasia are able to use computers independently with minimal assistance and with demonstrable benefits.[1–3] This knowledge, combined with recent advances in computer technology, has spurred increased interest in delivery of treatment via computers. Studies assessing this mode of service delivery are addressing feasibility, efficacy, and cost effectiveness. Feasibility includes the potential for translating an aphasia treatment typically provided by a therapist to one that is computer-based without human interaction. Efficacy refers to improvements brought about by carefully conducted research with a sample of rigorously selected patients from a clearly defined clinical population undergoing a specific treatment protocol delivered by a highly trained clinician.[4] Efficacy questions in relation to computer treatment are whether the treatment results in improvement in one or more communication areas and how these improvements compare to those obtained when treatment is delivered by a therapist. Effectiveness refers to improvements

obtained when treatment is delivered in the routine clinical environment.[4] Another aspect of effectiveness is the cost-benefit ratio: the relationship between the cost of resources expended for an intervention and its effects in the routine clinical environment. Cost-effectiveness considerations are of particular importance in the current health care environment in which treatment costs are carefully monitored during the acute phase of recovery and typically made unavailable to individuals with chronic aphasia. Identification of cost-effective treatments becomes even more important in light of recent research that intensity of treatment is a key factor in facilitating improved communication skills and inducing associated neuroplastic changes.[5–7]

To date, most computer programs for people with aphasia focus on tasks at the single-word level including verbal and written word finding, single-word auditory comprehension skills, and single-word visual recognition and reading comprehension.[3,8–13] We have recently demonstrated the feasibility of a computer program incorporating conversational practice.[14] AphasiaScripts™ provides a more realistic conversational context for practicing language skills than working on single-word tasks. We showed the efficacy of AphasiaScripts™ with three patients with clearly identifiable aphasia diagnoses (Broca's, Wernicke's, and anomic aphasia).[14] However, in clinical practice, patients with aphasia may not always fall into a definitive aphasia diagnostic category. Furthermore, they may have associated cognitive impairments that complicate the differential diagnosis and treatment. In this article, we describe the feasibility and efficacy of using AphasiaScripts™ in three individuals with aphasia and associated cognitive deficits.

Computerized Conversational Script Training

AphasiaScripts™ is a software program using an animated agent that serves as a virtual therapist for script training for individuals with aphasia. The virtual therapist is programmed to produce natural speech with correct movements of the speech articulators.[15] With AphasiaScripts™, the individual with aphasia and the therapist work together to develop individualized scripts on a topic that is meaningful and relevant. Once a script has been developed, it is typed into the program and recorded by the clinician. Scripts can be up to 20 turns long, with each turn being initiated either by the individual with aphasia or by the virtual therapist. Scripts also may be monologues, such as describing the events surrounding the stroke or giving a short lecture.

Using AphasiaScripts™, the individual with aphasia has repeated opportunities to practice the recorded conversations. Script practice has three phases. First the client listens to the entire script while it appears on the screen. Next, each sentence or conversation turn is practiced repeatedly in the following systematic sequence.

- The individual with aphasia reads the sentence twice in unison with the virtual therapist. If there are any problems with specific words, these words can be practiced repeatedly by clicking on them.
- The whole sentence is read aloud independently, and this response is recorded by the computer.
- The individual with aphasia has the option to listen to the recorded sentence. If the client is not satisfied with the production, he or she can practice and record it again.

Finally, the entire conversation is practiced by taking turns with the virtual therapist. Practice occurs with various forms of assistance depending upon the individual's needs. These include seeing the written word, hearing the virtual therapist's voice during choral speaking, and watching oral-motor movements of the virtual therapist. These cues are faded over time so that

eventually the client practices the conversation without cues as in a real conversation. Figure 1 shows an example of a screen from the AphasiaScripts™ software program.

The rationale for script-training methodology is derived from the instance theory of automatization.[16] Instance theory suggests that automaticity of skills is achieved by retrieving memories of complete, context-bound, skilled performances. These memories are formed with repeated exposures to and practice on the same task. In this view, many highly routine tasks are more appropriately practiced as a whole task (sentences and conversation) rather than being broken down into component subskills (phonemes and words). Prior research has indicated that script training may improve acquisition and effortless production of scripted speech, both in therapy situations and with novel conversation partners.[17,18]

Case Studies

Participants

We report on three participants with aphasia and concomitant cognitive deficits each occurring subsequent to a single left-hemisphere stroke confirmed by computerized tomography (CT) or magnetic resonance imaging (MRI) and medical history. Participants were at least 6 months post stroke. They were right-hand dominant, with no history of other premorbid neurological or psychiatric disorders. All participants had completed at least 12th grade and were literate in English prior to their strokes. Visual acuity was no worse than 20/100 corrected in the better eye; auditory acuity was no worse than 30 dB hearing loss at 500, 1000, and 2000 Hz, aided in the better ear. All participants provided written informed consent under the approval of the Northwestern University Institutional Review Board

Participant 1 was a 75-year-old right-handed female with a nonfluent aphasia following an ischemic stroke 4 years prior to her participation in this study. Participant 2 was a 50-year-old right handed male with a nonfluent aphasia following an ischemic stroke, also 4 years earlier. Participant 3 was a 67-year-old male with a fluent aphasia following a hemorrhagic stroke 1 year prior to enrollment. Table 1 shows their baseline Aphasia Quotient (AQ) scores on the Western Aphasia Battery (WAB).[19] The protocol for the study collected only screening data regarding cognitive status using either the Ravens Progressive Matrices (RPM)[20] or the Mini-Mental State Exam (MMSE).[21] Participants 1 and 2 scored poorly on the RPM with scores of 18 and 13, respectively. Participant 3 scored 15 on the MMSE. These objective data are supported by subjective observations in which all three participants displayed problems in working memory and encoding of new information.

Procedures

Table 2 summarizes the treatment protocol that was used for the development, assessment, and training of the scripts for each client; this has been described previously in detail.[14]

Three scripts were developed for each participant. The participants practiced these scripts sequentially for 3 weeks each. They were instructed to practice at home for a minimum of 30 minutes per day. Baseline measures of stability were taken for each script. These measures were taken with the written script available to the client and with the speech language pathologist reading aloud the lines of the virtual therapist. Each participant made weekly visits to the clinician who observed practice for 30 minutes to ensure that home practice had been proceeding correctly. The clinician administered weekly language probes to monitor progress on the scripts and downloaded computer data regarding amount of home practice. The baseline scripts and the final script production at the end of 3 weeks of practice were audiotaped, transcribed, and analyzed for content, grammatical complexity, and rate and were compared to the target scripts. Measures of content included number and percent of script-related words.

Grammatical complexity was measured by number of morphemes, nouns, verbs, and modifiers. Rate was defined as the number of script-related words produced per minute.

Participant 1's three scripts included talking at the breakfast Table about the morning activities, giving a monologue about her aphasia, and talking to her husband in a restaurant about what to order. For Participant 2, the three scripts were ordering breakfast in a restaurant, asking the grandchildren questions, and talking on the telephone with his wife about his activities and dinner preferences. For Participant 3, the three scripts were ordering breakfast in a restaurant, conversing with a salesperson at the men's clothing store, and giving a monologue to the congregation at church about his aphasia and recovery.

Standardized testing was conducted pretreatment, posttreatment, and at 6 weeks following the end of treatment. Testing included the WAB,[19] Quality of Communication Life (QCL),[22] Communication Activities of Daily Living-2 (CADL-2),[23] and the Communicative Effectiveness Index (CETI).[24] Additionally, at the time of the posttreatment assessment, an exit interview was conducted with the participant and/or significant other to determine their perception of change resulting from the script training and their satisfaction with the treatment program. Feedback about the computer treatment program was also solicited.

Results

Table 3 shows the amount of time each participant spent practicing each script as recorded by the computer. Practice times differed for each participant from week to week. However, neither Participant 1 nor Participant 3 achieved the required 450 minutes of practice per script over a 3-week period. Participant 2 achieved this average practice time for Script 3 and almost achieved it for Script 2.

Figure 2–Figure 4 show each participant's first baseline script performance and performance following 3 weeks of training for each measure for each script. Measures for the target scripts are also shown where appropriate.

For Participant 1, who had nonfluent aphasia, improvements on Scripts 1 and 3 were characterized by the inclusion of more scripted nouns and increased number of morphemes indicating greater grammatical complexity. She was able to produce these script-related nouns faster. At baseline of her first script and third script, she produced 38 and 24 script-related words per minute, respectively; she improved to a rate of 55 and 41 script-related words per minute at the end of 3 weeks' training on each script. Improvements were not noted on Script 2.

For Participant 2, who had nonfluent aphasia, improvements were noted on Script 2 and 3. These improvements were characterized by inclusion of more script-related words produced at a faster rate. The greatest changes were noted on Script 2, in particular, where percent script-related words increased from 58.8% to 84.3% and improved grammatical complexity characterized by increased morphemes, nouns, and verbs was noted. Improvements on Script 1 were only in rate of script-related words.

Although Participant 3 actually practiced three scripts, posttraining data for Script 3 was not available because of technical problems with the recorded tape. Similarly accurate timing of several of the scripts could not be obtained, so that rate measures are also not available. Percent script-related words changed from 30.91% to 34.55% for Script 1 and 31.75% to 39.68% for Script 2. These are not considered to be clinically significant changes.

Table 1 gives the results of standardized testing for the participants. Participant 1 improved between pre- and posttreatment testing from 51.4 to 57.6 on the WAB AQ, which is beyond

the 5-point standard error of measurement for this test. At the 6-week follow-up, continued changes were noted with a WAB AQ of 63 points. Support for these changes was reflected on the CETI, which was completed by her spouse. CETI scores increased from 51.8 to 58.6 at posttreatment testing and 72.5 at follow-up. No changes were noted, however, on the CADL. Participants 2 and 3 did not show changes on the WAB AQ. However, changes on the QCL were noted for Participant 2, with total QCL scores increasing from 64 at pretreatment to 74 at posttreatment and 80 at follow-up. CETI and CADL changes were not noted for Participant 2; these measures were not administered for Participant 3.

Exit interviews from Participants 1 and 3 were transcribed and analyzed by two independent reviewers for recurring themes. Five themes were identified as follows: increased verbal communication, improved communication skills evident in other modalities and situations, changes in communication noticed by others, increased confidence, and satisfaction with the computer program. Table 4 provides verbatim examples of each of these themes. Some of the verbatim examples may provide evidence for more than one theme, but they are included in only one category in Table 4.

Discussion

Three aspects of the current study are relevant both to aphasia treatment efficacy research and clinical practice: the nature of the population studied, the variability in results, and the treatment methodology that individualizes content to maintain motivation and optimize ability for independent and intensive practice.

In this study, we have collected data on individuals with aphasia and concomitant cognitive deficits, a group that is typically not included in treatment research studies. Most studies include individuals with aphasia without accompanying cognitive or other communication deficits. Therefore, clinicians have little evidence on which to base treatment decisions for patients with mixed deficits often seen in clinical practice.

The three participants in the current investigation demonstrated greater variability in improvement across scripts when compared to those with aphasia previously described by Cherney and colleagues.[14] In the prior study, all participants made improvements in information content, grammatical complexity, and rate on all scripts. In the current study, Participants 1 and 2 improved on only two of their three scripts, while Participant 3 did not make any noticeable changes on these measures for either of his scripts. Because variability in outcome is of paramount importance in the current clinical climate of cost control, it is important to account for this difference between results in the two studies.

The first factor that may have affected consistency of outcomes in this study was practice time and duration. In the current study, the participants did not always practice the required amount of time and were only permitted to practice each script for 3 weeks. Intensity of intervention is now seen as a critical component of outcome,[5–7] so it is conceivable that more practice for a longer period of time might have resulted in less variability and greater improvements. A good case in point was Participant 2. He practiced Script 1, the shortest and least complex of the three scripts, an average of only 77 minutes a week and showed no improvement. This contrasted with Scripts 2 and 3; the performance on both of these improved, and they were practiced an average of 142 minutes and 199 minutes per week, respectively. These practice times were generated by the computer and are considered reliable. It appears that in this case amount of practice, rather than script complexity, may have been important.

In addition to amount of practice, there are several script-related factors that may have contributed to the variability of performance across scripts. These include the type of script (monologue vs. dialogue), the topic, and level of difficulty (length and grammatical

complexity). For Participant 1, type of script and topic seemed more critical to outcome than script difficulty, because all three scripts were similar in difficulty level. Script 2, which showed no improvement, was a monologue about the aphasia; the other two scripts that improved were dialogues about everyday activities. For this participant, the practicality and functionality of those dialogues may have proved more interesting, motivating, or relevant to her daily life.

Finally, it is important to consider that informational content, grammatical complexity, and rate may not be the best measures to capture communication change over time. For example, Participant 3 made no changes on either of his scripts but demonstrated qualitative changes during his everyday activities that were described by his wife in the exit interview. She provided numerous examples of him using elements of the script in functional situations and exhibiting increased verbal communication and increased independence at home.

The AphasiaScripts™ provided a means by which the participants were able to practice frequently at home either independently or with support of a significant other. Despite the presence of their cognitive deficits, they were able to learn how to navigate through the computer program. The computer program allowed the scripts to be individualized to their specific interests and needs as well as to the severity of their aphasia and associated cognitive deficits. Additionally, the rate and intonation of the recordings could be tailored and, if needed, prosody coufd be exaggerated to maintain their participation on the task.

A unique feature of the AphasiaScripts™ is the presence of an avatar (referred to in this intervention as PAT [Personalized Animated Therapist]). For these participants, the avatar kept them involved in the task. Both family members and participants indicated that they enjoyed working with the avatar. As one of the family members stated in the exit interview, “Ms. PAT is now a member of the family.”

Summary and Future Directions

In this article, we have demonstrated the feasibility of using a computer for script training with individuals with aphasia and concomitant cognitive deficits. Despite the variability in performance, improvements were noted in informational content, rate, and grammatical complexity on some of the scripts for some of the participants. Replication of this study with a larger number of subjects is needed to further demonstrate the efficacy of this intervention. This study is a first step toward demonstrating effectiveness of the treatment, because the participants have cognitive deficits accompanying their aphasia and represent a segment of the population seen in the routine clinical environment. Although the intent of Aphasia Scripts™ is not to replace the speech-language pathologist,[25] it permits a cost-effective mechanism by which individuals can practice independently without incurring the expense of a speech-language pathologist at every treatment session.

Acknowledgments

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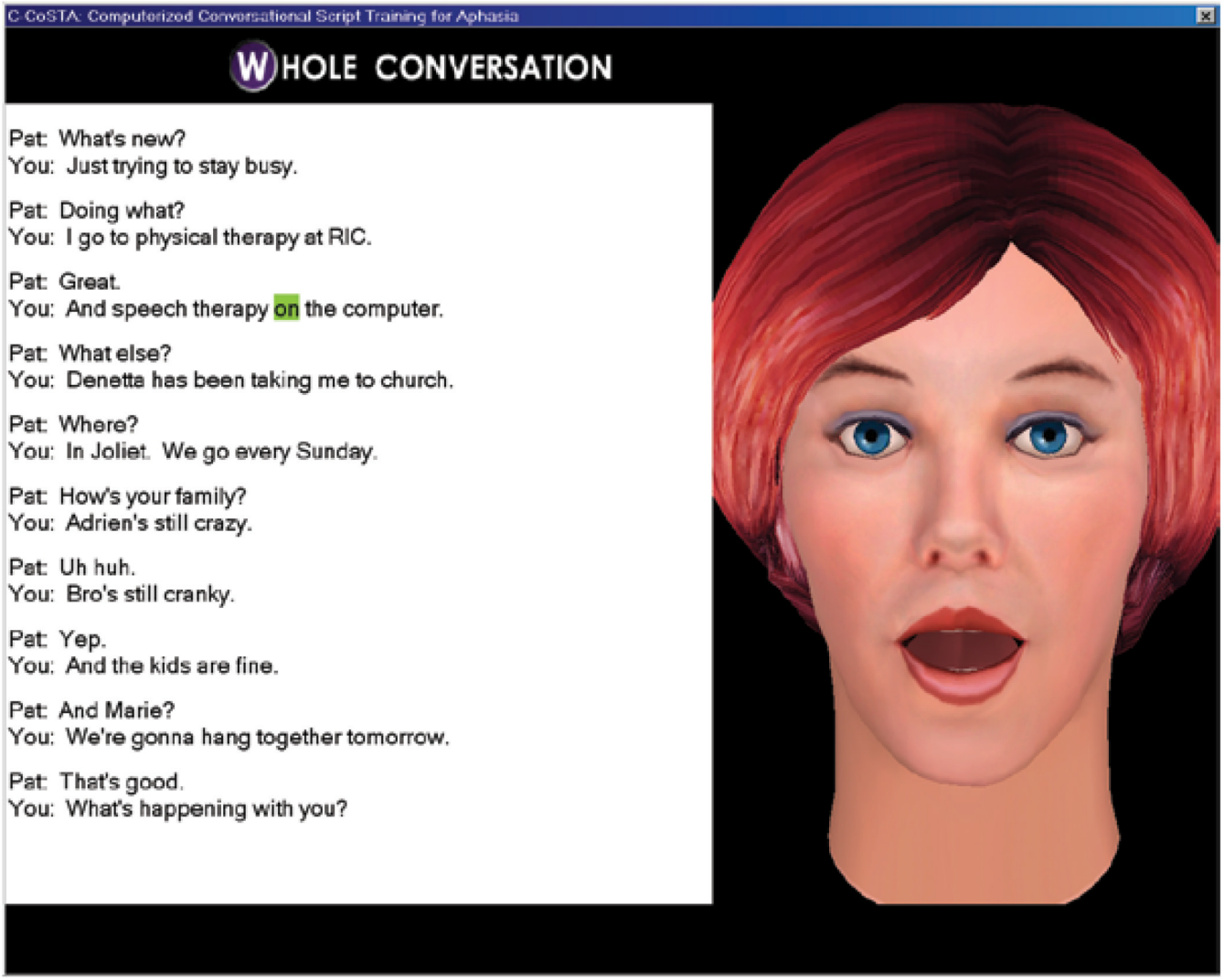

Figure 1.
Screen shot from AphasiaScripts™ showing the virtual therapist.

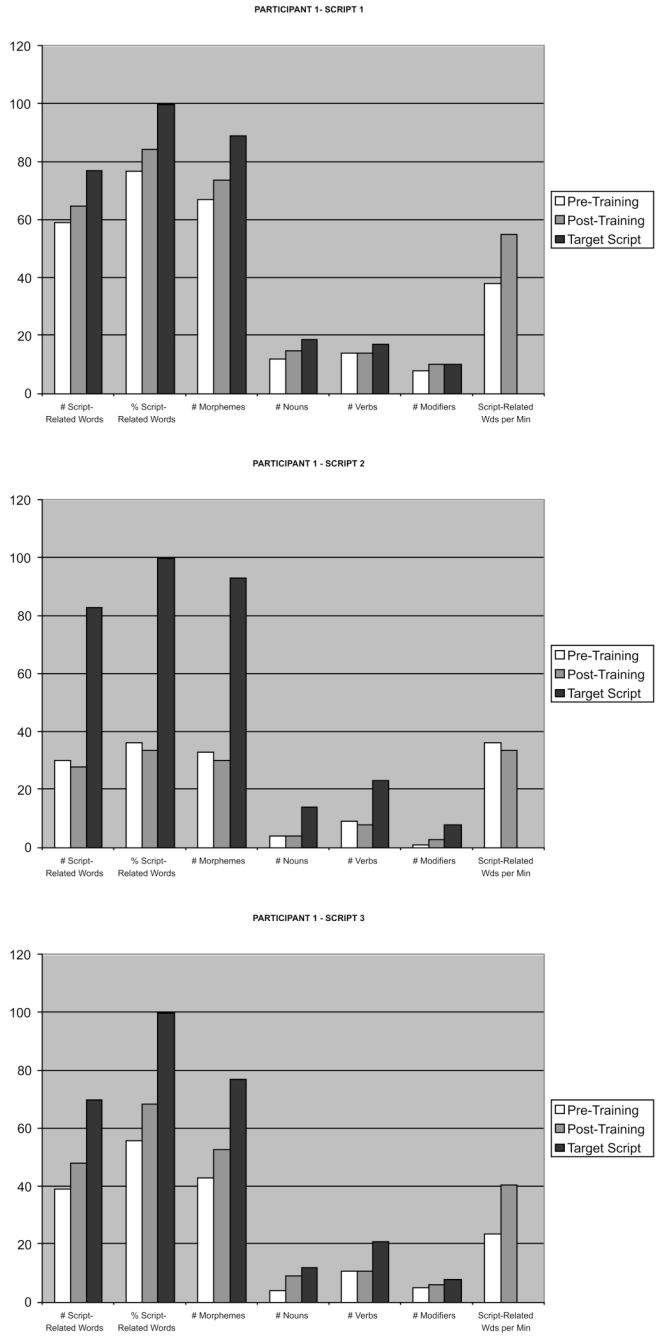

Figure 2.
Pretreatment and posttreatment script performance for Participant 1 with comparison to target performance.

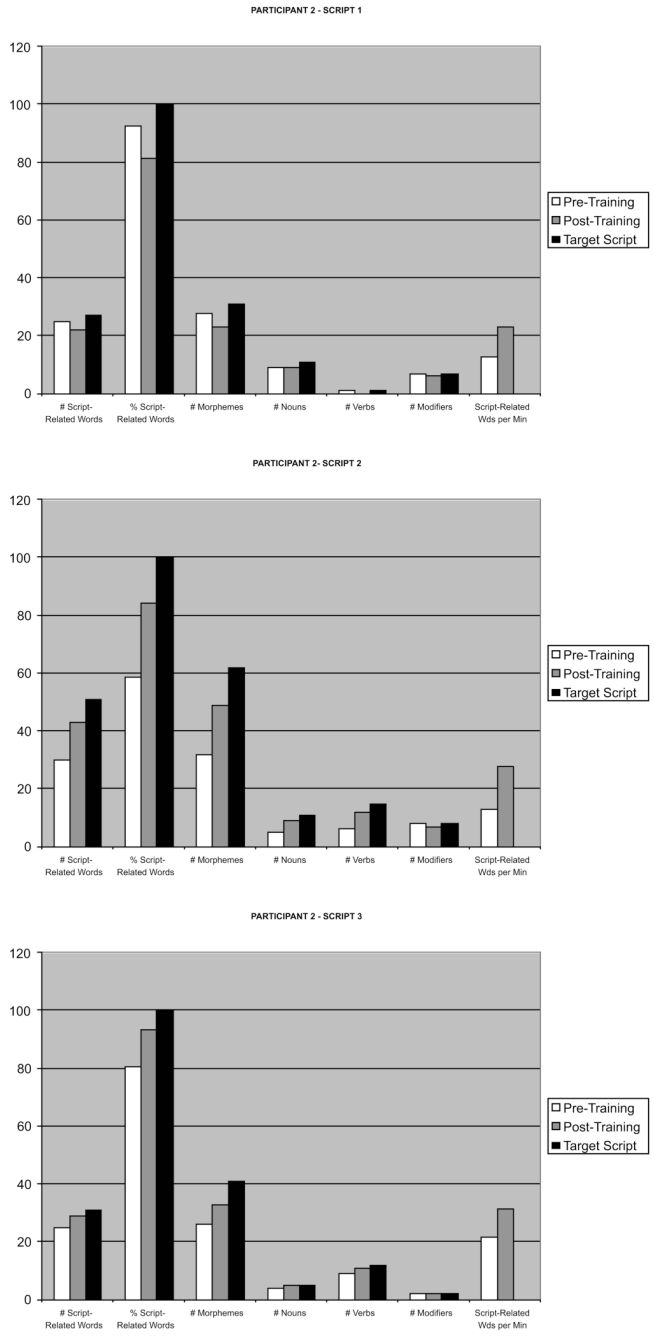

Figure 3.
Pretreatment and posttreatment script performance for Participant 2 with comparison to target performance.

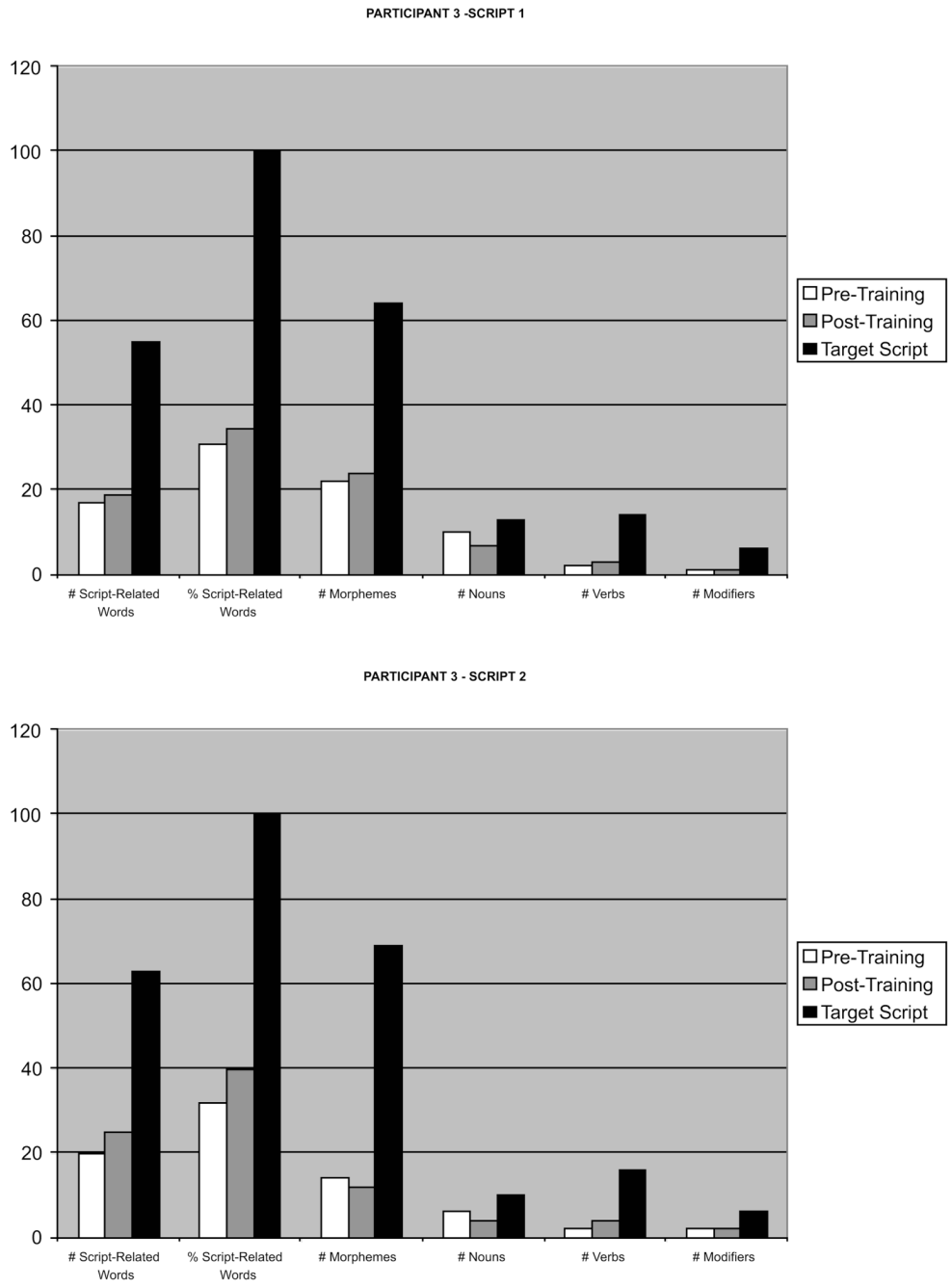

Figure 4.
Pretreatment and posttreatment script performance for Participant 3 with comparison to target performance.

Table 1

Pre- and posttreatment test data

	Participant 1 (nonfluent aphasia)			Participant 2 (nonfluent aphasia)			Participant 3 (fluent aphasia)		
	Pre-Tx	**Post-Tx**	**F/U**	**Pre-Tx**	**Post-Tx**	**F/U**	**Pre-Tx**	**Post-Tx**	**F/U**
WAB AQ	51.4	57.6	63	51.9	54	53.5	81	79	81.6
Total QCL[2]	70	63	61	64	74	80	71	60	75
CADL-2[3] raw score	54	47	50	38	28	33			
CETI	51.8	58.6	72.5	31.3	28.9	27.4			

Note: Pre-Tx = pretreatment; Post-Tx = posttreatment; F/U = follow-up; WAB AQ = Western Aphasia Battery – Aphasia Quotient; QCL = Quality of Communication Life; CADL = Communication Abilities of Daily Living; CETI = Communicative Effectiveness Index.

Table 2

Treatment protocol timeline of activities

Time	Activity
Week -1	Pretreatment assessment of speech, language, and quality of communication life
Week 0	Participant enrollment
Week 1	Needs assessment and identification of potential script scenarios and prioritization; initial brainstorming for content of scripts
Week 2–4	Development of three different short scripts
Week 5	Computer automation of script
Week 6	Baseline measures of script performance; training on use of laptop computer and software and completion of practice log
Week 7–9	Home practice on script 1 (minimum 30 min/day); weekly measures of script performance
Week 10–12	Home practice on script 2 (minimum 30 min/day); weekly measures of script performance
Week 13–15	Home practice on script 3 (minimum 30 min/day); weekly measures of script performance
Week 16	Posttreatment assessment of speech, language, and quality of communication life

Table 3

Weekly practice time in minutes

Weeks	Participant 1 (nonfluent aphasia)	Participant 2 (nonfluent aphasia)	Participant 3 (fluent aphasia)
Script 1, Week 1	127	100	81
Script 1, Week 2	56	83	109
Script 1, Week 3	49	50	108
Script 2, Week 1	76	63	56
Script 2, Week 2	56	47	71
Script 2, Week 3	66	315	66
Script 3, Week 1	30	200	111
Script 3, Week 2	45	194	68
Script 3, Week 3	44	202	88
Total practice	549	1254	758
	(9 hours, 9 minutes)	(20 hours, 54 minutes)	(12 hours, 38 minutes)

Table 4

Exit interview themes with examples

Themes	Participant 1	Participant 3
Increased verbal communication	C: Have you noticed any changes since she started participating? S: Oh yeah. C: What kind of…? S: Her speech and her ability to speak has improved substantially. C Really? S: Oh yeah. She's able to express herself in full sentences, and, uh, she's able to communicate where she wasn't able to before. C: Okay S: She'll say I want this, or I want that, or let's go here, or whatever, which she wasn't able to do before. S: So she can communicate much easier and substantially more communication.	S: Before April, I was hesitant to even correct him because he was so withdrawn. You know, he would sit for hours and say nothing. He's even started initiating conversation over what's happening on the TV. I'll leave and he'll say, have a good day, what's your schedule like today, or when will you be back? Things – this is the first time since January 14, 2002, that I've been questioned. What are you doing today? If I come home a little later than usual, he'll say, "You must have had a real long day." I say, "Well why would you say that?" He said, "Because its late." C: That's great for us to hear that. S: It's been a great inspiration to actually see Ben get back a lot of the liveliness he had before his aneurysm. S: If you notice when he comes in, he even initiates salutations. I'm sure you noticed that this morning: "good morning, how are you?" That's just his own personality. He's coming back.
Generalization to other modalities and situations	S: She's also able to give us more motion (and) language. She'll point to something, or she'll nod her head or whatever. C: So more gesturing. C: See if you can think of any specific examples of her saying things… S: …We've had friends over, where they come into the house, and she initiates the conversation by saying "How are you?" "nice to see you," things like that, which had never taken place before. She'd be very, she'd be mute. C: "Nice to see you" is actually in her script. C: Have you noticed any differences in her reading? S: Yes. My daughter gets a slew of magazines, and she takes to magazines, and she actually does some reading in the magazines. And that's pretty small type so she's been doing a good job on that. Newspapers she's reading …magazines, fashion magazines she gets very involved in. C: Is that something that's relatively new? S: Pretty new.	S: Four months ago, he wouldn't have been able to even react…. But he actually interacts, I'm telling you, and he remembers, he remembers his nurse's aide from the fourth floor, he says I know you. Before the study, I don't think he would have been able to articulate that…. So I would, I can see that Ben's memory is better. C: Did he ever use those specific scripts outside of the practice? S: Yes, yes. …A couple of few weeks ago, we went to lunch, and I got a call, so I go out and answer the phone because it was breaking up in the restaurant. When I came back, Ben had ordered…. So yes, he did practice the breakfast script. He ordered breakfast. And he ordered his pancakes and his sausage and everything in the script. [laughs] Because I think it's important that you know that he's actually using the materials that were generated for him and personalized. I'm telling you he ordered that exact breakfast. [laughed] Now when we went shopping,… he was getting a suit, and he asked specifically for the shirt and the slacks. And when he tried them on, he says, I don't know if he said hemmed or cuffed, but the bottom line he realized they needed to be altered.
Improvements noticed by others		C: What about from your daughter's perspective? Does she comment on things, notice things? S: I'll tell you what she notices. He's more independent.
Increased confidence		S: But it did give him a daily routine, which I pray for because all he was doing was looking at the TV. It did give him, I would say, the courage to speak regardless to the way it comes out. S: But again he is articulating more; before, if he said anything and it wasn't correct, mum would be the word for the next two or three days. Because he was never secure enough to trust what was going to come out of his mouth. Now, what comes up comes out. S: Yesterday, he was going upstairs. I said, "Where you going?" He said, "To get a cup of water." And I was so tempted to say, oh I'll get it. But then something told

Themes	Participant 1	Participant 3
		me no, no no no. He didn't ask you to get it. He said he was going to get it. There we go with the example of having more confidence in speaking, initiating other areas of your daily living skills. And I really think because he is able to better express himself, he is motivated to be more independent.
Satisfaction with program	S: Yeah. She'll repeat once, she'll repeat twice, then she's frustrated if she has to repeat it a third time. She feels that it's senseless. C: It was too repetitive? S: Too repetitive. I think so, too, but I'm not an expert in aphasia. S: Frankly, I didn't have any expectations. She's been in speech therapy for almost 5 years, and there's a little progress, but, in my interpretation, very minimal progress. I was very much surprised at the progress we encountered with the program. So we were happy with it. C: And other than her getting a little frustrated with having to practice, do you think it met her expectations, or she was satisfied? S: Yes, she's satisfied. She wasn't, I shouldn't say she wasn't, she's not unhappy with her need to practice. She was unhappy with the amount of repetitiveness.	S: But my whole point is, he's alive and he's interactive. He perhaps will not say things in the manner you or I would say them, but the manner which he expresses himself is accepted. So I just thank God for the study

Note: C = clinician; S = spouse.