Writing Treatment for Severe Aphasia: Who Benefits?

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Writing treatment that involved repeated copying and recall of target words was implemented with 8 individuals with severe aphasia in order to discern the best candidates for the treatment. Four of the 8 participants had strong positive responses to the copy and recall treatment (CART), relearning spellings for 15 targeted words during 10 to 12 weeks of treatment and up to 5 additional words during a month-long homework-based program. Of the 4 other participants, 3 learned the spellings of some target words but failed to reach criterion, and 1 had a poor treatment outcome. Insights regarding possible factors that limited success were gained by examination of individual responses to treatment as well as performance on the pretreatment assessments of semantic, phonological, and orthographic processes. Among the factors associated with success were (a) consistent, accurate completion of daily homework, (b) a relatively preserved semantic system, (c) the ability to discern words from nonwords, and (d) adequately preserved nonverbal visual problem-solving skills. Aphasia severity and minimal pretreatment spelling abilities did not necessarily limit the response to treatment. Participants with positive treatment outcomes demonstrated improved spelling of target words following repeated copying within a single treatment session, and accurately completed daily writing homework. Thus, pretreatment assessment and stimulability within initial treatment sessions provided indications of likely outcome.

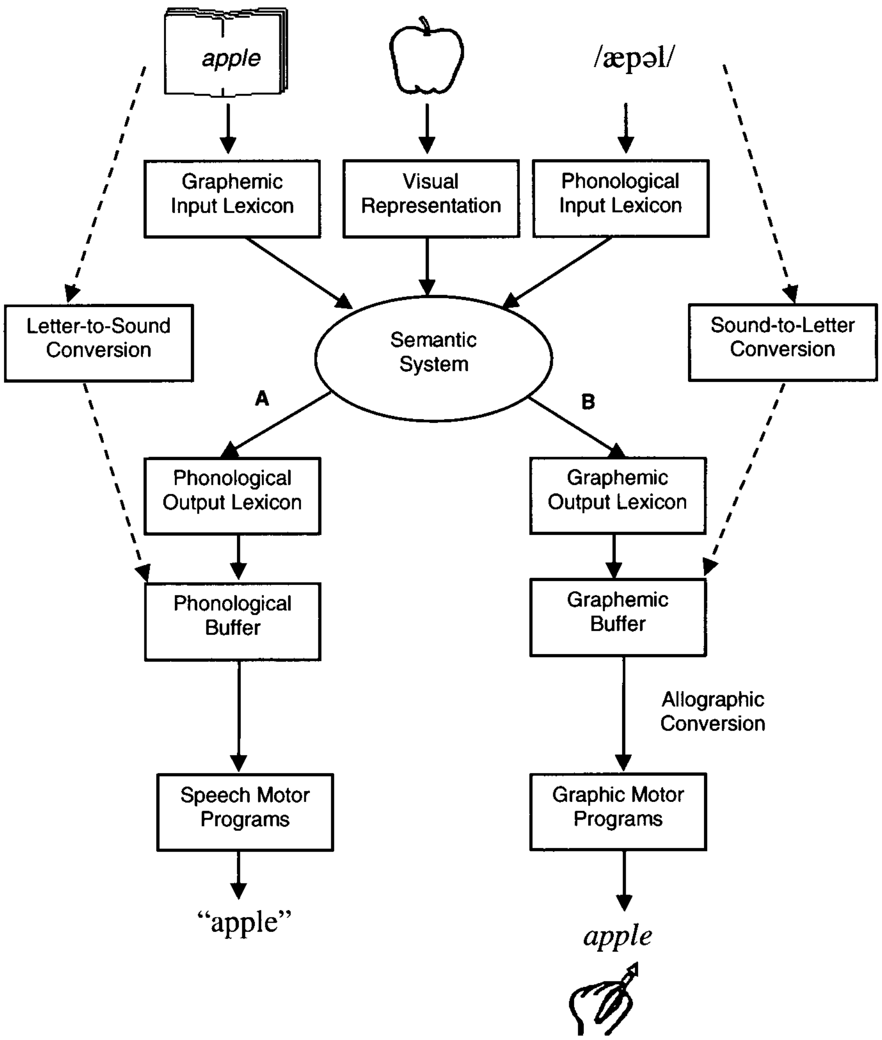
KEY WORDS: agraphia, aphasia treatment, aphasia, assessment, treatment procedures

Individuals with persistent, severe aphasia present a clinical challenge to speech-language pathologists. In many instances, severely impaired spoken language does not improve with treatment, and the utilization of other communication modalities such as writing, gesture, or drawing should be explored. Of these alternatives, writing most closely approximates the specificity of spoken language, and therefore may be an appropriate target for treatment. Most individuals with severe aphasia have concomitant impairments of spoken and written language; however, several case reports have documented better preserved written than spoken naming, suggesting that component processes for writing and speech can be selectively or differentially impaired (Basso, Taborelli, & Vignolo, 1978; Bub & Kertesz, 1982; Ellis, Miller, & Sin, 1983; Levine, Calvanio, & Popovics, 1982). In addition, recent case reports have documented a positive response to writing treatment in individuals with severe aphasia and persistent impairments of spoken language (Beeson, 1999; Beeson, Hirsch, & Rewega, 2002; Robson, Marshall, Chiat, & Pring, 2001).

To appreciate the improvement in writing in the face of marked impairment of spoken language, it is helpful to consider the cognitive processes involved in the comprehension and production of spoken and written words. Under normal circumstances, auditory or visual input provides access to semantic concepts as depicted in the simplified model of language processing shown in Figure 1 (after Beeson & Hillis, 2001; see also Ellis, 1993; Rapcsak & Beeson, 2000). Semantically guided retrieval of word forms from the phonological output lexicon (Path A in Figure 1) ultimately activates the appropriate motor programs for speech production. By analogy, the semantic system provides access to spelling knowledge stored in the graphemic output lexicon (Path B in Figure 1). These procedures are considered lexical–semantic processes because they involve links between lexical representations and the semantic system (Ellis, 1993; Margolin, 1984; Rapcsak & Beeson, 2002). Just as phonological representations must be translated to motor movements for speech, abstract graphemic representations are translated into handwriting through the process of letter selection (also referred to as allographic conversion) and the implementation of graphic motor programs.

It should be acknowledged that reading and writing can by accomplished via alternate routes that rely on phonological procedures rather than the lexical–semantic route (Ellis, 1993; Rapcsak & Beeson, 2002; Shallice, 1988). These alternate routes are shown in Figure 1, with dashed arrows indicating that written words may be decoded by letter-to-sound conversion (shown on the left) and spoken words may be spelled by sound-to-letter conversion (shown on the right). These procedures are considered sublexical in contrast to the lexical–semantic routes indicated by Paths A and B, and they support

Figure 1. Schematic representation of cognitive processing of single words. Path A indicates lexical-semantic route for accessing phonological word forms; Path B indicates lexical-semantic route for accessing orthographic word forms. Dashed arrows indicate sublexical (phonological) procedures for oral reading and spelling.



attempts to read and spell unfamiliar words and plausible nonwords by taking advantage of knowledge of letter–sound correspondences. The output from such conversions is held in the phonological buffer (for oral reading) or the graphemic buffer (for writing), as peripheral processes are planned and implemented for speech or writing, respectively.

This conceptual model is useful as we consider the residual abilities following brain damage. Extensive damage to perisylvian regions in the language-dominant hemisphere typically impairs phonological processes so that speech production is limited and sublexical strategies are not available for reading or writing (Coltheart, 1980; Rapcsak & Beeson, 2000, 2002; Roeltgen, 1994; Shallice, 1981). In other words, individuals with severe aphasia typically have markedly impaired phonological abilities so they are not able to use sublexical conversion strategies, and must rely on damaged lexical–semantic processing. In such cases, treatment may be directed toward strengthening lexical–semantic spelling procedures so that single-word writing may become a usable means of communication. Writing treatment may be more successful than that directed toward speech if orthographic representations are better preserved, or more amenable to treatment, than phonological representations. Similarly, motor control for the hand may be better preserved than that for the speech mechanism even in cases in which the nondominant hand is used for writing (Beeson et al., 2002).

A review of the aphasia treatment literature provides relatively limited documentation of successful treatment of writing in individuals with significant aphasia (see review in Beeson & Hillis, 2001). Of the few writing treatment studies reported before 1985, there was only modest support for lasting change in written spelling following treatment (Hatfield & Weddel, 1976; Seron, Deloche, Moulard, & Rouselle, 1980). More recent case reports provide stronger support for lexical–semantic approaches to writing treatment for individuals with moderate and mild aphasia (Aliminosa, McCloskey, Goodman-Schulman, & Sokol, 1993; Carlomagno, Iavarone, & Colombo, 1994; Hillis, 1989) and those with severe aphasia, including severe Wernicke's, Broca's, and global aphasia (Beeson, 1999; Beeson et al., 2002; Robson, Marshall, Chiat, & Pring, 2001; Robson, Pring, Marshall, Morrison, & Chiat, 1998). The treatment hierarchies used by Hillis (1989) and Beeson and colleagues (1999, 2002) included spelling by the arrangement of component letters (i.e., anagram task) and copying of target words. Carlomagno et al. (1994) also included direct, as well as delayed, copying of target words in their treatment, as was used by Hillis (1989), Aliminosa et al. (1993), Beeson et al. (2002), and Robson et al. (1998, 2001).

The Copy and Recall Treatment (CART) described by Beeson et al. (2002) exemplifies a lexical–semantic approach to writing treatment. It simply involves repeated copying of target words in the presence of pictured stimuli, followed by recall trials in the form of written picture naming. CART was initially used to structure homework for participants receiving anagram and copy treatment (ACT; Beeson, 1999; Beeson et al., 2002), but CART was also shown to be effective when implemented without ACT (Beeson et al., 2002). Using CART with two clinical sessions per week and daily homework, an individual with severe Broca's aphasia relearned written spelling for 46 words over 3 months (Beeson et al., 2002).

The experimental evidence to date supports the therapeutic effect of CART in some individuals with severe aphasia (Beeson, 1999; Beeson et al., 2002). In terms of the continuum of research necessary to establish treatment efficacy, these data may be considered part of Phase 1 of clinical outcome research as described by Robey and Schultz (1998), and suggest that the approach is worthy of further investigation. Because CART employs daily homework, it has the potential to be successfully implemented with a relatively modest amount of clinical intervention. The next phase of research should serve to refine the treatment procedures and determine the subset of individuals for whom treatment is most beneficial. This would be considered Phase 2 of treatment efficacy research, which precedes the implementation of large-sample efficacy testing (Robey & Schultz, 1998). In the present study, we sought to examine treatment outcomes when CART was administered with weekly clinical sessions and daily homework. In addition, our goal was to gather evidence regarding the nature and severity of cognitive and linguistic impairment of those who respond positively to CART versus those who do not.

Method

Participants

The 8 participants in this study were all at least 2-years poststroke with persistent severe aphasia as indicated by aphasia quotients less than 30 on the Western Aphasia Battery (WAB; Kertesz, 1982) and severity ratings of 1 according to the Boston Diagnostic Examination for Aphasia–Third Edition (Goodglass & Kaplan, 2001). Participants ranged in age from 65 to 79, and English was their primary language. Six of the participants were right-handed, but only 2 of them persisted in use of the right hand for writing after stroke (see Table 1). Two participants were left-handed prior to their stroke, and 4 participants used the nondominant left hand for writing after their stroke. Despite differences in handedness, all participants appeared to be left-hemisphere

Table 1. Participant characteristics.

Characteristic	D.R.	S.L.	W.K.	W.D.	M.B.	G.P.	J.F.	M.R.
Sex	Female	Male	Female	Male	Male	Female	Male	Male
Age (years)	70	65	78	66	64	79	70	76
Handedness pre/post	R/L	R/L	R/L	L/L	R/R	R/R	L/L	R/L
Education (years)	16	20	14	16	12	20	21	13
Time poststroke (years)	3.5	7	2	4	2	3	3	2
WAB AQ	28.8	23.6	14.7	24.7	24.0	16.8	15.7	15.8
Aphasia type	Severe Broca's	Severe Broca's	Severe Broca's	Severe Broca's	Wernicke's	Severe Broca's	Severe Broca's	Severe Broca's

Note. WAB AQ = Western Aphasia Battery Aphasia Quotient. Pre/post = before versus after stroke.

dominant for language, as evidenced by severe aphasia following damage to the left perisylvian region. All but 1 participant were nonfluent and experienced some degree of right hemiparesis. Although not documented explicitly in each case, it was likely that all 8 participants were globally aphasic at earlier stages of recovery. For this study, aphasia type was determined by performance on the WAB: 1 participant had Wernicke's aphasia and 7 were classified with severe Broca's aphasia as their auditory comprehension scores were just above the cut-off for global aphasia. All participants were in need of additional means of communication because of limited speech production. Although each participant had received individual treatment prior to this investigation, none had received treatment directed toward writing. During the course of this study, they remained participants in weekly aphasia groups that were intended to maximize conversational communication using all modalities.

Pre- and Posttreatment Assessment

Selected subtests from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1992) were administered to assess single-word processing abilities before and after treatment. The selected subtests from the PALPA allowed for examination of single-word reading (visual lexical decision and written word-to-picture matching), auditory comprehension (spoken word-to-picture matching), verbal repetition, written naming, and writing to dictation (see Table 2). In addition, the picture version of the Pyramids and Palm Trees Test (Howard & Patterson, 1992) was administered to examine the ability to make semantic associations. This test simply involves matching a target picture to a semantically related picture from a field of two. Peripheral writing processes were assessed using a case conversion task in which participants were asked to write uppercase letters when presented with lowercase letters, and vice versa. Additional information about graphomotor skills was obtained from each participant's performance on direct copying of written words.

Two measures of nonverbal cognitive skills were obtained for each participant: Coloured Progressive Matrices (CPM; Raven, Court, & Raven, 1990), which provides information about visual problem-solving ability, and the Tapping Forward Subtest from the Wechsler Memory Scale–Revised (WMS-R; Wechsler, 1987), which provides an indication of visual memory span. Finally, the oral language portions of the WAB (Kertesz, 1982) were readministered following treatment to examine whether any changes occurred in modalities other than writing (namely, auditory comprehension or verbal expression).

Treatment Materials

With input from family members, a list of potential target words was generated for each participant, reflecting their interests and needs. From this list, 20 picturable words were selected based on functionality and personal relevance. Word lists included predominantly common nouns (e.g., favorite foods, places, activities) and proper names (e.g., family names). Target words ranged in length from 2 letters (e.g., *TV*) to 9 letters (e.g., *telephone*), with an average word length between 4.2 and 5.5 letters across participants. To represent each word, a line drawing or photograph was obtained or created and was affixed to an index card. The word lists for each participant were divided into four sets of target words with five words per set.

Procedure

A single-subject, multiple baseline design was used to examine the effect of writing treatment with each participant. Prior to the initiation of treatment, participants were seen once a week for 3 weeks to probe written

Table 2. Participant performance on pre- and posttreatment measures.

Measure	Participant							
	D.R.	S.L.	W.K.	W.D.	M.B.	G.P.	J.F.	M.R.
Aphasia Quotient								
Pre	28.8	23.6	14.7	24.7	24.0	15.6	17.5	15.8
Post	23.9	24.6	12.9	25.7	21.8	16.7	15.7	16.7
Written Lexical Decision (PALPA 25)								
Pre	68/120[c]	87/120	115/120	117/120	64/120[c]	65/120[c]	106/120	72/120[c]
Post	59/120[c]	85/120	88/120	117/120	72/120[c]	67/120[c]	102/120	83/120
Written Word to Picture (PALPA 48)								
Pre	19/40	22/40	23/40	13/40	21/40	7/40[c]	17/40	9/40[c]
Post	28/40[a]	29/40	26/40	21/40	19/40	7/40[c]	22/40	8/40[c]
Spoken Word to Picture (PALPA 47)								
Pre	30/40	31/40	25/40	23/40	33/40	22/40	20/40	17/40
Post	29/40	36/40	29/40	17/40	31/40	20/40	15/40	16/40
Pyramids and Palm Trees								
Pre	44/52	42/52	38/52	33/52	47/52	28/52[c]	37/52	32/52[c]
Post	46/52	40/52	40/52	40/52	45/52	22/52[c]	28/52[c]	38/52
Verbal Repetition (PALPA 53)								
Pre	18/40	21/40	1/40	11/40	6/40	0/40	0/40	1/40
Post	20/40	30/40[a]	0/40	20/40[a]	3/40	0/40	0/40	1/40
Written Picture Naming (PALPA 53)								
Pre	0/40	0/40	0/40	0/40	0/40	0/40	0/40	0/40
Post	1/40	0/40	1/40	0/40	0/40	0/40	0/40	0/40
Writing to Dictation (PALPA 53)								
Pre	0/40	0/40	1/40	0/40	0/40	0/40	0/40	0/40
Post	2/40	0/40	1/40	1/40	0/40	0/40	0/40	0/40
Upper- to lowercase letters								
Pre	20/26	26/26	2/26	20/26	22/26	11/26	25/26	0/26
Post	25/26	26/26	0/26	9/26[b]	24/26	16/26	26/26	0/26
Lower- to uppercase letters								
Pre	0/26	25/26	6/26	21/26	23/26	19/26	24/26	0/26
Post	22/26	25/26	9/26	15/26	22/26	22/26	26/26	0/26
Direct copy words								
Pre	11/11	11/11	6/11	11/11	8/11	11/11	11/11	9/11
Post	11/11	11/11	9/11	11/11	7/11	11/11	11/11	10/11
Raven's CPM (Percentile)								
Post	95th	67th	75th	75th	3rd	5th	59th	5th
Forward Visual Span (Percentile on WMS-R)								
Post	18th	3rd	4th	3rd	1st	1st	44th	22nd

Note. Tx = treatment; PALPA = Psycholinguistic Assessment of Language Processing in Aphasia; CPM Coloured Progressive Matrices; WMS-R = Wechsler Memory Scale–Revised.

[a]Significantly better performance on posttreatment assessment. [b]Significantly poorer performance on posttreatment. [c]Performance at chance.

spelling for their respective target words to establish baseline performance. During each session, pictures for each participant's target words were presented in random order while the clinician provided the verbal label and asked the participant to write the word (e.g., "This is a dog. Can you write dog?"), as described in Figure 2.

After three pretreatment probes were completed, weekly treatment sessions commenced for Set 1 using CART, and probes continued for untrained words as depicted in Figures 3–10. The CART protocol outlined in Figure 2 used repeated copying and recall trials for each target word. Each hour-long session followed a similar format: The probes for trained and untrained sets were obtained, homework was reviewed to check for completeness and accuracy, and training of the current word set using CART was implemented. At the end of each treatment session, participants were provided with six homework packets, labeled for each day of the week they were not in treatment. The packets consisted of labeled pictures for the currently targeted word set. Participants were instructed to copy the target words 20 times each day on the lines provided, then cover all written words and attempt to recall the spelling of target words. In order to ensure that recall was attempted, each packet included daily test pages for written naming that included line drawings without a written model of the target word (see Figure 2).

Weekly probes were conducted in the same way as pretreatment probes and were intended to assess performance on the target set being trained, as well as maintenance of previously trained sets, and stability of untreated sets. It is important to note that the probe data reflected performance on the *first* trial for each word in the session, not performance following CART within the session. Criterion for mastery of spelling was defined as a participant's ability to write at least four of five words in a set over a minimum of two consecutive sessions. After a participant met criterion on one set of target words, training began on the next set. Continued practice with the mastered words was facilitated by inclusion in the homework packets (with half the frequency used during initial training), so that the maintenance condition also included a homework-based treatment component. When a participant met criteria for Sets 1–3, treatment sessions with the clinician ended and the participant was given a month's worth of daily homework for the mastered sets (1–3) and the untrained Set 4. One month later, the participant was seen for a final probe to assess maintenance of the trained sets, as well as the ability to independently learn the target words in Set 4.

In the event that a participant was unable to correctly spell any of the target words over the course of five consecutive sessions, training was discontinued for that set. If some improvement was demonstrated but criterion was not met, training was continued for 10 sessions. Training on a second word set was implemented to verify that the lack of success on the previous set was not a result of the particular words chosen in the first set. If treatment still failed to yield positive results, CART was discontinued.

As participants mastered the spellings of targeted words, the latter part of each treatment session focused on promoting conversational use of written words. During this part of the session, the clinician elicited the use of written words in a conversational manner. For example, if a participant mastered the spelling of the word *dog*, the clinician would ask a question such as, "What kind of pet do you have?" As needed, a variety of cues including verbal prompts and pictured examples of the target were used to elicit appropriate answers. Because of the informal nature of this interaction, data were not collected for formal analysis; however, a subsequent experimental study of conversational use of written words was implemented and is reported elsewhere (Clausen & Beeson, 2003).

Data Analyses

Treatment outcomes were analyzed for each participant by visual inspection of multiple baseline data, documentation of attainment of criterion for the word sets, and calculation of the treatment effect sizes using the f statistic (Kromrey & Foster-Johnson, 1996; see Appendix for a description of the method used to calculate the f statistic). An f statistic was computed to index change in level of performance from baseline to treatment/maintenance conditions for each word set. Thus, the f statistic was used to indicate the magnitude of change in the number of words correctly written before versus after the initiation of treatment. Average f values computed for each participant were weighted for the number of observations obtained for each word set targeted for treatment. The magnitude of f was interpreted relative to guidelines suggested by Cohen (1988). Specifically, we took the square root of the f^2 values suggested by Cohen, so that .14, .39, and .59 were considered to reflect small, medium, and large effects, respectively. Pre- and post-treatment assessment measures were compared using chi-square tests of independence.

Results

Each participant in this study was evaluated and treated over the course of 4–5 months. The work with all 8 participants was accomplished over a 2-year time frame. For ease of comparison, the case reports are ordered below in general accordance with their responsiveness to treatment, rather than the actual order in which they were treated. All participants gave informed consent prior to initiation of the study. Initials are used for participant reference, but they do not reflect actual identities.

Participant D.R.

D.R. was a 70-year-old, right-handed woman who experienced a left hemisphere stroke at age 65. The stroke resulted in persistent right hemiparesis and severe nonfluent aphasia. Prior to the present treatment, D.R. achieved an aphasia quotient of 28.8 on the WAB and a profile consistent with severe Broca's aphasia. Spoken utterances and attempts to repeat words were characterized by the stereotyped utterance, "What is dat?" D.R. was able to produce some correct, effortful

Figure 2. Copy and recall treatment protocol.

CART training during clinical session

1. Select line drawing from target set and present with a verbal cue
   Example: "Coffee. Can you write the word coffee?"
   → Correct: Give feedback and then present the next word.
   → Incorrect: Proceed through the following steps.

2. Present a handwritten model of the word. Model may be written by clinician, or may be an example from participant's homework or previous written responses.
   Prompt the copying of target word three times, providing feedback regarding accuracy.
   Example: "It looks like this. Coffee. Can you copy it?" ... "Write it again." ... "One more time, write coffee."

3. Remove all examples of the written word. Present line drawing and prompt recall of the word three times.
   Example: "Do you remember it now. Write coffee." [Give feedback, then cover the word]
   "Write it again." [Give feedback, then cover the word.]
   "One more time, write coffee."
   → Correct: Present the next word
   → Incorrect: Repeat steps 2-4

4. If unable to correctly write the word without a model after several trials, move on to next item. Return to the word later in the session, if possible.

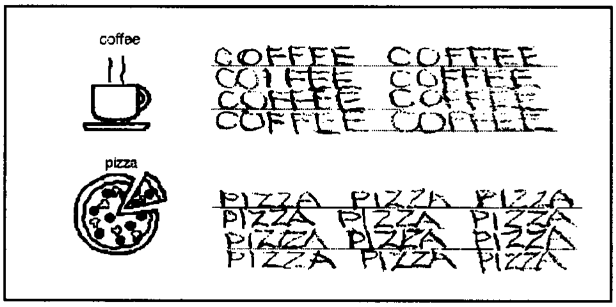
CART Homework

1. Provide daily homework pages for six days a week.
   Each day's homework includes labeled pictures, each with 20 lines for copying the written word. Also include a test page for each day with the target pictures provided (without written label) with a blank line for recall of written word.

2. As word sets are mastered, include homework for old and new word sets.
   Homework for mastered words may be reduced so that those words are practiced at reduced frequency.

Example homework pages.

Copying



Recall

productions of single words and some rote utterances that she practiced at home with her husband (e.g., counting, days of the week).

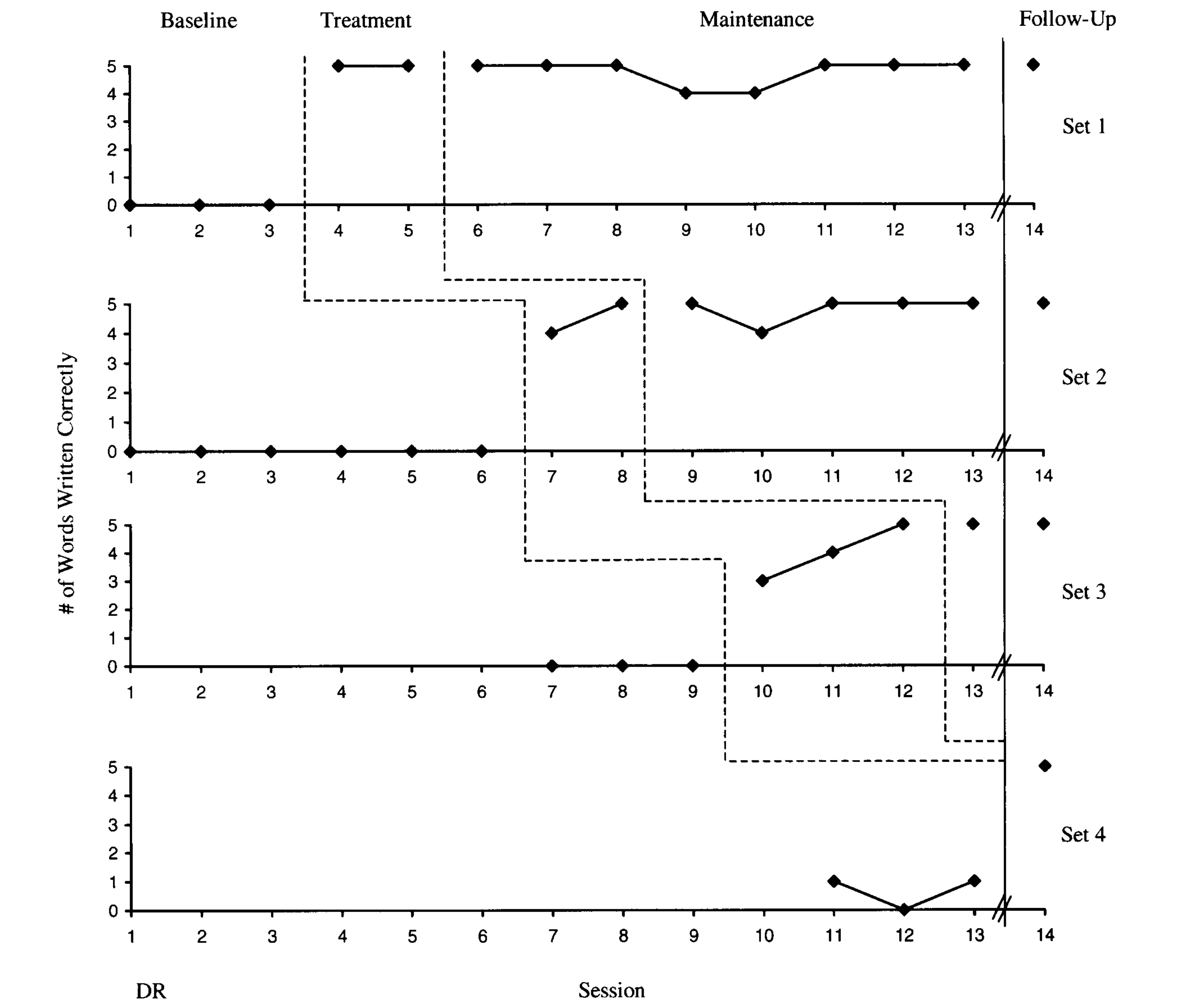
Pretreatment Assessment

D.R. had severe impairment to multiple levels of single-word processing, as shown in Table 2. She produced few appropriate spoken utterances, but was able to repeat some single words. Pretreatment assessment showed that she had diminished ability to retrieve graphemic information by way of the semantic system or phonology. Her single writing attempt was *Dod* for *dog*. When copying words, her writing was slow and somewhat unsteady, but all words were legible, indicating adequate graphomotor control of her nondominant hand. D.R. demonstrated a relative strength in her ability to identify semantic associations on the Pyramids and Palm Trees Test.

Response to Treatment

As shown in Figure 3, D.R. was able to spell only one of the target words (*pizza* in Set 4) prior to the initiation of CART, and she did so inconsistently. Her ability to write the target words improved as word sets were sequentially entered into treatment, and she relearned the spelling for 15 words over the course of 10

Figure 3. Participant D.R.: Writing performance on weekly probes taken during baseline, treatment/maintenance, and follow-up for four sets of single words. Initiation of treatment (for a given word set) is indicated by the leftmost vertical dashed line. Hash marks on the abscissa indicate a one-month interval of CART homework without clinical sessions.



treatment sessions. D.R. wrote an average of 4.67 out of 5 words per set following the initiation of treatment (see Table 3). Treatment effects were particularly large (f = 3.20), reflecting the fact that she met criterion rapidly on each word set (see Figure 3). Following the subsequent month of homework with the addition of Set 4, D.R. was able to correctly spell all 20 target words.

It was notable that D.R. began to verbalize target words during the course of treatment. She initially began repeating target items after the clinician said them, and by the end of treatment was occasionally naming targets prior to the clinician's verbal cue. In some instances, she also gave verbal responses to conversational probes for the target words, (e.g., she said "wine" in response to "What is your favorite drink?"). D.R.'s husband also reported increased verbalization of target words at home.

Posttreatment Assessment

As shown in Table 2, D.R.'s written word-to-picture matching improved significantly from 19/40 pretreatment to 28/40 posttreatment, $\chi^2(1, N = 80) = 4.18, p < .05$. This improved reading comprehension may have reflected D.R.'s increased exposure to print during the writing treatment; however, she still performed at chance level on the lexical decision task. D.R.'s performance on the writing tasks reflected the item-specific nature of treatment in that there was little generalization to writing of untrained items. Her few correct responses were items on the test that happened to have been targeted for treatment by her family (*fish* and *bread*). D.R. showed improved retrieval of partial word forms that had not been apparent in her pretreatment performance (e.g., *bids* for *bird*, *Mounc* for *mountain*, and *Lome* for *lemon*). Her performance on peripheral writing tasks improved in that she was able to convert lower- to uppercase letters (22/26).

Participant S.L.

S.L. was a 65-year-old, right-handed man who suffered a left hemisphere stroke at age 58 due to an occluded left middle cerebral artery. The stroke resulted in global aphasia, right hemiparesis, and right peripheral visual field defect. The global aphasia evolved to severe Broca's aphasia with persistent right hemiparesis, and apraxia of speech. Prior to treatment, S.L. communicated primarily through stereotyped utterances ("fine, fine," and "what? what?") using varied intonation and facial expression to convey meaning. He was able to produce a few automatic responses (e.g., yes/no and counting), inconsistently repeated single words, and occasionally completed high probability phrases. His aphasia quotient on the WAB was 23.6.

Pretreatment Assessment

As shown in Table 2, S.L.'s performance on pretreatment tasks indicated impairment to numerous components of language processing. He had fairly good comprehension of single spoken words, but had limited reading comprehension, and at least mild impairment to the semantic system. He was unable to write words using either phonological or semantic strategies, but his peripheral writing processes proved to be an area of strength despite use of the nondominant hand.

Response to Treatment

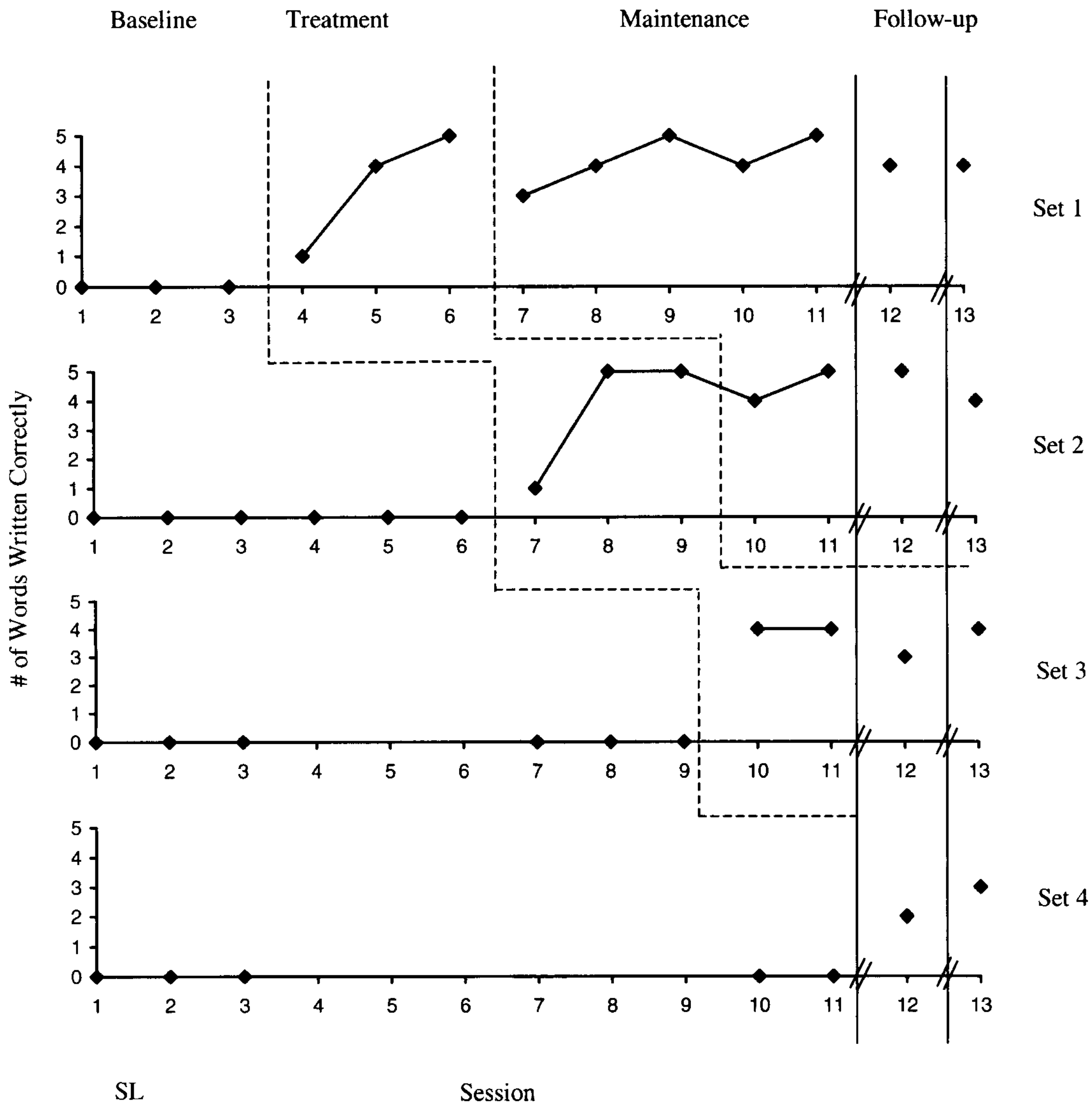
As demonstrated in Figure 4, S.L. was unable to write any of the target words before writing treatment was initiated, and steady improvement occurred after implementation of CART for specific word sets. S.L. met criterion for word Sets 1–3 within eight sessions, and his performance was maintained as subsequent sets were entered into treatment, yielding a large effect size (f = 1.03). S.L. averaged 3.93 correctly written words out of 5 after the initiation of treatment (see Table 3). It was noteworthy that over the course of the first eight treatment sessions, S.L. typically completed twice the daily homework requirement so that he copied the target words about 40 times each day. During the final month of treatment, when S.L. was given homework for the untrained word Set 4 as well as all the previously trained word sets, he was less diligent about his homework, finishing only 16 of 28 days' homework. The follow-up probe showed that he acquired just 2 of 5 words in Set 4, but he was able to correctly spell 14 of the total 20 target words. In a second follow-up probe conducted 1 month after termination of treatment, he wrote 15 of 20 words accurately and 2 more that were recognizable renditions.

It should also be noted that during the treatment sessions S.L. consistently repeated the words aloud as he wrote them. He typically requested that a word be repeated again if he had a difficult time producing it by saying "what? what?" He continued to request that the clinician repeat the word until he was able to accurately produce it and then repeatedly said the word aloud as he wrote it. Although S.L.'s wife indicated that he did not talk while completing his homework, she reported that he was attempting to repeat a variety of spoken words in daily interaction at home. Over the course of treatment, an increase in meaningful reactive utterances was documented by S.L.'s wife and aphasia group clinician, including phrases such as "what time is it?", "glass of water", and "why?".

Posttreatment Assessment

As shown in Table 2, there was little change in S.L.'s performance on the assessment measures following treatment. One notable exception was his significant

Figure 4. Participant S.L.: Writing performance on weekly probes during baseline, treatment/maintenance, and follow-up on two occasions for four sets of single words. Initiation of treatment for a given word set is indicated by the leftmost dashed vertical line. Hash marks on the abscissa indicate a 1-month interval of CART homework without clinical sessions.



improvement on the verbal repetition task, $\chi^2(1, N = 80) = 4.58, p < .05$, a finding that was consistent with his repetition of words during treatment.

Participant W.K.

W.K. was a 78-year-old, right-handed woman who experienced a large left hemisphere stroke at age 76. The stroke resulted in persistent right hemiplegia and severe nonfluent aphasia. W.K.'s spoken language was characterized primarily by stereotyped utterances such as "doodie, doodie," and "I know." At 2 years poststroke her aphasia quotient on the WAB was 14.7, with severe Broca's aphasia. W.K. communicated through intonation and facial expression, and it was necessary for communication partners to carry considerable burden during conversations.

Pretreatment Assessment

W.K.'s pretreatment performance, shown in Table 2, suggested damage to multiple cognitive processes necessary for comprehension and production of spoken and written words. Lexical–semantic and phonological processing for single words were markedly impaired. Impairment of the semantic system was confirmed by her poor performance on the Pyramids and Palm Trees Test and the presence of semantic errors on comprehension tasks. Her strengths included the ability to identify words versus nonwords, suggesting that access to the graphemic input lexicon was relatively preserved.

On the writing tasks, W.K. wrote only one correct word (*dog*). Her spelling attempts contained plausible letter combinations and occasional real words; however, no semantic or phonological relationships to the correct words were apparent (e.g., *SAME* for *comb*, *BAT* for *screw*, *WATE* for *bowl*). W.K.'s peripheral writing processes were moderately impaired as evidenced by difficulty with the case conversion and copying tasks (see Table 2).

Response to Treatment

As shown in Figure 5, W.K. was unable to correctly spell any of the target words prior to the initiation of the CART protocol. Over the course of 12 weeks of CART, her ability to write the target words improved with training, and she met criterion on Sets 1–3. Treatment effects were large relative to changes in level of performance from baseline to treatment/maintenance conditions (f = .97). Following the initiation of treatment, W.K. averaged 4.21 correctly written words per set of 5 (see Table 3). After a month's practice at home, W.K. maintained her ability to spell previously trained target words and was able to correctly spell four of the five target words for Set 4. During treatment, all of W.K.'s written responses were in uppercase, and the legibility of her writing with the nondominant hand improved over time.

Figure 5. Participant W.K.: Writing performance on weekly probes taken during baseline, treatment/maintenance, and follow-up for four sets of single words. Initiation of treatment for a given word set is indicated by the leftmost vertical dashed line. Hash marks on the abscissa indicate a one-month interval of CART homework without clinical sessions.

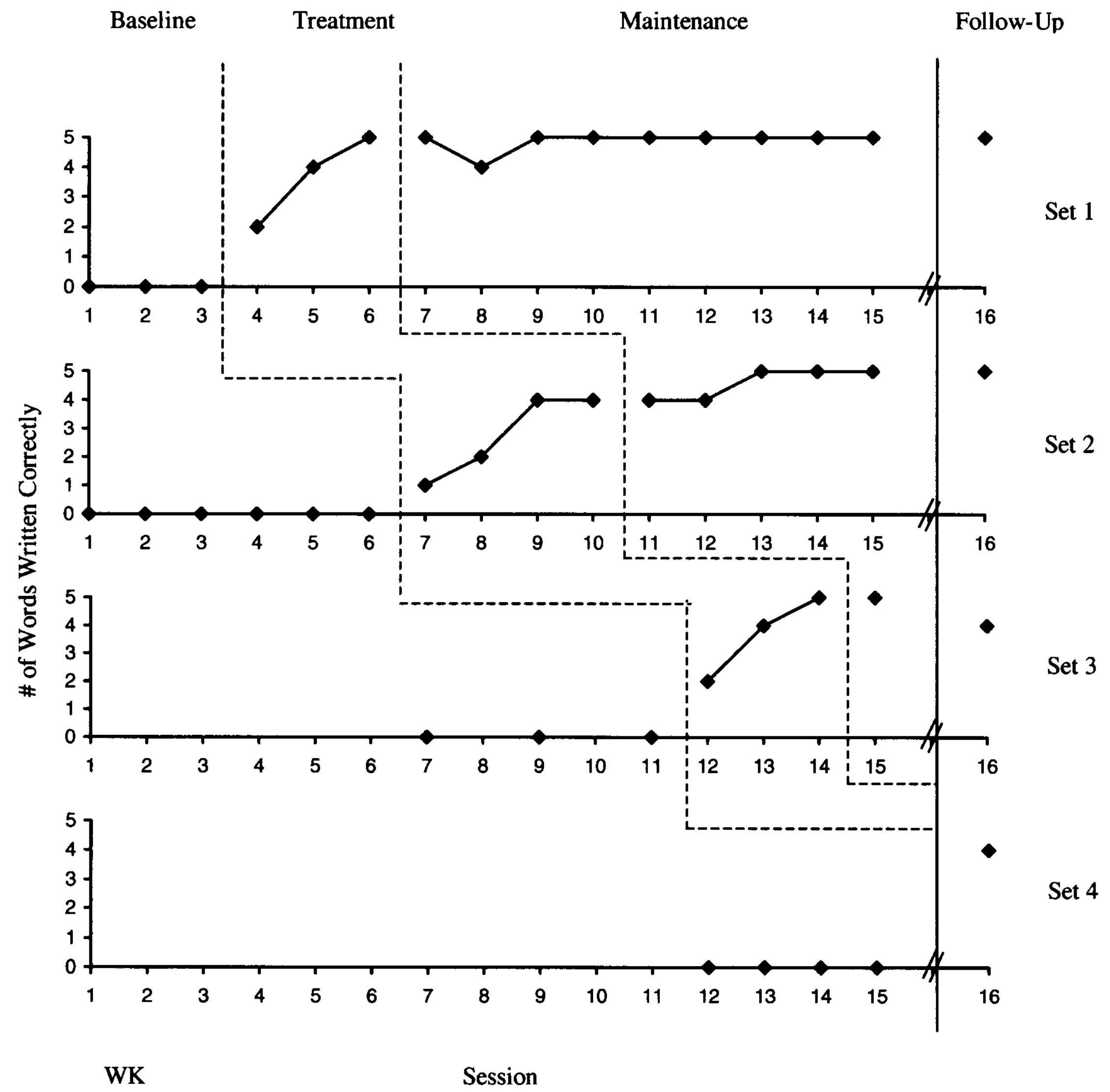


Table 3. Summary of participant responses to treatment.

	Participant							
	D.R.	S.L.	W.K.	W.D.	M.B.	G.P.	J.F.	M.R.
Average no. of words correctly written (per set of 5)								
Baseline condition	0.13	0.00	0.00	0.44	0.00	0.00	0.00	0.00
Treatment & maintenance conditions	4.67	3.93	4.21	3.93	1.93	2.17	1.67	0.00
Treatment effect size (*f* statistic[a])	3.20	1.03	0.97	.84	1.19	.96	0.23	0.00
Magnitude of effect size	Large	Large	Large	Large	Large	Large	Small	None
Criteria met for treated word sets	Yes	Yes	Yes	Yes	No	No	No	No
Follow-up (correct/possible)	20/20	14/20	18/20	20/20	6/10	8/15	2/5	—

Note. Follow-up data were not collected from M.R. [a] See Appendix regarding calculation of the *f* statistic.

Posttreatment Assessment

As summarized in Table 2, W.K. showed no significant improvement on any of the posttreatment measures. Her performance on the lexical decision task declined from 115/120 to 88/120 as she failed to correctly identify 29 real words; but when the test was readministered during a subsequent session, W.K. correctly identified 108/120, suggesting variability in her lexical decision abilities. With regard to writing, W.K. showed no improvement in spelling untrained words, indicating an item-specific response to writing treatment.

Participant W.D.

W.D., a 66-year-old ambidextrous man who used his left hand for writing, experienced a left frontoparietal stroke at age 62. The stroke resulted in right hemiparesis, apraxia of speech and limb, right visual field cut (lower quadrant), and severe nonfluent aphasia. At 4 years poststroke, W.D. achieved an aphasia quotient of 24.7 on the WAB, with performance that was consistent with a classification of severe Broca's aphasia. He communicated primarily by yes/no responses to questions, pointing to things in the environment, or responding to a choice of written words.

Pretreatment Assessment

As shown in Table 2, W.D.'s pretreatment assessment suggested a pattern of significant lexical–semantic and phonological impairment, although he had some ability to repeat spoken words. Written picture naming and writing to dictation were severely impaired, suggesting diminished ability to retrieve graphemic information via the semantic system or phonology. His spelling attempts were often characterized by perseveration of some of the letters (e.g., *doop*, *droop*, *drood* for *eye*, *bird*, and *rabbit*) and implausible letter combinations (e.g., *eppld* for *foot* and *cpole* for *toaster*). He had a relative strength in his ability to identify words versus nonwords, suggesting relatively preserved access to the graphemic input lexicon. He also demonstrated only mild impairment in converting letter cases and exhibited intact graphomotor control using his dominant left hand.

Response to Treatment

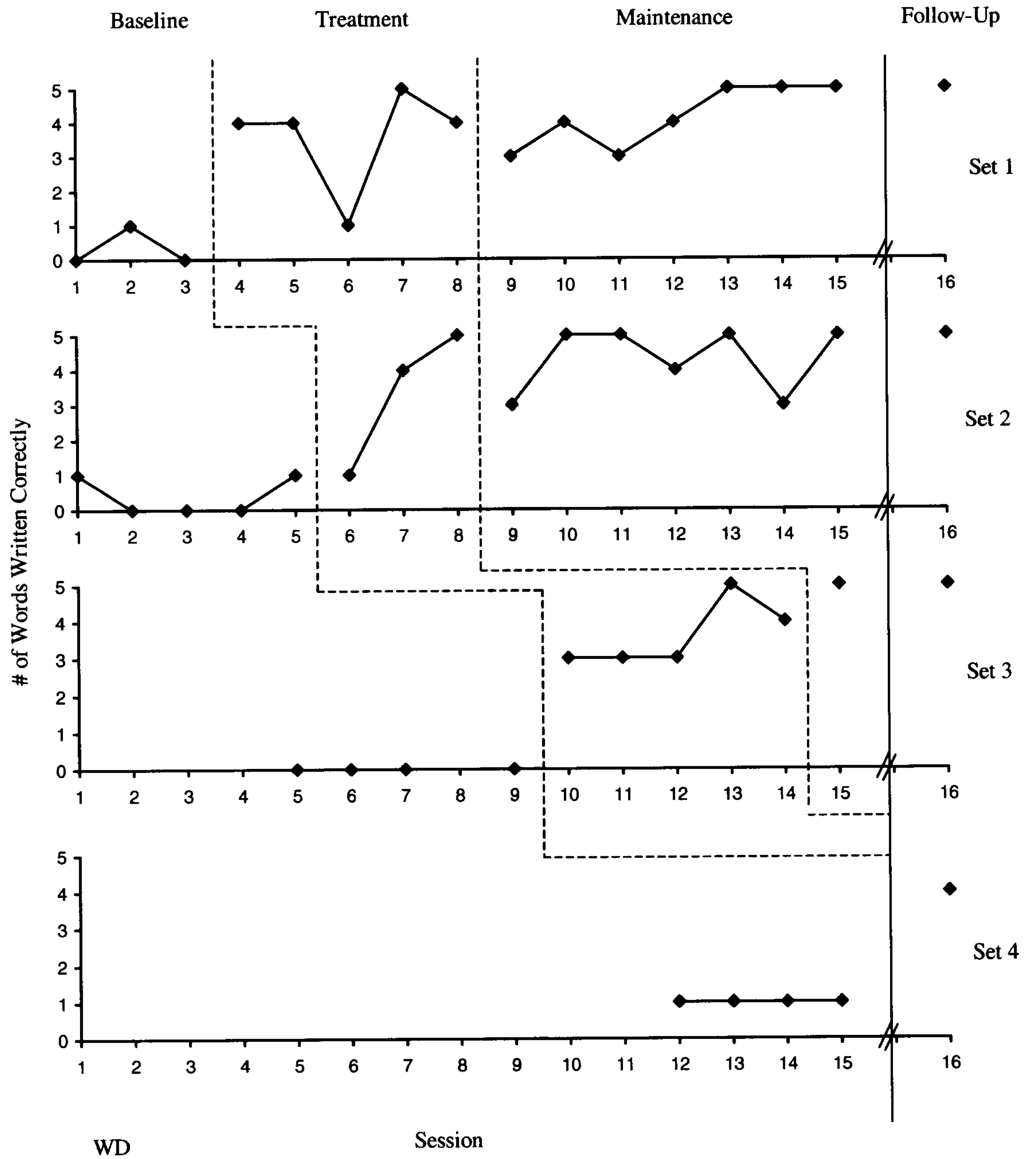
Prior to CART treatment, W.D. showed relatively stable performance on the probes for the words targeted for treatment (see Figure 6). His ability to write target words improved with training, and although his performance showed some inconsistency, W.D. was ultimately able to maintain mastery of Sets 1–3 by the end of treatment, and he achieved criterion on Set 4 following a month's practice at home. The calculated *f* statistic of .84 confirmed a large treatment effect, but it was smaller in magnitude than those of the first 3 participants reported, reflecting the greater variability in W.D.'s performance. After the initiation of treatment, W.D. averaged 3.93 correctly written words per set of 5 (see Table 3).

Like D.R. and S.L., W.D. often repeated words verbally before attempting to write them. In addition, he occasionally gave verbal responses to questions during conversational training (e.g., "What kind of pet do you have?"… "dog"). Aphasia group facilitators reported that W.D. made attempts to write during group sessions, and although spelling was not always error free, the words were used appropriately. Like D.R., W.D. increased verbalization of target items during group sessions as well.

Posttreatment Assessment

On the posttreatment assessment, W.D. performed similarly to pretreatment (see Table 2). It was noteworthy, however, that his verbal repetition improved significantly from 11/40 to 20/40 at post treatment, $\chi^2(1, N =$

Figure 6. Participant W.D.: Writing performance on weekly probes taken during baseline, treatment/maintenance, and follow-up for four sets of single words. Initiation of treatment for a given word set is indicated by the leftmost vertical dashed line. Hash marks on the abscissa indicate a one-month interval of CART homework without clinical sessions.



80) = 4.27, $p < .05$, a finding that was consistent with the observation that W.D. increased appropriate verbal utterances observed over the course of treatment. It was surprising to note that his performance on the case conversion task (upper- to lowercase) was significantly worse after treatment, $\chi^2(1, N = 52) = 9.43, p < .01$. A possible explanation was the fact that W.D. primarily wrote in uppercase letters during the treatment and homework, and he appeared to have perseverated on writing uppercase letters during the posttreatment assessment.

Participant M.B.

M.B. was a 64-year-old, right-handed man, who suffered a large left hemisphere stroke in the distribution of the left cerebral artery nearly 2 years before this study.

The stroke resulted in severe persistent aphasia and right hemiparesis that resolved. M.B.'s spoken utterances were fluent but lacking in content. His performance on the WAB revealed an aphasia profile consistent with Wernicke's aphasia and an aphasia quotient of 24.

Pretreatment Assessment

Performance on the pretreatment measures demonstrated that M.B. had impairment to multiple components of language processing, including comprehension of written words. Although M.B. made some semantic errors on the comprehension tasks, his performance on the Pyramids and Palm Trees Test did not reflect significant semantic impairment. With regard to speech production, M.B. did not name pictured items, but was able to repeat some words. His errors were typically neologistic utterances. M.B. failed to write any meaningful words on the writing tests. His attempts were characterized by implausible letter combinations unrelated to the target word (e.g., *Tueh* for *comb* and *hehe* for *bear*). Peripheral writing processes were a relative strength for M.B.

Response to Treatment

As shown in Figure 7, M.B. was unable to write any of the targeted words prior to initiation of treatment. CART was implemented for 14 weeks, during which M.B. consistently completed his homework. However, it is noteworthy that M.B. made frequent copying errors on his homework and during treatment sessions. Whereas other participants typically produced homework with few errors, M.B.'s accuracy on homework ranged from 20% to 85% correct. Efforts were made to improve accuracy by having M.B. identify and correct errors, and by explicitly reminding him to examine each word for accuracy as he copied it; however, copying errors persisted throughout treatment. M.B. showed improvement in his spelling ability, correctly writing two or three of the five words on most probes, but he was unable to reach criterion on Set 1 after 10 weeks of treatment (see Figure 7). His errors on the probes were generally visually similar substitutions (e.g., *cot* for *cat* and *novie* for *movie*), letter transpositions (e.g., *compture* for *computer* and *holle* for *hello*), and omissions (e.g., *comp* for *computer*). Although M.B. displayed difficulty mastering longer words, such as *computer* and *ice cream*, he also had trouble spelling shorter words such as *cat* and *flag*.

To ensure that M.B.'s inability to master Set 1was not a reflection of those particular words, treatment was initiated for Set 2. As he mastered two of the words in Set 2, his performance declined on Set 1 (see Figure 7), and his frustration was evident. Therefore, following 3 weeks of training on Set 2, treatment was terminated. Essentially, M.B. mastered the spellings for four words over 13 weeks of treatment, as shown at follow-up (see Figure 7). The calculated effect size was large (f = 1.19), reflecting a reliable change and minimal variance in level of performance on Sets 1 and 2. However, M.B. did not reach criterion for either set (averaging only 1.93 correct words per set of 5) so the clinical value of his improvement was not considered satisfactory given the time invested in treatment and homework to accomplish this change.

Posttreatment Assessment

As expected, M.B.'s performance on the posttreatment measures did not show any change (see Table 2). His failure to reach criterion on the word sets was relatively surprising in comparison to the success of others with severe aphasia; however, his difficulty with the accurate copying of words certainly appeared to be a contributing factor. M.B.'s self-correction of copying errors was poor, which was consistent with his marked difficulty in determining whether a word was spelled correctly or not on the visual lexical decision task of the pretreatment assessment. Although such impairment could be specific to degraded graphemic knowledge, M.B. also showed poor visual problem-solving abilities on the Raven's CPM, and a limited visual span that may have further impaired his ability to copy and compare his response to the target (see Table 2).

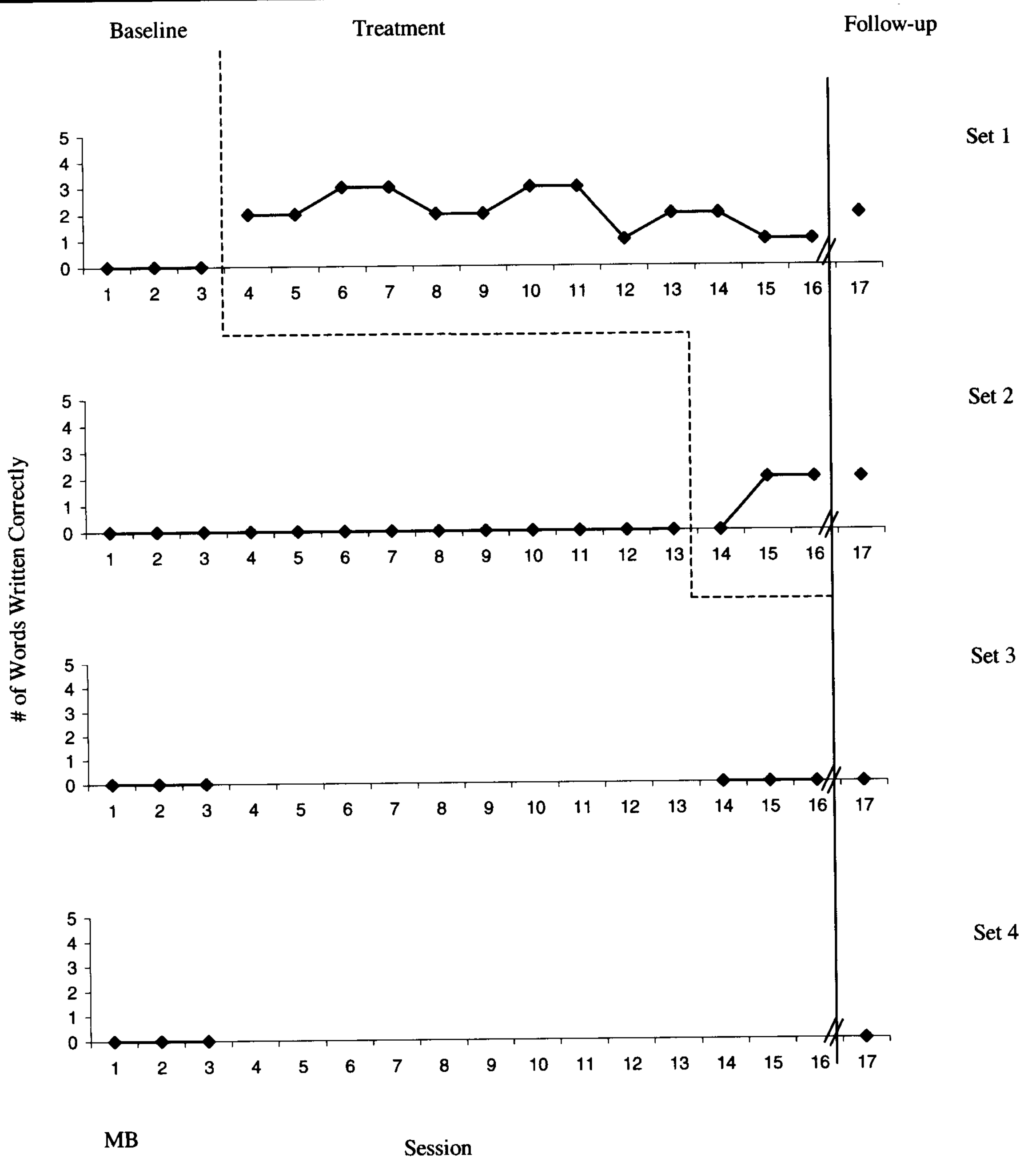
Participant G.P.

G.P. was a 79-year-old, right-handed woman who suffered a left hemisphere stroke at age 76. A CT scan showed an extensive infarct that included regions of the left middle and posterior cerebral arteries affecting the insular cortex, and portions of the posterior frontal, parietal, and occipital lobes. The stroke resulted in severe aphasia, apraxia of speech, right hemiparesis, and right visual field loss. At the time of this study, G.P. received an aphasia quotient of 16.8 on the WAB and was classified as having severe Broca's aphasia. Her primary mode of communication was neologistic jargon (e.g., "doh, dee, doh, doh, doh") with varied intonation to convey meaning.

Pretreatment Assessment

G.P.'s performance on the pretreatment measures showed severely impaired comprehension and production of spoken or written words. Impairment of the semantic system was confirmed by her chance performance on the Pyramids and Palm Trees Test (see Table 2). She was unable to verbally produce or repeat any of the words, suggesting significant phonological and/or motor speech impairment. G.P. also was unable to write any of the words on the writing tests, and her responses

Figure 7. Participant M.B.: Writing of single words on weekly probes during baseline and CART for two sets of words.

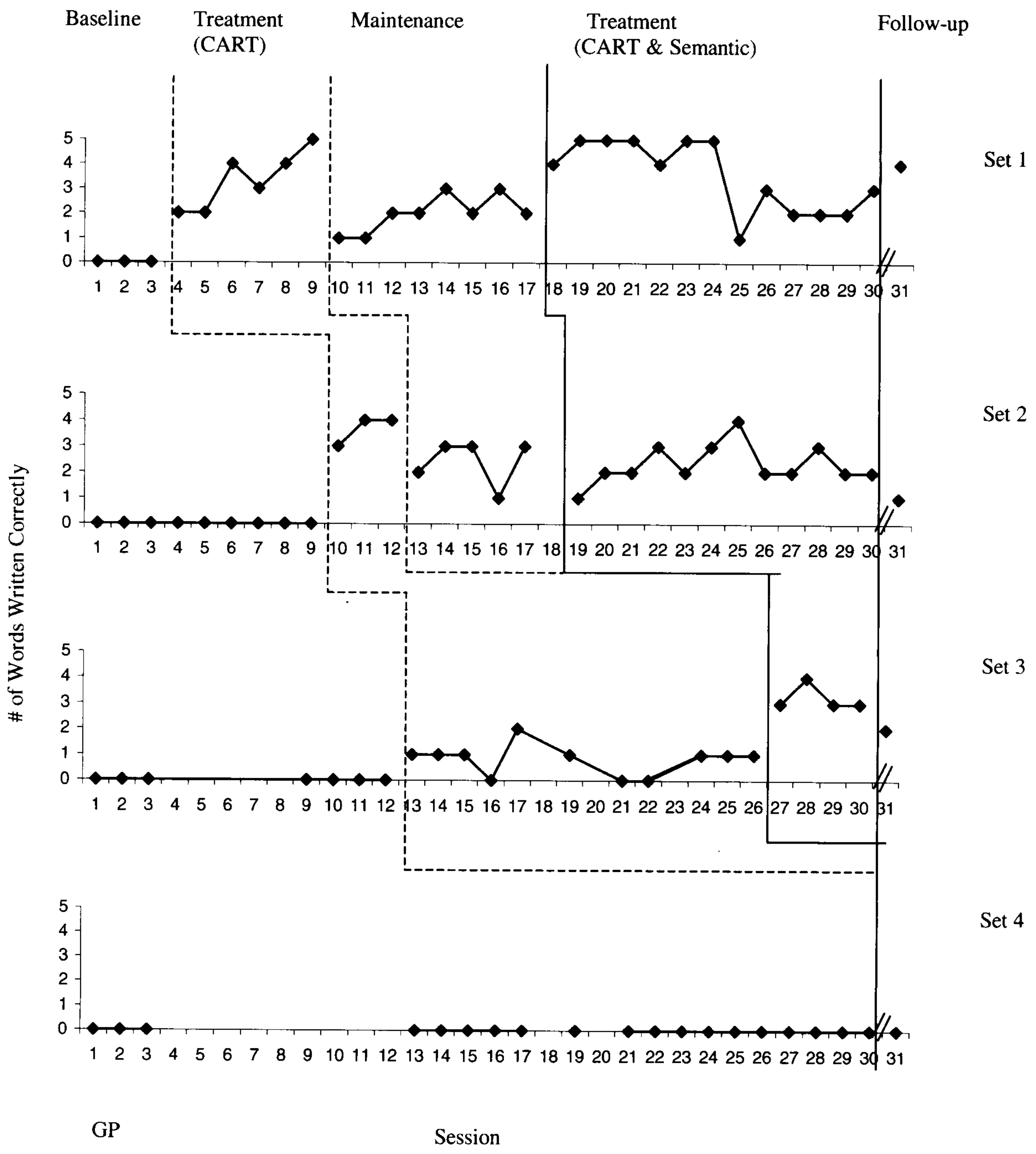


were attempts to draw the picture. Her peripheral writing abilities were adequate for copying written words, but she demonstrated moderate impairment on the case conversion task.

Response to Treatment

Prior to the initiation of the CART protocol, G.P. was unable to write any of the targeted words (see Figure 8). Over the course of 6 weeks of CART, she consistently completed the required homework and achieved mastery of written spelling for Set 1. When training commenced on word Set 2, however, G.P.'s performance on Set 1 markedly declined. A similar pattern of deterioration was noted when training for Set 3 was initiated (i.e., performance on words in Set 2 declined). G.P. typically wrote correctly spelled target words during probes, but they were often associated with the incorrect item (e.g., *Larry* for *movie*). Thus, as the number of items being trained increased, semantic confusion became evident.

Figure 8. Participant G.P.: Writing of single words on probes during baseline, treatment, and final probes for three sets of single words. The weekly CART protocol was followed by CART complemented by semantic treatment.



By the end of 14 weeks of CART, G.P. successfully wrote 7 of 15 targeted words. Although she was demonstrating improved spelling ability (effect size $f = .99$), it was evident that semantic confusion was becoming a significant detriment to progress. Her variable performance resulted in an average of 2.17 correctly spelled words per set of 5 (see Table 3). On week 17, the treatment protocol was modified for G.P. in an attempt to strengthen semantic associations and thereby increase accurate production of target words. An additional weekly session was added, and a word-to-picture matching task was used to strengthen the association between the written word and its concept. In addition, multiple exemplars of the target items (e.g., magazine pictures and drawings depicting the word) were presented for matching to the appropriate word. Corrective feedback was provided as needed on the matching tasks.

Following 14 additional sessions of treatment that included semantic training, G.P.'s production of single words during probes remained inconsistent (see Figure 8). Errors continued to include substitution of correctly spelled words from her list that were not necessarily related to the target (e.g., *pool* for *TV*). Treatment was discontinued after 30 total sessions because of G.P.'s failure to reach and maintain criterion performance, as well as her increasing frustration.

Posttreatment Assessment

Following treatment, G.P. showed few changes in performance on the posttreatment measures (see Table 2). Although still moderately impaired, G.P. showed some improvement on the case conversion tasks (see Table 2).

Participant J.F.

J.F., a 70-year-old, left-handed male, experienced a left middle cerebral artery stroke at the age of 67. Following the stroke, J.F. had severe aphasia, right hemiparesis, and a right visual field defect. His verbal production was limited to a low volume, mumbled "ruh ruh ruh." At the time of pretreatment assessment, J.F.'s aphasia quotient on the WAB was 15.7 with a profile consistent with severe Broca's aphasia.

Pretreatment Assessment

J.F.'s performance on the pretreatment battery suggested severe impairment of the linguistic processes necessary for reading, writing, and speaking (see Table 2). His written word recognition was relatively preserved, but there was evidence of impairment to the semantic system. On the writing tasks, J.F. made only a few attempts, and those responses were implausible letter combinations (e.g., *JANG* for *comb*, *DARD* for *bear*, and *DANG* for *horse*). Peripheral writing processes proved to be J.F.'s most preserved abilities, showing good transcoding and copying abilities with his dominant left hand.

Response to Treatment

Prior to commencement of writing treatment, J.F. was unable to write any of the targeted words as shown in Figure 9. Within each session, J.F. was able to recall the spelling of targeted words using the CART protocol, but he showed little learning from one week to the next (see Figure 9). Weekly review of J.F.'s homework revealed that he completed just 5% of the total homework requirement over the 10-week treatment period. The importance of the homework was repeatedly emphasized to J.F., but despite his compliance and apparent enjoyment during treatment sessions, he repeatedly failed to complete daily homework. On the average, J.F. correctly wrote only 1.67 words correctly (out of 5) after the initiation of treatment (see Table 3). He was often able to complete the spelling of target words when the first letter was written for him, but he failed to reach the 80% criterion for word Set 1. The calculated treatment effect size was small ($f = .23$). Because failure to meet criterion appeared to be due to lack of motivation rather than inability to learn, treatment was discontinued after 10 sessions.

Posttreatment Assessment

As anticipated, J.F. showed little change in comparison to pretreatment performance (see Table 2), with the exception of a drop in his performance on the Pyramids and Palm Trees Test to chance level, confirming the suspected impairment of semantic knowledge.

Participant M.R.

M.R., a 78-year-old, right-handed man, experienced a stroke at age 76 that resulted in right hemiplegia, a right visual field cut, and global aphasia. His aphasia profile evolved to severe Broca's aphasia with an AQ of 15.8 on the WAB. His verbal expression was limited to stereotyped utterances such as "I" and "Weee," so that he communicated primarily through facial expression and varied intonation.

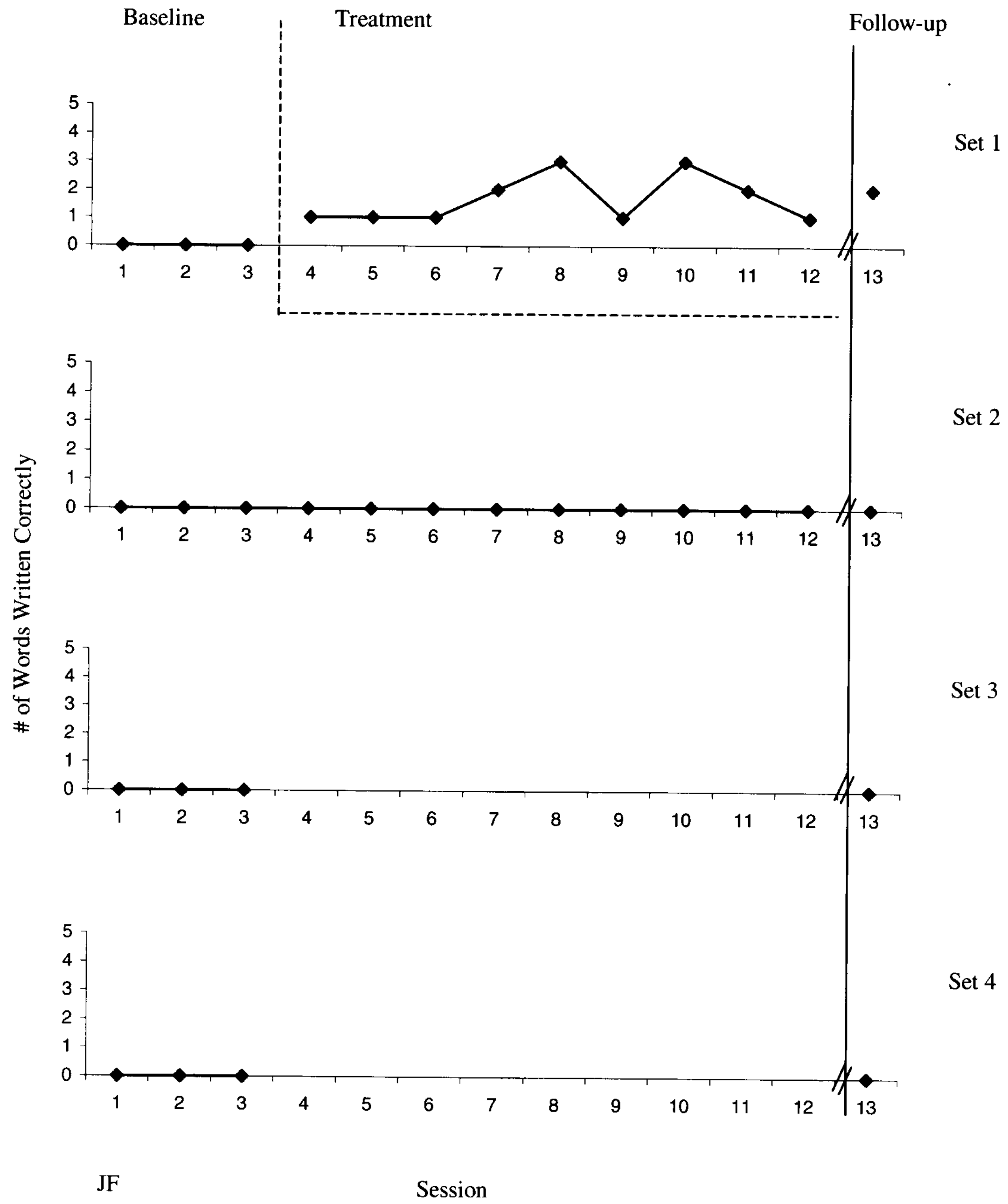
Pretreatment Assessment

Pretreatment assessment revealed significant impairment on all language tasks including visual word recognition, spoken naming, and verbal repetition. Semantic impairment was evident, and his ability to access graphemic information via semantics or phonology was severely impaired. On the writing tasks, M.R. attempted to write many of the items, but produced only single letters that were unrelated to the targets (e.g., *M* for *horse*, *e* for *anchor*). M.R.'s motor control of the nondominant hand was adequate to form legible letters, but he appeared to approach the copying task as if he were drawing nonlinguistic stimuli rather than letters. His ability to transcode upper- to lowercase letters was markedly impaired.

Response to Treatment

Following baseline probes (see Figure 10), the CART protocol was initiated with M.R. Two weeks after treatment began, he suffered a seizure that resulted in hospitalization. He did not come to therapy for 1 month during his recovery, and upon return, did not feel well for another 3 weeks. Therefore, treatment was reinitiated after a 7-week interruption. As shown in Figure 10, M.R. did not write any of the target words correctly on the pretreatment probes, and he also was

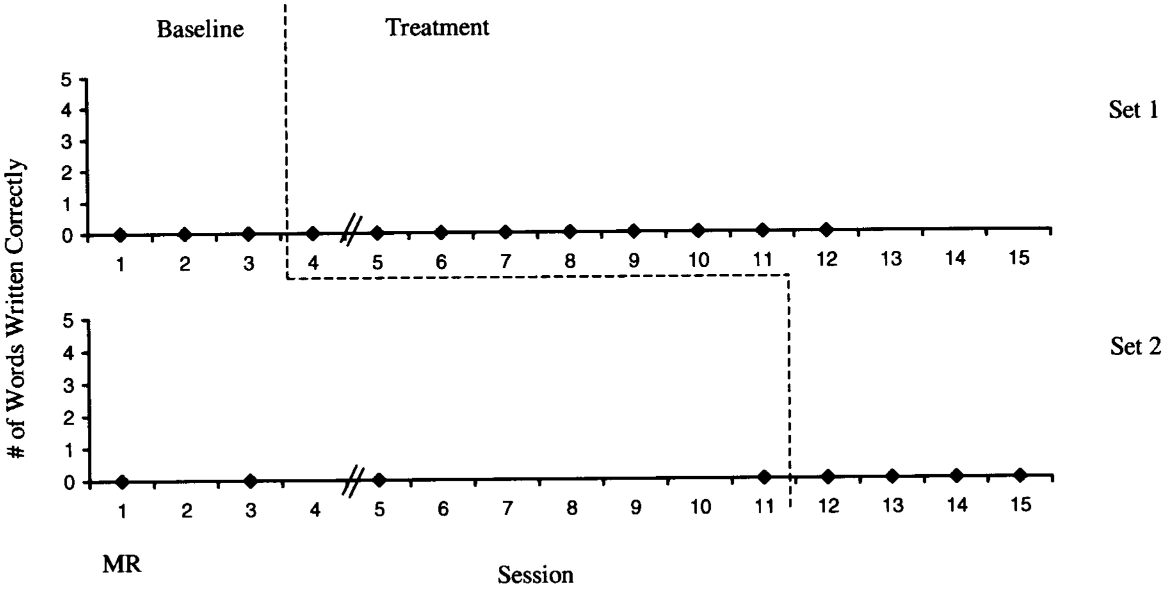
Figure 9. Participant J.F.: Writing performance on weekly probes during baseline and CART for one set of words.



unable to learn words in Set 1 after another 5 weeks of CART. It is noteworthy that within individual treatment sessions, M.R. showed great difficulty mastering the spelling of any of the target words despite repeated copying. For example, during one session M.R. copied his target word *car* as many as 15 times, but was still unable to recall the spelling when the model was removed. After 5 weeks, M.R. was able to write only two words within a session (*pool* and *car*), but was not able to maintain this performance on the probe test at the start of the following session. In fact, he often was unable to recall a word by the end of the treatment session when he had been able to write the word at one time during the session. In addition to his difficulty within the treatment session, M.R. did not consistently complete his CART homework on a daily basis. Despite encouragement to do so, he frequently completed the homework on only 2 or 3 days per week, rather than 6.

To ensure that his failure to respond to CART was not specific to the words selected for treatment, training was initiated for Set 2. After 5 weeks, M.R. could

Figure 10. Participant M.R.: Writing performance on weekly probes taken during baseline and CART for two sets of words. The vertical dashed lines indicate the initiation of treatment for a given word set. Hash marks on the abscissa indicate a 7-week interruption in treatment due to illness.



not write any of the Set 2 words correctly, so treatment was terminated.

Posttreatment Assessment

Posttesting began immediately after it was determined that M.R. would not meet criterion on Set 2. As expected, the results of post-testing were similar to pretest results (see Table 2). Regarding the assessment of peripheral writing skills, M.R. correctly copied 10/11 words and appeared to have improved graphomotor control in that his writing was less laborious, but he remained unable to convert letter case.

General Discussion

Of the 8 participants in this study, 4 (D.R., S.L., W.K., and W.D.) showed strong, positive responses to writing treatment. They mastered the spelling of at least 80% of 15 words over the course of 8 to12 weekly treatments supported by daily homework, and learned another 2 to 5 words following a month of self-directed homework, while maintaining spelling knowledge for previously learned spellings. Three other participants (M.B., G.P., and J.F.) showed some response to CART, in that they learned the spellings of some words; however, they failed to reach or maintain criterion for target words. Finally, 1 participant (M.R.) had a poor response to treatment. We first discuss the positive treatment outcomes, and then consider factors that may limit responsiveness to CART.

The response to writing treatment by Participants D.R., S.L., W.K., and W.D. was remarkable given the severity and persistence of their aphasia. They learned the spellings for words of varied lengths (ranging from 2 to 9 letters) and mastered irregular spellings (e.g., *friend* and *bread*) as well as regular spellings (e.g., *pants* and *fish*). Their treatment response was relatively item-specific in that little generalization occurred for writing untrained items. Thus, it appeared that CART served to strengthen the targeted graphemic representations (and access to them) for those participants. We consider this treatment protocol to provide the first step in establishing writing as an alternative means of communication. To be fully useful, the corpus of available written words should be expanded and patients must make effective use of written communication in a conversational manner. For those who responded positively to treatment, all were successful in acquiring new spellings during the final month of CART homework, suggesting that once the procedure was established, they were capable of building their written spelling vocabulary in a relatively self-directed manner. There was also informal evidence from conversational probes, as well as reports from family members and aphasia group clinicians, that these participants were beginning to appropriately write target words and partial word forms in conversation. These observations are further supported by a complementary study by Clausen and Beeson (2003), which documented conversational use of written words trained using CART.

There was evidence of additional benefit to some of the participants who responded to writing treatment. The CART protocol involved repeated exposure to the written and spoken words with the associated pictured stimuli during the weekly sessions. Participants D.R., S.L., and W.D. frequently repeated the target words as they worked on writing, so it was not surprising to see that S.L. and W.D. improved their verbal repetition following treatment. Participants D.R. and W.D. both began to spontaneously provide the spoken name for some of the target words, and S.L. showed an increase in reactive meaningful utterances as reported by his wife and aphasia group clinician. These observations suggest that inclusion of verbal repetition in conjunction with CART may serve to stimulate spoken as well as written language in some individuals. This possibility warrants further investigation, particularly with individuals who are able to repeat some single words.

The limited treatment response demonstrated by 4 of the participants in this study suggests that not every individual will be able to relearn written words using CART. For that reason, it is important to identify characteristics that may serve as prognostic indicators of those who will potentially benefit from CART as well as those who are not likely to be appropriate candidates. Two types of factors appeared to limit the likelihood of success: cognitive/linguistic impairments and failure to accurately complete CART homework.

All of the participants in this study had severe aphasia with very limited spoken and written language ability. In order to discern what pretreatment measures might provide an indication of response to treatment, Spearman rank order correlations were calculated between each of the pretreatment measures in Table 2 and the treatment effect size (f statistic). Two measures showed a significant positive correlation with treatment effect: Pyramids and Palm Trees Test ($r = .905, p < .05$) and PALPA-47 (spoken word to picture match; $r = .809$, $p < .05$). The former was a test specific to semantic knowledge, whereas the latter required auditory processing as well as semantic knowledge. It was noteworthy that the participants who performed at chance level on Pyramids and Palm Trees (G.P. and M.R.) had limited response to writing treatment. The semantic impairment was particularly evident for G.P. as she made an increasing number of semantic confusions as her written vocabulary grew. Despite treatment directed toward strengthening semantic associations to target words, her responses remained inconsistent. G.P.'s performance suggested that a significant semantic impairment could limit the functional success with CART for the obvious reason that written words must be linked to their meaning in order to be useful. Additional evidence of semantic impairment was available for G.P. and M.R. on the written-word-to-picture matching task on which both participants performed at chance level with numerous semantic errors.

Participant M.R., who had the poorest response to CART, had marked impairment on several pretreatment measures other than semantics, including aphasia severity, visual lexical decision, and peripheral writing abilities. He had one of the lowest AQ scores (15.8); however, aphasia severity does not appear to account for participants' responses to CART given that W.K. (who had a strong, positive response to CART) had a similarly low AQ of 14.7, and M.B. had an AQ of 24 but also had limited response to CART. In addition, a Spearman rank order correlation coefficient calculated between AQ and the treatment effect size (f statistic) was not significant ($r = .452, p > .05$). Thus, aphasia severity as measured by the WAB does not appear to provide predictive information regarding response to writing treatment.

Performance on the visual lexical decision task was thought to have a potential impact on response to CART in that it requires participants to distinguish correctly spelled real words from orthographically legal nonwords. Although the correlation between treatment effect size and lexical decision was not significant ($r = -0.428, p > .05$), 3 participants performed at chance on this task (M.B., G.P., and M.R.) and they all had limited response to CART. These 3 participants also performed poorly on the Raven's CPM (< 5th percentile), a test of nonverbal visual problem solving, whereas all other participants performed within the normal range. Participant M.B. showed the greatest impairment on these two visual tasks, and he also demonstrated difficulty recognizing whether or not he accurately copied target words during CART. This inability to recognize words from nonwords appeared to limit the usefulness of CART for M.B. because he failed to copy his homework correctly. Given that CART relies heavily on visual processing and visual memory, the lexical decision and CPM measures appear to be potentially useful screening measures for determining candidates for CART.

Regarding the peripheral aspects of writing, all participants (except W.D. and J.F., who were premorbidly left-handed) had some difficulty with graphomotor control of the nondominant hand. However, Participant M.R. also showed marked impairment of letter shape knowledge. He was unable to perform the case conversion tasks and struggled to form some letters on the copying task. These difficulties appeared to reflect an impairment of knowledge of letter shape, that is, at the level of allographic conversion. The case conversion performance by W.K. was only slightly better than M.R.'s, but she showed some improvement in case conversion following CART, whereas M.R. remained unable to perform those tasks. Thus, it appeared that M.R.'s extremely poor response to CART reflected an additive effect of impairment at cognitive–linguistic as well as peripheral stages of writing.

Several factors were of interest regarding participant performance with the CART protocol. Within the context of individual treatment sessions, all participants except M.R. were able to recall the spelling of several target words after repeated copying. Despite repeated copying, M.R. did not demonstrate the ability to master spellings within a treatment session. In other words, M.R. failed to show stimulability in response to the CART protocol. This suggests that a poor prognosis might be discerned within the context of one or two clinical sessions. Another clinical factor of importance was the participants' willingness and ability to accurately complete the CART homework. Participants J.F. and M.R., who showed limited response to treatment, failed to complete the assigned homework. In fact, J.F. completed such a limited amount of homework that he essentially provided a contrast between participants who received clinical treatment *with* and *without* concomitant daily homework. Participant M.B. (who also failed to reach criterion on the target word sets) consistently completed his homework, but with a large proportion of copying errors. Thus, M.B. demonstrated the obvious: repeated copying is only of value if it provides repetition of *correct* spellings.

The results from this study, combined with those of Beeson (1999) and Beeson et al. (2002), provide data from 12 individuals with severe aphasia who were treated using CART. Of those, 8 individuals responded positively to treatment, and 4 had outcomes that were not considered clinically significant. The present study provides valuable insights regarding potential indicators of those who may benefit from treatment. Specifically, positive treatment outcomes appeared to be influenced by the following factors: (a) a relatively preserved semantic system, (b) adequate processing of visual information, and (c) the individual's motivation and ability to accurately complete daily CART homework. The positive response to CART by those with severe aphasia indicates that writing should be considered an alternative modality for individuals who are unable to recover spoken language. Other treatment approaches should be investigated to address the communication needs of those who do not respond to CART.

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Appendix (p. 1 of 2). Method used to calculate the *f* statistic.

The *f* statistic was calculated based on equations and SAS programming from Kromrey and Foster-Johnson (1996). The equation to determine change in level of performance when the data show a trend is conceptually represented as

$$f = \sqrt{\frac{R^2_{\text{adjusted for trends}} - R^2_{\text{combined}}}{1 - R^2_{\text{adjusted for trends}}}}$$

where $R^2_{\text{adjusted for trends}}$ represents the coefficient of determination for the regression equation in which separate lines of best fit are computed for the baseline and treatment/maintenance conditions that are adjusted for different trends (slopes), and R^2_{combined} represents the coefficient of determination for the regression equation in which one line is fitted to the data across the two conditions (baseline and treatment/maintenance). Note that we report *f* rather than f^2, as suggested by Kromrey and Foster-Johnson, because squared values exaggerate the separation of effect sizes that are greater than 1 and those that are fractions.

Table A1 provides sample data and its associated *f* statistic.

Appendix (p. 2 of 2). Method used to calculate the *f* statistic.

Table A1. Example data from D.R.

	Set 1		Set 2		Set 3		Set 4	
Session	Condition	Score	Condition	Score	Condition	Score	Condition	Score
1	0	0	0	0				
2	0	0	0	0				
3	0	0	0	0				
4	1	5	0	0				
5	1	5	0	0				
6	2	5	0	0				
7	2	5	1	4	0	0		
8	2	5	1	5	0	0		
9	2	4	2	5	0	0		
10	2	4	2	4	1	3		
11	2	5	2	5	1	4	0	1
12	2	5	2	5	1	5	0	0
13	2	5	2	5	2	5	0	1
14[a]	3	5	3	5	3	5	3	5
No. observations	13		13		7		3	
f statistic	4.11		3.47		1.00			
Weighted *f*	3.20							

Note. Condition 0 = baseline; Condition 1 = treatment; Condition 2 = maintenance (with homework); Condition 3 = follow-up. Score = number correct out of five in a set. *f* was statistic calculated for words Sets 1, 2, and 3 individually and then weighted for number of observations per set.

[a]Follow-up data were not entered into the calculation of the *f* statistic because they were sampled at one time only.