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Writing Treatment for Aphasia: A Texting Approach

Pélagie M. Beeson[a], **Kristina Higginson**[a], and **Kindle Rising**[a]
[a]University of Arizona, Tucson

Abstract

Purpose—Treatment studies have documented the therapeutic and functional value of lexical writing treatment for individuals with severe aphasia. The purpose of this study was to determine whether such retraining could be accomplished using the typing feature of a cellular telephone, with the ultimate goal of using text messaging for communication.

Method—A 31-year-old man with persistent Broca's aphasia, severe apraxia of speech, global dysgraphia, and right hemiparesis participated in this study. Using a multiple baseline design, relearning and maintenance of single-word spellings (and oral naming) of targeted items were examined in response to traditional Copy and Recall Treatment (CART) for handwriting and a new paradigm using 1-handed typing on a cell phone keyboard (i.e., a texting version of CART referred to as T-CART).

Results—Marked improvements were documented in spelling and spoken naming trained in either modality, with stronger maintenance for handwriting than cell phone typing. Training resulted in functional use of texting that continued for 2 years after treatment.

Conclusions—These results suggest that orthographic retraining using a cell phone keyboard has the potential to improve spelling knowledge and provide a means to improve functional communication skills. Combined training with both handwriting and cell phone typing should be considered in order to maximize the durability of treatment effects.

Keywords

agraphia; rehabilitation; dysgraphia; texting; aphasia; typing; text messaging

The remediation of spoken language is typically a high priority for individuals with aphasia, with written language being of lesser concern. However, for those with limited spoken language ability, written communication may prove to be the primary modality for the successful exchange of information (Beeson, 1999; Clausen & Beeson, 2003; Robson, Marshall, Chiat, & Pring, 2001). In addition, with the increasing reliance on electronic communication, individuals who acquire aphasia may have the need, or desire, to communicate electronically. One obvious and potentially useful technology is cellular telephone text messaging, a communication mode that has yet to be empirically examined for individuals with aphasia. Text messaging, or *texting* (Merriam-Webster Dictionary, 2012), is prevalent in mainstream American society. In 2011, 83% of American adults owned cell phones, and 73% of adult cell phone users sent or received text messages (Smith, 2011). For individuals with aphasia, the potential benefits of cell phone texting are tempered by significant barriers that include impaired lexical retrieval, degraded spelling knowledge, and unfamiliarity with how to use the cell phone texting function (Greig, Harper, Hirst, Howe, & Davidson, 2008).

Correspondence to Pélagie M. Beeson: pelagie@u.arizona.edu.

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The prevalence of cell phone use in the general population is one of a number of reasons why text messaging is an attractive communication possibility for individuals with aphasia. Certainly its use is considered mainstream, and there is little increased cost for individuals who already own text-capable cell phones. An advantage of texting is the means to accomplish instantaneous communication over long distances with a portable device, yet the time taken to compose a text message is entirely up to the individual. Many cell phones have a memo pad function, which allows the user to type and save messages for future and repeated use. This feature can also be used to enhance face-to-face communication in a manner similar to the use of pen and paper to supplement, clarify, or replace spoken communication.

Although text messaging offers a potential alternative communication modality for individuals with aphasia, its use is dependent on adequate central language processing skills and the peripheral skills needed to implement the correct keyboard movements. Typing, like handwriting, involves semantically guided retrieval of appropriate words and their correct orthography. Spellings can be retrieved as lexical– orthographic representations or assembled with reliance on phonology (Hillis & Rapp, 2005; Rapcsak & Beeson, 2004; Rapp, 2002). However, the peripheral demands for keyboard and cell phone typing differ from those for handwriting, which requires specific letter shape (*allographic*) knowledge and graphomotor movements to construct individual letters. Typing places demands on spatiomotor knowledge to locate and implement the appropriate motor command for each key press, whether on a typewriter, a keyboard, or a phone (Ardila, 2004; Salthouse, 1986).

The typing patterns on a cell phone differ from keyboard typing due to the small size and novel configuration of various cellular phones. Just as there are proficient “touch typists” at the keyboard, who demonstrate integrated knowledge of letters and their respective spatial locations to achieve relatively automatic activation of motor patterns for key press sequences (Rieger, 2004, 2007), some individuals achieve considerable competency for texting. For most people, however, texting is a relatively new and self-taught skill, and it appears to lack consistency across and within individuals. When texting, many individuals use an approach that is akin to a “hunt-and-peck” method of typing that requires sustained visual search to find or confirm the location of correct keys while holding orthographic knowledge in a short-term buffer (Ardila, 2004).Whereas keyboard typing is typically a bimanual skill, texting is frequently accomplished with only one hand; a recent study of cell phone users found that 58.7% reported naturally using one hand to text (Lambert & Hallett, 2008). The ease of one-handed typing is clearly a potential benefit for individuals with aphasia who have comorbid hemiparesis.

When considering the barriers to cell phone typing for communication in individuals with aphasia, the status of the neural substrates and cognitive processes that support written language are relevant. From a neuroanatomical perspective, the central linguistic processes necessary for written communication rely on a left-lateralized neural network, including perisylvian regions, middle temporal gyrus, and the ventral temporo-occipital regions involved in processing visual word forms (Fiez, Tranel, Seager-Frerichs, & Damasio, 2006; Philipose et al., 2007; Rapcsak & Beeson, 2004; Rapcsak et al., 2009; Rapp, 2002). These regions are engaged for written language production, regardless of the output modality (oral spelling, writing by hand, and typing). The motor programming and graphomotor control for handwriting or texting require that at least one hand receive neural input from the contralateral primary motor cortex; however, the motor planning for these processes is typically reliant on a left hemisphere frontoparietal network. Specifically, functional neuroimaging research has shown that critical regions in the left premotor cortex just anterior to the primary motor area for the hand (i.e., Exner’s area) and the left intraparietal sulcus/superior parietal lobule are engaged for typing (Purcell, Napoliello, & Eden, 2011) in a manner similar to handwriting (Beeson, Rapcsak, et al., 2003). These findings are consistent with the lesion location associated with impairments of graphomotor control (Rapcsak & Beeson, 2002) and the few reported cases of acquired typing disturbances that were not attributable to central language impairment (Magrassi, Bongetta, Bianchini, Berardesca, & Arienta, 2010; Otsuki et al., 2002). Isolated damage to these ventral frontoparietal cortical regions is relatively uncommon, and they are often preserved in the case of left middle cerebral artery stroke. Thus, the neural substrates of written language production are consistent with the clinical observation that individuals with significant aphasia often have commensurate degradation of the central linguistic processes that support written language, but the motor planning skills for handwriting and/or typing may be relatively preserved (apart from issues related to hemiparesis).

This relative preservation of peripheral skills necessary for handwriting contributes to successful remediation of functional written communication in individuals with aphasia, including those who have marked, persistent impairments of speech production due to motor speech disorders or impaired phonological assembly (Beeson, 1999; Beeson, Rising, & Volk, 2003; Clausen & Beeson, 2003; Robson et al., 2001). A relevant point is that impairments of motor planning for speech may occur without concomitant difficulties in the motor control of the hand. In other words, apraxia of speech is not necessarily accompanied by apraxic agraphia, because the critical left premotor region for the hand is dorsal to that for the mouth (Rapcsak & Beeson, 2002). Typing offers an advantage over handwriting in the case of impaired letter-shape knowledge, so typing may be the better modality in individuals with relatively isolated peripheral allographic impairment. That is, letters are visible when typing, and that may be helpful to individuals who have an impairment that is specific to this more peripheral aspect of spelling. However, allographic knowledge is often preserved (or only mildly impaired) in the case of individuals with left perisylvian damage, so the availability of the visual letter shapes does not typically offer a particular advantage over handwriting. Although not documented empirically, our clinical experience indicates that typing is, in fact, more difficult than handwriting in most individuals with significant aphasia.

One treatment approach that has been shown to be effective in retraining single-word writing in this population is Copy and Recall Treatment (CART; Beeson, 1999; Beeson, Hirsch, & Rewega, 2002). The treatment is intended to strengthen orthographic representations through repeated copying and recall of target words in association with appropriate semantic information (often picture stimuli). Treatment studies have demonstrated the therapeutic value of CART and similar lexical writing treatments across a range of aphasia severity levels and spelling abilities (Aliminosa, McCloskey, Goodman-Schulman, & Sokol, 1993; Beeson et al., 2002; Beeson, Rising, & Volk, 2003; Raymer, Cudworth, & Haley, 2003; Robson et al., 2001). Among those with severe aphasia, CART has been most effective for individuals who have relatively preserved semantic knowledge, have the ability to visually differentiate words from nonwords (i.e., visual lexical decision tasks), and have relatively unimpaired visual problem-solving skills (Beeson, Rising, & Volk, 2003). CART has been implemented as an intervention for writing by hand, but, to our knowledge, the technique has never been directly examined for retraining other written modalities, such as typing or texting.

The present study was motivated by an individual with severe aphasia who had received, and responded well to, lexical spelling treatment using handwriting (CART). The written modality was particularly important for this individual (referred to here as Mr. J) because of his limited spoken language abilities. When we evaluated him on the Western Aphasia Battery (WAB; Kertesz, 1982) at 17 months post stroke, his Aphasia Quotient was 27.6, and his profile was consistent with severe Broca's aphasia. His spoken output was characterized by recurrent, meaningless utterances including the perseverative production of the syllable /tu/. His speaking rate was slow, with little prosodic variation, and the few intelligible content words often included distorted sounds. Deliberate efforts to produce speech showed evidence of groping for articulatory placement. Overall, his impaired motor control for speech was consistent with the criteria set forth by Duffy (2005, p. 320) for severe apraxia of speech.

Mr. J had received CART to improve single-word writing and spoken production of a standard set of 24 words. Over the course of the 6-week treatment, he improved from 11% to 90% correct spelling of targeted words using handwriting with the nondominant left hand. He improved his spoken naming of those same items from 12% to 46% correct. After the lexical treatment, Mr. J participated in an additional 6 weeks of phonological treatment directed toward training sound–letter/letter–sound correspondences. Although he made some improvements, Mr. J did not meet criterion in production or perception of the targeted sets of consonant sounds, so phonological treatment was discontinued at that time. Posttreatment assessment revealed that improvements in written language were primarily restricted to the trained items; however, he showed generalized improvement in speech production as measured by the WAB, and his Aphasia Quotient improved from 27.6 to 38.9.

After Mr. J's success relearning the spellings of targeted words, he conveyed a desire to learn how to communicate by text messaging. He owned a cell phone with a pull-out keyboard that he wanted to use to support his communication. His wife reported that prior to his stroke, Mr. J rarely used his cell phone for text messaging, but she was in agreement that texting might be a good way to communicate at that time in their lives. She was working outside of the home, while Mr. J was at home during much of the day. The severity of his communication impairment made their attempts at telephone conversations unproductive, so the use of cell phones for texting appeared to be an ideal plan. Informal assessment of cell phone use showed that he could open the phone, select the texting mode, and press buttons with his left hand, but he produced very few meaningful messages due to lexical retrieval difficulties and degraded spelling knowledge. Thus, it was apparent that continued spelling training was warranted, and Mr. J was highly motivated to incorporate cell phone typing into the spelling treatment protocol.

Because we were unsure regarding the probable treatment outcomes, the current study was designed to examine whether retraining via typing on a cell phone would result in mastery of targeted words in a manner similar to that documented with handwriting. We refer to this cell phone typing as *texting*, for although it did not serve a communication function during the training phase, the ultimate goal was to facilitate cell phone texting in a traditional manner as well as for use during face-to-face communication. We examined his response to a texting version of CART (T-CART) for training spelling and oral naming of targeted single words, as well as his response to CART for a comparable set of personally relevant words. The ultimate functional goal was to provide the skills necessary for Mr. J to engage in texting via his cell phone, but the experimental study was restricted to the examination of learning and maintenance of spelling knowledge.

Method

Participant

The participant, Mr. J, was a right-handed male with 12 years of education, who was 31 years old at the time of this study. He had worked as a 911 dispatcher prior to experiencing a left middle cerebral artery stroke that occurred 26 months prior to the initiation of this treatment study. Extensive left hemisphere damage resulted in persistent Broca's aphasia with marked apraxia of speech and dense right hemiparesis. A magnetic resonance imaging brain scan obtained approximately 2 years post stroke revealed a large left-hemisphere lesion affecting Broca's area, the insula, the auditory cortex, the supramarginal and angular gyri, and the superior and middle temporal gyri (see Figure 1). Analysis of the damage using standard lesion mapping methods (see Andersen, Rapcsak, & Beeson, 2010, for details) indicated a total lesion volume of 229 cm^3 comprising approximately 67% of the left perisylvian region.

Mr. J had received some speech-language treatment immediately after his stroke and had received 12 weeks of treatment immediately preceding this study as described above. No other speech–language treatment was administered during the present study. Informed consent was obtained for participation in this study in compliance with the University of Arizona Human Subjects Protection Program.

Pretreatment Assessment

Prior to the initiation of this treatment protocol, a battery of tests was administered to assess speech and language abilities, semantic knowledge, reading and writing skills, and nonverbal problem solving. Mr. J's speech production profile was still consistent with significant apraxia of speech, in that he had produced primarily nonmeaningful syllable productions, but the frequency of occasional intelligible single words had increased. On a single-word repetition task of primarily one- and two-syllable words, Mr. J produced only 25% of 40 items correctly. He was unable to repeat any syllables or syllable strings that were not real words.

On the WAB, Mr. J demonstrated a nonfluent aphasia profile with marked naming impairment and relatively strong auditory comprehension skills. His Aphasia Quotient was 38.9, and the overall language profile was consistent with severe Broca's aphasia. His naming impairment was even more dramatic on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983); he correctly named only one item out of 60. The Pyramids and Palm Trees Test (Howard & Patterson, 1992) was administered to examine semantic processing. Mr. J scored 48 of 52 on the picture version (picture-to-picture matching), indicating relatively good semantic processing, but his performance on the written version of the test (39 of 52) demonstrated some impairment of written word comprehension. On the visual lexical decision subtests of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1992), he was able to discern real words from implausible letter strings (57 of 60 on PALPA 24) but had more difficulty distinguishing real words from plausible nonwords (49 of 60 on PALPA 27). Single-word reading and writing ability was assessed with the Arizona Battery for Reading and Spelling (Beeson & Rising, 2010). Mr. J was able to read aloud only three of 80 words and write to dictation zero of 80 words, indicating severe alexia and agraphia. Mr. J wrote with his nondominant (left) hand using primarily uppercase letters, but he was able to copy single words and convert between lower- and uppercase letters, confirming adequate knowledge of letter shapes and graphomotor control for handwriting.

Mr. J's performance on the Raven's Coloured Progressive Matrices (Raven, Court, & Raven, 1990), a test of nonverbal visual problem solving, was 26 of 36, which fell more than 2 *SD*s below the mean for his age and education ($M = 32.6$, $SD = 2.9$). Although previous research has suggested that poor performance on this nonverbal test of visual problem solving was a negative prognostic sign for lexical writing treatment (Beeson, Rising, & Volk, 2003), Mr. J had already demonstrated the ability to relearn written spelling using the CART protocol.

Materials

In collaboration with his wife and clinician (second author), Mr. J identified 30 picturable words (22 common nouns and eight proper nouns) as appropriate targets for treatment. These items included names of family members, foods, objects, and hobbies that were relevant to his life. For treatment, the words were divided into six sets of five words per set. The sets were balanced for mean word length (an average of 6.2–6.4 letters per word across sets, with a range of 4–10 letters). Three of the sets were assigned to the CART condition, and the other three sets were assigned to the T-CART condition (see the Appendix). All of these words were important to Mr. J, so it is reasonable to assume that they occurred with relatively high frequency in his life. Color pictures and photographs were obtained to represent each word, including photos of family members and downloaded Internet images to depict the selected common nouns. Thus, all of the target words were highly imageable for Mr. J, as they were depicted by photographs or pictures, including the word *practice*, which referred to soccer or basketball practice in Mr. J's family. The words to be trained by CART did not differ significantly from the words trained using T-CART for the following variables (tested with the Wilcoxon rank–sum test): number of letters ($W = 235.5$, $p = .915$), number of phonemes ($W = 256$, $p = .325$), and number of syllables ($W = 239.5$, $p = .069$). After the proper nouns were excluded from the analysis, the lists did not differ with regard to word frequency ($W = 65.0$, $p = .701$) or imageability ($W = 28.0$, $p = .808$).

Procedure

For treatment, Mr. J was scheduled for 1-hr sessions twice weekly in a university clinic setting over the course of 13 weeks. A single-subject, multiple baseline design was used to examine Mr. J's response to treatment. Repeated probes of naming and spelling of the targeted items were obtained before treatment began (the baseline phase). The assessment of word sets to be trained using handwriting (CART) was implemented with pencil and paper. For the assessment of spelling of the words selected for texting (T-CART), Mr. J used his own cell phone, an Alltel LG cell phone with a slide-out QWERTY keyboard with raised bumps for each letter. Due to right hemiparesis, Mr. J used his left hand to write and to type on the phone keyboard.

Over 2 days of pretreatment testing, Mr. J correctly wrote only three of the 30 words targeted for treatment using handwriting and 0 of the 30 words targeted for typing. The slight advantage for handwriting was unavoidable because Mr. J had very little success with typing on the cell phone at that point, but he did have some residual orthographic knowledge that was evident on the handwriting task. On the day that treatment was to be initiated for Set 1 (handwriting), a third baseline probe was taken for all items to be trained. On that day, it was surprising that Mr. J improved to four out of five (80%) for the first set of items for CART, after having had difficulty with those items on the first two pretreatment probes. A review of the items indicated that he correctly wrote the four proper names in that set (including his own first and last name, which he had previously failed to achieve). Given that the handwritten form of CART had been previously implemented, it was quite likely that Mr. J had proceeded to work on his own on the proper names in the first CART set to be trained. This advantage for the CART items reduced the ability to compare the learning for CART versus T-CART, but it did not interfere with the primary objective of this study: to determine whether this individual could relearn spellings using cell phone typing and whether this facilitated his ability to achieve text messaging.

Spelling treatment alternated between CART and T-CART for successive sets of words, so that each set was trained either solely with CART or solely with T-CART. Although spoken naming was not the main focus of this study, Mr. J's significant apraxia of speech prompted extensive speech production practice during both CART and T-CART conditions in order to also maximize the treatment benefit for spoken communication.

CART condition—For each of the three sets of words trained using handwriting, the procedures were consistent with previous CART studies that included repeated copying and spoken repetition of target words (e.g., Beeson & Egnor, 2006). First, the clinician presented a picture of the target word and said the name aloud. Mr. J repeated the word until he said it accurately, receiving multiple spoken models as needed. There was not a prescribed limit to the number of times that Mr. J was stimulated in order to achieve correct production, but, in general, three to five corrections would be typical during instances of production difficulty. This speech stimulation was not the primary focus of this study; however, the treatment was intended to be as robust as possible for both the CART and T-CART conditions in order to maximize the benefit to the participant. After repetition of the target word, the clinician wrote the word with pen and paper, and Mr. J copied the word until he spelled it correctly three times. Each time Mr. J wrote the word, he named it aloud as well (with the spoken model provided as needed). Finally, all spellings were covered from view, and Mr. J was asked to write the word from memory. If he made an error, he was directed to look at the model and, again, copy it three times until he was able to correctly write the word from memory.

Each set of five words was trained until Mr. J met the criterion of 80% or better on probes taken at the start of two consecutive sessions. The criterion to advance to the next set was based on spelling accuracy only; spoken naming accuracy was recorded but not considered in the criterion.

T-CART condition—In the T-CART condition, training procedures were kept as similar as possible to those of the CART condition. However, instead of using paper and pen, Mr. J used the keyboard on his cell phone. He independently put the phone in text-message mode. He chose to turn caps-lock on so that all letters were capitalized, thus mimicking his handwritten words, which also tended to be capitalized. As in CART, treatment was directed toward five words at a time, and the criterion to move to the next set was 80% accuracy for typed spelling on the probes taken at the beginning of each session. Spoken naming treatment was incorporated into the T-CART intervention as it was in the CART condition.

Training in the texting modality involved the clinician modeling the correct spelling by typing the word on the phone and then showing it to Mr. J, who then typed the word until he spelled it on the phone correctly three times. A single space was entered between each typed word. All words were then erased from the screen, and Mr. J typed the word from memory. If he made an error, the clinician erased the misspelled word and typed it out correctly. Mr. J then looked at the model and, again, typed it three times correctly until he was able to type the word from memory.

Homework—Daily homework for the word set being trained was provided at the end of each therapy session in the modality matching the treatment procedure (texting or handwriting). As treatment progressed, homework was provided for the items in training plus some of the previously trained sets, assigned on a rotating basis. Picture stimuli were provided in a photo album with audio-recording capabilities. The clinician recorded a clear spoken production of each word and, when possible, recorded Mr. J's own production of the target word as well. Mr. J was trained to name the word every time he spelled it and to check his accuracy by listening to the audio recordings.

For spelling practice, a printed homework page was generated for each set. As shown in Figure 2, there were pictures of each word at the top of the page. For words trained by

CART, eight lines were printed below each picture to prompt Mr. J to repeatedly copy the word. For words trained by T-CART, eight check boxes were printed below each picture for Mr. J to mark after typing the word into the cell phone. For both CART and T-CART, Mr. J could check his spelling accuracy by referring to a written model of each target word provided on the back of the picture in the photo album. The clinician checked homework for completeness and accuracy every session and recorded an estimate of the time spent on homework.

Results

Mr. J participated in 15 hr of clinician-directed treatment and completed approximately 15 hr of homework over a 9-week period. As shown in Figures 3 and 4, he improved his spelling and naming of all word sets, whether trained with CART or T-CART. Mr. J met criterion for spelling accuracy for most sets on the second session after training began (the shortest time possible). His response to treatment was item specific in that there was little to no generalization from previously trained sets to untrained sets. However, once trained, Mr. J consistently performed with high accuracy.

Follow-up probes were conducted 19 and 22 weeks after treatment ended. Mr. J demonstrated retention of spelling for all words in the first two sets trained with CART, with some errors on words in the last CART set (Set 5). For the T-CART words, he showed some decline in performance on the follow-up probes. From a functional perspective, it was notable that about half of the words spelled in error were recognizable approximations of the target (e.g., *violen* for “violin,” *famile* for “family”). On follow-up probes of spoken naming, Mr. J correctly named all but one item that had been trained during CART and made six errors across two probe sessions on the words trained with T-CART (see Figure 4). Furthermore, he had recognizable, functional spoken approximations (i.e., typically one phonemic deletion, distortion, or substitution) for all but one of the words on which he made errors. These approximations are not included in the graphs or in the calculation of treatment effect sizes, but they represent additional functional improvements relative to baseline performance.

Figure 5 provides a more direct comparison of pre and posttreatment performance across the two training modalities for both the targeted written and spoken naming responses. Both treatment methods resulted in mastery of the trained words, and Mr. J demonstrated relatively good preservation of his spelling knowledge and spoken productions at follow-up probes taken 19 and 22 weeks after the last therapy session. However, maintenance of spelling knowledge was better for CART words (M = 86% words correct) than for T-CART words (M = 60% words correct). In order to examine whether the difference in follow-up scores was significant, we compared performance on the two follow-up probes to the last two posttreatment scores for the six sets of words trained. To do so, we followed the procedure suggested by Conover and Iman (1981) intended to facilitate parametric analysis of nonparametric data. The scores for each set of words were rank transformed and then analyzed with a two-way analysis of variance (time of probe, type of treatment). There was a significant main effect for time, $F(1, 20) = 20.55$, $p = .0002$, indicating that performance had declined at follow-up, and there was a significant Time × Treatment interaction, indicating that maintenance was worse at follow-up for words trained on the cell phone (T-CART) than for those trained with handwriting (CART), $F(1, 20) = 9.03$, $p = .007$. The same analysis was performed for spoken naming, for which there was a slight decline at the follow-up test of the T-CART words, but this difference was not significant, $F(1, 20) = 0.84$, $p = .3714$.

Treatment effect sizes were calculated in order to provide a standardized index of change associated with the treatments. Specifically, the effect size reflected the difference between the average pretreatment performance relative to maintenance performance after criterion was met, and this difference was divided by an estimate of pretreatment variance. The weighted effect sizes were computed as described in Beeson and Robey (2006), using Busk and Serlin's (1992) procedures for *d1* and *d2* statistics, which are variations of Cohen's (1988) *d* statistic. The values for the CART treatment were d = 4.50 for spelling and d = 3.81 for spoken naming. For the T-CART scores, there was no variance in either the baseline scores (all 0%) or maintenance performance (all 100%), so effect sizes could not be calculated in the traditional manner. In order to approximate the effect size, a variance estimate was derived by pooling the maintenance and follow-up data from T-CART. This resulted in a *d* of 6.12 for spelling and 4.25 for spoken naming. These values are consistent in magnitude relative to those calculated from the data reported in other writing treatment studies (Clausen & Beeson, 2003; Rapp & Kane, 2002; Robson et al., 2001) and also in comparison with a cohort of 14 individuals with global agraphia who were treated with CART in the handwriting modality (mean d = 4.5; P.M. Beeson & K. Rising, personal communication, April 5, 2011). Because this is the first study to our knowledge of writing treatment using cell phone typing, these effect sizes can be used for future comparisons.

Posttreatment Assessment

The WAB was readministered 20 weeks after the last treatment session to sample Mr. J's language skills. At that time, the severity of his Broca's aphasia had lessened, as indicated by an increase in his Aphasia Quotient from 38.9 to 45.4. As shown in Table 1, improvement was noted on spoken language tasks, including the content of Mr. J's picture description, repetition, object naming, word fluency, and sentence completion. A full reassessment of reading and spelling was not administered for untrained words at that time because it was evident that Mr. J's improvements were specific to the trained items. This was confirmed several months later when a short sample (n = 5) of words from the Arizona Battery for Reading and Spelling was administered and reflected Mr. J's limited orthographic knowledge for the items. Additional follow-up testing long after the completion of this study included readministration of the Ravens Coloured Progressive Matrices, with the exact same raw score of 26 of 36 obtained prior to treatment. This validated that Mr. J's visual problem-solving skills were below those expected for his age and education.

Feedback regarding the functional value of treatment was collected by interview and a rating form. Mr. J judged his spelling and his overall communication abilities to be "better" after treatment. He judged his ability to write words trained with pen and paper as "somewhat better" and the words trained by typing on the phone to be "a lot better." He also rated his overall ability to say the words that were trained as being "a lot better." Mr. J reported independently sending text messages to his family to communicate simple messages when they were not together. He also indicated that he preferred to use texting rather than pen and paper to communicate face-to-face. It was interesting to note that his wife judged his spelling for items learned by pen and paper to be "better," but the words trained using the cell phone as "somewhat better." She agreed that his ability to say the words that he had practiced and his overall communication ability were "better."

A follow-up interview was also conducted with the participant and his wife 2 years after treatment was implemented. The wife stated that Mr. J still uses his cell phone texting feature to communicate over distances (with her and other family members), as well as a means to convey content during face-to-face communication. Mr J. had purchased a new phone that included both the pull-out keyboard as well as a touch screen for typing, and he was equally proficient at both. He showed some preference for the touch screen, where the delete button was easier to use as he self-corrected his errors. Mr. J used the texting feature to communicate words in conversation, either by typing words and showing the screen to his conversation partner, or he pulled up stored written words from his cell phone memo pad. In other words, the cell phone also served as a personal communication device in a manner similar to how communication books might be used. Mrs. J estimated that roughly 40% of all of Mr. J's successful communication was achieved with the assistance of his cell phone.

Discussion

The purpose of this study was to evaluate the use of cell phone typing to retrain single-word spelling in an individual with severe Broca's aphasia and global dysgraphia. This texting version of CART (T-CART) was evaluated for the training of 15 words, and another set of 15 words was trained with the conventional spelling treatment using handwriting (CART). Over 13 weeks of treatment that included daily homework along with twice-weekly face-to-face training, the participant showed marked improvement in spelling and oral naming of targeted items under both training conditions, with each approach taking approximately the same amount of time to reach criterion for spelling accuracy. Thus, both handwriting and texting were successful modalities to retrain written communication, and accurate spoken production of target items was facilitated in both treatment paradigms.

The treatment outcomes for the two approaches (CART and T-CART) differed in that written performance on the items trained with handwriting was better maintained at 5 months posttreatment than was performance on items trained with texting. The difference in the durability of words learned via handwriting rather than texting may indicate that encoding was stronger in the former modality. The motor movements for typing (and texting) require memory for spatial location of finger placement but do not require recall of specific motor movements to produce the individual allographs as is necessary for handwriting. The typing movements are clearly less unique for each letter and may not facilitate encoding for long-term retention to the same extent as writing the component letters of words. This finding appears to be consistent with the work of Longcamp et al. (2008), who found that individuals recognized the orientation of shapes better and over a longer period of time for shapes that they had handwritten than for shapes they had typed. Longcamp and colleagues concluded that the distinct hand movements and spatial memory associated with shape reproduction contributes to the character recognition and recall processes. One possible way to further improve the long-term durability of words trained in the texting modality would be to also provide CART homework using handwriting. Examination of such a concurrent approach is a logical next step for this line of research.

The follow-up data from Mr. J also showed that the last sets of items trained were not as well remembered as the earlier trained sets (i.e., Set 5 for CART and Set 6 for T-CART compared with Sets 1–4). This may have been related to the fact that Mr. J had less clinician-directed practice on the final sets as compared with previous sets. Although copies of all homework sheets were given to Mr. J at the end of treatment, there was not consistent accountability for home practice during the posttreatment interval as there was during earlier phases of treatment. This may suggest the value of *overlearning*, or treating beyond criterion, to adequately strengthen retrained skills. Recent behavioral and brain imaging research provides support for the notion that overlearning results in more efficient neural processing and better long-term maintenance (Kurland et al., 2008). At a practical level, these findings suggest that extending training beyond criterion and establishing a means of accountability for continued home practice should be considered.

In addition to demonstrating considerable improvement in writing, typing, and spoken naming of trained items, Mr. J showed significant increase on the WAB Aphasia Quotient, from 38.9 to 45.4. This increase of 6.5 points reflected improvements on speech production tasks, including repetition, confrontation naming, and sentence completion. These improvements were likely the result of clinician-directed guidance to achieve correct spoken production of target words, along with repeated spoken naming as part of the CART and T-CART homework. It was encouraging to note that the improvement in speech production generalized to untrained items, reflecting a general rehabilitative effect on speech and language skills. Thus, this treatment proved to be an efficient method of improving both written and spoken language skills in an individual with severe aphasia and apraxia of speech. It is also worth noting that over the full course of our treatment with Mr. J (from 17 months to 35 months after onset of stroke), his Aphasia Quotient improved from 27.6, to 38.9, to 45.4. This overall gain of 17.8 points is impressive and is important evidence of the potential for long-term recovery of aphasia.

We should note that Mr. J's positive response to treatment occurred despite his relatively poor performance on a test of visual problem solving. In a previous case series of eight individuals with severe aphasia, poor performance on the Raven's Coloured Progressive Matrices was associated with poor response to lexical spelling treatment (Beeson et al., 2003). These findings will need to be examined relative to a larger cohort with similar aphasia severity to better determine the predictive value of this measure.

Overall, we viewed Mr. J to be an excellent candidate for text messaging as a communication modality. He was within the age range of adults who commonly use text messaging, he already owned a cell phone with a pull-out keyboard, and he had the motivation and desire to learn to use his phone for texting. Despite right hemiparesis, Mr. J easily held the phone and pushed keys using his left hand. He could independently put the phone into the text-messaging mode, and after treatment, he routinely used text messaging to communicate with his family. After treatment, Mr. J often used the texting function as a replacement for speaking on the telephone to communicate with family across distances. This was an important alternative for Mr. J because of his limited intelligible speech. He also used his phone to type messages in person rather than producing handwritten communication, when he could not say what he wanted to communicate. In other words, the cell phone was used as a communication device for face-to-face communication as well as for over distances. Although his response to treatment was item specific in that he required training for each word, the functional benefit to Mr. J was considerable because the target words were carefully chosen to ensure personal relevance. By the end of treatment, Mr. J and his family were capable of targeting additional words to relearn in order to increase written vocabulary even after formal treatment sessions had been discontinued.

In summary, the results from this study suggest that a copy and recall methodology can be effective for training single-word spelling using the texting function on a cell phone in a manner similar to that with pen and paper. The time required to train words and the accuracy immediately after treatment were comparable for both modalities, but for this participant, long-term retention was stronger for words trained with pencil and paper compared with those trained with the cell phone. Future research should explore the benefits of concurrent CART and T-CART for the same words as a means to achieve durable relearning along with the benefit of the texting modality. It will also be beneficial to determine the best candidates for T-CART, considering factors such as age, prestroke familiarity with texting, and overall comfort level with technology. The outcome from this participant suggests that the value of using T-CART to train spelling and to stimulate oral naming in a severely language-impaired individual has strong potential as a complement to the traditional CART approach.

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Appendix

Appendix

List of Stimuli

No. of letters	CART	T-CART	No. of letters
	Set 1[a]	**Set 2**[a]	
8	*computer*	*Precious*	8
7	*Alberta*	*Jackson*	7
6	*Mickey*	*family*	6
6	*Junior*	*hammer*	6
5	*Maria*	*Cindy*	5
M = 6.4			*M* = 6.4
	Set 3	**Set 4**	
10	*dispatcher*	*basketball*	10
7	*Walmart*	*stroke*	6
5	*music*	*violin*	6
5	*pizza*	*pills*	5
5	*water*	*apple*	5
M = 6.4			*M* = 6.4
	Set 5	**Set 6**	
8	*homework*	*bathroom*	8
6	*doctor*	*practice*	8
6	*banana*	*garbage*	7
6	*boxing*	*sink*	4
5	*bacon*	*meat*	4
M = 6.2			*M* = 6.2

Note. CART = Copy and Recall Treatment; T-CART = texting version of Copy and Recall Treatment.

[a]Proper names have been changed, but they maintain the same number of letters and syllable structure as the original stimuli.

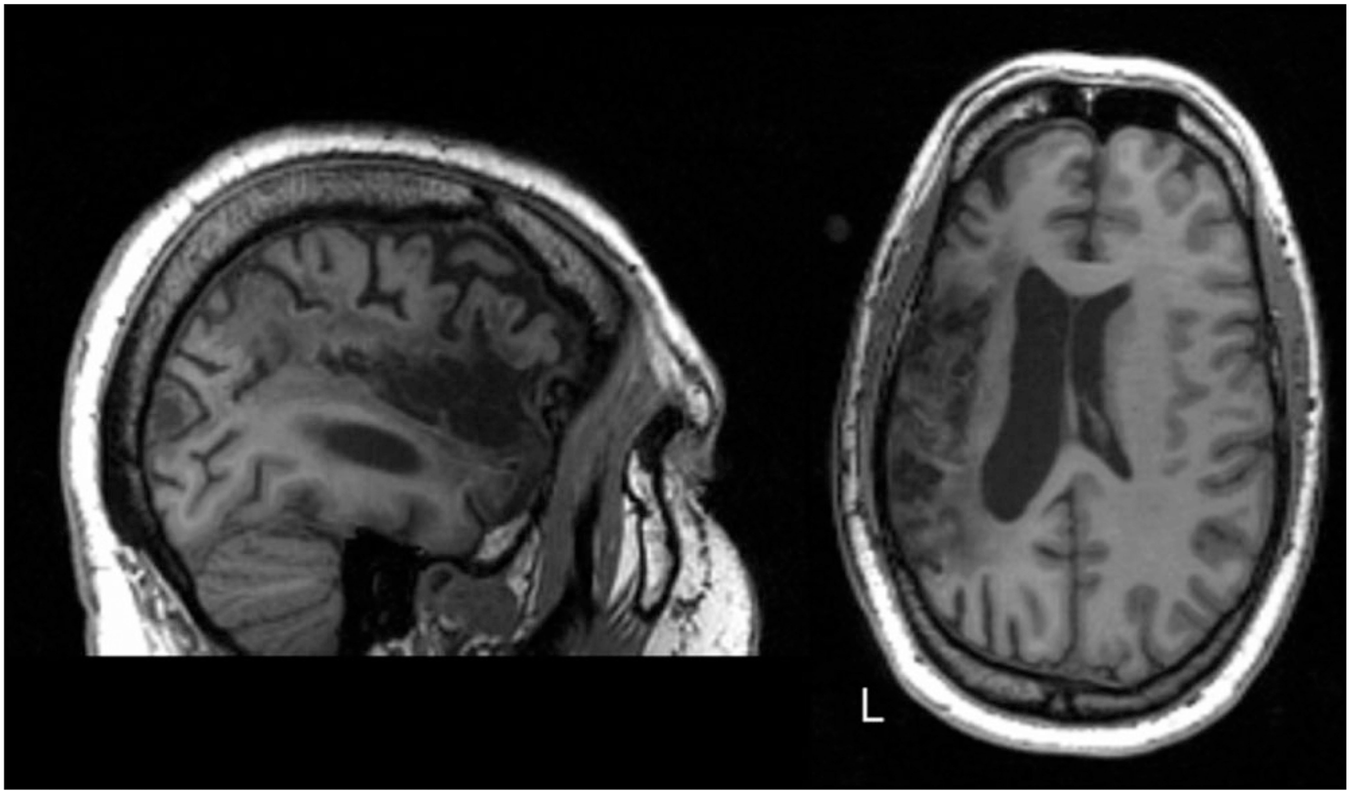

Figure 1.
Time 1 magnetic resonance imaging head scan showing extensive left-hemisphere damage. L = left.

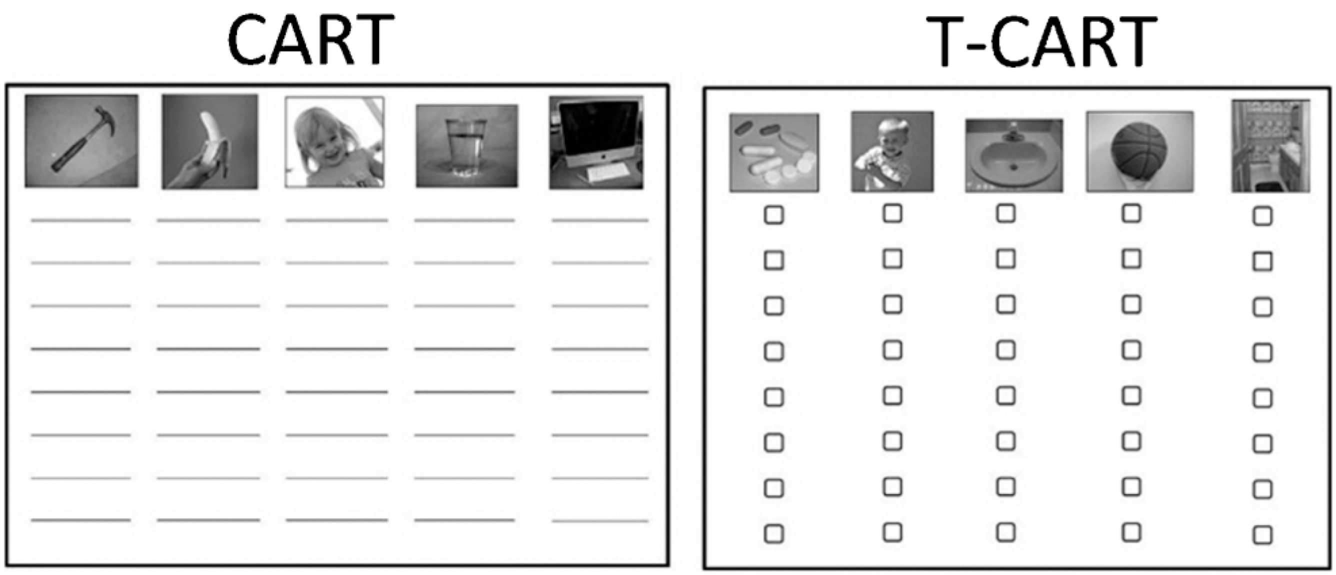

Figure 2.
Example of the typical format of homework sheets for Copy and Recall Treatment (CART) and the texting version of Copy and Recall Treatment (T-CART).

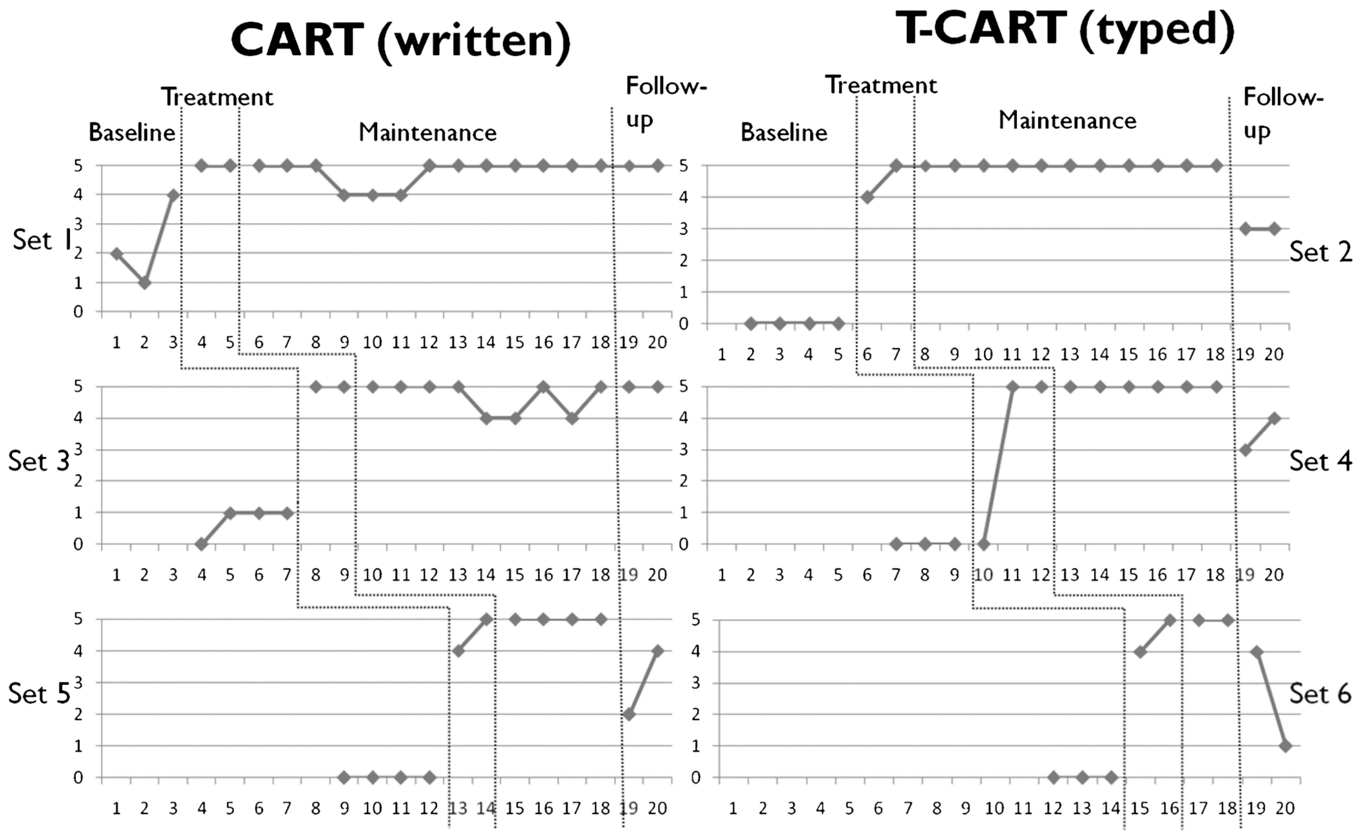

Figure 3.
Mr. J's spelling performance on probes during pretreatment baseline, treatment, maintenance, and follow-up (~ 5 months posttreatment) phases for all word sets for the two training conditions.

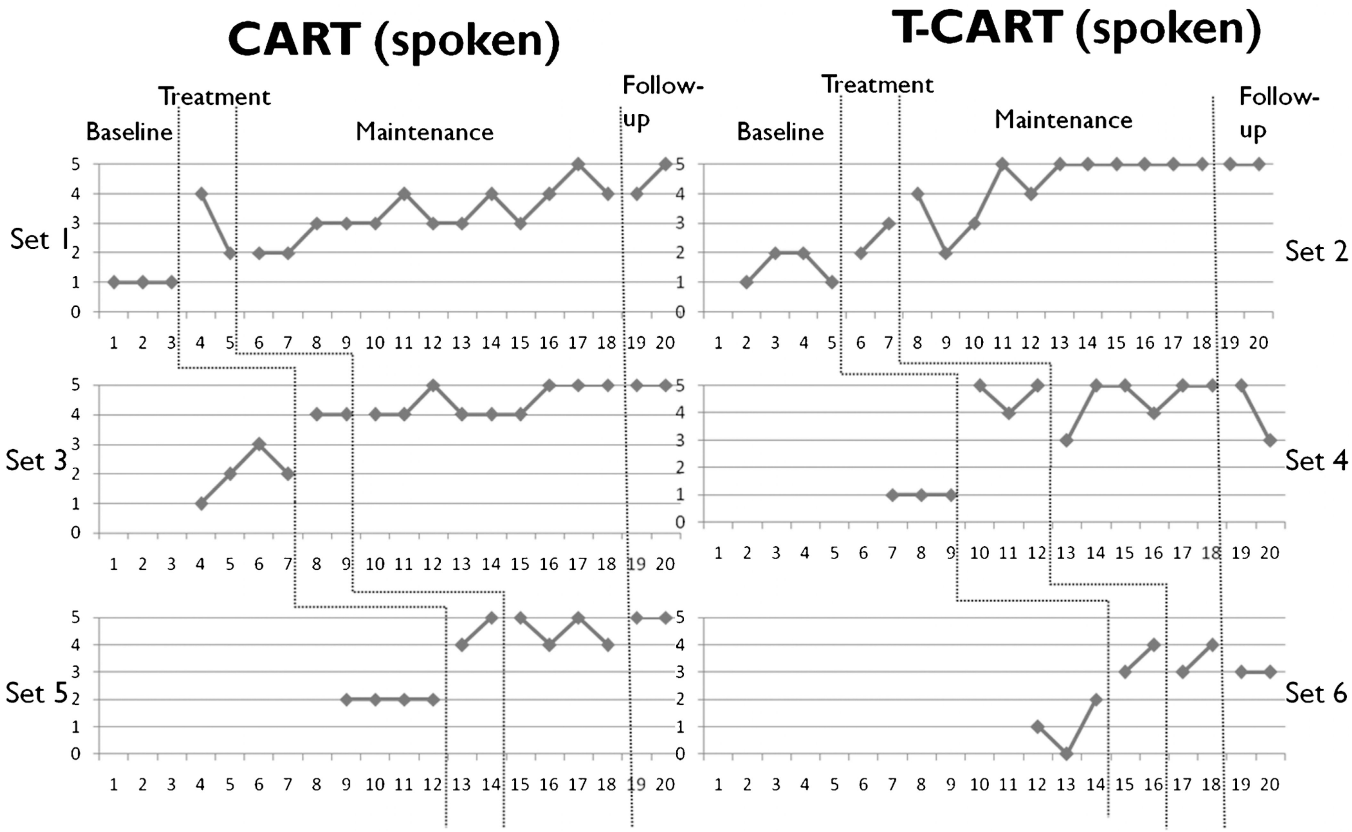

Figure 4.
Mr. J's spoken naming performance on probes during pretreatment baseline, treatment, maintenance, and follow-up (~ 5 months posttreatment) phases for all word sets in the two training conditions.

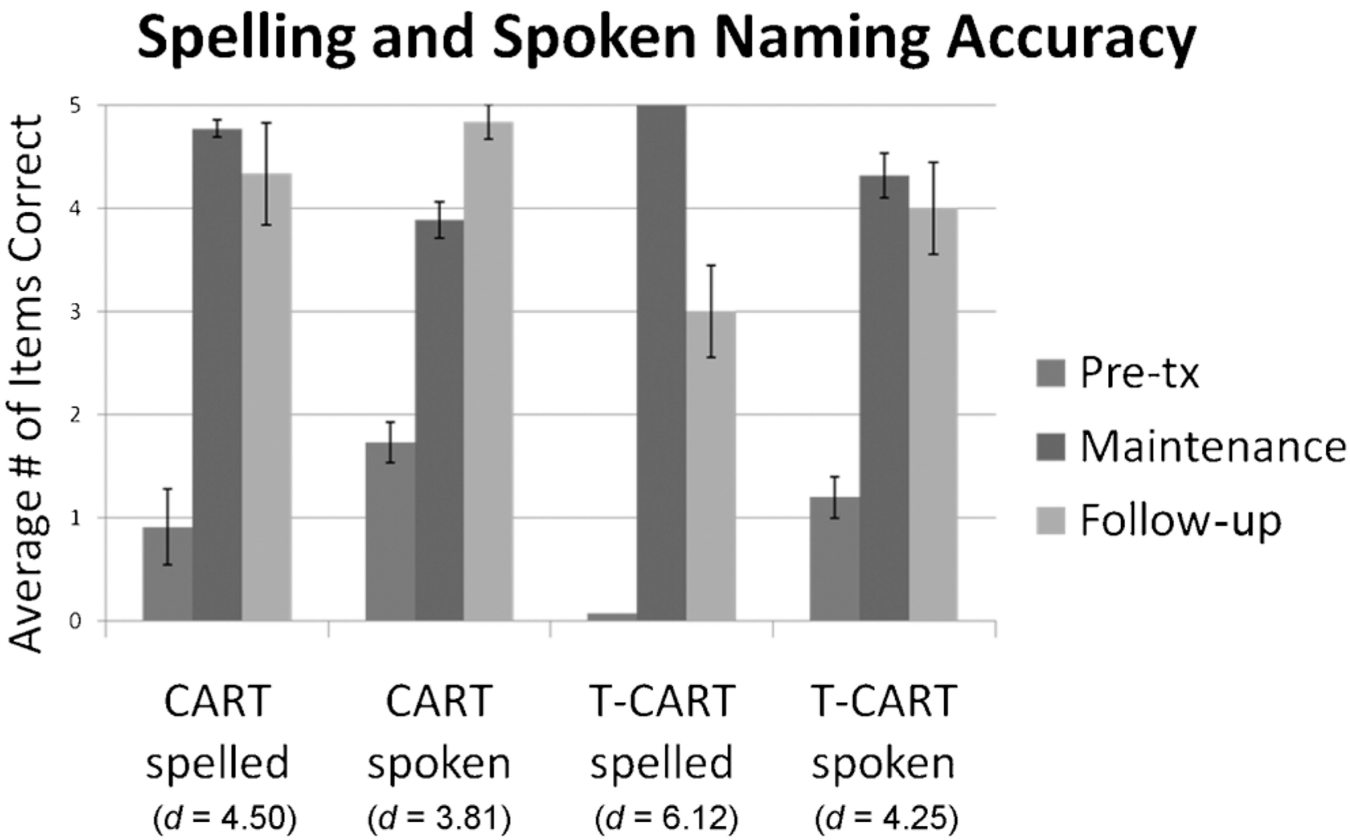

Figure 5.
Summary of Mr. J's mean performance for each condition during each phase—includes treatment effect sizes (*d* statistic) for baseline scores relative to performance during maintenance and follow-up phases.

Table 1

Mr. J's subtest scores from the Western Aphasia Battery before and after treatment.

Subtest (possible score)	Pretreatment	Posttreatment
Spontaneous Speech		
Information Content (10)	7	8
Fluency (10)	2	2
Auditory Comprehension		
Yes/No Questions (60)	54	51
AuditoryWordRecognition (60)	35	35
Sequential Commands (60)	50	46
Repetition (100)	15	28
Naming		
Object Naming (60)	15	22
Word Fluency (20)	1	3
Sentence Completion (10)	2	6
Responsive Speech (10)	2	2
Aphasia Quotient (100)	38.9	45.4