Effect of Model-Based Treatment on Oral Reading Abilities in Severe Alexia: A Case Study

Swathi Kiran, Ph.D.

Maitreyi Viswanathan, M.A.

Communication Sciences & Disorders
University of Texas at Austin

The present treatment examined a model-based treatment to facilitate oral reading skills in a patient with anomic aphasia and severe alexia. Pretreatment evaluation revealed that this patient presented with impaired grapheme to phoneme conversion, impaired connection between visual input lexicon (VIL) and semantic system (SS), and milder impairments in speech output lexicon (SOL) and grapheme output lexicon (GOL). Using a case study design, treatment was initiated on oral reading on one set of words, whereas generalization was tested to oral reading on a set of semantically related words as well as written naming and visual lexical decision of trained and untrained words. Results revealed improvement on oral reading of trained words, semantically related untrained words, written naming of trained and untrained items, and to a list of untrained words varied in letter length (drawn from the Psycholinguistic Assessment of Language Processing in Aphasia [PALPA]). A follow-up evaluation conducted two and half years post stroke revealed maintenance of reading skills. These results suggest that model based treatment and semantic feature analysis are useful in facilitating improvements and generalization to oral reading and written naming. These results further suggest that therapy provided during the early phase of recovery may have long lasting beneficial effects on reading abilities.

Recently, research has focused on understanding the nature, characteristics and treatment for acquired alexia. There are several types of acquired alexia that have been delineated in the literature, namely, pure alexia, phonological alexia, surface alexia, and deep dyslexia (Coltheart, 1981). Correspondingly, several treatment approaches that target the specific locus of impairment have been proposed to alleviate reading disturbances in patients with aphasia. The present article is focused on rehabilitation of reading deficits in a patient with severe alexia, mild anomic aphasia, and acquired agraphia and is based on a cognitive neuropsychological model of single word reading (Ellis & Young, 1988).

MODELS OF READING

Several models of single word reading have been proposed (Ellis & Young, 1988; Hillis & Caramazza, 1992; Newcombe & Marshall, 1984). Most of these models agree that the basic construction of the process of reading comprises a dual route process that involves whole word reading and sublexical conversion. Specifically, most models suggest

Journal of Medical Speech-Language Pathology
Volume 16, Number 1, pp. 43–59

that a written word stimulus undergoes an initial peripheral featural analysis followed by recognition as a familiar or unfamiliar word, which in turn activates the corresponding representation in the semantic system. The semantic system (SS) and/or the visual input lexicon (VIL) consequently activate the speech output lexicon (SOL) to allow oral reading. This route, termed the whole word differs from the sublexical route. The sublexical route involves the activation of the visual analysis system (VAS), which in turn activates the sublexical conversion mechanism (grapheme to phoneme conversion, GPC). The purpose of this module is to convert each grapheme to its corresponding phoneme, the output of which activates the phoneme level (PL) representation. These models, however, differ in the subtle connections between the various modules involved in the process of converting print to a spoken word. For instance, some models suggest that SOL activates the GOL (Ellis & Young, 1988), whereas other models do not (Basso, Marangolo, Piras, & Galluzzi, 2001). In general, the models have been useful in identifying the nature of acquired alexia and the potential cause of impairment. For instance, these models have been useful in dissociating breakdown in sublexical conversion that results in phonological alexia whereas a breakdown in the direct lexical route results in surface dyslexia.

TREATMENT FOR ACQUIRED ALEXIA

There are several treatment approaches that have been proposed to alleviate reading impairments in acquired alexia (the reader is referred to Cherney, [2004] and Friedman [2002] for a recent review of treatment studies). For the most part, treatments have been designed to address the underlying impairment and therefore, have varied from tactile kinesthetic letter identification approach (Greenwald & Gonzalez-Rothi; 1998; Lott, Friedman, & Linebaugh, 1994) to multiple oral re-reading (Moody, 1988; Moyer, 1979) depending upon the specific type of alexia (i.e., surface, deep, phonological or pure). Only treatments relevant to the present experiment are reviewed here.

Treatments that have utilized semantic information in facilitating oral reading skills have included tasks involving homophone training (Hillis, 1993) or have the patient name the semantic category for the target word (Moss, Gonzalez-Rothi, & Funnell, 1991), both of which are applicable for patients with surface alexia. Some researchers have attempted treatment programs which encouraged the semantic access capability for patients with pure alexia by disengaging the compensatory letter-by-letter reading process that is often observed in these patients (Gonzalez-Rothi & Moss, 1992; Maher, Clayton, Barrett, Schober-Peterson, & Gonzalez-Rothi, 1998; Gonzalez-Rothi, Greenwald, Maher, & Ochipa, 1998).

Another treatment approach targets grapheme-phoneme correspondence rules with the assumption that patients with impaired sublexical reading route could profit from relearning grapheme-phoneme correspondences in order to read words. This approach has been applied to patients with deep dyslexia (de Partz, 1986; Mitchum & Berndt, 1991) and phonological alexia (Kendall, McNeil, & Small, 1998). For example, de Partz (1986) trained grapheme to phoneme correspondence rules by employing a relay word for each phoneme in her patient who presented with deep dyslexia. Therefore, treatment was aimed at establishing visuolexical associations which was followed by associating each letter with the first phoneme of the relay word. The patient was then trained to successfully blend phonemes into syllables. At the end of therapy, the patient's word-reading skills improved significantly both on the trained items as well as untrained items. Other studies, however, have reported difficulty replicating this treatment in other patients with deep alexia (Mitchum & Berndt, 1991; Nickels, 1992). For instance, patients reported by both Mitchum and Berdnt (1991) and Nickels (1992) were able to learn specific grapheme to phoneme correspondences but were unable to blend phonemes to syllables. Slight variations of this approach have been employed (Kendall, Conway, Rosenbek, & Gonzalez-Rothi, 2003; Yampolsky & Waters, 2002), in which commercially available hierarchical steps at improving oral reading were employed.

Bastiaanse, Bosje, and Franssen (1996) investigated the effect of training grapheme to phoneme conversion skills in a patient with severe oral reading and naming deficits as a result of grapheme to phoneme conversion deficits. The patient was first trained to learn grapheme to phoneme conversion rules for letters, which was then applied to nonwords. The patient was encouraged to formulate self-cueing strategies during oral reading of words/nonwords. During confrontation naming, the patient was required to write the initial graphemes of the target and use that as a self-phonemic cue. Improvements after treatment were observed in oral reading, naming, and letter sounding.

A recent study by Stadie and Rilling (2006) examined the effectiveness of semantic and phonological primes during a priming task in a patient with deep dyslexia. This treatment was followed by grapheme to phoneme conversion and blending procedures to facilitate generalization to untrained items. Both treatments were equally effective in improving reading skills, although generalization to untrained items was only observed in the nonlexical procedure.

Finally, Kiran, Thompson, and Hashimoto (2001) investigated a model-based treatment approach focused on improving grapheme to phoneme as well as phoneme to grapheme conversion skills to train oral reading skills in two patients (13 and 27 months postonset) with severe oral reading and naming deficits. In this study participants were trained to read real words that emphasized grapheme to phoneme conversion. Treatment involved oral reading, repetition, oral spelling, letter selection from distracters, and reading the letters of the target word. The duration of treatment for participants 1 and 2 was 36 and 30 sessions, respectively. Results indicated that training grapheme to phoneme conversion resulted in improved oral reading of both trained and untrained words in patients with alexia. In addition, improved oral reading resulted in improved oral naming of trained words, suggesting that the same spoken word representations were accessed during oral reading and oral naming. Further improved spoken word representations during oral reading/naming resulted in improved access to written word representations during written naming of the trained items. This study provided evidence that training grapheme to phoneme conversion skills during oral reading resulted in generalization to untrained words, thereby facilitating access to phonological representations of both trained and untrained words in the phonological output lexicon.

THE PRESENT STUDY

The present treatment aimed at replicating the treatment approach proposed by Kiran et al. (2001) to establish the efficacy of a model-based treatment approach in treating individuals with heterogeneous patterns of reading deficits. The participant in the present study was an individual with severe alexia enrolled in treatment 3 months following his stroke. JS, an English professor, had recovered most of his language abilities except reading. Based on extensive pretesting, it was determined that JS presented with impairment at the visual input lexicon and access to the semantic system as well as impairment in sublexical conversion. This patient also presented with mild writing deficits characterized by semantic errors and was unable to read what he had just written. Additionally, testing revealed that the semantic system itself was intact but access to the semantic system from written words was severely impaired. Therefore, treatment comprised a combination of sublexical conversion and semantic attribute analysis (Boyle & Coelho, 1995; Edmonds & Kiran, 2006) to address different aspects of the patient's impairment. Based on Kiran et al.'s findings, it was predicted that a combination of spelling to sound conversion and semantic attribute analysis for each target word would consequently improve oral reading of trained words and semantically related untrained words. It was predicted that emphasizing semantic attributes of target words should result in strengthening corresponding target representations within the semantic system. Therefore, improvements in oral reading of trained and related untrained words were predicted to facilitate written naming of trained and untrained items. It was also predicted that the semantic task in treatment would strengthen the feedback connection between the visual input lexicon and the semantic system, thereby facilitating improvements in visual lexical decision for trained and untrained words. Finally, improvements observed for regular words would translate to improvements in irregular words on similar tasks because of the semantic nature of treatment.

As this patient was only 3 months postonset of stroke, a supplemental aim of the study was to examine the effects of treatment on oral reading during the acute phase of recovery, as most studies discussed in the introduction have involved patients who ranged from 6 months to 3 years postonset of the stroke (Greenwald & Gonzalez-Rothi, 1998; Mitchum & Berndt, 1991; Nickels, 1992; Stadie & Rilling, 2006; Yampolsky & Waters, 2002). Further, follow-up testing approximately 3 months and 30 months following completion of treatment was administered to assess maintenance of treatment effects.

METHODS

Case Report

Initial Testing

JS was a 76-year-old, monolingual right-handed male who suffered a unilateral left CVA on July

11, 2004, three months prior to our initial evaluation. An MRI scan taken a day after the stroke revealed a left occipito-temporo-parietal lobe lesion (Figure 1). At the time of the stroke, JS was an English professor with over 24 years of education and more than 40 years of teaching experience. Following his stroke, he received general speech and language treatment at the rehabilitation center until discharge. As seen in Table 1 on the Western Aphasia Battery (WAB) (Kertesz, 1982), his WAB Aphasia Quotient score was 96. JS presented a pattern consistent with fluent anomic aphasia, including fluent spontaneous speech with semantic paraphasias and impaired oral reading. His comprehension, repetition and spelling were all within normal limits. Performance on the Boston Naming Test (BNT) (Goodglass, Kaplan, & Weintraub, 1983) indicated naming impairments accompanied with paraphasic errors. Several subtests of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1992) and Pyramids and Palm Trees (PAPT; Howard & Patterson, 1992) were administered to identify the locus of impairment (Tables 2 and 3). The following were results of the assessment from the two tests.

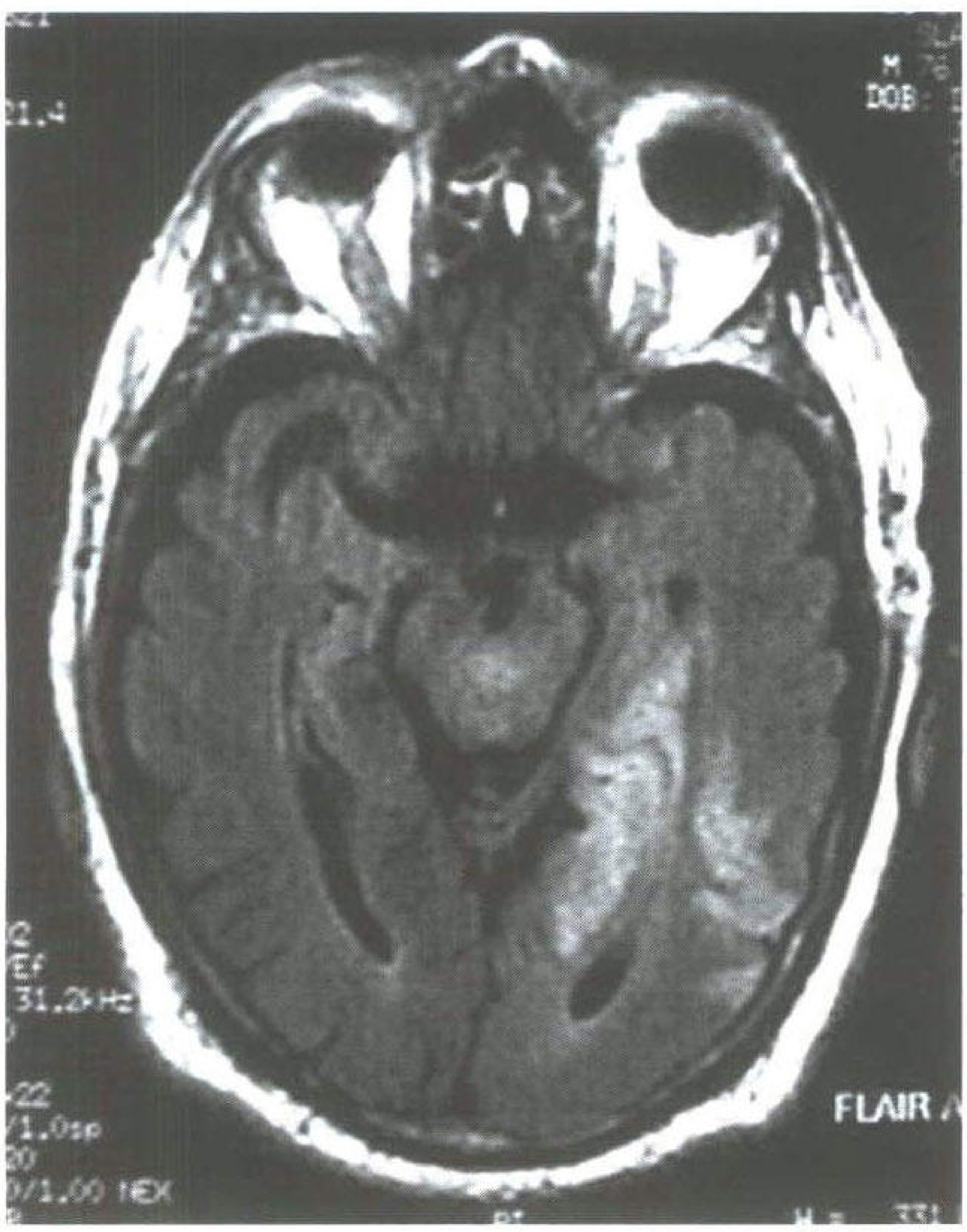

Figure 1. MRI scan for JS taken 1 day after the stroke.

Phonological Awareness

JS demonstrated relatively accurate performance (84% accuracy) on a task examining phonological segmentation abilities (e.g., identify the initial sound of the word nose). Oral repetition was at 100% accuracy.

Visual Analysis System

JS demonstrated relatively adequate performance (80% or higher accuracy) on Letter Discrimination–Mirror Reversal task (e.g., D/ Я), Letter Discrimination–Upper/Lowercase Matching (e.g., p/P), and Letter Discrimination–Words and Nonwords (e.g., BENCH/bench, lcokc/LCOKC).

TABLE 1. Performance on the Western Aphasia Battery (WAB; Kertesz, 1982); Boston Naming Test (BNT; Goodglass et al., 1983).

Test Details	Pretesting	Posttesting
Western Aphasia Battery		
Aphasia Quotient	96	97.4
Fluency	20	20
Auditory Comprehension	10	10
Naming	8	8.7
Repetition	10	10
Boston Naming Test		
Naming Accuracy	28.33%	75.00%

TABLE 2. Performance on reading and spelling tests prior to and following treatment on various PALPA subtests (Kay et al., 1992).

Test Details	Pretesting	Posttesting	30-Month Follow-up
PALPA			
Phonological Segmentation–Initial Sounds (#16)	84.4%	91.1%	
Word Repetition (#53)	100.0%	100.0%	
Letter Discrimination–Mirror Reversal (#18)	100.0%	100.0%	100.0%
Letter discrimination–Upper/Lower case Matching (#19)	92.3%	100.0%	
Letter Discrimination–Words and Nonwords (#21)	80.0%	96.7%	95.0%
Visual Lexical Decision (#25) (% correct rejections)	UC	93.3%	
Auditory Lexical Decision (#5)	95.6%	96.3%	
Homophone Decision (#28)	UC	58.3%	
Letter Length Oral Reading (#29)	UC	100.0%	95.8%
Grammatical Class Oral Reading (#32)	0.0%	96.3%	87.5%
Lexical Morphology and Reading (#34)	0.0%	93.3%	
Oral Reading–Regularity (#35)	UC	93.3%	
Oral reading (#53)	0.0%	95.0%	
Letter Naming and Sounding (#22)	31.0%	86.5%	92.3%
Oral Reading–Nonwords (#36)	UC	87.5%	87.5%
Spoken Letter–Written Letter Matching (#23)	84.6%	100.0%	100.0%
Spelling to Dictation: Letter Length (#39)	87.5%	100.0%	
Spelling to Dictation: Regularity (#44)	70.0%	77.5%	70.0%
Written Spelling (#53)	82.5%	95.0%	

Note: UC stands for Unable to complete which indicates that JS attempted the task but could not progress beyond the first few items.

TABLE 3. Performance on lexical access and semantic processing tests prior to and following treatment on the PALPA (Kay et al., 1992) and PAPT (Howard & Patterson, 1992).

Test Details	Pretesting	Posttesting	30-Month Follow-up
PALPA			
Spoken Word Picture Matching (#47)	97.5%	100.0%	
Written Word-Picture Matching (#48)	UC	92.5%	
Auditory Synonym Judgement (#49)	100.0%	100.0%	
Written Synonym Judgement (#50)	UC	95.0%	95.0%
Word Semantic Association (#51)	UC	83.3%	80.0%
Spoken Word–Written Word Matching (#52)	53.3%	80.0%	86.0%
Oral Naming (#53)	95.0%	100.0%	92.5%
Written Naming (#53)	65.0%	92.5%	
PAPT			
Three Pictures	90.38%	84.61%	
Three Words	7%	98.07%	

Note: UC stands for Unable to complete which indicates that JS attempted the task but could not progress beyond the first few items.

Visual Input Lexicon/Auditory Input Lexicon

JS was unable to complete the visual lexicon decision task as he reported that all items looked like plausible words to him. On the other hand, his performance on the auditory lexical decision task was 95%.

Phonological Output Lexicon/Oral Reading

JS attempted all the reading tasks he was administered but was unable to progress beyond the first few items on several of those including (a) Homophone Decision (e.g., pear/pair, vore/voar), (b) Letter Length Oral Reading (e.g., key, house, church), (c) Grammatical Class Oral Reading (e.g., suffer, entire, concept), (d) Lexical Morphology and Reading (e.g., hairy, tore, smiled), (e) Oral Reading–Regularity (e.g., effort, iron), and (f) oral reading (e.g., comb, mountain). On all these tasks, JS produced neologisms instead of the target (e.g., KNIFE–kirkle, GLOVE–chock, CONCEPT–kovihik, SANG–sak, LUCK–nucole). JS often "read" the presumed letters out prior to reading the word aloud.

Phonological Output Lexicon/Oral Naming

As seen in Table 1, JS showed errors in naming on the BNT (17/60). Errors on this task were mainly semantic errors (e.g., PRETZEL–pastry; VOLCANO–eruption). Oral naming on the PALPA, however, was 95% accuracy, presumably due to the high frequency and imageability of the latter pictures (see Table 3).

Grapheme to Phoneme Conversion

JS demonstrated marked impairments on Letter Naming and Sounding task (31% accuracy) and was unable to complete the Oral Reading–Nonwords task (e.g., ked, hoach). His errors on the nonword reading task were similar to those on the real word tasks (e.g., DOOP–por, SOAF–jomal).

Phoneme to Grapheme Conversion

JS demonstrated relatively adequate performance (70% or higher accuracy) on tasks examining phoneme to grapheme conversion including (a) Spoken Letter–Written Letter Matching, (b) Spelling to Dictation–Letter length (e.g., duck, square), (c) Spelling to Dictation–Regularity (e.g., elephant, nest), and (d) written spelling. When JS made errors, the spellings were usually close to the target (e.g., CHEESE–cheeze; HOLIDAY–holliday) and often included addition of a letter (e.g., FORK–forke, COMB–combe).

Grapheme Output Lexicon

Written naming was assessed on the PALPA and accuracy on this task was 65% (see Table 3). Errors on this task were mainly semantic (e.g., SCREW–nail, THUMB–finger). Written spelling of the same stimuli was relatively higher in accuracy (82.5%) and errors were minor additions/substitutions (e.g., GLOVE–clove, FORK–forke).

Access to Semantic System

As seen in Table 3, tasks examining access to the semantic system revealed a clear modality specific deficit. Performance on tasks examining (a) Spoken Word Picture Matching, (b) Auditory Synonym Judgment on the PALPA and the three pictures test on the PAPT was relatively high in accuracy (90% or higher). In contrast, performance on access to the semantic system through written words was impaired on (a) Written Word–Picture Matching, (b) Written Synonym Judgment, and (c) Word Semantic Association. No consistent errors were observed on these tasks. For instance, on the word semantic association task, where JS was required to select words that were closest in meaning from distracters, JS picked LEMONADE for PALACE and POND for GRASS. On a task examining Spoken Word–Written Word Matching, JS's performance was mixed (53% accuracy). Errors on this task were either semantic foils (e.g., PHANTOM-Shadow) or unrelated foils (e.g., DUSK–beach).

Summary of Evaluation

To summarize, analysis of the various subtests on the BNT, PALPA, and PAPT revealed a relatively intact auditory input lexicon, visual analysis system, semantic system, and the phoneme to grapheme conversion pathway. Impairments were observed at the level of the visual input lexicon, their connections to the semantic system, and the grapheme to phoneme conversion pathway. Although JS presented with a relatively intact semantic system, he was unable to utilize the whole-word semantic route or reading-via-meaning route when tested with written stimuli, as he performed poorly on oral reading of both regular and irregular words alike. Further, concomitant deficits were noted for JS at the level of speech output lexicon (naming/reading impairments), graphemic output lexicon (written naming impairments). Although these characteristics are consistent with impairments seen in deep dyslexia, JS's inability to read any word and the lack of semantic errors during reading precludes a confirmatory diagnosis. Alternatively, the inability to read any word is consistent with pure alexia but the fact that JS also had agraphia decreases the likelihood for this diagnosis as well (see Figure 2 for hypothesized loci of impairment).

Treatment Approach

Based on the patient's impairment, a combination of sublexical conversion mechanisms and semantic feature task were developed for treatment. The main focus of therapy was to facilitate oral reading of target words; hence, several tasks in therapy involved sublexical conversion (both grapheme to phoneme conversion and phoneme to grapheme conversion) as used by Kiran et al., (2001). Since the semantic system itself was intact but access to the semantic system from written words was severely impaired, a semantic feature analysis step (following procedures used in Edmonds & Kiran, 2006) was incorporated into treatment. The rationale for this task was to strengthen semantic representations of trained words, thereby strengthening the connection between visual input lexicon and the semantic system. A consequence of this step was predicted generalization to oral reading of semantically related untrained words. The combined sublexical conversion and semantic feature analysis approach was integral to treatment as it was expected to address different aspects of the patient's impairment. It was hypothesized that only sublexical conversion treatment would not necessarily facilitate generalization to written naming of trained and untrained items. Likewise, it was hypothesized that a purely semantic approach would facilitate improvements in oral reading to semantically related untrained words but would have limited influence on untrained unrelated words (which would require the patient to apply sublexical conversion mechanisms).

Experimental Stimuli

Prior to treatment, JS was presented with 100 single regular words and 20 single irregular words and was required to read the words and name their corresponding pictures. JS was not provided any feedback on this task. From this set of 100 regular words, 22 words that the participant could neither read nor name were selected for the exper-

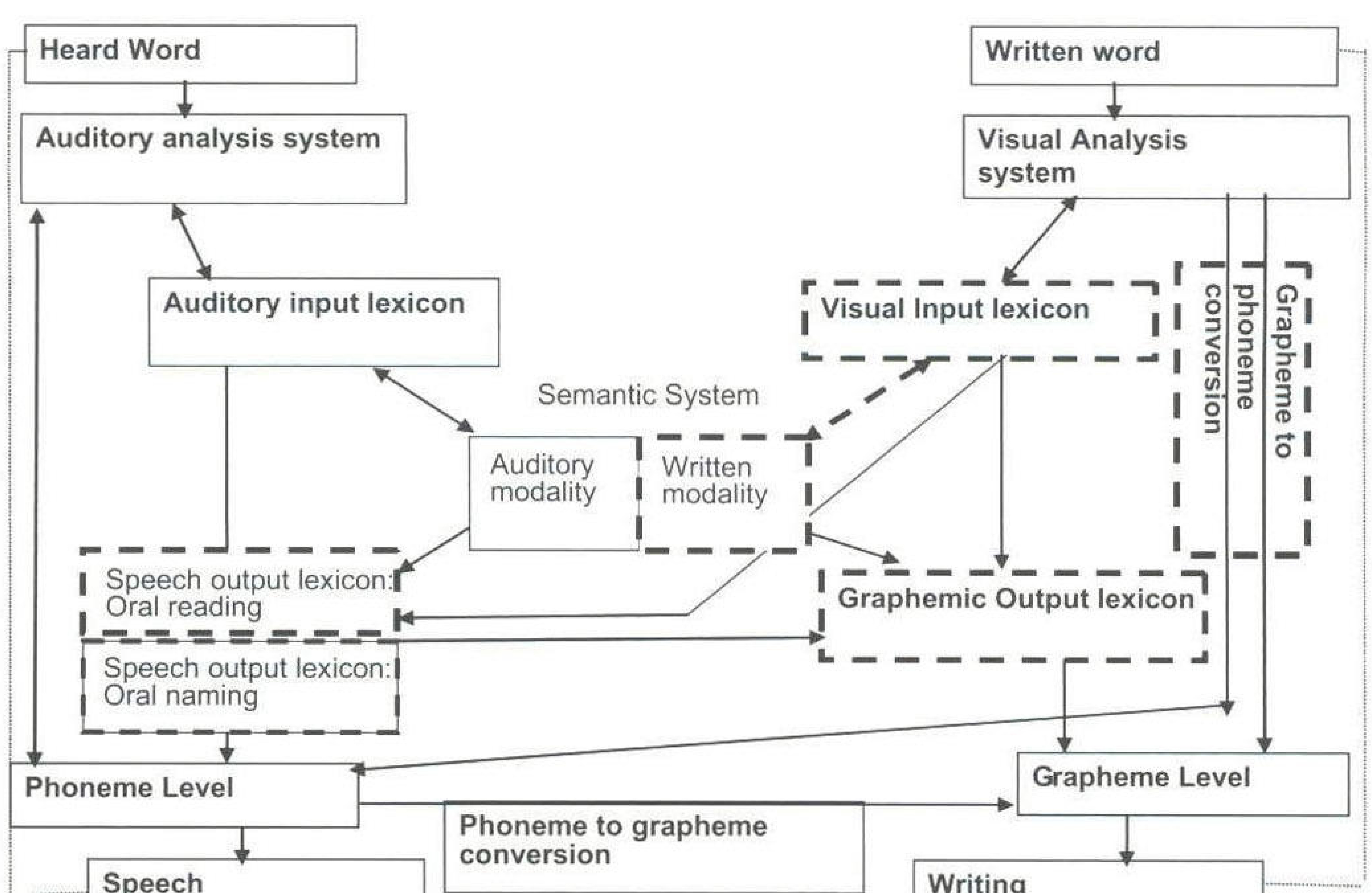

Figure 2. Adaptation of model of single word processing by Ellis and Young (1988) for patient JS. Hashed boxes indicate potential impairment as revealed by pretesting measures.

iment. These 22 words were concrete nouns and ranged between high and mid frequency-based written word frequency norms (Frances & Kucera, 1982). The chosen 22 words were randomly divided into two sets (trained and untrained) based on the following guidelines: (a) the average frequency of occurrence of words in both lists was matched ($t(10) = 1.8$, NS), (b) words in both lists were matched for the number of letters ($t(10) = .23$, NS) and the number of syllables ($t(10) = 0$, NS), (c) words were matched for semantic relatedness (each regular word in the trained set and its corresponding pair in the untrained set were semantically related) (Edmonds & Kiran, 2004), and (d) all pictures were equally imageable (see Table 4 for a list of stimuli).

From the set of 20 irregular words, 5 irregular words that the participant was unable to read/name were also selected to assess generalization to oral reading, written naming, and visual lexical decision. The selected experimental stimuli (27 words) were printed in large print (font = 20 point) on individual cards to be used for the oral reading task. For each card corresponding color pictures (approx 5" × 4" in size) were selected for use on the written naming task. A set of nonwords for use in the visual lexical decision task were selected from the ARC Nonword database (Rastle, Harrington, & Coltheart, 2002) and consisted of orthographically legal sequences and monomorphemic syllables. The 27 experimental stimuli and 36 nonword stimuli were typed on to a sheet with Arial 24 point font for the visual lexical decision task. Additionally, a list of 24 words that consisted of words with three, four, and five letters, drawn from PALPA (Letter length oral reading #29) was administered in the beginning of every session.

Design

A case study design across multiple behaviors was employed to examine generalization from trained to untrained items across tasks. Prior to treatment, the patient's performance on oral reading, written naming, and visual lexical decision of the experimental stimuli (22 pictures and corresponding words) was assessed. Treatment was initiated on oral reading of one set while generalization was assessed on (a) written naming and visual lexical decision of trained items and (b) oral reading, visual lexical decision, and written naming of untrained semantically related words. The experimental design also tested performance on oral reading, written naming and visual lexical decision of five irregular words.

Since JS's treatment was initiated approximately 3 months following his stroke, it was deemed important to measure the effects of spontaneous recovery on improvements on oral reading. However, given JS's relatively high performance on other aspects of language processing, it was difficult to develop a control task that was not already at ceiling levels or that would not change as a function of treatment. As a potential solution for this

TABLE 4. Stimuli used for patient JS.

Trained Set	Frequency	Number of Letters	Number of Syllables	Untrained Set	Frequency	Number of Letters	Number of Syllables
Shark	0	5	1	Whale	0	5	1
Chain	50	5	1	Ring	47	4	1
Bee	11	3	1	Butterfly	2	9	3
Spider	2	6	2	Ant	6	3	1
Alligator	4	9	4	Lizard	0	6	2
Dresser	1	7	2	Cupboard	2	8	2
Cabbage	4	7	2	Cucumber	0	8	3
Paintbrush	0	10	2	Painting	59	8	2
Potato	15	6	3	Onion	15	5	2
Soap	22	4	1	Razor	15	5	2
Shirt	27	5	1	Vest	4	4	1
Average	**13.6**	**6.0909**	**1.8182**		**13.63**	**5.90**	**1.8182**

issue, a list of 24 words drawn from PALPA subtest #29 (Letter length oral reading) was administered prior to every session. By administering the test every session (and twice often as other probe measures) it was hypothesized that improvements resulting from repeated exposure to stimuli could be examined.

Baseline Measures

Two baseline measures were administered for this patient. First, oral reading of a word list of 24 words from PALPA #29 was tested followed by oral reading, written naming, and visual lexical decision on the experimental stimuli. The same stimuli were used across all tasks oral reading, written naming, and visual lexical decision. The tasks were sequenced in a manner such that processes involved in the previous tasks would least likely influence performance in the later tasks. Therefore, written naming was tested first followed by visual lexical decision in order to prevent a possible transfer of orthographic information. Finally, oral reading was tested last, as access to the phonological information is aided by the orthographic information provided. Within each task the trained and untrained words were presented randomly. During written naming, JS was presented a picture and was required to write the name of the picture. During visual lexical decision, JS was required to decide whether a written string of letters was a word or nonword. For oral reading, he was instructed to read word cards presented one at a time. Feedback on accuracy of response was not given during baseline, but periodic encouragement was provided.

A response was counted as correct only when it was the target word. Consistent with the errors made during assessment of PALPA subtests, JS's errors on the baseline tasks were predominantly neologisms or unrelated words (e.g., WHALE–fark, RAZOR–Pabol). For written naming, a response was counted as correct only when the letters were clear and legible and all the letters of the word were accurate. One to two self corrections were allowed. Errors on this task were mainly semantic errors (e.g., CUCUMBER–lettuce), minor additions/substitutions (e.g., ANT–aunt) or a combination of the two (e.g., ALLIGATOR–crockodile).

Treatment Protocol

Treatment consisted of reading 11 regular words, none of which JS could read/write during pre-testing. Treatment steps for each word included: (a) oral reading of the word, (b) written spelling while saying the letters/sound aloud (engaging phoneme to grapheme conversion), (c) selection of the letters/sound of the target word from distracters while saying each letters/sound aloud (engaging grapheme to phoneme conversion), (d) identification of target word letters/sound presented randomly (engaging grapheme to phoneme conversion), (e) reading the letters/sound of the target word while pointing to the letters (engaging grapheme to phoneme conversion), (f) generation of six semantic attributes for the corresponding target picture (engaging analysis of semantic features), and g) oral reading of target word. For the specific instructions that were used see the Appendix at the end of this article.

Scrabble™ letter blocks were used for treatment steps that required manipulation of letters and the sounds of the target word. These steps included selection of letters of the target word, identification of the target word letters presented randomly, and reading the letters of the target word aloud (Kiran et al., 2001). Distracters used with the target letters were selected prior to the treatment and were based on the following criteria: (a) the number of distracter letters equalled the number of target letters (e.g., for the word *Ant*, three distracter letters were used e.g., *dom*), (b) at least one of the distracters was phonologically similar to a target letter (e.g., *d* for *t*), and (c) at least one of the distracters was orthographically similar to a target letter (e.g., *m* for *n*). The distracters were pseudorandomized before each treatment session such that no set of distracters for a target word was used consecutively. Accuracy on each of the steps on the treatment protocol was charted through the course of treatment. Treatment was conducted two times per week for 2 hours each. A total of 18 treatment sessions were conducted for JS. At the beginning of treatment JS could only practice 3–4 items per session. By the end of treatment, JS was able to practice all 11 items within the 2-hour session. It is noteworthy that JS was extremely motivated throughout treatment even though his performance was relatively poor at the beginning of treatment. As treatment progressed, performance on the treatment steps improved substantially.

Treatment Probes

Throughout treatment, oral reading, written naming, and visual lexical decision probes like those presented in the baseline were administered to assess performance on the various tasks. All the 22 regular words (11 trained and 11 untrained) and 5 irregular words were tested on oral reading, written naming and visual lexical decision every second session. Additionally oral reading of PALPA test #29 was administered at the beginning of every session. The order of the tasks was kept consistent with baselines (visual lexical decision, written naming, and oral reading). Responses to these probes were scored in the same way as in baselines, and served as the primary dependent measure in the study. Treatment was discontinued when oral reading of trained items was 100% accurate over two consecutive sessions. Generalization to untrained items was considered to have occurred when levels of performance changed by at least 45% over baseline levels.

Posttreatment Probes

Oral reading, written naming, and visual lexical decision of the experimental stimuli (22 regular words and 5 irregular words) were assessed approximately 3 months and 30 months following completion of treatment. Procedures for collecting probe measures were identical to those followed during baseline and treatment probes.

Reliability

All baseline and probe sessions were recorded on video tape and 30% of the responses were also scored online by the primary examiner and by an independent observer seated behind a one-way mirror. Point-to-point agreement was greater than 90% across probe sessions. Additional reliability on the independent variable of treatment was conducted on approximately 30% of the treatment sessions and was 99%.

RESULTS

The data derived from the treatment probes during baseline and treatment phases of the study are illustrated in Figures 3 through 6 respectively. Results of each task will be discussed separately.

Oral Reading of Trained and Untrained Items

As seen in Figure 3, during baseline, JS's ability to read aloud the trained items remained stable at 9% correct for both the baseline sessions. Follow-

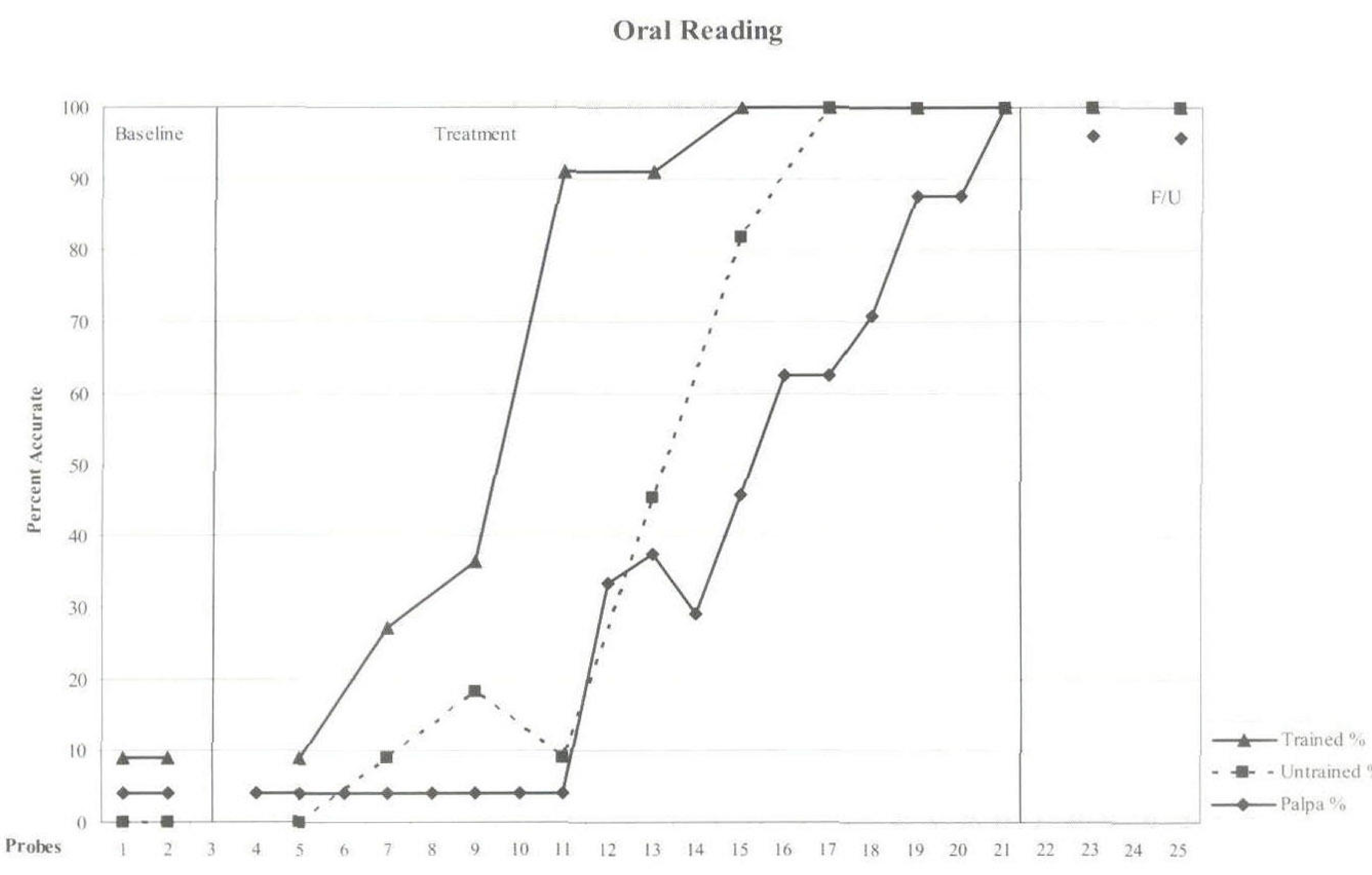

Figure 3. Percent accuracy on oral reading of trained items, untrained items and on PALPA #29 during baselines, treatment, and follow-up phases.

ing treatment, oral reading gradually improved to 100% accuracy. Additionally, generalization to the untrained set was noted from 0% accuracy during baseline sessions to 100% accuracy at the final treatment probe.

Generalized Oral Reading on PALPA #29

As seen in Figure 3, JS's ability to read aloud the list of 24 words (drawn from subtest #29) remained stable at 4% correct for both baseline sessions. Recall that this list was administered at the beginning of every session and twice as often as the rest of the probes. JS improved from 4% accuracy during baseline session to 100% accuracy on this list. It is important to note that improvement on this set of stimuli commenced on session 12, subsequent to improvements on the trained items (session 9).

Written Naming of Trained and Untrained Items

As seen in Figure 4, written naming of trained items during baseline was stable at 27% accuracy for both the baseline sessions. Following treatment, generalization to these items was observed with written naming improving to 100% accuracy. Likewise, written naming of untrained items which was at 45% accuracy during baseline sessions also improved to 100% accuracy during probes.

Visual Lexical Decision of Trained and Untrained Items

During baselines, performance on visual lexical decision was 100% correct for the trained items. This performance remained stable throughout the treatment. Visual lexical decision for untrained items improved from 82% accuracy during baselines to 100% accuracy during the treatment probes (Figure 5). In addition to the trained and untrained real words, performance on nonwords was also plotted over time. Notably, JS demonstrated decreased percentage accuracy for correct nonword rejections during the course of treatment (i.e., from 69–72% in baseline to 47% at the end of treatment).

Performance on Irregular Words

As predicted, treatment of oral reading of trained items facilitated generalization to oral reading,

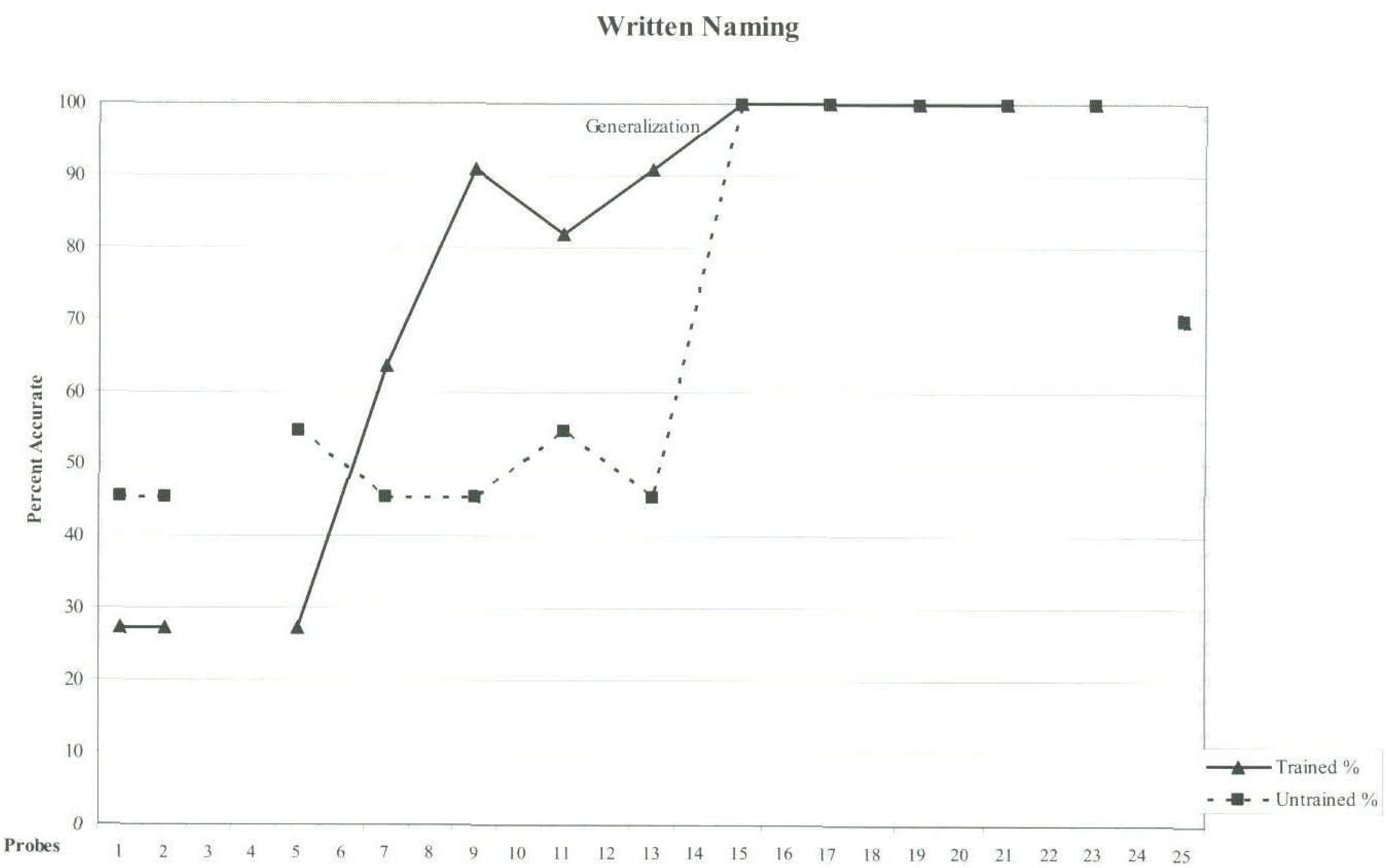

Figure 4. Percent accuracy on written naming of trained and untrained items examining generalization.

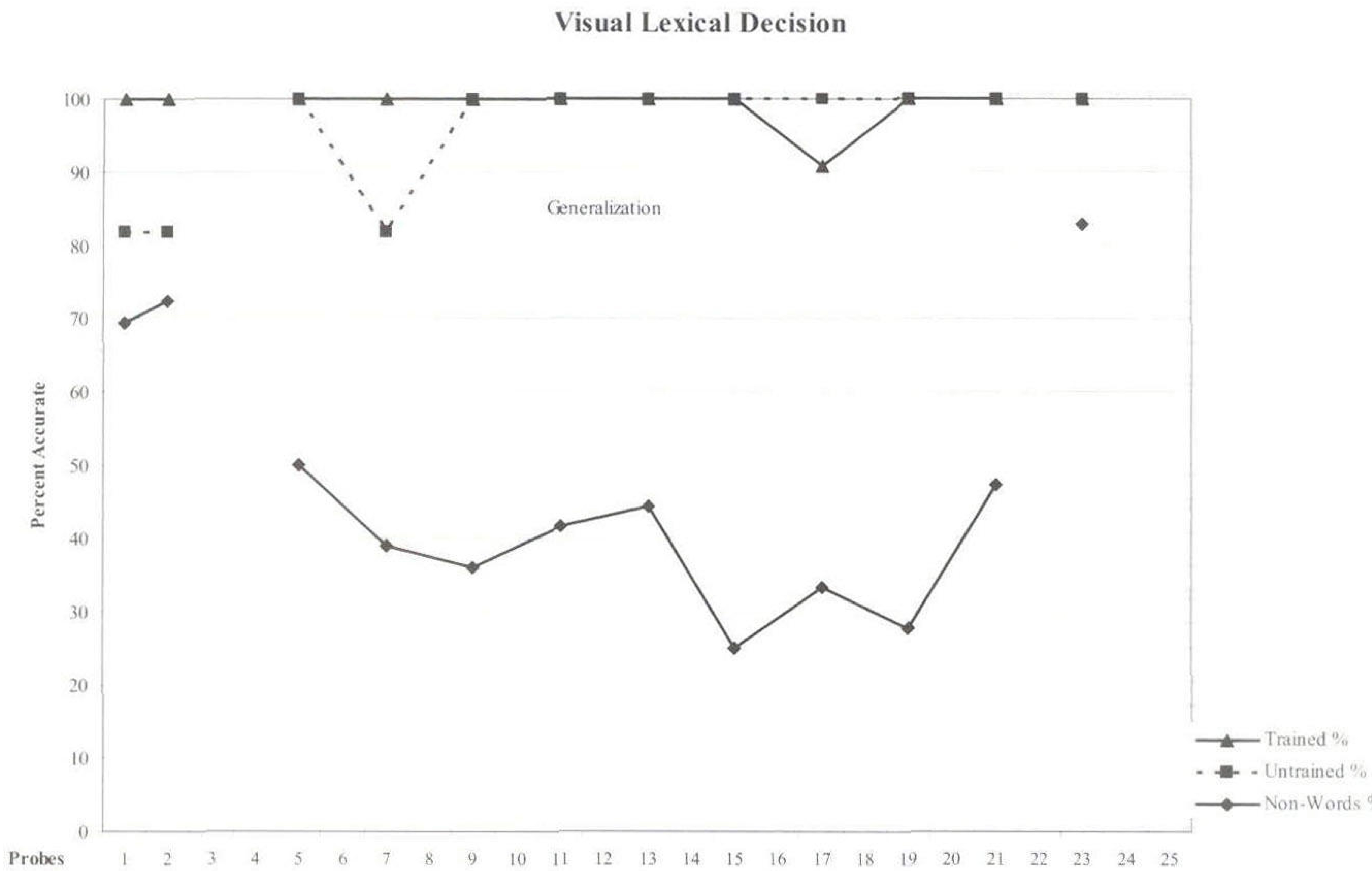

Figure 5. Percent accuracy on visual lexical decision of trained items and untrained items examining generalization.

written naming and visual lexical decision of irregular words (N = 5). Oral reading for irregular words gradually improved from 0% accuracy during baseline sessions to 100% accuracy at the final treatment probe as seen in Figure 6. Similarly for written naming of irregular words, JS improved from 60% (3/5 items) accuracy to 100% accuracy (5/5 items) during baselines. Performance on this task was maintained at 100% during treatment. On the visual lexical decision task, JS was at 100% accuracy during baselines and treatment.

Maintenance Probes

Results of the posttreatment/maintenance probes conducted approximately 3 months and 30 months after completion of treatment are reported in Figures 3 through 6. At the 3-month follow-up, performance on all tasks was maintained at levels comparable to treatment and generalization levels. At the 30-month follow-up, only oral reading and written naming tasks were administered. Whereas performance on oral reading was maintained at levels comparable to treatment levels, performance on written naming had declined from 100 to 70% for both trained and untrained items.

Performance on Standardized Measures

Pretreatment and posttreatment performances on WAB (Kertesz, 1982), BNT (Goodglass et al., 1983), and PALPA (Kay et al., 1992) are shown in Table 1. A slight improvement was observed on WAB AQ (from 96 to 97.4), whereas greater improvements were observed on the BNT (28 to 75%). Of greater interest, however, are the improvements noted in the subtests examining reading and spelling skills (see Table 2). JS demonstrated significant improvements in performance on tasks that required oral reading and spelling (t (15) = –5.18, $p < .0001$). Further, JS also demonstrated significant improvements on tests examining lexical access and semantic processing (see Table 3; t (9) = –3.0, $p < .05$). A representative sample of tests administered approximately 30-month following completion of treatment revealed maintenance of performance on most tasks (see Tables 2 and 3). Performance, however, declined on the written naming subtest of PALPA (#53) from 92.5 to 60% (around pretreatment levels). Consistent with performance on the written naming probes, JS's errors indicated either addition of letters (e.g.,

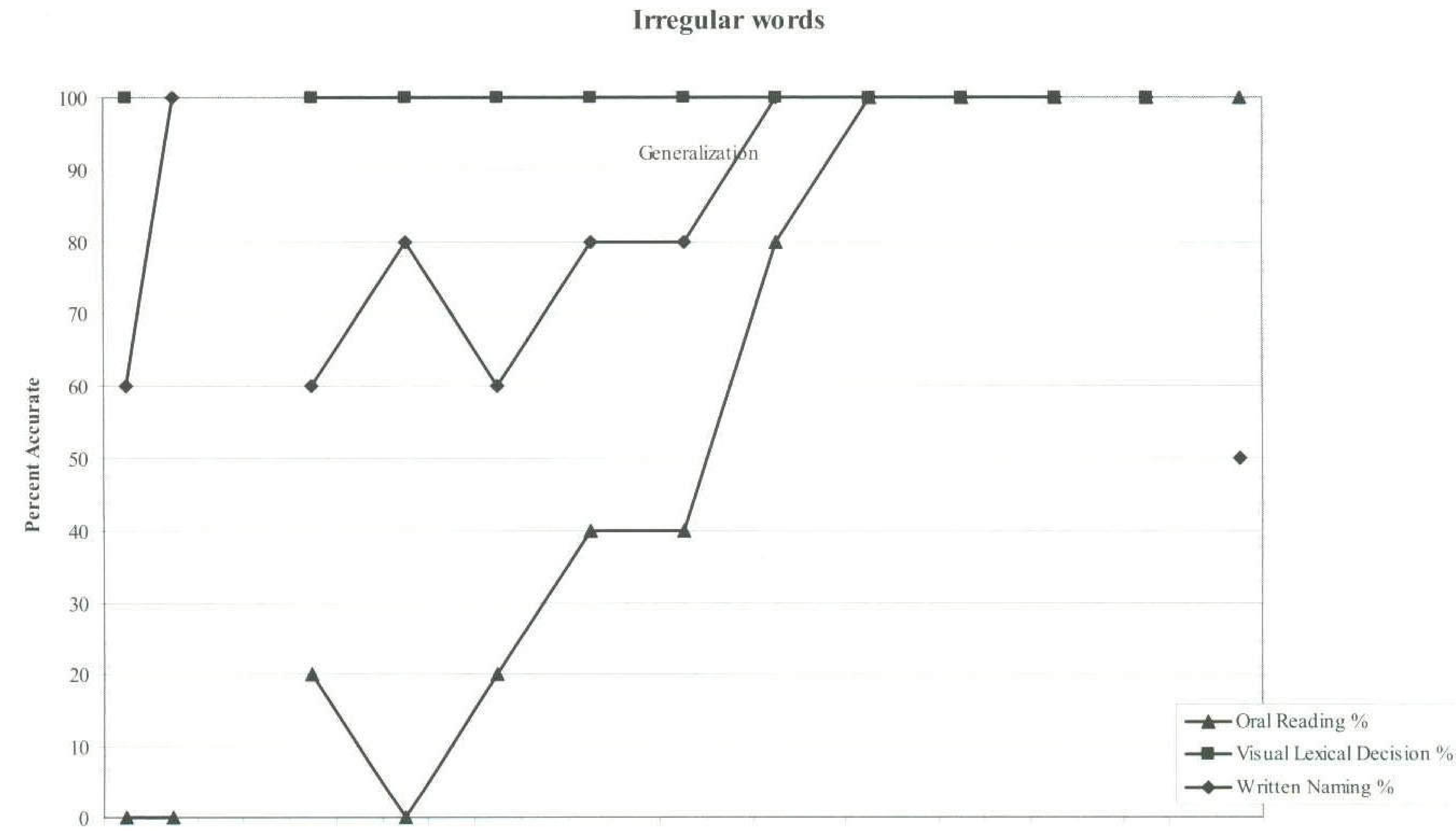

Figure 6. Percent accuracy on untrained irregular words tested during oral reading, written naming, and visual lexical decision examining generalization.

IRON–irone, BIRD–birde) or semantic errors (e.g., BOWL–cupe, GLOVE–mitten) on this task.

DISCUSSION

The present experiment examined the effect of therapy to alleviate reading impairments in one patient with anomic aphasia and severe alexia. Based on extensive pretreatment assessment, it was determined that this patient presented with impairments in the VIL (Visual Input Lexicon), connection between the semantic system and VIL, SOL (Speech Output Lexicon), GOL (Graphemic Output Lexicon), and GPC (Grapheme to Phoneme Conversion). Therefore, treatment was focused on sublexical conversion and semantic attribute analysis which resulted in broad improvements in oral reading and written naming on the treatment stimuli as well as on standardized language tests examining oral reading skills.

To explain the results observed for this patient, we revert to the model by Ellis and Young (1988) as this model best explains the results observed. Since training sublexical conversion during oral reading of the 11 words resulted in improvements to those items, related untrained words and on several reading subtests of the PALPA, it can be surmised that the ability to successfully convert graphemes to phonemes facilitated access to phonological representations during oral reading. Moreover, we have previously suggested that training sublexical conversion strengthens a heretofore previously unspecified connection between grapheme to phoneme conversion and speech output lexicon in this model (Kiran et al., 2001). The present study provides further evidence for this claim. Another finding of the present study is that improvements in oral reading were associated with concomitant improvements in oral naming manifested as increased naming accuracy on the BNT, an observation initially made by Nickels (1992) and corroborated by Kiran et al. (2001).

Another finding of the study was that improvements in oral reading of semantically related untrained words were supplemented with improvements in written naming of trained and untrained words. One possible explanation for these improvements may be that strengthened representations in the speech output lexicon may have strengthened corresponding graphemic representations in the graphemic output lexicon. This is consistent with the claim made by Kiran et al., (2001) to explain similar improvements observed in their two patients. An alternate, more plausible explanation for improved written naming in the present study may relate to a step in treatment involving explicit semantic feature analysis of target words. In this step, JS was required to generate and write six semantic attributes for the target word, which presumably resulted in strengthening semantic representations of the target words. Although JS never wrote the trained words or the untrained words during treatment, it is possible that analyzing semantic attributes facilitated access to graphemic representations for the trained words and the untrained words. These results are notable since a recent study by Stadie and Rilling (2006) that used semantic and phonological primes to improve reading performance for content and function words in a deep dyslexic patient did not find generalization to untrained words. Stadie and Rilling suggested the lack of adequate semantic overlap between the trained and untrained words to be a possible factor contributing to the lack of generalization. The results of the present study suggest that explicit semantic feature analysis, using treatment steps employed by Boyle and Coelho (1995) and Edmonds and Kiran (2006) have beneficial effects in facilitating generalization to oral reading and written naming of semantically related untrained words. In other words, it is believed that the present treatment was successful in strengthening connections between the semantic system and the speech output lexicon and the semantic system and graphemic output lexicon.

It should be noted that improvements in oral reading and written naming of trained and untrained words was maintained on probes conducted at 3 months and at 30 months. Further, 30 months after his stroke, JS was able to read single words fairly accurately, although reading was slow and laborious. JS read the newspaper every morning, began to write more, and attended a book club for a few months at the UT-Austin Speech and Hearing Center. These long-term improvements in reading abilities clearly illustrate the beneficial effects of early intensive theoretically motivated treatment.

One ambiguous aspect of the data concerns the results of the visual lexical decision tasks during treatment. Since performance on trained and untrained items was at ceiling levels during baselines and in treatment, it is difficult to discern the full effect of treatment on visual lexical decision. Indeed, performance on visual lexical decision of nonwords indicates a decrease in JS's ability to accurately reject nonwords. That performance on visual lexical decision on PALPA (#25) improved from 0 to 95% accuracy suggests that treatment did have some effect on visual lexical decision, at least on stimuli tested by PALPA.

Improvements in accuracy on subtests of the PALPA involving letter naming and sounding and oral reading of nonwords further underscore the claim that treatment aimed at improving sublexical conversion improved this patient's grapheme to phoneme conversion skills. Although this patient did not demonstrate major impairments in phoneme to grapheme conversion prior to treatment, improvements on subtests written spelling, spelling to dictation, and spoken letter to written letter matching suggest that this mechanism may also have improved consequent to treatment.

Similarly, improvements on written word to picture matching, written synonym judgment, and written word semantic association on the PALPA and the three written word subtest on the PAPT emphasize the beneficial effects of treatment on processing written word stimuli, presumably strengthening the connections between Visual input lexicon and Semantic System.

The issue of generalization to untrained stimuli and untrained tasks in treatment for acquired alexia has produced mixed results. While some studies have shown generalization to oral reading of untrained stimuli and to untrained tasks such as nonword reading and written naming (Bastiaanse, Bosje, & Franssen, 1996; Kiran et al., 2001; Yampolsky & Waters, 2002), others have shown limited generalization to untrained words (Gonzalez-Rothi & Moss, 1992; Greenwald & Gonzalez-Rothi, 1998). One explanation for these mixed findings is the nature and extent of associated deficits in the participants studied. For example, patients reported by Nickels (1992) and Mitchum and Berndt (1991) did not improve as much as the patient reported by de Partz (1986) despite following the same treatment approach, because the former two patients were unable to blend phonemes in CVC words. In the present study, our patient JS's main impairment was reading through the semantic and sublexical route. All other aspects of language processing including spelling, oral naming, written output, and comprehension were relatively stronger. Clearly, this patient's strengths in other aspects of language may have positively influenced the extent of generalization patterns that were observed to untrained stimuli and untrained tasks as a function of treatment.

The results of the present study are unique in several ways. As discussed above, performance on trained and untrained stimuli and accuracy on all oral reading and spelling tasks on the PALPA improved dramatically to near ceiling levels. This apparent "recovery" of reading skills can be potentially attributed to spontaneous recovery mechanisms that could have aided improvement of reading skills. As stated in the methods, it was difficult to develop a control task that was not already at ceiling levels or that would not change as a function of treatment. For example, tasks such as written naming (Stadie & Rilling, 2006) and oral reading of irregular words (Kiran et al., 2001) that are typically used as control tasks were, in the present study, predicted to improve as a function of treatment. Likewise, tasks such as oral repetition and auditory lexical decision, which would be predicted to remain unchanged as a result of treatment, were already at ceiling levels. One attempt at examining the influence of spontaneous recovery was the administration of PALPA subtest #29 twice as often as the treatment probes. Accuracy on this task only improved *after* improvements on oral reading of the trained and untrained stimuli commenced. This observation, however, does not conclusively suggest that spontaneous recovery was not a factor in the reading recovery process. A more parsimonious explanation for the improvements observed in the present study may be that the process of spontaneous recovery may have facilitated improvements in oral reading. Indeed, Gonzalez-Rothi (1995) has suggested that physiological restoration subsequent to stroke occurs during the early stages of recovery (first 6 months after the stroke) and hence, treatment strategies that emphasize "restitution" of function have greater outcomes during early stages of recovery (Gonzalez-Rothi, 1995). Additionally, in a recent computational network simulation of rehabilitation of reading deficits, Wellbourne and Lambon-Ralph (2005) trained a computer network to read words, lesioned the network, and retrained the network on specific target words varied by frequency and regularity. Additionally, the network's performance during an early recovery phase (with and without retraining) was contrasted with performance following retraining during the late phase. Results obtained from the simulations suggested that early therapy for reading deficits was more beneficial than later therapy. These authors also observed that therapy that utilized regular stimuli was more effective in improving access to untrained items that therapy focused on irregular word stimuli (Welbourne & Lambon-Ralph, 2005). The results of the present study are resonant with these findings both in terms of early rehabilitation and with respect to the nature of the stimuli used. Finally, it may be that the need to dissociate generalization from spontaneous recovery may not be that important after all. In a meta analysis of studies that have examined recovery of language deficits during acute phase, postacute phase, and chronic phase, Robey (1994) found that treatment provided during the acute stage of recovery (0–4 months poststroke) resulted in treatment effects that were nearly twice as large as changes measured with spontaneous recovery alone (Robey, 1994).

CONCLUSIONS

In conclusion, findings from this experiment indicate that grapheme to phoneme conversion treatment and semantic attribute analysis is useful in improving oral reading and written naming skills. Even though our patient did not have a definite diagnosis of deep dyslexia, the present treatment may be applicable for patients with deep dyslexia since it combines sublexical conversion and semantic processing of written words, both of which are difficult for patients with deep dyslexia. The present treatment has limited potential for patients with surface dyslexia who cannot access the whole-word route but are fairly successful letter-by-letter readers. Likewise, for patients with phonological alexia (inability to use grapheme to phoneme conversion route), the present treatment may not be wholly effective since these patients can use the semantic route adequately, rendering the semantic component of treatment unnecessary.

Address correspondence to Swathi Kiran, Ph.D., CMA 7.210, Department of Communication Sciences & Disorders, University of Texas at Austin, Austin, TX, 78712 USA.
e-mail: s-kiran@mail.utexas.edu

REFERENCES

Basso, A., Marangolo, P., Piras, F., & Galluzzi, C. (2001).

Acquisition of new "words" in normal subjects: A suggestion for the treatment of anomia. *Brain and Language, 77*(1), 45–59.

Bastiaanse, R., Bosje, M., & Franssen, M. (1996). Deficit-oriented treatment of word-finding problems: Another replication. *Aphasiology, 10*(4), 363–383.

Boyle, M., & Coelho, C. (1995). Application of semantic feature analysis as a treatment for aphasic dysnomia. *American Journal of Speech-Language Pathology, 4*, 94–98.

Cherney, L. R. (2004). Aphasia, alexia, and oral reading. *Topics in Stroke Rehabilitation, 11*(1), 22–36.

Coltheart, M. (1981). Disorders of reading and their implications for models of normal reading. *Visible Language, 15*, 245–286.

de Partz, M. P. (1986). Re-education of a deep dyslexic patient: Rationale of the method and results. *Cognitive Neuropsychology, 3*, 149–177.

Edmonds, L., & Kiran, S. (2004). Confrontation naming and semantic relatedness judgements in Spanish/English bilinguals. *Aphasiology, 18*(5–7), 567–579.

Edmonds, L., & Kiran, S. (2006). Effect of semantic based treatment on cross linguistic generalization in bilingual aphasia. *Journal of Speech, Language and Hearing Research, 49*(4), 729–748.

Ellis, A. W., & Young, A. W. (1988). *Human cognitive neuropsychology*. Hove, UK: Lawrence Erlbaum Associates.

Frances, N., & Kucera, H. (1982). *Frequency analysis of English usage*. Boston: Houghton Mifflin.

Friedman, R. B. (2002). Clinical diagnosis and treatment of reading disorders. In A. E. Hillis (Ed.), *Handbook of adult language disorders* (pp. 27–47). Hove, UK: Psychology Press.

Gonzalez-Rothi, L. J. (1995). Behavioral compensation in the treatment of acquired language disorders resulting from brain damage. In R. A. Dixon & L. Mackman (Eds.), *Compensating for psychological deficits and declines: Managing losses and promoting gains* (pp. 219–230). Mahwah, NJ: Lawrence Erlbaum Associates.

Gonzalez-Rothi, L., Greenwald, M., Maher, L. M., & Ochipa, C. (1998). Alexia without agraphia: Lessons from a treatment failure. In N. Helm-Estabrooks & A. Holland (Eds.), *Approaches to the treatment of Aphasia*. San Diego: Singular Publishing.

Gonzalez-Rothi, L., & Moss, S. (1992). Alexia without agraphia: Potential for model assisted therapy. *Clinical Communication Disorders, 2*(1), 11–18.

Goodglass, H., Kaplan, E., & Weintraub, S. (1983). *Boston Naming Test*. Philadelphia: Lea & Febiger.

Greenwald, M. L., & Gonzalez-Rothi, L. J. (1998). Lexical access via letter naming in a profoundly alexic and anomic patient: A treatment study. *Journal of International Neuropsychological Society, 4*(6), 595–607.

Hillis, A. E. (1993). The role of models of language processing in rehabilitation of language impairments. *Aphasiology, 7*(1), 5–26.

Hillis, A. E., & Caramazza, A. (1992). The reading process and its disorders. In David Ira Margolin (Ed.), *Cognitive neuropsychology in clinical practice* (pp. 229–262). New York: Oxford University Press.

Howard, D., & Patterson, K. (1992). *Pyramids and palm trees*. London, UK: Harcourt Assessment.

Kay, J., Lesser, R., & Coltheart, M. (1992). *The Psycholinguistic Assessment of Language Processing in Aphasia (PALPA)*. Hove, UK: Lawrence Erlbaum Associates.

Kendall, D. L., Conway, T., Rosenbek, J., & Gonzalez Rothi, L. (2003). Phonological rehabilitation of acquired phonologic alexia. *Aphasiology, 17*(11), 1073–1095.

Kendall, D. L., McNeil, M. R., & Small, S. L. (1998). Rule-based treatment for acquired phonological dyslexia. *Aphasiology, 12*(7–8), 587–600.

Kertesz, A. (1982). *The Western Aphasia Battery*. Philadelphia: Grune & Stratton.

Kiran, S., Thompson, C. K., & Hashimoto, N. (2001). Training grapheme to phoneme conversion in patients with oral reading and naming deficits: A model-based approach. *Aphasiology, 15*(9), 855–876.

Lott, S. N., Friedman, R. B., & Linebaugh, C. W. (1994). Rationale and efficacy of a tactile-kinaesthetic treatment for alexia. *Aphasiology, 8*(2), 181–195.

Maher, L. M., Clayton, M. C., Barrett, A. M., Schober-Peterson, D., & Rothi, L. J. G. (1998). Rehabilitation of a case of pure alexia: Exploiting residual abilities. *Journal of the International Neuropsychological Society, 4*(6), 636–647.

Mitchum, C. C., & Berndt, R. S. (1991). Diagnosis and treatment of the nonlexical route in acquired dyslexia: An illlustration of the cognitive neuropsychological approach. *Journal of Neurolinguistics, 6*(2), 103–137.

Moody, S. (1988). The Moyer reading technique re-evaluated. *Cortex, 24*, 473–476.

Moss, S., Gonzalez-Rothi, L. G., & Funnell, E. B. (1991). Treating a case of surface dyslexia after closed head injury. *Journal of Clinical Neuropsychology, 6*, 35–47.

Moyer, S. (1979). Rehabilitation of alexia: A case study. *Cortex, 15*, 139–144.

Newcombe, F., & Marshall, J. (1984). Varieties of acquired dyslexia: A linguistic approach. *Seminars in Neurology, 4*, 181–195.

Nickels, L. (1992). The autocue? Self-generated phonemic cues in the treatment of a disorder of reading and naming. *Cognitive Neuropsychology, 9*(2), 155–182.

Rastle, K., Harrington, J., & Coltheart, M. (2002). 358,534 nonwords: the ARC nonword database. *Quarterly Journal of Experimental Psychology A, 55*(4), 1339–1362.

Robey, R. R. (1994). The efficacy of treatment for aphasic persons: A meta-analysis. *Brain and Language, 47*(4), 582–608.

Stadie, N., & Rilling, E. (2006). Evaluation of lexically and nonlexically based reading treatment in a deep dyslexic. *Cognitive Neuropsychology, 23*(4), 643–672.

Welbourne, S. R., & Lambon-Ralph, M. A. (2005). Using computational, parallel distributed processing networks to model rehabilitation in patients with acquired dyslexia: An initial investigation. *Aphasiology, 19*(9), 789–806.

Yampolsky, S., & Waters, G. (2002). Treatment of single word oral reading in an individual with deep dyslexia. *Aphasiology, 16*(4–6), 455–471.

APPENDIX

Treatment Protocol

1. The clinician presented the first word (e.g., *bee*) and asked him to read the word. If JS was incorrect, feedback was provided as "Good try, but that wasn't quite right. Let's go through the training steps and I'll give you some help."
2. Then, the clinician would say the word to him and ask him to write the word while saying the letters aloud.
3. The clinician then presented scrabble letters (only the word letters and equal number of distracters). JS was asked to select the first letter of the word (e.g., BEE: select the letter B, sound /b/). If he was unable to select the right letter, the clinician provided feedback and selected the letter for him. The clinician guided JS through the selection of the rest of the letters to form the word. Throughout the selection, the clinician ensured that JS said the letter/sound of the words aloud as he was selecting them.
4. Next, each scrabble tile was presented one at a time (in random order), and JS was asked to say what the letter/sound of the specific tile was. The clinician gave JS one chance to say the letter and sound. If unable to do so, JS was asked to repeat the letter/sound after the clinician. The clinician then presented the next letter.
5. The clinician then formed the word using the scrabble tiles and asked JS to read each letter aloud while pointing to the corresponding letter). Then, JS was asked to read the word aloud. Once he was able to read the letters and the word consistently consecutively twice without cue, the clinician proceeded to the next step.
6. Next, the clinician presented a picture of *bee* with a transparency sheet on top of it. JS was asked to answer the following questions: (a) superordinate label (e.g., belongs to), (b) function (e.g., is used for), (c) characteristics (e.g., has/is), (d) physical attributes (e.g., is made of/appears), (e) location (e.g., is found), and (f) association (e.g., reminds me of). JS was required to orally say each feature and write each one on appropriate locations on the board. Spelling errors were allowed.
7. The clinician presented the word card (e.g., *bee*) and asked him to read the word. Feedback regarding accuracy was provided. The clinician proceeded to the next word.