UNIVERSITY OF CINCINNATI

Date: *May 9, 2005*

I, *Elizabeth M. Thompson*,

hereby submit this work as part of the requirements for the degree of:

Master of Arts

in:

Communication Sciences and Disorders

It is entitled:

Spelling Accuracy with Non-Fluent Aphasia: Word Processing vs. Word Prediction Computer Software

This work and its defense approved by:

Chair: Angel Ball, PhD

Sandra Grether, PhD

Jean Neils-Strunjas, PhD

Spelling Accuracy with Non-Fluent Aphasia: Word Processing vs. Word Prediction Computer Software

A thesis submitted to the

Division of Research and Advanced Studies
of the University of Cincinnati

In partial fulfillment of the
Requirements for the degree of

MASTER OF ARTS

in the Department of Communication Sciences and Disorders of the College of
Allied Health Sciences

2005

by

Elizabeth M. Thompson

B.S., University of Cincinnati, 2003

Committee: Angel Ball, PhD (Chair)
Sandra Grether, PhD
Jean Neils-Strunjas, PhD

ABSTRACT

The purpose of this pilot investigation was to gather preliminary information on whether a word prediction treatment protocol developed by thesis committee members Angel Ball, PhD and Sandra Grether, PhD., which utilized the word prediction computer software Co:Writer® 4000, would increase spelling accuracy in individuals with non-fluent aphasia. Given the indisputable uniqueness of individuals in this population, this study was conducted using a multiple case study design, which included three participants (mean age of 55) presenting with chronic non-fluent aphasia up to eleven years post onset. Pre- and post-treatment data were collected within two different circumstances: 1) using a word processing application only; and 2) using Co:Writer® 4000 word prediction software. Each participant was asked to perform the same three sentence level writing tasks under each of these circumstances: 1) sentences given picture representations of 4 nouns and 4 verbs with no contextual cueing; 2) sentences given 10 active pictures with verbal contextual cueing; and 3) spontaneous "Cookie Theft" picture description. The results of this study illustrated the uniqueness of the participants involved, and indicated that word prediction software may be more suitable for individuals with non-fluent aphasia who demonstrate no more than a mild impairment in auditory and reading comprehension. Only one of the three participants in this study demonstrated improved overall spelling with the word prediction program. This participant had a higher comprehension level and ability to utilize the features of the word prediction program than the other two participants.

ACKNOWLEDGEMENTS

I would like to thank my committee members, Dr. Sandra Grether and Dr. Jean Neils-Strunjas, for all of their help and support during the writing of this thesis. I greatly appreciated the feedback and suggestions I received from them, as well as the resources they provided to help me fine-tune the countless details.

Many, many thanks to my committee chair and research advisor, Dr. Angel Ball. There are no words to describe how fortunate I feel to have worked with this intelligent and compassionate woman. When my spirit was dwindling and time was becoming scarce, Dr. Ball was able to provide reassurance, inspiration and a good, swift kick in the butt! I am more grateful than I could possibly illustrate with simple words on a page.

I would also like to thank my classmates who seemed to know me better than I know myself. It's a wonderful group of individuals who can find the time to bolster others when they need encouragement themselves.

Thanks to my dad, who kept the humor in an otherwise humorless process. I needed to be reminded that there was more to life than my thesis project.

All of my love and gratitude to my best friend, my shoulder to cry on, and the one who calmly bore the brunt of my stress. Thank you, Mom.

Finally, I must thank the one who remained by my side and watched out for me throughout this process. With his support, everything seemed to miraculously go my way.

Thank you to all of the beautiful people in my life!

TABLE OF CONTENTS

LIST OF TABLES, FIGURES, AND APPENDICES

Page

TABLES

FIGURES

APPENDICES

CHAPTER 1

Introduction

The following pilot study examined the effects of the word prediction computer software, Co:Writer® 4000 (Don Johnston), on the spelling accuracy of individuals with non-fluent aphasia. Given the indisputable uniqueness of individuals in this population, this study was conducted using a multiple case study design, which included three participants presenting with chronic non-fluent aphasia up to eleven years post onset. This study hinges on a simultaneously conducted pilot study by thesis committee members, Angel Ball, PhD, and Sandra Grether, PhD (2004). While their study explored the mechanics of a new treatment protocol utilizing word prediction software on syntactical complexity in sentences, this study aimed to determine efficacy of that treatment protocol on spelling through pre- and post-treatment data collection and analysis.

This pilot study was designed to meet two primary objectives: 1) To investigate the success of word prediction software in writing rehabilitation for individuals with non-fluent aphasia regarding spelling at the sentence level, and 2) To determine if this treatment program using word prediction software had any influence on participants' spelling abilities without the use of word prediction software. For the purpose of the latter objective, pre- and post-treatment data were collected with and without the use of word prediction software.

It was hypothesized that the treatment program would have a positive influence on the participants' spelling accuracy across all tasks presented post-treatment when using word prediction software. It was further hypothesized that there would be a decrease in participants' mean percents of spelling errors post-treatment when writing with word processing software only.

CHAPTER 2

Literature Review

<u>Cognitive Mechanisms of the Spelling Process</u>

Writing is a critical communication modality addressed in all domains of everyday life. A key constituent of writing is spelling. In order to convey meaning through writing, the writer must be able to accurately spell his/her message so it is comprehensible to the communication partner. Many schematic models have been developed, which outline the cognitive components of the theoretical spelling process. These models have been referred to as cognitive neuropsychological interpretations and have evolved over the past two decades (See Margolin & Goodman-Schulman, 1992 for a description of revisions of the schematic spelling model). One of the first versions of this model was developed by Ellis (1982), and others have offered similar schematic representations (Beeson & Rapcsak, 2002; Beeson, Rewega, Vail & Rapcsak, 2000; Friedman & Alexander, 1989; Hatfield & Patterson, 1984; Rapp & Kane, 2002; Roeltgen & Rapcsak, 1993). This theory of spelling has become widely accepted after being the subject of such extensive research.

While variations between models can be observed, all of these models contain many of the same features. Most of the notable variations lie in the differences in terminology, as well as some conceptual differences that address certain features within the models (See Roeltgen & Rapcsak, 1993 for a full description). All of the models emphasize two separate pathways or routes through which spelling can be produced—lexical and sublexical. The lexical pathway uses information about words that has been stored in long-term memory, while the sublexical pathway uses knowledge of the common sound to letter relationships of English (Rapp & Kane, 2002).

The lexical pathway is employed in the spelling of known words and orthographically irregular, highly ambiguous words (Roeltgen & Rapcsak, 1993). Irregular or exceptional words are words that cannot be spelled accurately by direct phoneme-to-grapheme conversion (e.g., isle, yacht, and choir) (Raymer, Cudworth & Haley, 2003; Roeltgen & Rapcsak, 1993). In these situations, an auditorily presented word activates the phonological input lexicon, which is a phonological representation of the word in long-term memory storage (Rapp & Kane, 2002). This activation allows access to a representation of the word's meaning in the semantic system, which, in turn, activates a representation of the word's spelling in the orthographic output lexicon (OOL) (Rapp & Kane, 2002). This OOL is the storage area for the spellings of familiar words that have been previously learned and stored in the individual's long-term memory (Raymer et al., 2003).

The sublexical pathway is employed in the spelling of pronounceable non-words (e.g., herm) or as a back-up system for spelling regular real words of limited ambiguity (Roeltgen & Rapcsak, 1993). The sublexical pathway does not discriminate between inputted phonological strings and does not require that the listener be familiar with the stimulus word (Rapp & Kane, 2002). Activation of this pathway results in a phonologically plausible spelling of the inputted phonological string through the use of sound to written letter associations (e.g., "yacht" spelled as YOT) (Rapp & Kane, 2002).

Regardless of which pathway is activated, once a spelling representation is derived it is sent to the graphemic buffer. The graphemic buffer is the short-term working memory store that maintains the activation of a spelling until the orthographic information decays or the letters of the word can be converted into concrete letter shapes (Roeltgen & Rapcsak, 1993). Finally, the letter shape representations are translated into writing of well-formed letter shapes for the selected case, font, or style of writing via the allographic conversion process (Raymer et al., 2003). Access to the appropriate graphic motor programs specify the necessary strokes to form each letter of written spelling, while retrieval of typing motor programs is necessary for the production of typewritten spelling (Margolin & Goodman-Schulman, 1992).

Spelling in Non-Fluent Aphasia

Aphasia is an acquired language disorder caused by brain damage. By definition, a diagnosis of aphasia dictates the existence of some type of neuropathological involvement. Cerebral vascular accident (CVA), or stoke, is probably the most common single cause of aphasia. Since 1973, the prevalence of strokes in adults younger than 65 has increased significantly, while the stroke mortality rate has consistently declined (Muntner, Garrett, Klag, & Coresh, 2002). Professionals are presented with an increase in number of stroke survivors potentially living with disabilities in need of care and rehabilitation. While not noted as frequently as CVA, there are multiple other aphasia-producing pathologies including: intracranial neoplasms, traumatic brain injury, intracranial infection (e.g., encephalitis, meningitis), and degenerative disorders (e.g., Alzheimer's Disease) (Benson, 1979).

The classification of different types of aphasia is determined by the language symptoms demonstrated by the effected individual. D. Frank Benson (1979) stated, "The resulting aphasic syndromes represent one of the most confusing aspects of the complex topic of language disturbance" (p. 57). For the purpose of this paper, only the basic language characteristics of the non-fluent aphasia type will be described given the complexity of the classifications of aphasia. Overall, there will most likely be observable deficits in repetition of spoken language, confrontational naming, reading aloud, reading comprehension, and writing. Comprehension of spoken language will remain relatively intact, although a spectrum from near normal to distinctly abnormal can be observed. The conversational speech in non-fluent aphasia can be accurately described as non-fluent. Benson (1979) effectively describes characteristics of this non-fluent verbal output:

> It is sparse, poorly articulated, consists of very short phrases (characteristically one word in length or, following improvement, telegraphic), is produced with considerable effort, particularly on initiation of speech and is strikingly dysprosodic. The output consists almost exclusively of substantives such as nouns, action verbs, significant modifiers or stock phrases (clichés). The marked deficiency or absence of syntactical, structural words (functors) makes the output strikingly abnormal, even to casual observation. The comparatively rich substantive quality of the output, however, enables the patient with [non-fluent] aphasia to communicate some ideas despite severe deficiencies in verbal output (p. 65-66).

Written language deficits, especially in narrative writing, often mirror the characteristic spoken language deficits in non-fluent aphasia (Benson, 1979; Bollinger, 1996; Lorch 1995; Sgaramella, Ellis & Semenza, 1991). When compared to verbal comprehension, verbal production and reading, writing is usually the most severely impaired modality for aphasic patients (Lesser, 1990; Lorch, 1995). This loss or impairment in the ability to produce written language is referred to as dysgraphia. The significant brain damage associated with aphasia usually produces some degree of dysgraphia, regardless of the location of the lesion, however, specific deficits in the cognitive processes of lexical tasks will vary depending on the location of the lesion in the brain (Benson, 1979; Lorch, 1995). For instance, Wapner and Gardner (1979) found that an anterior lesion, as is the case with non-fluent aphasia, resulted in incomplete spellings or semantic paragraphias, which did not benefit from the regularity of word spellings. Wapner and Gardner (1979) also found that individuals with non-fluent aphasia gave less evidence for a preserved sublexical, phoneme to grapheme conversion system than individuals with posterior lesions.

Knowledge about the spelling pathways, which are thought to be essential for normal spelling production, has been developed primarily from the study of patients with acquired dysgraphia (See Ellis & Young, 1988; Margolin & Goodman-Schulman, 1992; and Roeltgen & Rapcsak, 1993 for thorough reviews of early literature; also Beeson et al., 2000; Rapp & Kane, 2002; Raymer et al., 2003). These patients have produced observable patterns of performance that seem to be consistent with selective dysfunction in one of the cognitive components of the two spelling routes (Roeltgen & Rapcsak, 1993). Disruption of one or both of these routes may result in one of two primary syndromes referred to as deep or phonological dysgraphia and surface dysgraphia (Beeson et al., 2000; Bollinger, 1996; Hatfield & Patterson, 1984; Roeltgen & Rapcsak, 1993).

Impairment of one cognitive process necessary for spelling may result in dependence on residual, unimpaired processes (Beeson et al., 2000; Hatfield & Patterson, 1984)). In deep dysgraphia the sublexical, phoneme to grapheme conversion system is disrupted, causing spelling to be accomplished exclusively by the lexical semantic route. In the case of deep dysgraphia, individuals present with visual, derivational, and semantic errors, as well as extreme difficulty spelling pronounceable non-words (Hatfield & Patterson, 1984). In contrast, spelling errors in surface dysgraphia are characteristically phonologically plausible, as the lexical semantic pathway is disrupted and the individual must rely on the unimpaired sublexical route (Hatfield & Patterson, 1994). A third syndrome, graphemic buffer dysgraphia, is due to a disruption in the graphemic buffer. Individuals with this type of dysgraphia will present with letter omissions, substitutions, insertions and transpositions, and increased errors as the length of the target word increases (Rapp & Kane, 2002; Roeltgen & Rapcsak, 1993).

Treatment for Spelling Rehabilitation

Once written spelling deficits have been assessed, those deficits must then be treated. Writing treatment can be beneficial in enhancing, or at least maintaining, cognitive skills and specific levels of retention, attention, visual-motor matching, sequencing, and monitoring skills required by graphic output tasks (Bollinger, 1996). In fact, writing activities may serve as the core of a treatment program for individuals with acute and chronic aphasia. The remediation of written language deficits may sometimes prove to be more successful than the remediation of spoken language deficits and may also constitute a successful way to reinstate functional communication skills (Rapp & Kane, 2002). More research has been done in the area of writing and spelling rehabilitation since 1979 when Wapner and Gardner stated, “Relatively little is known about the remaining skills involved in the use of an alphabet, such as writing and spelling” (p. 363). However, the research remains sparse, to date, as there are a limited number of studies concerned with the treatment of central spelling deficits (See Beeson & Rapcsak, 2002 for a review; Rapp & Kane, 2002).

These studies have given rise to suggested intervention techniques for maximizing graphic output when working with individuals with aphasia. A study by Beeson, Rewega, Vail and Rapcsak (2000) supports a problem-solving approach to spelling that was derived from one dysgraphic patient’s insight into her own spelling strategies, which were then developed into a home treatment program that was subsequently facilitated in a second patient. The problem-solving strategies implemented by Beeson et al. (2000) included writing partially correct responses, attempting self-correction, using sound-to-letter correspondences, and finally, using an electronic speller to check spellings or find correct spellings. These strategies were intended to promote interaction between the lexical and sublexical spelling pathways. Their homework-based treatment plan facilitated the stimulation of weakened processes with corrective feedback from an electronic speller to help stabilize the correct responses. Word level spelling accuracy improved for both patients.

Another study by Beeson, Hirsch and Rewega (2002) supports a treatment program of copying letters and words and structured home activities. This treatment technique includes an anagram and copy treatment (ACT) in which the patient is asked to spell a word based on a visual cue and semantic information. If the target word is not written correctly, random component letters are provided until they are put in the correct order. Following successful arrangement, three copies of the word are written. The written copies are removed and the participant is asked to spell the target word three times. This program also includes a copy and recall treatment (CART) in which patients are given homework with drawings and target words they are asked to copy repeatedly. All four participants in this study were able to master the targeted words, and homework alone was found to be a successful treatment. This study noted an increase in writing as a means of communication, however treatment effects for spelling were not generalized beyond the target words.

A study conducted by Raymer, Cudworth and Haley (2003) also supports the use of a copy and recall spelling treatment for individuals with dysgraphia. During treatment the patient starts by copying a written target word. Next the clinician covers the first two letters of the word and the patient tries to recall and write those first two letters then copies the rest of the word. If the patient is correct, the clinician covers two additional letters (the first four letters) of the word, and the patient again writes the hidden letters and copies the rest. This sequence continues until the clinician covers the entire word and the patient is able to correctly recall the complete spelling. With any error, the patient repeats the prior step. Homework is assigned to copy each training word three times each day. The subject in this study showed improved spelling of two sets of trained words, as well as generalized improvements in spelling some untrained whole words.

A study by Conway et al. (1998) supports the use of an Auditory Discrimination in Depth (ADD) program to train phonological awareness in the presence of mild phonological alexia and mixed dysgraphia following a left hemisphere infarction. The ADD program consists of oral awareness training, simple nonword training, complex nonword training, and multisyllable nonword-word training. It was found that when the participant could not immediately recall a word's spelling or see it in his mind's eye, he was able to learn how to sound out and spell the word one phoneme at a time. The participant in this study demonstrated improved phonological awareness, reading and spelling of nonwords, and reading and spelling of real words. Treatment gains in phonological awareness and reading were maintained two months post-treatment.

Rapp and Kane (2002) reported evidence that supports a delayed-copy treatment protocol in exhibiting long lasting word-specific benefits. Treatment techniques consist of a pre-treatment baseline where the subject hears a word that is read aloud, repeats it, and attempts to spell it correctly without receiving any feedback, and a treatment phase. During the treatment phase the patient repeats what is done during the pre-treatment baseline. After the initial response, regardless of its accuracy, the subject is shown the correct spelling of the word on a note card while the experimenter says aloud each of the letters of the word. The patient is instructed to study the correct spelling on the card with no time limit. If the patient's initial attempt at spelling the word is correct, this step is omitted. Otherwise, after the note card is removed, the patient is given another chance to spell the word correctly. This procedure is repeated until the patient correctly spells the word. Both subjects in this study benefited from treatment and these benefits were still evident 20 weeks after the termination of treatment.

Seron, Deloche, Moulard and Rousselle (1980) presented a computer-controlled rehabilitation plan for writing impairments associated with aphasia. Subjects are asked to type a list of words to dictation. Each time a letter is typed in its correct position in a word, that letter is displayed on the computer screen. If a letter is not typed in its correct position it is not displayed in order to avoid visual reinforcement of incorrect choices. The dictated list of words is stored in the computer memory, and the computer is programmed to check the spelling of any word typed in order to determine whether a given typed letter should be displayed on the screen. All five subjects in this study showed significant improvements in spelling at the first posttest. A computer was utilized during the entire treatment program outlined by Mortley, Enderby and Petheram (2001) to facilitate intensive repetitive practice. Their study supports graphic output tasks such as repetitive copying to enhance word retrieval strategies (See reference for a full description of treatment protocol). This intervention proved to be successful and the participant showed generalization of treatment gains to untreated words.

All of the aforementioned treatment programs are geared towards spelling remediation at the word level. While this focus on single words has yielded important insights, disregard for the other levels of writing brings with it the danger that some aspects of writing impairment may be overlooked (Sgaramella et al., 1991). Word writing, sentence writing to dictation, sentence writing to command, spontaneous sentence writing, and narrative writing are markedly different tasks. For instance, while all writing tasks have certain commonalities, narrative writing requires the application of written discourse rules, interpretive ability, and memory skills that are not required of word writing or sentence writing to dictation (Bollinger, 1996). Sgaramella et al.

(1991) found that having their subjects write connected text revealed errors that would not be seen if the task had been to write single words to dictations. Error types included word blends, word movement errors, and movements of letters between words.

Given the array of possible options for spelling remediation, treatment approaches must be determined carefully as the unique nature of the aphasias and their resultant dysgraphias are taken into consideration. Different therapy approaches will be necessary for different types of impairments. Individuals with relatively severe language deficits may not have information from multiple processing mechanisms available for interactive use (Beeson et al., 2000). It may be most beneficial to focus therapy on an individual's more preserved spelling pathway in order to let that relative strength support their weaknesses in the other impaired pathway (Hatfield & Patterson, 1984). In addition, it is essential to ascertain the premorbid level of attainment in writing and spelling skills if treatment goals are to reasonably set (Lorch, 1995; Roeltgen & Rapcsak, 1993).

Word Prediction Software

One treatment approach that has yet to be extensively investigated in regards to its potential benefit for aphasic individuals is the use of word prompt or word prediction computer software (Murray & Karcher, 2000). Many of these programs were originally designed to assist individuals with physical disabilities and have since been commonly used to address writing deficits with individuals with developmental learning and language problems (Murray & Karcher, 2000). Word prediction software can be easily used in conjunction with any current word processing programs. Predictive software can assist the writer in generating words, spelling those words, and formulating sentences (Co:Writer® 4000, 2003). As an individual works with the program, it builds up a list of the most likely words that the user prefers. By typing the first letter(s) of a word, predictive software will predict possible targets based on grammar, user's frequency and recency of use, and semantic association (Co:Writer® 4000, 2003). The program becomes individualized as the writer uses the program.

Writing is a complex perceptual-motor skill (Ellis & Young, 1988). This technology could potentially decrease the writing process time and physical effort required by the writer by minimizing the number of strokes required to type a word (Co:Writer® 4000, 2003). A left hemisphere stroke will often lead to a right side arm paresis or paralysis, which can significantly impair the motor process of writing. This hemiparesis is commonly a result of the more anterior lesions associated with non-fluent aphasia due to the proximity of these lesions to the motor cortex. This poses the problem of having to write with either the impaired hand or the non-dominant left hand. Using a computer keyboard minimizes the motor component of writing and allows a closer look at the spelling system. For this reason, typing with a keyboard and the concurrent use of word prediction software may be a more efficient writing mechanism for the non-fluent aphasic population than writing by hand.

Research with students with learning and/or language disabilities has indicated that the use of word prediction software can increase the quality and quantity of written output, however, these improvements may be obtained at a substantial cost in rate of writing due to extensive use of the word prediction and constant attention to the generated word lists (MacArthur, 1998a, 1998b, 1999). Using word prediction software with subjects with aphasia is a relatively new realm of research, however, current literature supports the use of word prediction programs to remediate and compensate for acquired dysgraphia associated with aphasia (Armstrong & MacDonald, 2000; Murray & Karcher, 2000). Armstrong & MacDonald (2000) and Murray &

Karcher (2000) each utilized the word prediction program, Co:Writer® with a case study to analyze the program's effects on written language expression.

Armstrong and MacDonald (2000) provided evidence of more normal written output at the word and sentence levels by their case study with non-fluent aphasia through the use of two separate methods of compensation: splinting of the hemiplegic dominant arm and hand with a prosthesis for handwriting; and use of lexical and grammatical prediction (Co:Writer®) and synthesized auditory feedback (Write:OutLoud® program) for typewriting. Both compensation methods resulted in improved quantity and quality of written output than that produced during baseline assessment, as well as some positive effect on spelling. Both methods aided the subject in the more accurate spelling of longer regular words, although word prediction allowed for more improved spelling of irregular or exception words than the prosthesis. The authors suggested that both aides allowed for more abstract and complex written expression at the sentence level accompanied by fewer spelling errors overall but more grammatical and semantic errors due to an increased number of words associated with increased complexity.

Murray & Karcher (2000) provided research that supported graphic output techniques involving repetitive copying to enhance word retrieval, specifically verb retrieval. The treatment protocol consisted of a cueing hierarchy, word prompt software, and home practice. The cueing hierarchy led to verb or sentence copying, and to progress through the hierarchy the client could use Co:Writer® to aid with word retrieval. Spelling was not a focus in this study, as written responses were scored only in terms of initial letter accuracy and the number of correct letters per word, regardless of correct order.

The patient, presenting with severe Wernicke's aphasia, demonstrated improvements in writing trained verbs at both the word and sentence levels, which reportedly improved daily writing tasks. There was no generalization to untrained verbs. Eight weeks after treatment the patient's handwritten accuracy began to decline but continued to exceed baseline accuracy rates. Notably, when he was allowed to use the word prediction software during this final assessment, his writing accuracy came close to or exceeded what he had achieved immediately following the end of the last treatment phase. During this study the authors were unable to use the audible version of word prediction choices, so this aspect of the program was not evaluated.

Given these findings, the features of word prediction software could be potentially valuable for a writer with non-fluent aphasia, depending on his/her skills in the area of self-cueing and the extent of the remaining lexical system. Accessing of spelling is especially difficult for patients with non-fluent aphasia. The rationale for using word prediction software is that it cues the individual with aphasia to the correct spellings of words allowing for potentially longer, more complex written output with fewer spelling errors.

It is known that individuals with non-fluent aphasia do not usually retain enough linguistic skills to use a word prediction program independently, without clinical training. However, there is a paucity of literature in regards to treatment protocols utilizing word prediction software in the writing rehabilitation of individuals with aphasia. Even less is known about the treatment potential of word prediction software for spelling remediation with non-fluent aphasia. Only Armstrong and MacDonald (2000) have specifically addressed this issue with their case study, MD.

The purpose of this pilot investigation was to gather preliminary information on the spelling outcome of a new word prediction treatment protocol developed by thesis committee members Angel Ball, PhD and Sandra Grether, PhD. Through the collection and analysis of pre- and post-treatment data, it was proposed that the results of this study would contribute to the value of studying the use of word prediction software to increase spelling accuracy with individuals with non-fluent aphasia.

CHAPTER 3

Materials and Methods

Participants

This study was conducted using a multiple case study design, given the uniqueness of individuals in this population. Three participants previously diagnosed with non-fluent aphasia will be discussed separately in terms of background histories, experimental results, and discussions. Participant selection criteria included dysgraphia as a result of an acquired brain injury post onset at least 6 months. Screening criteria required for participation in this study included demonstrating a non-fluent type aphasia of severity 1-4 on the *Boston Diagnostic Aphasia Examination-Third Edition (BDAE-3)*. Participants were required to demonstrate baseline performance above the 60^{th} percentile for either the reading or auditory comprehension subtests of the *BDAE-3* short form. All participants were, at minimum, able to write their names and accurately copy 75% of a given sentence containing nine words. Each participant was required to pass a screening for visual field and visual acuity for computer screen and keyboard, as well as a sound field hearing screening at 25dB bilaterally. All participants were familiar with a computer keyboard due to previous experience. No participant was enrolled in any other speech-language treatment during the course of this study.

Informed consent was obtained from each participant following the above screening procedures. A verbal and written explanation of experimental procedures was made available and a number was assigned to each participant for data tracking and analysis to ensure participant confidentiality. This study was approved by the Institutional Review Board of the University of Cincinnati, IRB #04-10-04-02.

Participant A1-05

A1-05 was a premorbidly right-handed, 43-year-old female, who worked as a registered nurse prior to onset of aphasia. Earlier job experience involved managing computer systems. Her premorbid educational level included some years of college without a resultant degree. In June of 2000, almost five years prior to the initiation of this study, A1-05 was diagnosed with non-fluent aphasia secondary to Rasmussen's Encephalitis (RE), also known as Rasmussen's Syndrome and Rasmussen's Disease. RE is an extremely rare, progressive, central nervous system disorder typically diagnosed in childhood. The disease is characterized by inflammation of the brain, mental deterioration, seizures, and hemiparesis. The etiology of RE is unknown, however, viral and autoimmune causes have been hypothesized. Treatments of immune globulin (IVIG) infusion have shown various degrees of effectiveness. A1-05 initiated IVIG treatments in May of 2003 and had received monthly IVIG treatments to manage the disease until November of 2003, for a total of six months. Treatments had been put on hold for an unspecified observation period. Subjective observations indicated that the participant had experienced significant physical and psychological improvements, which increased her capabilities for verbal output, although no overt language improvements were noted.

A1-05 received private speech-language therapy following her diagnosis in June of 2000. Due to increased episodes of aphonia, the participant was referred by her speech-language pathologist for an augmentative and alternative communication evaluation in June of 2003. At that time, A1-05 presented with aphasia across all expressive modalities, mild dysarthria, and intermittent speech. The participant demonstrated right side facial clonus, spelling difficulties, word finding difficulties, slow processing, and impaired auditory processing. She was able to read simple paragraphs of three to four sentences before experiencing a breakdown.

A1-05 was provided with a pocket size Daily Communicator® as a low technology device to use for functional communication while awaiting funding of the recommended augmentative communication device. In January of 2004, the participant received a DynaVox Series 4 (DV4), which is a high technology communication device with a dynamic touch screen. Both devices were still being used during the time of this study, although they were not utilized during data collection sessions. Home language practice included programming the DV4, word find puzzles, and handwriting practice. There was no computer in the home.

This study's baseline diagnostics revealed a subjective *BDAE-3* severity rating of 2, which indicates frequent failures to convey messages, however, conversation about familiar subjects is possible with the help of the listener (Goodglass, Kaplan & Barresi, 2001). The participant used her left, non-dominant hand for all writing tasks. She was receiving occupational and physical therapies during the course of this study.

Participant A2-05

A2-05 was a right-handed, 58-year-old male who experienced a left hemisphere stroke in July of 2003 with resulting right side hemiparesis. He was subsequently diagnosed with a moderate expressive aphasia, mild to moderate receptive difficulties, and severe verbal apraxia. A2-05 had been receiving continuous speech and language therapy since the time of diagnosis, with a focus placed on the use of augmentative and alternative communication devices. The participant had received Home Parrot software but was not utilizing the software. However, he was effectively utilizing a pocket size Daily Communicator® and a Franklin Language Master, which is a small spelling device that requires the user to know the correct number of letters in a word in order for the device to generate the desired word. Other home language practice included crossword puzzles, looking at the newspaper weekly with a news-4-you program, and listening to books on tape.

At one year, five months post onset, this study's baseline diagnostics revealed a subjective *BDAE-3* severity rating of 1, which indicates that all communication is through fragmentary expression. A limited range of information can be exchanged and the listener carries the burden of communication (Goodglass et al., 2001). A2-05 required the use of bi-focals at all times. The participant initially used his non-dominant left hand for all writing tasks but then began using his right dominant hand intermittently by choice. Weak paresis was noted in the right hand but did not prevent the participant from holding a pen and utilizing the computer mouse. Per spousal report, the participant had started home practice of exercises from previous occupational therapy for hand strengthening during the course of this study.

Participant A3-05

A3-05 was a right-handed, 65-year-old male who experienced a left hemisphere stroke in February of 1994 with resulting right side hemiparesis. He was subsequently diagnosed with a severe non-fluent aphasia. The participant's premorbid educational level included eight years of college with an ensuing MBA and a master's degree in chemistry. He was working as a financial planner prior to his stroke. A3-05 had been multi-lingual since childhood. His languages included English, Gujarati, and Marathi. The participant stated that he used English primarily for writing. He had not reacquired his Indian languages since his stroke in 1994.

A3-05 received formal speech-language services until approximately June of 1997. The participant then continued with aphasia support groups until the year 2000. Home language practice at the time of this study consisted of listening to books on tape, being read to once a week by the Association for the Blind, and reading, video recording and studying closed caption television programs. The participant reported minimal home practice with writing and had recently given away his personal computer.

At 11 years post onset, this study's baseline diagnostics revealed a subjective *BDAE-3* severity rating of 3, which indicates that the participant can discuss almost all everyday problems with minimal to no assistance, however, conversation abut certain material can remain difficult or impossible (Goodglass et al., 2001). A3-05 reported an unspecified hearing loss in his right ear, but was able to pass a sound field screening at 25 decibels. Right hemiparesis had significantly improved since the onset of stroke, and the participant was able to use his dominant right hand for all writing tasks. A3-05 was not receiving any therapy services during the course of this study.

Materials

This study incorporated the use of the *Boston Diagnostic Aphasia Examination-Third Edition (BDAE-3)* (Goodglass et al., 2001). The *BDAE-3* is a tool used to identify and distinguish among disorders of language function and neurologically recognized aphasic syndromes. This assessment tool was utilized in the current study for pre-diagnostics, determination of eligibility for participation, and picture stimuli to elicit written expression.

The *Sentence Production Program for Aphasia* (*SPPA*) is a hierarchical approach to the management of agrammatism associated with acquired non-fluent aphasia (Helm-Estabrooks & Nicholas, 2000). This program was used in the current study for picture stimuli to elicit written expression.

Co:Writer® 4000 (2003) is word prediction software with built in grammatical assistance. This software works in conjunction with a word processing program or other text-based application. Microsoft Word or Word Pad were used independently and with Co:Writer®

4000 (2003) to facilitate writing samples used for pre- and post-treatment data collection and analysis. Arial font size 16 was used consistently for all cases for legibility purposes.

A data tracking log for pre- and post-treatment testing for the *SPPA* was designed by Angel Ball, PhD (see Appendix A). This form was used to track the process of writing each sentence, including participants' verbalizations, actions, revisions, choices made from Co:Writer® 4000 generated word lists, and researcher observations. While initially intended to track sentences elicited by the *SPPA*, this form was manually modified to track sentences elicited by the other stimuli as well.

Procedures

Prior to participating in the word prediction treatment program designed by Ball and Grether (2004), each participant was subject to individual pre-treatment testing within two different circumstances for the current study: 1) using a word processing application only; and 2) using Co:Writer® 4000 word prediction software. Each participant was asked to perform the same three sentence level writing tasks under each of the two circumstances.

Under the first circumstance a new document was opened in either Microsoft Word or Word Pad text-based application and the font was set to Arial size 16. The first task involved writing sentences given picture representations of nouns and verbs with no verbal contextual cueing. Each participant was presented with the 'objects' card 102 in the *BDAE-3* stimulus manual and asked to write sentences using each of the four pictures as pointed to by the researcher (i.e., tree, hanger, canoe, trellis). The participants were then presented with the 'actions' card 103 of the *BDAE-3* stimulus manual and asked to write sentences using each of the four pictures as pointed to by the researcher (i.e., eating, sweeping, praying, juggling). The form in Appendix A was manually modified to represent each of the above targets and the process of writing all eight sentences was tracked by at least one of the researchers. Tracking included participants' verbalizations, actions, revisions, and researchers' observations. The word processing document was then saved with the date as "Pre N-V MS Word" under the participants' assigned research numbers.

The second task under the first circumstance involved writing sentences given active pictures with verbal contextual cueing. One picture from each of six sentence types and two pictures from each of the remaining two sentence types presented in the *SPPA* were selected for stimuli to elicit sentences. These 10 pictures were presented in order of sentence type (see Appendix B), and probe B for all pictures was read to the participants. The level B probe provides a contextual clue about the picture without including the target sentence in the probe (e.g., Nick's school bus arrives in 15 minutes and he is still asleep. So what does his mother tell him to do?) (Helm-Estabrooks & Nicholas, 2000). Participants were encouraged to listen to the entire probe before they began to type. One repetition was given if requested. The form in Appendix A was used to track the process of writing each of the 10 sentences. Tracking included the same as for the first task. The word processing document was then saved with the date as "Pre *SPPA* MS Word" under the participants' assigned research numbers.

The final task under the first circumstance involved a spontaneous description of the "Cookie Theft" picture on card 1 of the *BDAE-3* stimulus manual. The participants were presented with the stimulus and asked to write as much as they could about what was happening in the picture. Tracking for this task was done on a plain piece of lined paper and included the same as for the first two tasks. The word processing document was then saved with the date as "Pre Cookie Theft MS Word" under the participants' assigned research numbers.

Following completion of all three tasks under the first circumstance of pre-testing, each participant received two introductory thirty-minute training sessions on the functions and use of Co:Writer® 4000 word prediction software before completing pre-testing in the second circumstance. These sessions usually occurred over the course of two days. Subsequent to this introduction to Co:Writer® 4000, participants were subject to individual pre-treatment testing within the second circumstance.

Under the second circumstance Co:Writer® 4000 word prediction software was launched. The New Writer Wizard was utilized to set up writer files for each of the participants. Writer files were named after each participant's assigned research number. All writer files were set up for the intermediate level of difficulty, showing six word choices without numbering, using the synthesized voice titled "Reed". When prompted to select a program to use with Co:Writer® 4000, Microsoft Word was chosen if available, otherwise Word Pad was chosen. This text program was then set to Arial font size 16.

The three aforementioned tasks were repeated as stated above under this second circumstance utilizing Co:Writer® 4000. Tracking remained relatively the same, only expanding to include choices made from Co:Writer® 4000 generated word lists and at what point in a word selections were made. The word processing documents resulting from these three tasks were saved as "Pre N-V Co:Writer®", "Pre *SPPA* Co:Writer®", and "Pre Cookie Theft Co:Writer®", respectively. Documents were saved with the date under the participants' assigned research numbers.

After pre-testing was completed, participants took part in the simultaneously conducted pilot study by thesis committee members, Angel Ball, PhD, and Sandra Grether, PhD (2004), focusing on the mechanics of a new treatment protocol utilizing word prediction software on syntactical complexity in sentences. This was a four-week treatment program with a total of eight treatment sessions, each of which utilized the *SPPA* and trained one sentence type per session using a cueing hierarchy. The cueing hierarchy was used if a participant hesitated beyond 30 seconds or was unable to initiate the spelling of a target word known to the investigator (e.g., key). Step one in the hierarchy was to provide the first phonemic sound cue (e.g., /k/). If this was not successful, the participant was provided with the verbal letter (e.g., “try the letter K”). If this was not successful, the participant was provided with the letter on a visual letter board. If the participant remained unsuccessful at initiating the spelling of the target word the investigator would then type the letter for the participant. The same was repeated for the second letter and each subsequent letter of a word as needed.

Directly following this four-week period, participants were subject to post-testing under the same two circumstances for the same three tasks as described above in the detailed description of pre-testing. All six documents for each participant were saved with the date under the participants’ assigned research numbers and were generally titled “Post” followed by the given task.

No direct cueing was provided during pre- and post-treatment testing aside from probe B used with the *SPPA* task. If a participant asked for assistance statements such as, “Just do your best” or “I can’t help you at this time” were acceptable. Participants were instructed to insert dashes (--) when they could not retrieve a word or could not initiate the correct spelling of a word to indicate that they had intended for a word to be in that place. Some prompts were necessary at times to get participants to discontinue spelling attempts that would have otherwise gone on for an indefinite amount of time. Otherwise, no time limitations were placed on any task. Breaks were taken during testing whenever participants indicated that one was needed.

Scoring and Reliability

A total of 12 documents each were saved under participants' assigned research numbers, representing the three writing tasks pre-testing without Co:Writer® 4000, the three writing tasks pre-testing with Co:Writer® 4000, the three writing tasks post-testing without Co:Writer® 4000, and the three writing tasks post-testing with Co:Writer® 4000.

Each document was reviewed individually by the investigator, and a percentage of spelling errors was calculated using the number of misspelled words in the writing sample divided by the total number of words produced in the writing sample. Pre-treatment percentages for each of the three tasks were compared to post-treatment percentages in order to determine if Ball and Grether's (2004) word prediction treatment program contributed to improved spelling accuracy for typed writing samples using Co:Writer® 4000 word prediction software. Mean percentages of spelling errors for the three tasks were calculated for pre- and post-testing conditions using word processing software only and were compared to determine if the treatment program facilitated a decrease in mean percentages of spelling errors without the use of Co:Writer® 4000.

A set of determining factors was put into place in order to accurately and consistently calculate percentage of spelling errors within and across participants' writing samples: 1) When reviewing spelling errors in a transcript, if the target is unknown and the typed word is in the dictionary it is counted as a correct spelling; 2) If the target is known or spoken by the participant in an effort to spell and the typed word is not spelled as the target it is counted as an incorrect spelling; 3) Dashes (--) are only counted towards the total number of words and as spelling errors if tracking found that there was an initial attempt at a word that was then skipped or deleted due to an inability to spell the word (e.g., constant revisions/self-corrections that never lead to the correct spelling, therefore, dashes were inserted to show that the participant had intended for a word to be there); 4) Dashes (--) are not counted towards the total number of words or as spelling errors if tracking found that no attempt was made to type/spell the word, even if it had been verbalized; 5) All revisions counted as part of the total word count (with the exception of one writing sample by A3-05, in which he retyped two entire sentence to add “is” to the sentences).

Given these determining factors, 25% of the participants’ writing samples were rescored for spelling errors by an undergraduate in the field of speech-language pathology at the University of Cincinnati. This undergraduate was familiar with the study and the participants. The list of determining factors was reviewed for clarification purposes, and then 25% of the writing samples were randomly selected for rescoring. Interjudge agreement for number of spelling errors was 100%.

CHAPTER 4

Results

The first hypothesis was that the word prediction treatment program introduced by Angel Ball, PhD and Sandra Grether, PhD would have a positive influence on the participants' spelling accuracy across all three tasks presented post-treatment when using Co:Writer® 4000 word prediction software. A comprehensive summary of the results for each participant is represented in Table 1. Secondly, it was hypothesized that there would be a decrease in each participants' mean percentages of spelling errors post-treatment when writing with word processing software only (table 2).

Participant A1-05

Hypothesis 1: Consistent with this hypothesis, A1-05 demonstrated increased spelling accuracy through decreased percentages of spelling errors across all tasks presented post-treatment when using Co:Writer® 4000 when compared to the pre-treatment condition using Co:Writer® 4000. On the *BDAE-3* objects and actions task, A1-05's percentage of errors decreased from 2.56% to 0% (figure 1). On the *SPPA* task, percentage of errors remained the same at 0%. On the spontaneous "Cookie Theft" description task, percentage of errors decreased from 7.69% to 6.06%.

Table 1. Detailed summary of results across tasks

	MS Word		BDAE N-V Sentences	Co:Writer® 4000		
	Total # Words Pre N-V MS Word	**# Errors**	**% Errors**	**Total # Words Pre N-V Co:Writer®**	**# Errors**	**% Errors**
A1-05	40	3	7.50	39	1	2.56
A2-05	18	8	44.44	46	1	2.17
A3-05	46	1	2.17	52	1	1.92
	Total # Words Post N-V MS Word	**# Errors**	**% Errors**	**Total # Words Post N-V Co:Writer®**	**# Errors**	**% Errors**
A1-05	39	1	2.56	30	0	0
A2-05	26	6	23.08	42	3	7.14
A3-05	45	3	6.67	44	2	4.55
	MS Word		*SPPA* Sentences	Co:Writer® 4000		
	Total # Words Pre SPPA MS Word	**# Errors**	**% Errors**	**Total # Words Pre SPPA Co:Writer®**	**# Errors**	**% Errors**
A1-05	64	1	1.56	86	0	0
A2-05	31	7	22.58	93	0	0
A3-05	87	4	4.60	88	1	1.14
	Total # Words Post SPPA MS Word	**# Errors**	**% Errors**	**Total # Words Post SPPA Co:Writer®**	**# Errors**	**% Errors**
A1-05	60	2	3.33	53	0	0
A2-05	35	6	17.14	36 (Incomplete)	1	2.78
A3-05	88	2	2.27	92	0	0
	MS Word		BDAE Cookie Theft Description	Co:Writer® 4000		
	Total # Words Pre CT MS Word	**# Errors**	**% Errors**	**Total # Words Pre CT Co:Writer®**	**# Errors**	**% Errors**
A1-05	30	1	3.33	26	2	7.69
A2-05	9	0	0	21	0	0
A3-05	30	1	3.33	38	1	2.63
	Total # Words Post CT MS Word	**# Errors**	**% Errors**	**Total # Words Post CT Co:Writer®**	**# Errors**	**% Errors**
A1-05	32	1	3.13	33	2	6.06
A2-05	7	0	0	10	0	0
A3-05	42	3	7.14	35	0	0

Figure 1. Example of *decrease* in A1-05's spelling errors on the *BDAE-3* objects/actions task. Picture target = hanger

Pre-testing with Co:Writer® 4000:	**It a fa .**
Post-testing without Co:Writer® 4000:	**I hanger my clothes.**

Hypothesis 2: Consistent with this hypothesis, A1-05 demonstrated a decrease in mean percentage of spelling errors post-treatment (3.01%) using word processing software only when compared to her mean percentage of spelling errors pre-treatment (4.13%) using word processing software only. A1-05 demonstrated a 1.12% decrease in spelling errors under the post-treatment condition. See Appendix C for a list of participant spelling errors and the intended targets.

Table 2. Mean percentages of spelling errors calculated across tasks for pre- and post-testing conditions using word processing software only

Participant	Pre MS Word	Post MS Word	Difference
A1-05	4.13	3.01	↓ 1.12
A2-05	22.34	13.41	↓ 8.93
A3-05	3.37	5.36	↑ 1.99

Participant A2-05

Hypothesis 1: Contrary to this hypothesis, A2-05 demonstrated decreased spelling accuracy for the *BDAE-3* objects and actions task and the *SPPA* task post-treatment when using Co:Writer® 4000 when compared to the pre-treatment condition using Co:Writer® 4000. A2-05's percentages of spelling errors actually increased for these tasks in the post-treatment condition. On the *BDAE-3* objects and actions task, the percentage of errors increased from 2.17% to 7.14% (figure 2). On the *SPPA* task, the percentage of errors increased from 0% to 2.78%. On the spontaneous "Cookie Theft" description task, percentage of errors remained the same at 0%. Significant increases in spelling errors may have been due to the fact that the participant was notably fatigued throughout this session. He was unable to complete the *SPPA* task due to this fatigue. Continuation of post-testing on a different day was not possible as the participant was leaving for vacation the next afternoon.

Figure 2. Example of *increase* in A2-05's spelling errors on the *BDAE-3* objects/actions task, presumably due to fatigue factor.
Picture target = sweeping

Pre-testing with Co:Writer® 4000:	**The times are brooms for man.**
Post-testing without Co:Writer® 4000:	**This is borr.**

Hypothesis 2: Consistent with this hypothesis, A2-05 demonstrated a decrease in mean percentage of spelling errors post-treatment (13.41%) using word processing software only when compared to his mean percentage of spelling errors pre-treatment (22.34%) using word processing software only. A2-05 demonstrated an 8.93% decrease in spelling errors under the post-treatment condition. See Appendix C for a list of participant spelling errors and the intended targets.

Participant A3-05

Hypothesis 1: Contrary to this hypothesis, A3-05 demonstrated decreased spelling accuracy for the *BDAE-3* objects and actions task when using Co:Writer® 4000 when compared to the pre-treatment condition using Co:Writer® 4000. A3-05's percentage of spelling errors actually increased for this task in the post-treatment condition (from 1.92% to 4.55%) (figure 3). This may have been due to the fact that the participant did not regularly utilize the features of the word prediction software, but preferred to generate spellings on his own. Notably, spelling accuracy did increase post-treatment for the other two tasks when using Co:Writer® 4000. For the *SPPA* task, percentage of errors decreased from 1.14% to 0%. For the spontaneous "Cookie Theft" description task, percentage of errors decreased from 2.63% to 0%.

Figure 3. Example of *increase* in A3-05's spelling errors on the *BDAE-3* objects/actions task
Picture target = juggling

Pre-testing with Co:Writer® 4000:	**She is juggling with three balls.**
Post-testing without Co:Writer® 4000:	**She is jigger in three balls.**

Hypothesis 2: Contrary to this hypothesis, A3-05 demonstrated an increase in mean percentage of spelling errors post-treatment (5.36%) using word processing software only when compared to his mean percentage of spelling errors pre-treatment (3.37%) using word processing software only. A3-05 demonstrated a 1.99% increase in spelling errors under the post-treatment condition. This is difficult to explain considering his total number of words produced remained relatively similar across tasks and across pre- and post-testing conditions. See Appendix C for a list of participant spelling errors and the intended targets.

Summary of Results

The hypotheses presented in this study were not supported for all three participants. Only the spelling performance of participant A1-05 was consistent with both hypothesis 1 and hypothesis 2. The spelling performance of participant A2-05 was contrary to hypothesis 1 but supported hypothesis 2. A fatigue factor was noted with A2-05 during the last post-testing session that may have compromised these results. The spelling performance of participant A3-05 was contrary to both hypothesis 1 and hypothesis 2. This may be due to the fact that this participant relied heavily on his own writing and spelling capabilities and only inconsistently utilized the features of Co:Writer® 4000 throughout treatment and pre- and post-treatment testing. The results for each pre- and post-treatment testing task are illustrated in figures 4-6.

Figure 4. Participants' results for the *BDAE-3* objects/actions task

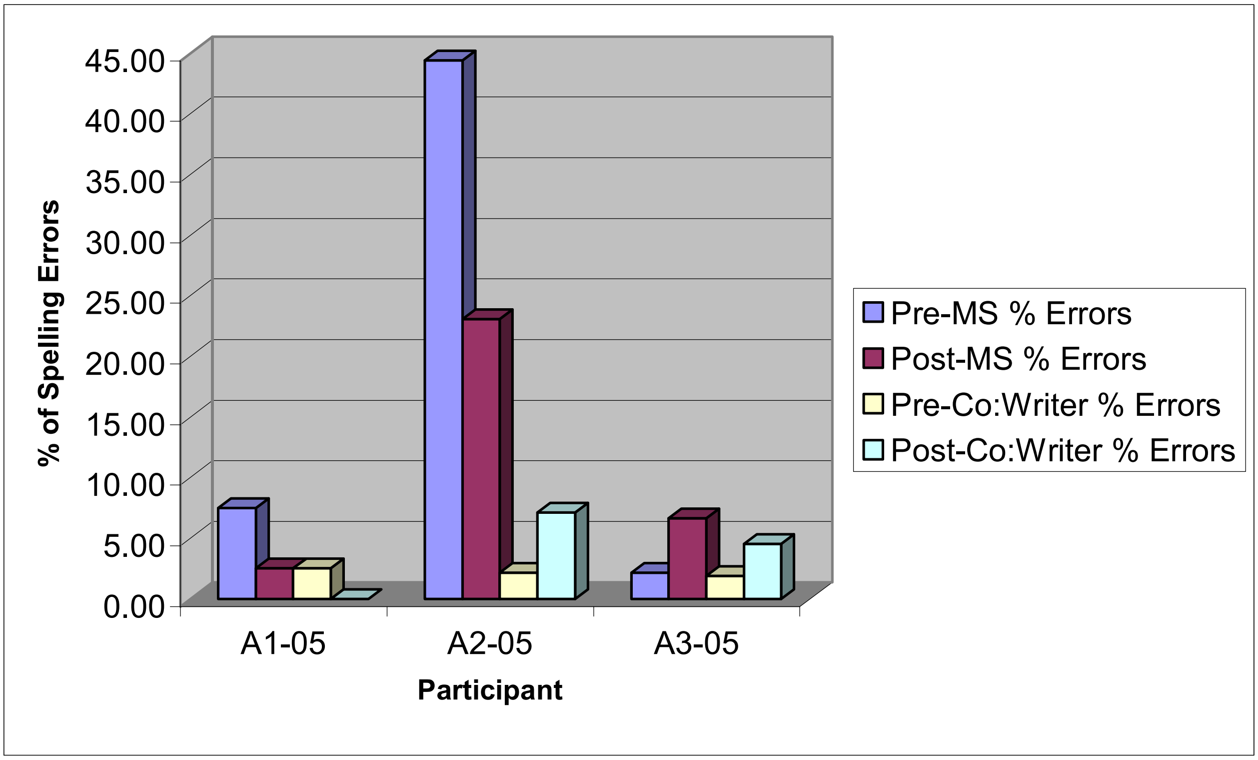


Figure 5. Participants' results for the *SPPA* task

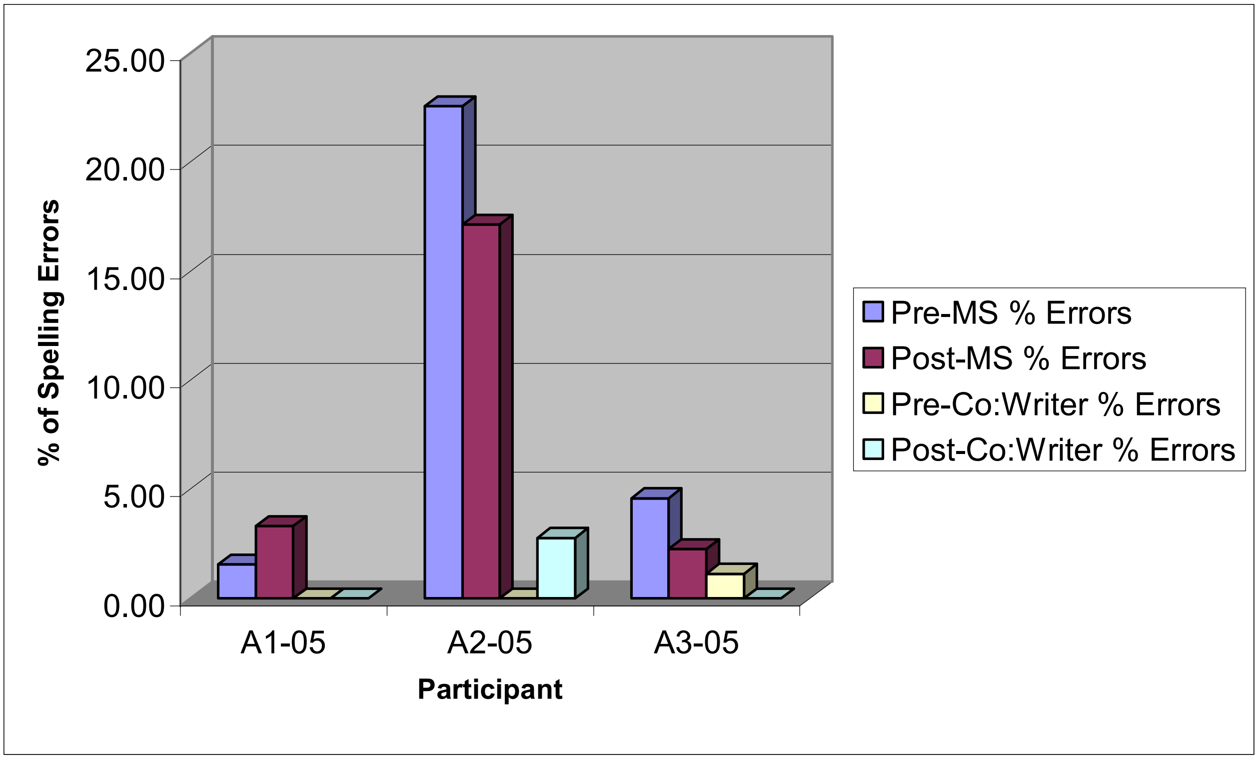
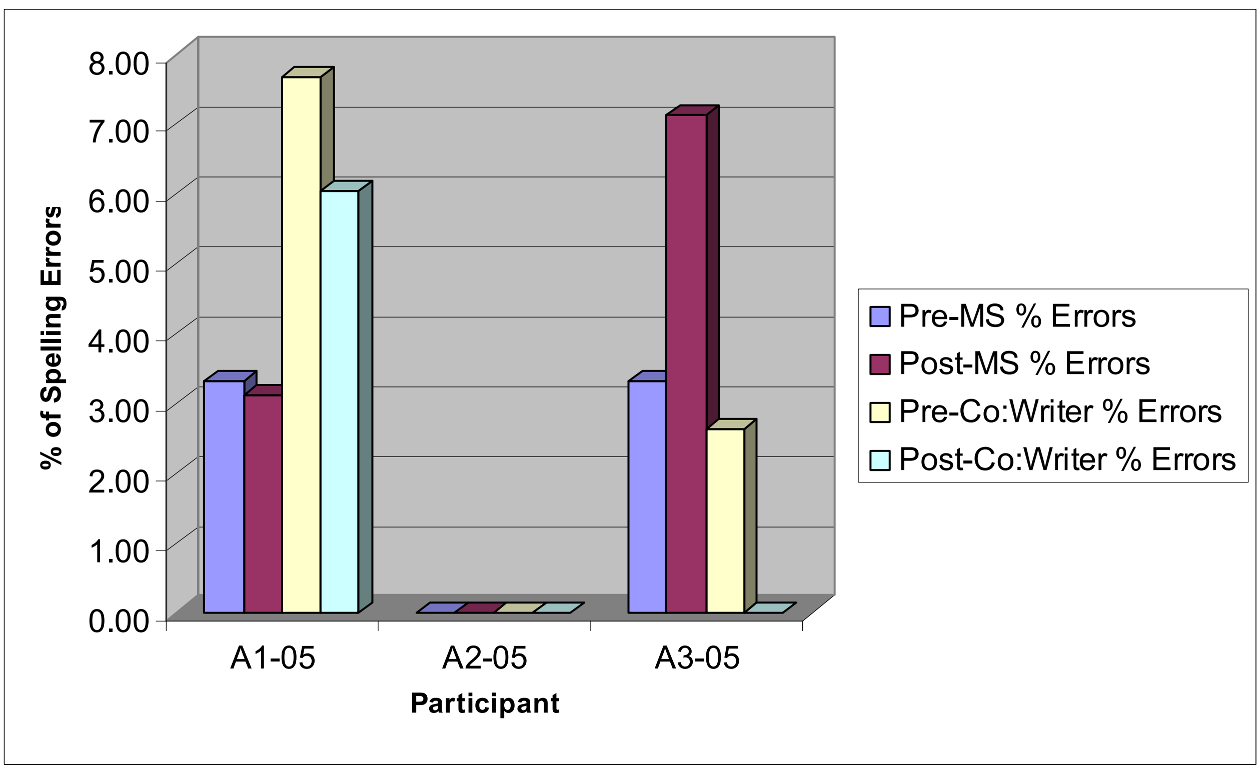


Figure 6. Participants' results for the spontaneous "Cookie Theft" description task



CHAPTER 5

Discussion, Limitations, and Conclusions

Discussion

The results of this study were not particularly significant in themselves. The ultimate goal was to determine if the use of word prediction software, specifically Co:Writer® 4000, had a positive effect on the spelling outcomes in the writing of individuals with non-fluent aphasia. The results of this study illustrated the uniqueness of the participants involved, and indicated that word prediction software may be more suitable for some individuals with non-fluent aphasia than others. In this respect, the most telling aspects were seen more in the process of each participant's writing rather than the product.

Participant A1-05, who's results supported both presented hypotheses, was able to utilize the features of Co:Writer® 4000 efficiently and effectively in order to demonstrate improvements. A1-05 was able to input the first letter(s) of a word and then select from the subsequently generated word list without losing the original intent of the message. This participant demonstrated minimal spelling revisions when using Co:Writer® 4000. It was noted that A1-05 was more likely to choose a different word if experiencing spelling difficulties with the target word. Some revisions reflected the participant's dissatisfaction with the general wording of sentences. During the course of the study, A1-05 reported purposeful home practice of the spontaneous "Cookie Theft" description task. Following completion of the current study, Angel Ball, PhD, research advisor, reported that the participant was independently practicing writing sentences with Co:Writer® 4000 at least two hours per week given a random set of picture stimuli. A1-05 stated that she "love Co:Writer®."

Participant A2-05 was less able to utilize the features of Co:Writer® 4000 effectively. He was often unable to input the correct first letter(s) of a word and, therefore, the program generated a word list unrelated to the word the participant was targeting. This led to constant, unsuccessful revisions in an attempt to see the targeted word as a choice on the generated word list (e.g., broom: pot→be→bom→bon→bogg→bog→boe→boww→bow→bod→bog→boh→ borr). Other times the participant relied heavily on the generated word choices and lost the original intent of his message (e.g., The[se have you for the new and easy person with you]). The resulting sentences typically had minimal to no relevance to the picture stimuli. This participant also demonstrated a strategy of copying the initial letter of words in the palm of his hand or on his thigh as he rehearsed the initial phonemes of words to initiate spelling. This proved to be an unsuccessful strategy, as the participant could not transfer this traced grapheme to a typed grapheme.

It should be noted that participant A2-05 demonstrated the highest percentage of spelling errors across all tasks except the spontaneous "Cookie Theft" picture description. On this task, the participant remained consistent with 0% spelling errors across all circumstances. It was postulated that this discrepancy between tasks might be due to more familiarity with the vocabulary presented in the "Cookie Theft" picture, as A2-05's spelling errors, in general, appeared to demonstrate an effect of lexical frequency (i.e., high-frequency words being spelled more accurately than low-frequency words).

Participant A3-05 proved to be a less than optimal candidate regarding the use of word prediction software, as he seemed to prefer to write on his own without this aid. Although he regularly utilized the auditory feedback feature of Co:Writer® 4000, he rarely utilized the generated word lists. On occasion, the participant was observed looking at a generated word list, however, he would proceed to type the word himself even if it was present on the list. Regardless, it was noted that, at times, the use of word prediction software would not have aided this participant when he could not initiate the correct spelling of the targeted word (e.g., tired: t→ try→ta→te→tr→td→tf→tg→th→tj→tx→tl→tra→tri→trey→trieng→trying). This participant also utilized the strategy of copying the initial letters of words in the palm of his hand to initiate spelling. This was rarely a successful strategy, as the participant could not transfer this traced grapheme to a typed grapheme. It was noted that A3-05 consistently verbalized all sentences before starting to type and demonstrated a slow process of rehearsing these verbalizations.

Limitations

Given that this is an initial pilot study, there are a number of aspects that may be improved upon during future development of this research. Firstly, given the small sample size of this pilot study, conclusions from this study should be interpreted cautiously. Future studies should incorporate more participants in order to establish a strong research base for spelling rehabilitation with non-fluent aphasics. In addition, future studies would benefit from placing more focus on the neural anatomy aspect of stroke and aphasia. Knowing the specific site and extent of the lesion in the brain would be particularly beneficial when examining the affects of spelling remediation with a given individual.

The criteria for qualification of participation in future research should be clearly specified. While this study accepted a passing score on either the reading or auditory comprehension subtests of the *BDAE-3* short form, future research should require proficiency on both subtests. Notably, the only participant who supported both hypotheses for this study, A1-05, was also the only participant who met participation requirements for both of these subtests. The other two participants demonstrated proficiency on the reading subtest but showed decreased capabilities on the auditory comprehension subtest. In addition, this study required that the participants pass only a sound field screening at 25dB. Future research would benefit from a strict pure-tone hearing screening requirement at 25dB in both ears considering the reliance of hearing on the auditory feedback feature of Co:Writer® 4000.

Further research in this area of study would greatly benefit from videotaping testing sessions and/or utilizing tracking software in order to better document the sometimes rapid revisions participants make while writing. Specific criteria need to be set regarding how long participants will be allowed to revise any given word, as some participants would be willing to make revision attempts for lengthy periods of time if allowed. Modifications to the presentation of probe B in the *SPPA* task may result in sentences that more closely approximate the targets. Participants often lost connection with the story once they began typing and did not answer the questions presented in the prompts. Future research may call for the verbalization of prompt B two times, showing the picture stimuli during the second verbalization to direct better attention to the verbal prompt. Finally, the length of time it takes for this population to write must be taken into consideration, as it will limit the number of words to be analyzed.

Conclusions

The quantitative and qualitative results of this study supported findings from previous studies conducted by Armstrong and MacDonald (2000) and Murray and Karcher (2000). The results of their studies supported the use of word prediction computer software, specifically Co:Writer® 4000, in the compensation and remediation of acquired writing deficits associated with aphasia. Armstrong and MacDonald, in particular, provided support for the use of Co:Writer® 4000 in spelling remediation with an individual with non-fluent aphasia. Their case study maintained spelling accuracy or demonstrated improvements in spelling in the post-treatment testing condition depending on the task (e.g., maintained 5% errors in a spontaneous picture description task, and decreased spelling errors from 35% of total words to 8% of total words in a sentence level definition task). This study provides further support for the use of Co:Writer® 4000 to increase spelling accuracy in the writing of individuals with non-fluent aphasia at the sentence level.

Overall, there remains a startling lack of literature in regards to treatment protocols utilizing word prediction software in the writing rehabilitation of individuals with aphasia. Even less is known about the treatment potential of word prediction software for spelling remediation with non-fluent aphasia. It must be recognized that results of individual cases can only account for the efficacy of a given treatment with that particular participant with aphasia (Armstrong & MacDonald, 2000). As mentioned previously, not all participants in this study turned out to be optimal candidates for the use of word prediction software. Screening diagnostics (e.g., auditory comprehension) and individual personality characteristics may serve as the most influential factors when determining if word prediction software will benefit a given individual.

REFERENCES

Armstrong, L., & MacDonald, A. (2000). Aiding chronic written language expression difficulties: A case study. *Aphasiology, 14*(1), 93-108.

Ball, A. L., & Grether, S. M. (2004). *Word Prediction Technology with Writing Rehabilitation in Aphasia*. Unpublished manuscript, University of Cincinnati, Ohio.

Beeson, P. M., Hirsch, F., & Rewega, M. A. (2002). Successful single-word writing treatment: Experimental analyses of four cases. *Aphasiology, 16*, 473-491.

Beeson, P. M., & Rapcsak, S. Z. (2002). Clinical diagnosis and treatment of spelling disorders. In A. E. Hillis (Ed.), *Handbook on adult language disorders: Integrating cognitive neuropsychology, neurology, and rehabilitation* (pp. 101-120). New York, NY: Psychology Press.

Beeson, P. M., Rewega, M. A., Vail, S., & Rapcsak, S. Z. (2000). Problem-solving approach to agraphia treatment: Interactive use of lexical and sublexical spelling routes. *Aphasiology, 14*(5/6), 551-565.

Benson, D. F. (1979). *Aphasia, alexia, and agraphia*. New York, NY: Churchill Livingstone Inc.

Bollinger, R. L. (1996). Treatment of writing impairment. In G. L. Wallace (Ed.), *Adult aphasia rehabilitation* (pp. 243-258). Boston, MA: Butterworth-Heinemann.

Conway, T., Heilman, P., Rothi, L., Alexander, A., Adair, J., & Crosson, B. et al. (1998). Treatment of a case of phonological alexia with agraphia using the auditory discrimination in depth (ADD) program. *Journal of the International Neuropsychological Society, 4*, 608-620.

Co:Writer® 4000 (2003). Volo, IL: Don Johnston Inc.

Ellis, A. W. (1982). Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions* (pp. 113-146). London: Erlbaum.

Ellis, A. W., & Young, A. W. (1988). Spelling and writing. In A. W. Ellis, & A. W. Young (Eds.), *Human cognitive neuropsychology* (pp. 163-190). Hillsdale, NJ: Lawrence Erlbaum Associates Ltd.

Friedman, R. B., & Alexander, M. P. (1989). Written spelling agraphia. *Brain and Language, 36*, 503-517.

Goodglass, H., Kaplan, E., & Barresi, B. (2001). *Boston Diagnostic Aphasia Examination* (3rd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Hatfield, F. M., & Patterson, K. E. (1984). Interpretation of spelling disorders in aphasia: Impact of recent developments in cognitive psychology. *Advances in Neurology, 42*, 183-92.

Helm-Estabrooks, N., & Nicholas, M. (2000). *Sentence Production Program for Aphasia* (2nd ed.). Austin, TX: Pro-Ed.

Lesser, R. (1990). Superior oral to written spelling: Evidence for seperate buffers? *Cognitive Neuropsychology, 7*(4), 347-366.

Lorch, M. P. (1995). Disorders of writing and spelling. In H. S. Kirshner (Ed.), *Handbook of neurological speech and language disorders* (pp. 295-324). New York: Marcel Dekker.

MacArthur, C. A. (1998a). From illegible to understandable: How word prediction and speech synthesis can help. *Teaching Exceptional Children, 30*(6), 66-71.

MacArthur, C. A. (1998b). Word processing with speech synthesis and word prediction: Effects on the dialogue journal writing of students with learning disabilities. *Learning Disability Quarterly, 21*, 1-16.

MacArthur, C. A. (1999). Word prediction for students with severe spelling problems. *Learning Disability Quarterly, 22*(3), 158-172.

Margolin, D. I., & Goodman-Schulman, R. (1992). Oral and written spelling impairments. In D. I. Margolin (Ed.), *Cognitive neuropsychology in clinical practice* (pp. 263-295). New York: Oxford University Press.

Mortley, J., Enderby, P., & Petheram, B. (2001). Using a computer to improve functional writing in a patient with severe dysgraphia. *Aphasiology, 15*(5), 443-461.

Muntner, P., Garrett, E., Klag, M. J., & Coresh, J. (2002). Trends in stroke prevalence between 1973 and 1991 in the US population 25 to 74 years of age. *Stroke, 33*, 1209-1213.

Murray, L., & Karcher, L. (2000). A treatment for written verb retrieval and sentence construction skills. *Aphasiology, 14*(5/6), 585-602.

Rapp, B., & Kane, A. (2002). Remediation of deficits affecting different components of the spelling process. *Aphasiology, 16*(4/5/6), 439-454.

Raymer, A. M., Cudworth, C., & Haley, M. A. (2003). Spelling treatment for an individual with dysgraphia: Analysis of generalisation to untrained words. *Aphasiology, 17*(6/7), 607-624.

Roeltgen, D. P., & Rapcsak, S. Z. (1993). Acquired disorders of writing and spelling. In G. Blanken, J. Dittmann, H. Grimm, J. C. Marshall & C. W. Wallesch (Eds.), *Linguistic disorders and pathologies: An international handbook* (pp. 262-278). Berlin; New York: Walter de Gruyter, Inc.

Seron, X., Deloche, G., Moulard, G., & Rousselle, M. (1980). A computer-based therapy for the treatment of aphasic subjects with writing disorders. *Journal of Speech and Hearing Disorders, XLV*, 45-58.

Sgaramella, T. M., Ellis, A. W., & Semenza, C. (1991). Analysis of the spontaneous writing errors of normal and aphasic writers. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 27*(1), 29-39.

Wapner, W., & Gardner, H. (1979). A study of spelling in aphasia. *Brain and Language, 7*(3), 363-74.

Appendix A

Data Tracking Log for Pre- and Post-Treatment Testing

Data Log Pre / or Post-testing Computer only /OR Co-WR participant # ___________ date ______

Instructions:
Computer: Set up MS Word to Arial font size 16
Co-Writer: Set up intermediate difficulty, 6 word choices without numbering, voice= Reed
Stimuli: use "Sentence Production Program for Aphasia" materials, Sentence Probe B
Tester reads the Probe B statement and question. May repeat once if requested. Encourage participant to listen before starting. May not say target words or provide cueing. Verbal statement such as "just do your best" or "I can't help you at this time" are allowed but no direct cueing.
There is no time limitation.

1. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

2. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

3. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

4. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

5. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

Page 2 Post-testing

6. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

7. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

8. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

9. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

10. Picture #:__________ Sentence type_____________
Record any self-corrections or revisions, indicate original word or partial word and how revised. Indicate target if known. Record revisions even if changes a correct spelling to an incorrect.

Tester: Be sure to print out hard copy of sentences AND save file to floppy diskette.
Record any other comments or observations below:

Appendix B

Sentence Types and Picture Numbers Selected from the *SPPA*

1. Sentence Type 1: Imperative Intransitive Picture # 14
2. Sentence Type 2: Imperative Transitive Picture # 15
3. Sentence Type 3: *Wh*- Interrogative—What and Who Picture # 14
4. Sentence Type 3: *Wh*- Interrogative—What and Who Picture # 15
5. Sentence Type 4: *Wh*- Interrogative—Where and When Picture # 14
6. Sentence Type 4: *Wh*- Interrogative—Where and When Picture # 15
7. Sentence Type 5: Declarative Transitive Picture # 15
8. Sentence Type 6: Declarative Intransitive Picture # 15
9. Sentence Type 7: Comparative Picture # 15
10. Sentence Type 8: Yes-No Questions Picture # 15

Appendix C

Participants' Spelling Errors and Intended Targets

Participant	Errors with MS Word	Targets	Errors with Co:Writer®	Targets
A1-05	darking	barking	felling (x3)	falling
	flease	leaves	spool	stool
	Krogro	Kroger	fa	hanger
	canor	canoe		
	felling	falling		
	braining	thinking		
	turking	turkey		
	kar	karate		
	(--)	finished		
A2-05	he	hanger	hanging	hanger
	cane	canoe	borr	broom
	fis	fish	jittery	juggling
	bratte	target unknown	nea	please
	ceit	target unknown	cane-	canoe
	gens	target unknown		
	bloo	broom		
	wo	woman		
	begge-	target unknown		
	co-	target unknown		
	caney	canoe		
	tunkey	turkey		
	ri-	target unknown		
	plo-	floor		
	thoug	target unknown		
	hamger	cheeseburger		
	pick	pickle		
	go	graduation		
	r-n	target unknown		
	stomack	stomach		
	r-	target unknown		
	b-	target unknown		
	be	bus		
	newspe	newspaper		
	re	team		
	mi-	mail		
	s-	sick		
A3-05	slippers	slipping	slippery	splashing
	kitchern	kitchen	sweping	sweeping
	washern	washing	jigger	juggling
	hangren	hanger	spool	stool
	conoe	canoe	(--)	his
	jidder	juggling		
	--t	pointing		
	bacause	because		
	flouding	flooding		
	juglind	juggling		
	pesting	pestering		
	argused	arguing		
	was	wants		
	exitice	excited		