EVALUATING WORD PREDICTION SOFTWARE FOR STUDENTS WITH PHYSICAL DISABILITIES

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ABSTRACT

Although word prediction software was originally developed for individuals with physical disabilities, little research has been conducted featuring participants with physical disabilities. Using the Co:Writer 4000 word prediction software, three participants with physical disabilities improved typing rate and spelling accuracy, and two of these students were able to replicate this later in the study. This study indicates that word prediction software may be effective to increase typing rate and improve spelling accuracy for some participants with physical disabilities, but its effectiveness depends on individual characteristics.

Students with physical disabilities often have difficulty writing efficiently and accurately. Because of motor impairments, a significant number of these students must type their work. However, typing requires complex gross and fine motor skills and motor perceptual integration (Lueck, Dote-Kwan, Senge, & Clarke, 2001) which can be a challenge for students with physical disabilities. In addition, students with physical disabilities frequently have limited strength and endurance for typing tasks and may have a slow typing rate. Some students may also have poor spelling abilities. Depending on the type of physical disability manifested, assistive technology may be used to promote access to typing and increase typing fluency. Word prediction software is one type of assistive technology that may help students to increase typing rate and to improve spelling accuracy.

Students with physical disabilities often have involuntary motor patterns, affecting both fine and gross motor movements. These motor patterns can lead to limitations and miscalculations in the motor movements involved in typing. This can negatively impact typing fluency (Lewis, Graves, Ashton, & Kieley, 1998), which is the length, speed, and accuracy of typing responses. Cerebral palsy, spina bifida and muscular dystrophy are three conditions that can affect motor planning, gross and fine motor coordination, finger strength and manipulation, and eye-hand coordination (Lueck, Dote-Kwan, Senge, and Clarke, 2001). A student with cerebral palsy often displays abnormal and involuntary motor patterns which may negatively impact key selection and typing flow. Motor dysfunction in a student with muscular dystrophy includes declining strength and range of motion in the fingers, wrists, and arms which may lead to errors in key selection and a reduction in passage length. Students with spina bifida may have perceptual and fine motor deficits that negatively effect motor planning, eye-hand and coordination, and finger manipulation (Tam, Reid, Naumann, & O'Keefe, 2002a; Tam, Reid, Naumann, & O'Keefe, 2002b). For these students, typing fluency can be negatively impacted due to difficulty with the physical planning and execution of typing.

Another factor that affects typing fluency is knowledge of the standard keyboard layout (Lewis et al., 1998). Students with physical disabilities may have limited exposure to keyboards. They may lack formal instruction in keyboard layout and use and typically have spent less time using a keyboard than their non-disabled peers. Lack of familiarity impacts a typical student's typing fluency and may interrupt thought while searching for the correct key.

Literacy and language deficits may also negatively impact typing fluency and spelling with students with physical disabilities (Sandberg, 2001; Sandberg, 1998). Some students with physical disabilities have poor expressive language skills that result in a significant discrepancy between intellect and written expression (Dorman, Hurley, & Laatsch, 1984). Deficits in written expression may be attributed to poor phonological knowledge, receptive and expressive language deficits, and deficits in short term memory (Sandberg 1998; Sandberg, 2001). McCutcheon (1995) reported that attention to the mechanics of writing may significantly tax a writer's working memory. This could impact students with physical disabilities who do not have strong expressive skills and need to spend time composing their sentences in correct grammatical format. Fluency may be slowed as students struggle with writing in appropriate grammar and spelling.

Students with physical disabilities may have difficulty spelling due to poor spelling ability, but spelling errors may also occur due to motor problems. These can occur even when assistive devices are used because arm, hand, and finger controls are impacted by involuntary motor patterns (Heller, 2005; Cook, & Hussey, 2002). Some students with physical disabilities type inefficiently with standard word processors and other students cannot handwrite effectively, so assistive technology is needed (Castellani, & Jeffs, 2001).

Word Prediction Use

One way to assist students with physical disabilities with written expression is through assistive technology. Assistive technology may be used to address some of the motor problems associated with typing fluency and spelling errors. Lueck, Dote-Kwan, Senge, and Clarke (2001) suggested that assistive technology decisions should: (a) promote individual independence, (b) consider functional needs, and (c) consider personal preferences.

There are several types of assistive technology that may promote writing. For students with severe physical disabilities, alternate keyboards may be needed when their physical impairments prevent them from using a standard keyboard. However, typing rate may still be slow and spelling errors may still occur. One type of assistive technology that may address typing speed and spelling errors is word prediction.

Word prediction software may be an effective tool to assist students with physical disabilities in increasing typing speed and accuracy, and reducing spelling errors. This technology was developed to assist students with physical disabilities, yet much of the research has focused on students with learning disabilities (MacArthur, 2000). This software allows users to reduce keystrokes, also known as rate enhancement, potentially saving time and physical energy that may increase typing speed (Merbler, Hadadian, & Ulman, 1999).

Word prediction software works in conjunction with any standard word processor. The prediction program typically features a separate window that can be moved so that users may view both windows simultaneously, or there may be a separate tool bar placed somewhere on the screen. The user types either in prediction window or the word processor depending on the particular program. To begin, the user types the first letter of a word in the prediction window and a numbered set of words is offered by the program. If one of the number choices is the word the user wants, the user selects it by typing the number associated with the choice or by clicking on the choice. The software then places the complete word into the sentence and the user types the first letter of the next word in the sentence. With prediction programs that feature a separate window, the user selects end punctuation and software transfers the complete sentence to the word processor. When words are selected from the prediction menu, keystrokes are saved and rate enhancement may be achieved.

Rate enhancement is achieved because the software permits users to generate more characters (letters) than they physically select on a keyboard (Cook & Hussey, 2002). Rate enhancement is accomplished when a user types one or two letters of a word and then indicates one of the complete word choices by selecting the number associated with the chosen word. The software then places the selected word into the sentence for the user. Word prediction software also reduces keystrokes by automatically capitalizing the first word in a sentence, capitalizing most proper nouns, and by providing appropriate spacing between words and sentences.

There are also other factors that may impact the effectiveness of word prediction on typing rate. Koester and Levine (1998) suggested that word prediction may vary in its effectiveness based on the user's list search time (scanning the word prediction list), keypress time (time it takes to motorically press the key), and keypress delay (time to takes to decide what to press). Additional factors that were identified as affecting word prediction effectiveness included the configuration of the word prediction system and keystroke savings, as well as the strategy used to search the word list. Several different search strategies were presented by Koester and Levine (1997), such as searching the word prediction list before each selection, selecting two letters and then searching the word prediction list before subsequent selections, and discontinuing the search if the word is not found after so many letters. The model simulations constructed in this study showed that the effectiveness of word prediction varied based upon the keypress time, list search time, and search strategy. Tam et al. (2002b) reported that placement of the word prediction window was found to be an important variable in using word prediction. They found that having the word prediction window in the lower middle border of the screen led to improvements in text entry.

Word prediction has the potential to increase spelling accuracy since the user is presented with a list of potential words which are spelled correctly and can be selected and placed in a document with a single keystroke. This can be of benefit to students with physical disabilities because some spelling errors are due to weak phonological skills (Sandberg, 1998) and weak literacy knowledge (Sandberg, 2001). Word prediction may have advantages over computerized spell check which has been reported to have limited effectiveness for students with language and learning disabilities. Users were unable to locate the correct word in the spell checker, or the word was a homonym and went unrecognized by the spell checker (MacArthur, 2000).

WORD PREDICTION STUDIES

Several research studies have examined the use of word prediction with students with disabilities. Lewis, Graves, Ashton, and Kieley (1998) studied 132 students with learning disabilities to determine whether word prediction improved typing rate when compared to hand writing and to word processing. The authors used a pretest-posttest control design with three minute sessions. They reported that participants made greater typing gains using word prediction versus word processing, but handwriting was the fastest word production method. The authors suggested that a lack of keyboard practice may explain why handwriting was superior to word prediction. In another study with students with learning disabilities (Golden, 2001), one student did poorer with word prediction than typing. In this instance, the authors thought that the student's typing rate was slowed due to the time it took the student to visually search the word prediction list.

Gains in spelling have also been found in studies with students with learning disabilities. MacArthur (1998) conducted a multiple baseline and withdrawal study featuring students with learning disabilities to assess whether spelling accuracy improved using word prediction software. He reported that 4 of the 5 participants made gains in spelling accuracy. MacArthur (1999) reported gains in spelling accuracy in a series of studies featuring the same 3 participants with learning disabilities. The first study used an alternating treatment design to compare handwriting to word prediction to word processing in a journal writing activity. Only 1 of the 3 participants made gains in spelling accuracy. However, the second study placed higher vocabulary demands on the participants possibly causing participants to use word prediction more often.

Some research has been conducted on the use of word prediction with students with physical disabilities. Koester and Levine (1996) lead a study featuring 8 participants without disabilities and 6 with high level spinal cord injuries who used mouth sticks to access keyboards. They reported that word prediction would only increase text generation rate if the amount of keystrokes that are saved using word prediction exceeds the selection rate (which is influenced by such cognitive and perceptual factors as search time, deciding on the selection, and key press time). The study found that even though fewer keystrokes were used with word prediction, each selection took significantly longer to make, especially for users with spinal cord injuries. This was attributed to the cognitive and perceptual factors needed for word prediction. In this study, word prediction decreased text generation rate for those with spinal cord injury by an average of 41% in contrast with typing without word prediction.

In another study with students with physical disabilities (Tumlin and Heller, 2004), word prediction effects on increasing typing fluency were found to vary based upon the severity of the physical disability and the student's typing speed. Students with the most severe physical disabilities and slowest typing speeds (2.9 wpm, 4.7 wpm) had increases in typing speed using word prediction software. However, the students with faster typing speeds (10.9 wpm, 14.6 wpm) and less severe physical disabilities showed no improvement or typed slower using word prediction software. The study concluded that fatigue, attention, keypress rate, and motor planning issues are additional factors that may impact typing performance of students with physical disabilities, and that severity of the disability and preintervention typing rate may play a key role in the effectiveness of word prediction use.

Tam, Reid, Naumann, and O'Keefe (2002a) conducted a brief 20 day study of word prediction with four students with spina bifida and hydrocephalus ages 10 to 14 using five minute typing sessions. The authors reported no gain in typing rate with word prediction for all participants. They suggest that a lack of practice with word prediction, the short length of the study, issues relating to methodology, and population may explain why students failed to make gains in typing rate with word prediction.

More research is needed to determine the effectiveness of word prediction software with students with physical disabilities. The purpose of this study was to examine the use of word prediction software on typing fluency and spelling accuracy.

METHOD

Participants and Setting

Three students with physical disabilities were selected for this study. In order to be selected for this study, the student had to: (a) meet the Georgia requirements for orthopedic impairments (students have mild intellectual disabilities or no intellectual disabilities along with a physical disabilities), (b) be receiving services through an orthopedic impairment special education program, (c) have a physical disability involving fine motor problems, (d) be middle school age, (e) have used word processing for a minimum of one year, (f) have a below average typing rate and/or making spelling errors on over 5% of their work (either due to motoric or learning issues), (g) have had no formal instruction in the use of word prediction software, and (h) have had prior experience using the word processor on a computer.

The three students selected for this study were all in the seventh grade and were wheelchair users with gross and fine motor deficits (see Table 1). Sarah had spina bifida and hydrocephalus. James had Duchenne's muscular dystrophy. Tim had moderate spastic cerebral palsy.

Sarah, a thirteen year old young lady with average intelligence, had spina bifida and hydrocephalus. She used a manual wheelchair and had wheelchair accessible desks in each of her general education classes. Sarah had a strong preference for handwriting because she did not want to look different from her peers. She was able to type and she was familiar with word processing.

James was a 13 year old young man with average intelligence who had Duchenne's Muscular Dystrophy. He used a manual wheelchair and accessible desk. James preferred to hand write all assignments except lengthy reports and projects. James' handwriting was legible for short writing assignments, but became less legible for assignments taking longer than 10 minutes. James was familiar with word processing.

Tim was a 13 year old young man with moderate quadriplegic spastic cerebral palsy, mild dysarthric speech, attention deficit disorder, and low average intelligence. He used a power wheelchair independently and he had wheelchair accessible desks in each of his classes. Tim completed most work by hand with a pencil, but his handwriting was difficult to read due to moderate motor planning and fine motor deficits. Legibility became worse toward the end of the day due to fatigue. Tim rarely accessed a computer. However, school personnel provided Tim with a standard laptop computer during the course of the study and began training 60 minutes per week.

The study took place in a resource room for students with Orthopedic Impairments (OI). Students were instructed by the OI teacher using the classroom desktop computer (a Dell Dimension PC) or Dell laptop computers. Observation during word processing tasks in the daily study skills class indicated that all students were able to use word processing to type. Microsoft Word was selected as the word processing software since it was known by all participants. All spelling and grammar check features were disengaged during the study.

Word Prediction Software

Co:Writer 4000 (Johnston, 1992) was the word prediction software for this study. This commercially available word prediction program can be used with any word processor by students in elementary through high school age. The prediction program features a separate window that is typically placed in the

TABLE 1.
Participant Characteristics

Name	Age/ Ethnicity	Diagnosis	Est. I.Q	Writing/typing usage	Baseline WPM/ % Spelling Errors
Sarah	14 African-American	Spina Bifida/ Hydrocephalus V/P shunt	Not tested†	Handwrites	17 wpm* 12%
James	13 African-American	Duchenne Muscular Dystrophy	Not tested	Handwrites short assignments, types long assignments	13 wpm 11%
Tim	14 Caucasian	Moderate Spastic CP/ Mild athetosis ADD***	70–75 DAS**	Handwrites short assignments, types longer assignments	7 wpm 12 %

* WPM = words per minute
** DAS = Differential Abilities Scales
*** ADD = Attention Deficit Disorder
† I.Q. not needed for O.I. classification

bottom half of the screen. Users view both windows simultaneously. The user types the first letter of a word in the prediction window and the program offers a numbered set of words. If one of the numbered choices is the word the user wants, it is selected by typing the number associated with the choice, or by clicking on the choice. Next, the program places the complete word into the sentence and the user types the first letter of the next word. If the correct word is not in the list, the user continues to type and the list of predicted words changes accordingly. When ending punctuation is selected, the software transfers the complete sentence from Co:Writer 4000 to the word processor.

Co:Writer 4000 was set on the intermediate dictionary and the voice feature was disengaged. The program was set to display five word choices, and font size was adjusted between 12 through 18 to meet individual preferences. Other utilized features included predict ahead, predict in line, and learn new vocabulary.

Procedure

Writing sessions. The writing sessions consisted of the students being instructed to write a short paragraph about true events in their daily routine or other familiar topics. Students were provided with a writing prompt such as "What did you learn in your science class?" or "What is your favorite TV show?" The teacher or paraprofessional then discussed the writing prompt with the student. After the discussion about the writing assignment, the students were first provided 10 to 20 minutes to pre-write their answers (via handwriting or typing with spelling and grammar features turned off). Next, the students copied their prewritten answers using a word processor alone or word prediction (depending on the treatment condition). This method avoided pauses or breaks in typing due to cognitive issues such as the student thinking about what to type next. Students were instructed to type from their prewritten sample and were timed for either 3 or 6 minutes depending on the session. Unlike studies in which the student copied from something written by someone else, copying from their prewritten sample allowed spelling errors to occur.

A teacher or paraprofessional printed the page when the student completed typing. Each page was headed by the teacher with name, date, and writing prompt. Words per minute and spelling errors were calculated.

Determining baseline writing rate and spelling errors. Students were tested to determine baseline typing rate and spelling accuracy. Six sessions were conducted in which the participants typed using only word processing. Typing rate was determined by counting individual words. Spelling errors were calculated as the percent of words spelled incorrectly.

Previous research using word prediction featured typing sessions from two to five minutes. Tumlin and Heller (2004) used two minute sessions and five minute probes in their study of students with physical disabilities, however, the authors suggested that future research with participants with physical disabilities should consider longer typing sessions while monitoring for fatigue. Lewis et al. (1998) used three minute sessions in a study of students with learning disabilities. Tam, Reid, Naumann, and O'Keefe (2002) used five minute sessions in their study with students with spina bifida and hydrocephalus. Three minute typing sessions were selected for the first two phases of the present study since this length was the most common in the literature. However, since three minute sessions might not reflect typical or authentic academic assignments, or adequately demonstrate a decline or improvement in typing rate over time, six minute typing session were used for the rest of the study.

The word per minute (wpm) rate was calculated by taking the total number of words typed already in the word processes in each session and dividing by the number of minutes in each typing session. It was sometimes necessary to add the words in the word prediction window to the words in the word processor before calculating as some users had not selected enter and transferred the remaining words to the word processor when the session was completed.

Co-Writer Instruction. Before the study began, students received individualized instruction on the use of Co:Writer 4000 from their OI certified teacher during a study skills class. The teacher described, demonstrated, and then modeled the features of the software. Participants were first provided with one hour of guided practice, then permitted independent practice. During guided practice, the students were taught to: (a) choose a word, (b) type the first letter of the word, (c) look at the word list to see if the choice was offered, (d) select the choice (by clicking or selecting the number on the keyboard) or continue typing the next letter, (e) look at the word list to see if the choice was offered, (f) select the choice (by clicking or selecting the number on the keyboard) or continue typing the next letter. The student would proceed until the sentence was complete and was sent to Word.

Instruction of Co:Writer 4000 continued for each student until it was observed that each was able to achieve 100% accuracy on the checklist. Items on the checklist included opening Co:Writer 4000 with Microsoft Word, typing, scanning the list after each typed letter, selecting the word from the list., finishing the sentence, adding punctuation which automatically sent the sentence to Word, and getting back into Co:Writer 4000.

DESIGN

The dependent variables in this study were typing rate and percentage of spelling errors. The independent variable was the use of word prediction software. A withdrawal design (which alternates between baseline and word prediction phases) was selected to display a functional relationship between the use of word prediction and typing rate, and word prediction and spelling accuracy (Kazdin,1982; Richards, Taylor, Ramasamy, & Richards, 1999). To replicate studies that used 3 minute typing sessions, and to allow students time to adjust to the procedure of writing and coping their work, an initial baseline and intervention phase was introduced using 3 minute sessions. This was followed by a traditional withdrawal design of using 6 minute timed sessions.

A six session pretest established typing rate and percent of spelling errors. The results of the pretest served as the initial baseline in the study. During this baseline, participants only used the word processor with spelling and grammar features disengaged.

After the 3 minute baseline, the first intervention phase was introduced with 3 minute timed sessions. The participants used Co:Writer 4000 in combination with the word processor during the intervention phase. Typing rates and spelling errors were calculated for each session. All intervention phases were conducted for a minimum of three sessions. This phase was terminated when the user achieved at least 5% improvement in the mean typing rate or spelling accuracy across at least three consecutive sessions, or after no more than ten sessions.

Upon completion of the initial two phases, the study moved to 6 minute typing sessions. As with the first baseline, the six minute baseline featured only the word processor. This was followed by a 6 minute word prediction phase that used the same procedures as the first intervention except for the length of time. This phase was terminated when the user achieved at least 5% improvement in the mean typing rate or spelling accuracy across at least three consecutive sessions, or after no more than ten sessions.

To replicate the design of the 6 minute timed sessions, a second 6 minute baseline (6 minute baseline 2 phase) and word prediction phase (6 minute word prediction 2 phase) was introduced. It used the same procedure and criteria as the other baseline and intervention phases.

Reliability

Inter-observer reliability (IOR) was calculated across 20% of each baseline phase, and at least 20% of each of the intervention phases. A paraprofessional was trained as the second observer. Both observers calculated rate of typing in words per minute and percent of spelling errors. Treatment integrity was provided through a checklist of training in Co:Writer.

Social Validity

Social validity was assessed through a written pre-treatment and post-study questionnaire. The questionnaire consisted of several questions designed to assess the subjects' sense of self efficacy using Co:Writer 4000 (i.e., it will help me get higher grades; it will help me save time; my work looks neater when I use word prediction; I make fewer mistakes when I use word prediction). Answers were given using a 3 being agree, 1 being disagree, and 2 being unsure.

RESULTS

This study examined the effects of word prediction software on typing rate for students with physical disabilities. Words per minute were calculated for each session across baseline and word prediction conditions. Results indicated that the use of word prediction software increased typing rate and spelling accuracy for all three participants in six minute phases.

Sarah. During the 3 minute baseline, Sarah's mean number of words per minute was 17.1 (range14–20) and after the introduction of the word prediction software, the mean typing rate rose to 20.4 wpm (range 20–21). This is a typing rate increase of 19.2% per minute. (See Figure 1.) In the next four phases, six minute typing sessions were used. In the first 6 minute baseline, Sarah's typing was a mean of 14.6 wpm (range 13–16) and during word prediction (6 minute word prediction 1) the mean typing rate rose to 22.5wpm (range 21–24). This is a typing increase of 54.1%. When the second 6 minute baseline was reintroduced, the mean number of words per minute fell to 16.0 (range 0). After the reintroduction of word prediction in the final phase (6 minute word prediction 2), Sarah's typing rate rose to 20.5wpm (range 20–21), an increase of 28.1% from the baseline.

The percent of overlap of correct responses between phases was calculated. For the 3 minute phases, there was a 60% overlap between 3 minute baseline and word prediction. For the first 6 minute phases, there was a 0% overlap between baseline and word prediction, a 0% overlap between word

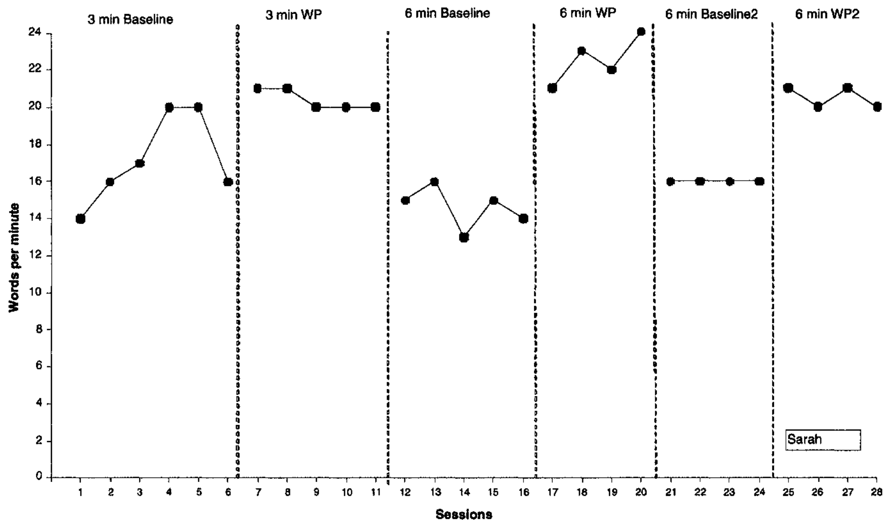

Figure 1.

Mean number of words typed per minute for Sarah across baseline (using Microsoft Word) and intervention (using Co:Writer 4000 word prediction software).

prediction and the second 6 minute baseline, and 0% overlap between second 6 minute baseline and word prediction. According to Alberto and Troutman (2003), the lower the percentage of overlap, the greater the impact of the intervention on the dependent variable. In this instance, there was a weak functional relationship for typing rate in the 3 minute phases, and a strong functional relationship in the 6 minute phases.

As seen in Table 2, Sarah made gains in spelling accuracy during the word prediction phases. In 3 minute baseline, Sarah's mean percent of spelling errors was 13.6% (range 12–19), but dropped to 2.4% (range 1–5) in word prediction. In the 6 minute baseline, spelling errors rose to 6.6% (range 4–9), but fell to 0.0% in word prediction. Percent of spelling errors rose to 5.2% (range 5–6) when the second six minute baseline was introduced, but returned to 0.0% (range 0) in the second six minute word prediction phase.

James. During the 3 minute baseline phase, James' mean number of words per minute was 13.2 (range11–16). (See Figure 2). After the introduction of the word prediction software, the mean typing rate rose to 15.6 wpm (range 13–18). This was a typing rate increase of 18.1% per minute. In the first 6 minute baseline, James' mean typing rate fell to a mean of 12.0 wpm (range 11–13) and in word prediction, the mean typing rate rose to 17.5wpm (range

TABLE 2.
Percent of spelling errors across three students and all phases of the study.

	3 min. B*	3 min. WP**	6 min. B1	6 min. WP 1	6 min. B2	6 min. WP2
Sarah	13.6	2.4	6.6	0.0	5.2	0.0
James	10.6	2.6	8.0	0.0	5.7	1.5
Tim	12.2	4.1	12.2	2.2	10.5	3.2

* B = baseline; ** WP = word prediction

21–24), representing a gain of 45.8% in typing rate. In the second six minute baseline, the mean number of words per minute fell to 14.0 (range 0). After the reintroduction of word prediction in the final phase, James' typing rate rose to 18.7wpm (range 18–20), an increase of 33.5%.

The percent of overlap of correct responses between phases was calculated for James. For the 3 minute phases, there was a 50% overlap between base-

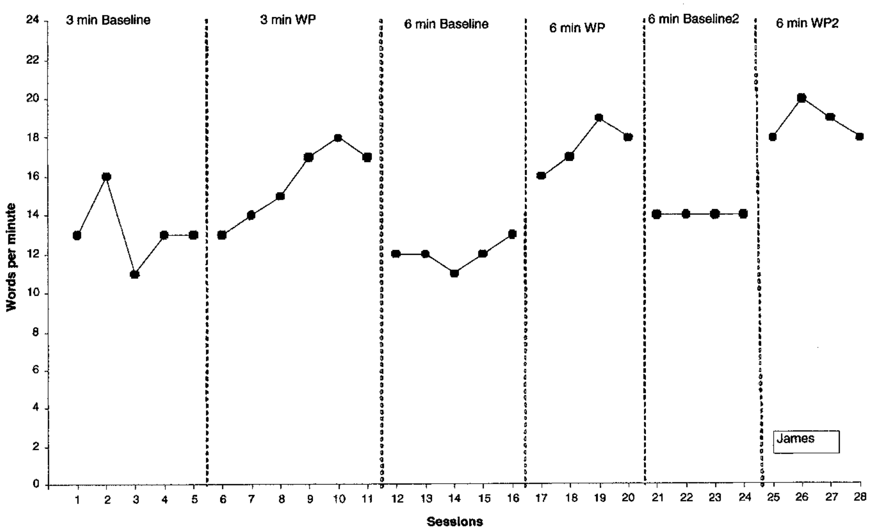

Figure 2.

Mean number of words typed per minute for James across baseline (using Microsoft Word) and intervention (using Co:Writer 4000 word prediction software).

line and word prediction. For the 6 minute phases, there was a 0% overlap between baseline and word prediction, a 0% overlap between word prediction and the next baseline (six minute baseline 2), and 0% between baseline and the final word prediction. As with Sarah, there was a weak functional relationship for typing rate in the 3 minute phases and a strong functional relationship in the 6 minute phases.

James' mean percent of spelling errors in 3 minute baseline was 10.6% (range 4–15), but dropped to 2.6% (range 0–6) in word prediction. In the first 6 minute baseline, spelling errors rose to 8.0% (range 7–10), but fell to 0% in word prediction. The percent of spelling errors rose to 5.7% (range 5–7) when the six minute baseline was reintroduced, but dropped again to 1.5% (range 0–3) in the final six minute word prediction phase.

Tim. In the 3 minute baseline, Tim's mean number of words per minute was 7.2 (range 5–9). (See Figure 3). After the introduction of the word prediction software, the mean typing rate rose to 8.8 wpm (range 6–11). This is a typing rate increase of 22.2% per minute. In the first 6 minute baseline, Tim's mean typing was a mean of 6.4 wpm (range 5–7) and in word prediction, the mean typing rate rose to 10.0 wpm (range 0). This was a 36.0%

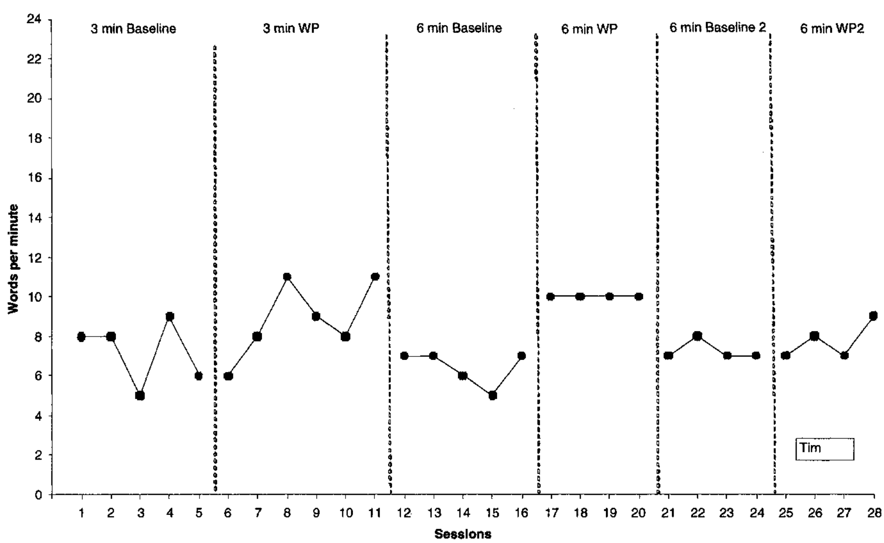

Figure 3.

Mean number of words typed per minute for Tim across baseline (using Microsoft Word) and intervention (using Co:Writer 4000 word prediction software).

increase. When the second six minute baseline was reintroduced, the mean number of words per minute fell to 7.2 (range 7–8). After the reintroduction of word prediction in the final phase, Tim's typing rate rose to 8.0 wpm (range 7–9), an increase of 11.1%.

The percent of overlap of correct responses between phases was calculated for Tim. For the 3 minute phases, there was a 66% overlap between baseline and word prediction. For the 6 minute phases, there was a 0% overlap between baseline and word prediction, a 0% overlap between word prediction and the second 6 minute baseline, and 75% overlap between the second six minute baseline and the second six minute word prediction phase. Although a strong relationship was suggested in the first 6 minute phases, there was a weak functional relationship for typing rate in the initial 3 minute phases and in the second 6 minute phases, suggesting an overall weak functional relationship.

Tim's mean percent of spelling errors in 3 minute baseline was 12.2% (range 0–29), but fell to 4.1% (range 0–9) in the 3 minute word prediction. In the first 6 minute baseline, spelling errors rose back to 12.2% (range 8–16), but dropped to 2.2% (range 0–3) in the first 6 minute word prediction phase. Percent of spelling errors rose to 10.5% (range 9–12) when the second 6 minute baseline was reintroduced, but fell again to 3.2% (range 2–7) in the second six minute word prediction phase.

Inter-observer reliability (IOR) and treatment integrity were calculated through checklists. IOR was calculated across 20% of each baseline and intervention phases. One of the classroom paraprofessionals served as the second observer. IOR was determined to be 96% in baseline and 94% in intervention. Analysis of discrepancies reveals that the researcher failed to deliver the one minute warning procedure several times throughout the study. Treatment integrity was provided through a checklist of training sessions and was determined to be 100%.

Social validity was assessed through a pre and posttest survey (See Table 3). Prior to the beginning of the study, all three participants reported uncertainty or negative feelings about word prediction software except Tim who thought it would help him earn better grades. At the conclusion of the study, all three participants related that they thought Co:Writer would help them make better grades in school. Sarah and James reported that their work looks neater and they made fewer mistakes when they use word prediction software. Tim thought that word prediction would save him time on his homework and that he would like to use it at home.

TABLE 3.
Participant survey.

		Sarah	James	Tim
1. Using Co:Writer will help me get better grades	Pretest	2	2	3
	Posttest	3	3	3
2. Using Co:Writer will help me save time.	Pretest	2	2	2
	Posttest	2	2	3
3. More work looks neater when I use Co:Writer.	Pretest	2	2	1
	Posttest	3	3	1
4. I make fewer mistakes when I use Co:Writer.	Pretest	3	2	1
	Posttest	3	3	1
5. I would use Co:Writer at home If I had it.	Pretest	1	1	2
	Posttest	2	2	1

3 = agree, 2 = unsure, 1 = disagree

DISCUSSION

The purpose of this study was to determine if word prediction would increase typing rate and decrease spelling errors of students with physical disabilities. Few studies have been conducted verifying whether word prediction software is effective with students with physical disabilities. In this study, all three participants showed increases in typing speed with the use of word prediction software during the six minute typing sessions, as well as decreases in spelling errors. However, the results were not consistent during the replication phase of the study for Tim, or during the three minute intervals.

Sarah and James showed a strong relationship between the six minute conditions, indicating that word prediction did indeed increase their typing speed. Tim, however, only showed an increase in typing speed during the first six minute intervention and failed to replicate this increase during the second six minute intervention. This may be attributed to outside factors. The final six minute intervention phase was conducted during the last week of the school year. During this time there were end of year activities and celebrations, including schedule changes. Tim had attention deficit disorder and the end of year activities may have increased his distractibility during this time. Also, anecdotal records showed that Tim complained and attempted to avoid the final four typing sessions, although he never asked to discontinue participation. This lack of motivation and possible increases in distractibility may have negatively affected the last intervention phase and account for why no increases in typing speed was present. His performance in the first six minute sessions is thought to more accurately show his performance.

Although this study demonstrated increases in typing speed for the subjects during the six minute sessions, this was not found during the three minute sessions. One possibility is that the students were still adjusting to copying their work and using word prediction. This is supported by the mean word per minute rate in the three minute word prediction sessions being the lowest for all three students, as compared to all other word prediction phases (except for Tim's last phase in which lack of motivation seemed to be a problem). Another possibility is that six minute sessions were needed to really show the difference between using word prediction and not using it in light of the student's typing rates and level of disability. A six minute typing session is also more aligned to what occurs in the school systems (as opposed to three minutes) so it may be a more accurate reflection of their abilities.

Although there were increases in typing speed when the students were using word prediction, the difference may have been higher for James if the study continued. There was a possible learning or practice effect shown in James' graph (Figure 2). Upon visual inspection of James' graph, each word prediction phase had a higher overall mean. Future studies on word prediction with students with physical disabilities may want to continue a study for a longer period of time to determine if typing speed will continue to increase with the use of word prediction over time.

This study also found that there were fewer spelling errors with the use of word prediction for all three students. However, even with the use of word prediction, some spelling errors occurred. Upon closer examination of their errors, some of these errors would not be picked up by word prediction, such as missed possessives (e.g., friend's) or typographical errors in which the first letter is misspelled (e.g., typing the "y" instead of the "t" and getting "yalked" instead of "talked"). Other errors were spelling or typographical errors that word prediction would have caught, but the student ignored (e.g., typing "vidio" for video). Even though some spelling errors occurred with word prediction, there was a substantial decrease in spelling errors when word prediction was used.

There are several limitations of this study. As with all single subject design studies, further replication studies are needed over a larger pool of students to determine word prediction effectiveness. Also, it is important that the study be replicated with a wider range of students with physical disabilities. The students in this study did not have severe physical disabilities that greatly affected hand use. Studies with students requiring alternate access to the computer would be of benefit. Also, this study was unique in having the student prewrite their answers and then copy the answers either using word prediction or word processor. This was thought to better reflect typing speed by eliminating thinking time yet allow the student to make spelling errors which could be occur if the student was copying something prewritten by someone else. Further research into using this methodology is needed.

More research is also needed to further investigate the best ways to teach students to use word prediction. Tumlin and Heller (2004) examined the use of word prediction with more severely physically involved students. Word prediction benefited the most severely physically involved students who had very slow typing rates (i.e., 2.4 wpm, 4.7 wpm), but, unlike this study, the student with faster typing rates (14.6 wpm) did poorer with the use of word prediction. This may be due to differences in procedures in which Tumlin and Heller required the students to look at word list after each letter was typed, whereas the present study obligated them to look after the first letter and second letter (if needed). They had the option of looking at the word prediction list with subsequent letters. The list search time required with the search strategy used by Tumlin and Heller may have caused their faster typist to type slower when using word prediction. The impact on the type of search procedure used is hypothesized by Koester and Levine (1998) as a major factor on the effectiveness of word prediction. Further investigation is needed on the utility of a various word prediction search strategies with a range of students with physical disabilities.

Examination of the data from this study indicates that all three students did increase their typing rate during the six minute sessions, and two students were able to replicate this. After using word prediction, Tim (the slowest typist) reported that he felt using word prediction would help save him time, and the other two students reported that using word prediction would decrease their mistakes. Although further studies are needed, this study indicates that word prediction software may be a useful tool in assisting certain students with physical disabilities to increase their typing speed and decrease their spelling errors.

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