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The Effects of Word Completion and Word Prediction on Typing Rates Using On-screen Keyboards

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Abstract

Word prediction is often recommended by therapists as a means to improve typing speed for clients with physical limitations. While literature suggests that word prediction does have an effect on writing proficiency, increased speed is not one of it's benefits when used with a standard keyboard. One reason given for the failure of word prediction to accelerate typing is that the user must look

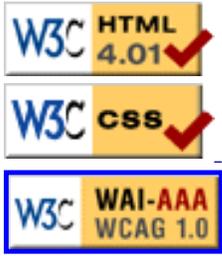
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• [Research in](#)

[Progress](#) The focus of this research was to determine whether word completion or word



prediction programs would increase typing speed when used with an input method (an on-screen keyboard) that also requires looking away from the source document. Ten people, five males and five females with ages ranging from 20 to 38 years old, participated in this study. The study used a single-subject, successive intervention design to test typing speed and accuracy using an on-screen keyboard with integrated word prediction software. Seven participants had their fastest typing speed with word prediction. Two participants had their fastest typing speed with word completion. Only one participant demonstrated no improvement in speed when using these two programs. Overall, these results show that the use of word prediction and word completion may assist on-screen keyboard users to improve typing speed.

Key Words: on-screen keyboard, word prediction, word completion, typing speed, assistive technology.

Literature Review

Occupational therapists may use meaningful activities as modalities to restore function and teach compensatory strategies, or may help clients achieve access to meaningful activities as a goal in itself. They may use an occupation as a therapeutic tool to achieve a secondary goal. "Occupation includes the day-to-day activities that enable people to sustain themselves, to contribute to the life of their family, and to participate in the broader society" (Crepeau, Cohn, & Schell, 2003, p.28) Furthermore, occupational therapy requires its practitioners to use enabling and meaningful activities to promote health. As stated by

Crepeau, Cohn, & Schell (2003), "The overarching goal of occupational therapy is to improve the health and quality of life of people through engagement in meaningful and important occupations" (p. 28).

In today's society, computers have revolutionized the way people access information; perform work and school assignments, and correspond with others. Computers have evolved from being novelties to a tool that is necessary to access the world around us (Anson, 1997). Since computers have become such a necessity to function in today's world, occupational therapists must consider the use of this tool as a meaningful activity for obtaining information, performing work and school tasks, and communicating with others. So pervasive has information seeking become that the search engine, Google, has entered the vocabulary as a verb (e.g. "Have you googled yourself?"), and is a primary means of gathering information on any subject for a large segment of the population. For a person with a disability, communication via the computer includes the typical application of communicating with individuals who are at a distance (i.e. through email) but may also include communicating with individuals in the immediate environment (i.e. augmentative communication). Furthermore, students at various levels in their education require the use of computers as a means to enhance their learning. "Brandon Hall estimates the e-learning sector will grow from \$10.3 billion in 2002 to \$83.1 billion in 2006, and eventually swelling to over \$212 billion by 2011. The trend is evidenced by an 80% growth by the University of Phoenix Online, whose virtual campuses boasted 72,230 students as of May 2003" (Greenspan, 2003). Lastly, in today's

competitive job market, computer familiarity and use is a skill that is highly encouraged by employers because their employees are required to rely more on technology to perform optimally. "Most U.S. workers feel at ease with technology, according to a new Society of Financial Service Professionals survey of 1,130 members. Using technology increases knowledge in the workplace, said 87% of participants, while 80% said technology develops job skills" (Kelsey, 2001).

An able-bodied person commonly accesses the computer through the keyboard and mouse. When a person acquires a disability (or is born with a disability), the keyboard and mouse may cease to be tools that promote access and become barriers to participation in computer based activities. The use of the keyboard and mouse maybe limited by restrictions in range of motion, decreased fine motor skills, or inability to coordinate movements across multiple joints.

Finding alternative means for people with physical disabilities to access a computer system is imperative in assisting them to obtain information, perform work and school tasks, and communicate with others. A broad range of computer access technologies are currently on the market (Anson, 1997).

Computer access technologies include input technologies, output technologies, and enhancement technologies. Input technologies are devices or programs that enhance the ability of the user to enter information into the computer. These include items such as expanded keyboards, mouse emulators, or on-screen keyboards. Output technologies allow the user to obtain information from the computer other than through the conventional display. Output technologies

include devices such as alternative sound systems, screen enlargers, and refreshable Braille. Finally, enhancement technologies are intended to compensate, at least in part, for lower performance of a person with physical or sensory limitations, and to improve productivity. Enhancement technologies include strategies such as macros, abbreviation expansion, and word prediction.

For individuals who have difficulty using a standard keyboard effectively, but who can use a standard mouse or mouse emulator with good facility, an on-screen keyboard is an access method that is easily learned, draws on prior experience to generate text on a computer, and allows reasonable levels of productivity. An on-screen keyboard is an image of a keyboard that is located on the screen of the computer. To type using an on-screen keyboard, the user positions the mouse pointer over the desired letter, and performs an action (generating a mouse click, performing a gesture, or simply waiting for a prescribed period of time), and the character is sent to the computer application being used. While an on-screen keyboard makes typing possible for the individual who can only move the mouse pointer, it does not allow a person to type at the same rate as an able-bodied person using the standard keyboard. Where the standard keyboard allows typing with all ten fingers, an on-screen keyboard only allows a single "digit" (the mouse pointer) to be used. As a result, an able-bodied person types significantly slower on an on-screen keyboard than with the standard keyboard. Since an individual with a disability may have decreased ability to move the mouse pointer, he or she may type even slower. To minimize the effect of single-digit typing and decreased motor control, some

means of accelerating typing is needed to improve the productivity of this input method.

One approach that may potentially improve typing speed for users of on-screen keyboards is to incorporate word completion or word prediction. Word completion and word prediction were originally developed for individuals with physical disabilities to decrease the number of keystrokes required to type words and sentences (MacArthur, 1996). Word completion provides the user with one or more predictive suggestions after the user has typed the initial letters of a word (Hunnicuttt & Carlberger, 2001). Word prediction is a feature of some word-completion programs that, after a selection has been made for the current word, attempts to predict the next word in the sentence.

Prior research indicates that using a word completion or word prediction program has some advantages for the user. Individuals who have low endurance could benefit from the reduction in keystrokes that word prediction and word completion can provide. Word prediction has been noted to reduce the number of keystrokes by up to half (Raskind & Higgins, 1998; Langer & Hickey, 1999; Klund & Novak, 1997). This reduction of keystrokes while using word prediction could allow the typist with limited endurance to accomplish more work with the limited energy available for task completion. People with poor keyboarding skills find typing with word prediction easier than keyboarding alone since a single difficult keystroke can replace many of equal difficulty (Raskind & Higgins, 1998).

In addition to keystroke savings, researchers have noted several other potential advantages to using word prediction. Word prediction programs can act as a compensatory spelling aid (Raskind & Higgins, 1998), cueing the typist that the initial letters of a word may be incorrect since the balance of the word has not appeared on the prediction list. Word prediction has also been shown to increase user attention span, improve self-esteem, increase ability to write independently, and improve language and vocabulary development (Klund & Novak, 1997). Although research indicates that keystroke reduction and other benefits occur when using word prediction, none of these studies suggest that this keystroke reduction increased typing speed when using a standard keyboard.

While word prediction has been shown to have advantages for some users, it can also make the composition process more complex, which may slow the typist. First, the word list may distract the user, as the ever changing presentation draws the attention away from the sentence being constructed. The cognitive process of selecting words from a prediction list may disrupt the creative process and interfere with the flow of composition, especially for people who have significant difficulty in word recognition (Raskind & Higgins, 1998; Anson, 1993; Gibler & Childress, 1982). Word prediction can provide too much of a good thing. Hunnicutt and Carberger (2001) state that, "As the number of predictions grow, the increase in keystroke savings diminish (i.e. the keystroke savings plateau)" (p. 263). As more predictions are listed, the user must inspect a longer word list and the chance of missing the desired word on the list

increases. Some users may only look at the predictions at the top of the list and ignore the words lower on the list.

According to Soede and Foulds (1996) word prediction is successful in reducing the motor load typing at the expense of increasing the cognitive and perceptual load on the user. Horstmann and Levine (1991) state, "Use of a word prediction feature requires additional cognitive and perceptual processes, and these are the major contributors to the increase in selection time" (p. 100). Visual search of the prediction list and the user's decision about whether the word is on the list are two of the processes researchers attributed to increased selection time (Anson, 1993; Gibler and Childress, 1982). Cognitive and perceptual loads imposed on the user are associated with a time cost that can offset and even overwhelm the keystroke savings provided by word prediction (Koester & Levine, 1996).

According to Tam, Reid, Naumann, and O'Keefe (2002) individuals with lower intelligence scores and low scores in memory and reading may have trouble keeping track of their place on the copy material. Anson (1993) found the participants who reported no impairment in intelligence and memory also had difficulty keeping track of their place on the source document. The participants in this study reported that, because they had to look up from the source copy to scan the word prediction list, they often lost their place. The time saved due to keystroke reductions was outweighed by the loss of time to search for their place. In fact, for seven out of ten participants in this study, word prediction reduced the typing speed in direct proportion to the number of times it was used

(Anson, 1993).

Since a person using an on-screen keyboard must already look away from the source document to generate text, the decrease in keystrokes afforded by word prediction may increase typing speed since the benefits of word prediction will be independent of having to look away from the source document. Preliminary data collected by Anson suggested that, for typists using on-screen keyboards, word completion might produce a performance gain (Anson, 1993).

The focus of this research is to determine whether word completion or word prediction programs will increase typing speed when used with an input method (on-screen keyboard) that also requires looking away from the source document. We hypothesize that the addition of word completion to an on-screen keyboard will enhance typing performance as compared with the use of an on-screen keyboard without word completion. Since word prediction requires even fewer keystrokes, we hypothesize that the addition of this feature will improve typing speeds over both the on-screen keyboard alone and the on-screen keyboard with word completion.

Methodology

Research Design

This study used a single-subject, successive intervention design to test typing speed and accuracy using an on-screen keyboard with integrated word prediction software. The goal of this study was to determine whether word

completion and word prediction helps or hinders the typing process when used in conjunction with the on-screen keyboard. To make this analysis, the participants were tested using each of the following options: on-screen keyboard only, on-screen keyboard with word completion, and on-screen keyboard with word prediction.

Participants

Ten able-bodied people, five males and five females, participated in this study. The participant's ages ranged from 20 to 38. Each of the participants had vision adequate to read a document printed in 12 point, Times New Roman font, was able to read and speak English fluently, and was able to sit unsupported for more than 30 minutes at a time in an armless chair.

Instrumentation

Equipment/Measurement tools. Each participant used a single computer for all typing trials. All text was entered into one of five Windows-based, standard laptop computers, with Windows XP operating systems, Pentium or higher processors operating at a minimum of 500 MHz. Each of the computers used in this study had at least 128 MB of RAM memory. All text was typed into Microsoft Word. During text entry, the laptop computers were set up with the keyboard covered to remove the temptation to use the physical keyboard for incidental action or data entry.

All text entry was performed using ScreenDoors 2000 [1](#) and a Microsoft

compatible mouse. ScreenDoors 2000 has a number of options for keyboard layouts . To standardize the size of the keyboard, the researchers created a paper template with a "window" 7 inches wide and 2.5 inches high. The on-screen keyboard was sized to just fill this window prior to each trial. The word-prediction tool bar was positioned horizontally at the top of the onscreen keyboard. (The word-prediction window was not included inside the template space.)

The on-screen keyboard was located on the bottom of the computer screen with the blank Microsoft Word document was located at the top of the screen. The window for Microsoft Word was sized so that no portion of it was covered by the on-screen keyboard, but with the document window as large as possible in the remaining area of the display.

Each researcher used a Radio Shack Rotary digital timer to time the 20-minute typing interval for each trial. The printed text was placed on a vertical document holder, which the subject was allowed to place on his or her preferred side of the computer screen.

Source Document . Participants were asked to type test segments from *A Case of Identity* , by Sir Arthur Conan Doyle . The researchers separated the source document into approximately 500 word chunks prior to beginning of data collection. (Each segment ended at the end of a paragraph that contained the 500 th word.) The entire novel was imported into Screendoors' dictionary in order to familiarize the system with commonly used words and word patterns of

the text. The documents were formatted to remove extraneous line breaks, and to be in Times Roman font, double-spaced. The participants were given segments of the novel in sequential order. The novel used only had thirteen segments. If a participant required more than thirteen segments to complete the research, the participant would return back to the first segment of text.

Operational Definitions

Accuracy: .The Compare Documents feature of Microsoft Word was used to analyze the differences between a typing trial compared to the original source document.

Error Count Errors could include deleted letters, letter reversals, deleted words, word reversals, or deletions of entire sentences. While a given difference identified by the Compare Documents feature might have included one or more of these individual errors, each identified "difference" between the documents was counted as a single error. While this may undercount individual differences, it did assure that agreement of count could be obtained. In the course of data analysis, it was discovered that the AutoFormat feature of Microsoft Word had changed some characters (e.g. double quote into "open-double-quote" and that some of the differences were in the number of spaces at the end of a sentence. Because these differences were not under the control of the participants, they were not included in the error count.

Percent Accuracy =

Plateau While continued exposure to any assistive technology over long periods of time will generally result in improved performance, a research study must control exposure to allow timely results. For the purposes of this study, a participant was considered to have reached a proficiency plateau when the number of words typed for three consecutive trials had an inter-trial difference of no more than 7%. Earlier studies have demonstrated that normal typing can show typing speed variations over 20 minutes of greater than 5% and that a 10% difference can be obtained while a participant continues to make substantial gains in performance. The 7% standard seems to balance the issues, and can be achieved when significant progress has slowed.

Words Per Minute (WPM): Words per minute was calculated using the formula:

WPM =

Setup

The environment for each trial was arranged the same. The individual was positioned 18 to 36 inches from the monitor screen to provide a neutral focus distance. The laptop computer was placed on a table and the participant was seated in an armless chair. A cover was positioned over keyboard of the laptop. The mouse and mouse-pad were positioned on the user's dominant side relative to the screen. The vertical document holder was placed on the participant's preferred side next to the monitor.

Procedures

Prior to the start of research trials, training took place to familiarize each person with the use of the on-screen keyboard, word completion, and word prediction software. A standard explanation of each feature was read by the researchers to the participants. Participants were asked to try each feature by typing one sentence from the consent form after each explanation was provided. After this initial training, participants began the trials. The order of precedence of each modality (on-screen keyboard, on-screen keyboard with word completion, and on-screen keyboard with word prediction) was balanced across subjects to control for possible order effects.

At each typing session, the participants were allowed to perform up to three 20-minute typing trials, with no more than two sessions per day, and a minimum of one hour for rest between sessions. This assured that fatigue would not be an issue in typing speed or accuracy. The participants repeated trials using each method for data entry until their scores reached a plateau.

At each trial, the participants were provided with the pre-selected text for reproduction using the on-screen keyboard with the appropriate enhancements. The researcher set the digital timer for twenty minutes and gave the participant the following instructions, "When I say go, I'd like you to type this document as quickly and accurately as you can. Are you ready? Go!" The researcher started the timer. After twenty-minutes, the researcher said "Stop." Any partial word at the end of the document was discarded and the document saved.

Data Analysis

Speed and accuracy of the completed text were analyzed using the word count and compare documents tools of Microsoft Word. After each session the participant's scores were plotted on a graph to determine whether or not a plateau in scores had been reached. For purposes of comparison across entry modalities, the scores of the three trials that establish plateau were averaged, and these averages compared within each subject. (Because this is a single-subject study, comparisons across subjects would not be valid.

Results

Participant Number	Words Per Minute			Percent Error		
	No Word Prediction	Word Completion	Word Prediction	No Word Prediction	Word Completion	Word Prediction
1	9.6	9.5	10.5	2.4	1.6	1.1
2	9.2	10.7	11.1	4.5	2.9	2.7
3	9.3	10.1	10.3	1.6	1.1	.8
4	8.9	9.3	9.0	.9	.5	1.3
5	12.0	10.5	10.7	.3	.5	.3
6	9.1	8.8	9.8	.6	.6	.7

7	9.3	9.7	10.1	1.1	1.9	1.5
8	11.9	12.5	11.0	1.4	.9	1.4
9	6.9	7.3	7.9	3.4	.7	1.5
10	6.8	9.5	9.9	.5	.7	1.7

As shown in Table 1, seven out of the ten participants had the highest typing speed for word prediction. Five out of these seven people had the second highest typing speed using word completion and the lowest speed while typing using no word prediction (See Table 1). Two out of the seven had the second highest typing speed using no word prediction and the slowest speed when using word completion (See Table 1).

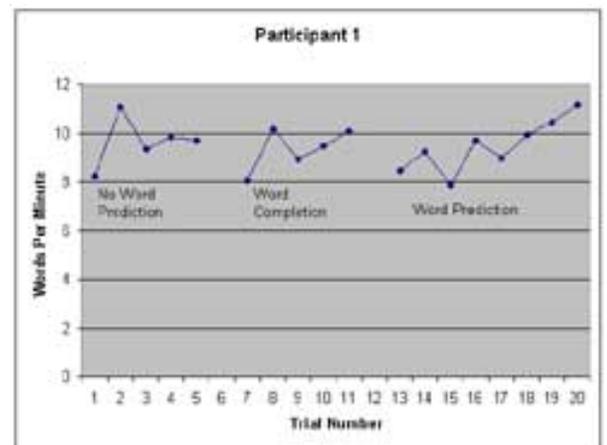


Figure 1. Typical user with best typing speed using word prediction (Click image for a larger view)

Word completion was, as predicted, also faster than the on-screen keyboard alone in seven out of the ten participants. Five of these participants had their highest speed with word prediction followed by word completion and no word prediction. Two participants had their fastest speed with word completion, followed by word prediction.

The typing of the participants was also examined for differences in error rate. All methods were found to be highly accurate, and no systematic differences in error rate were identified between the methods. It does appear that, for those individuals with high error rates without word prediction, that the use of word prediction and word completion reduced typing errors. This affect could be explained by the fact that the typists were hitting fewer keys themselves when using this technology, so had less opportunity to make errors.

The results of our study show that seven out of ten of the participants had the fastest typing speed when using word prediction software. In addition, seven out of the ten participants had faster speeds when using word completion than the on-screen keyboard alone. The seven people who typed the fastest using word prediction required 5 to 8 trials to plateau at 7%. In contrast, the three people who typed the fastest on word completion or no word prediction required only 3 to 6 trials to plateau at 7% with word prediction. It is possible that, given more practice, these individuals would have learned to use word prediction more efficiently, and shown additional improvement in typing speeds, however, our protocol did not allow for continued practice once the 7% proficiency standard was achieved.

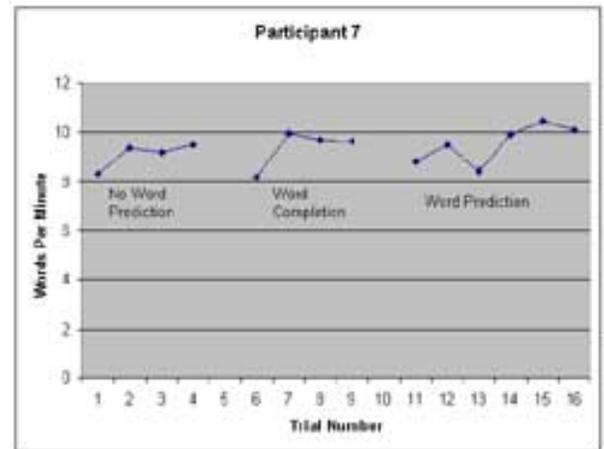


Figure 2. Data from a typical user.

(Click image for larger view)

Although the majority of the participants had the fastest speed using word prediction, most of these participants felt that using word prediction was the most frustrating of the three methods of access used in the research process. Nine out of the ten participants stated that they disliked looking away from the document to search the list because they lost their place on the copy. (Note that these were able-bodied typists, who may have been frustrated by using the on-screen keyboard and confused this with the word prediction process.) Eight out of the ten felt that searching through the word list was tedious and distracting. After all trials were completed, three out of the seven participants who had their fastest speed on word prediction felt that using word prediction was beneficial to increasing their typing speed.

Discussion

Historically, word prediction and word completion programs have been shown not to improve typing speed when used with a standard keyboard. This has

been attributed to the user looking away from the source copy to search the word prediction list. For individuals using an on-screen keyboard, looking away from the source copy is already required by the input method, and the addition of word prediction will not add this factor to the process of typing. It is therefore reasonable to assume that, when the input method inherently requires looking away from the source, the keystrokes savings of word prediction might result in improvements in typing speed.

In this study, most participants were able to type faster using word prediction as compared with both word completion and the on-screen keyboard alone.

Similarly, most typists were able to type faster using word completion than with the on-screen keyboard alone. Thus, the use of word completion and word prediction to improve productivity for the users of on-screen keyboard users is supported by this study.

A second source of delay for users of word prediction is considered to be the cognitive load afforded by the need to scan the word list and make selections from it. While this factor was not directly explored by this study, the supposition is supported. Most of those who were able to type fastest using word prediction also found it to be the most "frustrating" input method in this study. This frustration cannot have been due to the need to look away from the source copy, as all three input methods shared this demand. However, word prediction requires scanning the input list during the typing of a word and again after the selection of a word from the list. This increased need to scan the word list, and

its accompanying cognitive load, may have been the source of the reported frustration.

Given that word completion and word prediction can improve productivity, they are potentially valuable aids for the typist with a disability. However, they are also learned skills, and, without adequate support from the clinician, may be abandoned before the advantages become apparent. The majority of the participants felt that searching through the word list was tedious and distracting. Learning when and how often to scan the word list may minimize this distraction. When an individual is learning how to use the on-screen keyboard in conjunction with word prediction it is imperative that the individual goes through a training process to become proficient at using this program.

Conclusion

The focus of this research was to determine whether word completion or word prediction programs would increase typing speed when used with the on-screen keyboard. We first hypothesized that the addition of word completion to an on-screen keyboard would enhance typing performance as compared with the use of an on-screen keyboard without word completion. The results show that the addition of word completion to the on-screen keyboard increased typing speed for the majority of the participants in this study. Since word prediction requires even fewer keystrokes than word completion, we further hypothesized that the addition of this feature would improve typing speeds over both the on-screen keyboard alone and the on-screen keyboard with word completion. This

hypothesis was also substantiated since the majority of the participants in this study had their fastest typing speed using word prediction with the on-screen keyboard.

Historically, word prediction and word completion have not been found to increase typing speed when using a standard keyboard or other methods of input that do not require the individual to look away from the source document. This study differed from earlier work by combining word prediction and word completion with input methods that included the need to look away from a source document, so that this factor would be constant. This study demonstrated that these features could increase typing speed for individuals using such input methods but that the cognitive load of the tools continues to distract users.

In spite of the improved typing speeds achieved, many of the individuals in this study considered word prediction and word completion to be "frustrating." This frustration may stem from the cognitive demands of scanning the word list, or from the interruption in the flow of ideas when using word prediction. Further research should explore whether the frustration of using a word prediction program can be limited by different means of list presentation or through experience with the input method.

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