Can Automatic Abbreviation Expansion Improve the Text Entry Rates of Norwegian Text with Compound Words?

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ABSTRACT

Text entry can be challenging for users with reduced motor function. Prefix-based prediction has been successfully applied for text in English and other languages. However, prefix-based text prediction does not work optimally in Germanic languages such as Norwegian where long words are constructed through linguistic compounding. This study explored automatic abbreviation expansion as a means for improving text entry performance. A mixed text entry experiment involving n = 36 participants without reduced motor function was conducted. Three types of input devices designed for individuals with reduced motor function were used in the experiments, namely a virtual keyboard operated by a touchpad, a software head mouse, and keyboard scanning. Physical QWERTY keyboards were also included for reference. The results show that the abbreviation only lead to a marginal improvement with the slowest of the four input techniques, namely keyboard scanning. Abbreviations yield slower text entry performance with the other text entry modes.

CCS Concepts

• Human-centered computing~Accessibility technologies

Keywords

Text entry; abbreviation; reduced motor function; head mouse; scanning keyboard.

1. INTRODUCTION

Individuals with certain types reduced motor function may experience difficulties operating computers in the office, operating appliances in the home [31] and operating technologies in public spaces such as self-service kiosks [13]. Text entry is one of the most widely used modes of operating computers and the literature on text entry is vast [33, 34, 27]. Reduced motor function can take many forms including stiffness, tremor, slowness, missing body parts, paralysis, etc. A wide range of techniques has been proposed to facilitate the operation of computers for users with reduced motor function [40]. Examples include text input with pens [42], joysticks [38, 30], switches [25, 36], head mouse [3], eye-gaze [17, 21], eye-blink [18] and tapping [35]. Several innovative means of inputting text for individuals with reduced motor function has also been proposed such as chording [28, 32] where each finger of one hand is assigned a specific key and various key combinations are used to input text. Keyboard scanning [10] allows users to select the desired key once it is highlighted by an automatically moving cursor. Text prediction [7, 11] works by suggesting complete words before the entire word is completed. Ambiguous keyboards [19] allow the input of text with fewer keys than characters by assigning multiple characters to each key and using dictionaries to resolve the ambiguities. Text entry based on gestures can be beneficial for both certain types of reduced mobility and reduced vision as the user makes relative motions instead of hitting absolutely positioned targets [37, 5]. In some context, text input can be avoided altogether such as with QR-codes scanned with smartphones [16].

Input techniques are sometimes combined, for example can scanning keyboards and word prediction be applied together [15]. With such a combined approach, users produce the basic characters with the scanning keyboard, while in addition they utilize word prediction to quickly complete the input of words being suggested. As fewer steps are needed the text entry performance is improved. The scanning input technique and word prediction are independent of each other as scanning can be used without word prediction and word prediction can be performed with other input means such as physical QWERTY keyboards [2]. Other input techniques explored include control through uttered sounds [8], speech [1], phonemes instead of letters [39] and EEG signals [9].

Automatic abbreviation expansion has been proposed as a substitute for word prediction in languages characterized by compound words such as German and Norwegian [41, 24, 29]. The rationale is that prefix-based text prediction works better for languages with few compound words. Compound words are composed by two or more basic words and therefore can be quite long. For example, fylkestrafikksikkerhetsutvalgssekretariatsleder-funksjonene (chair of the secretariat of the county-committee for traffic-safety) is one of the longest Norwegian words. It has 58 characters and is composed from the seven words fylke (county), trafikk (traffic), sikkerhet (safety), utvalg (committee), secretariat (secretariat), leder (leader) and funksjonene (functions).

According to the Norwegian Language Council there are 300 000 words in the Norwegian language as listed in formal dictionaries. Most of these entries are compound words [23]. Typically, Norwegians tend to actively use between 5 000 and 6 000 words, and most native Norwegian speakers have knowledge of about 30 000 to 40 000 words.

For languages with compound words the tree of possibilities is too large to be presented on a single display given short prefixes. Often the user needs to enter long prefixes before accurate predictions can be made. The idea of abbreviation expansion is that the user will instead input certain characters throughout the word that sufficiently characterize the word. A practical abbreviation strategy is only to input consonants. For example, to input the word "consonants" the user simply enters "cnsnts" giving a saving of three characters. Clearly, abbreviations are not necessarily useful with shorter words, but become potentially more beneficial with longer words as more characters can be dropped, giving larger savings in input effort.

The documented research on automatic abbreviation expansion is scarce. This is probably because only a subset of languages combines words and most of the focus in the English research literature is indeed English-language computer systems. Consequently, there is a lack of empirical data. Another complicating factor could be the challenge of recruiting participants from the target group, which has been repeatedly commented on in the keyboard scanning literature [4, 10].

In one related study of prefix-based suggestions and corrections [26] it was found that users subjectively prefer to enter text although suggestions reduce the number of input steps. Moreover, the process of evaluating and selecting suggestion alternatives interferes with the text entry flow and may thus impair the performance.

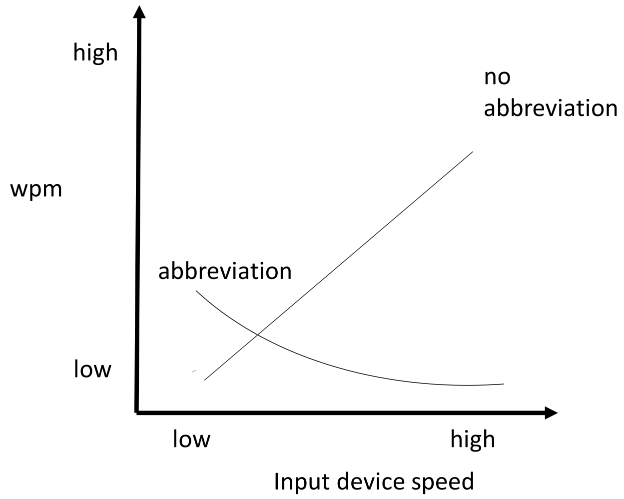

Figure 1. Expected results with abbreviation.

This study thus presents preliminary experimental results with abbreviation-based text entry conducted on participants without reduced motor function. Several input devices typically used by users with reduced motor function were explored. It was predicted that the benefit of automatic abbreviation expansion is more prevalent in situations where users need to either invest much physical effort or waiting time to enter text. If the input of text can proceed at a relatively rapid rate it was expected that the cognitive load required to abbreviate words is too high for automatic abbreviation expansion to be beneficial. Figure 1 illustrates the predicted effect of abbreviations as opposed to having no abbreviation. Clearly, the text entry performance measured in terms of words per minute (wpm) is linearly related to the speed of the input device. Hence, a fast input device such as a keyboard that affords direct keypresses is faster than keyboard scanning where the user must wait for the desired key to be highlighted. With input devices that allows high input speeds the abbreviations provide no gains, while the gain of abbreviations is predicted to be beneficial at certain point for devices with low input speeds (where the two curves cross).

2. METHOD

2.1 Experimental Design

The purpose of this experiment was to explore the effect of automatic abbreviation expansion on text entry performance. A mixed experimental design was conducted with one between-group factor and one within-group factor. Each participant was exposed to one of the input methods under both the abbreviation and no abbreviation conditions, namely the physical keyboard, touchpad, head mouse and the scanning keyboard. A mixed design was chosen instead of a within-group design as it was considered unrealistic to expose each participant to all four variations due to the amount of physical and mental effort involved.

Abbreviations versus no abbreviations was thus the first independent variable (within-groups). Input device was the second independent variable (between-groups) with four levels, namely a regular physical keyboard, pointing with the Microsoft On Screen (virtual) Keyboard (OSK) using a touchpad, pointing with OSK and a head mouse and OSK in scanning mode. The rationale for choosing these input devices was that they exhibit different levels of input speeds, where the keyboard is the fastest, followed by virtual keyboard, virtual keyboard in scanning mode and head mouse in scanning mode. Input productivity in terms of words per minute was the dependent variable. Although the observation of error is of key importance this preliminary study only focused on the text entry performance. The participants were asked to ignore errors and continue when they made incorrect selections.

2.2 Participants

A total of 36 participants comprising a mix of males and females in their twenties were recruited for the experiment. Most of the participants were students at the author's institution. No participants reported having any reduced motor function. All the participants were regular computer users, but none of them had any experience with scanning keyboards and automatic abbreviation expansion prior to the experiment.

2.3 Experimental Software Platform

A dynamic abbreviation expansion engine with a simple experimental test environment was implemented in Java. The user simply enters text or abbreviations in a text window. The system proposed suggested expansion as the user entered text.

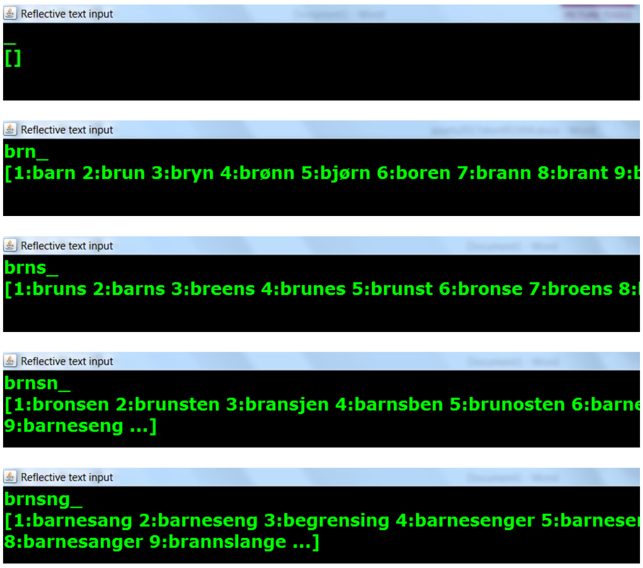

Figure 2. Entering the word barnesanger (children's songs) with the abbreviation brnsng.

Up to 9 abbreviations are suggested and the user selects an abbreviation by selecting the number associated with a given suggestion. The abbreviation expansion engine waits for three letter-keystrokes before attempting to find suggested words for the abbreviation. As additional characters are input the abbreviations become more focused. The system was thus used for both the abbreviation-based condition and the condition without abbreviations to maintain the experimental conditions fixed (with suggestions disabled).

Figure 2 shows how the word barnesanger (children's songs) is input using the software. First, the system displays a prompt and obviously no alternatives. The user must enter three characters brn before the system starts to display any alternatives. Once the user has entered the six characters brnsng the correct alternative is displayed. This word is selected by inputting the digit 8. Thus the 11-character word is input with a total of 7 characters.

Abbreviations are expanded by doing a brute force search on a full wordlist of Norwegian words with all grammatical forms (a total of 181 739 words). An algorithm for finding the least common subsequence [14] was used to match the text string against all the entries in the word list. All the words in the wordlist with matching subsequences to the input sequence are retrieved. The list of retrieved words is often quite large. Only nine words are displayed to exploit the availability of numeric keypads on physical and virtual keyboards. To select the most likely nine words to display from the list, the shortest words are chosen as well as those with matching prefixes. Hence, the system also benefits from prefix-based prediction in the cases where prefixes are applicable.

To speed up the processing separate wordlists were pre-generated for each word lengths. Only lists with words of the same length as the query string or longer are searched. Despite the exhaustive search it took usually less than a second to conduct the search using a laptop computer.

2.4 Experimental Setup

The experiments were performed using a Windows laptop computer with a regular QWERTY keyboard, a built-in webcam and a touchpad.

The default Windows OSK scanning setup was used where the entire keyboard is scanned in three phases. First, the rows on the keyboard are scanned from top to bottom. Next, groups of keys along each row are scanned. Finally, the keys within a group of (usually) three keys are scanned. Digits are thus accessible via the first row before the letters. Backspace is positioned after the digits in the last group. The digits are the most easily accessible with the fewest number of scanning steps. In total, three selections are needed to enter a character. The number of scanning steps depends on where the desired key is located on the keyboard. Generally, keys on the left towards the top require fewer scanning steps than the keys on the right side towards the bottom. Clearly, the total waiting time depends on the number of scanning steps. If the user misses a selection during the scan of one of these three phrases the scan rolls-around and starts from the beginning. If the user makes an incorrect selection of row or group, the user can wait for the scan to roll around twice and the current input process will timeout.

The default dwell time of 1 seconds was used. A dwell time of one second is relatively slow compared to what is reported for trained users. However, it was chosen as it was considered manageable by the participants who were unfamiliar with keyboard scanning.

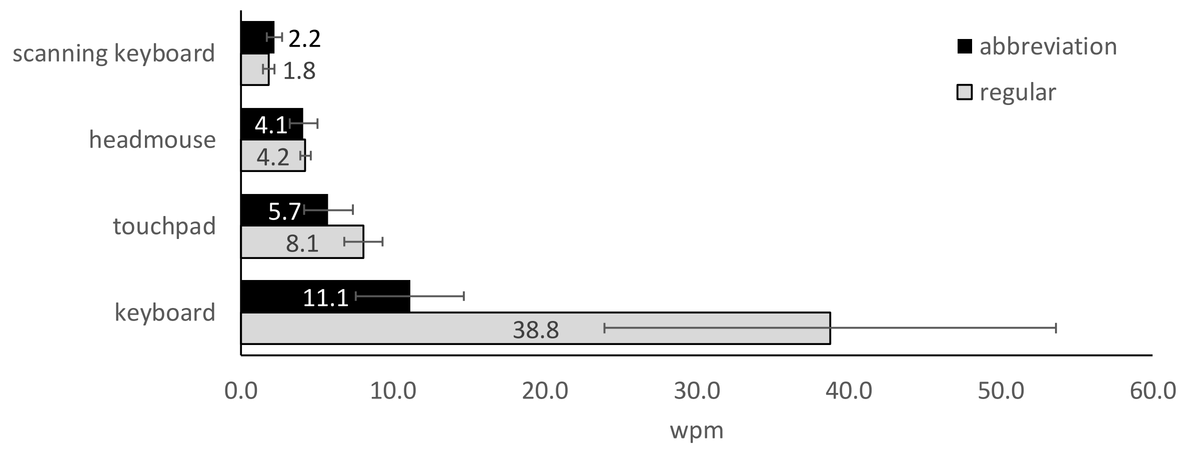

Figure 3. Effect of abbreviation expansion. Error bars show standard deviation.

The Windows On Screen Keyboard was used for both the virtual keyboard-pointing conditions with touchpad and head mouse. The Windows On Screen Keyboard was also used in scanning mode for the scanning input condition with the default setting of spacebar as a switch.

2.5 Materials

A head mouse was used for head tracking (http://www.cameramouse.org/). This program allows the mouse pointer to be moved using head movements captured by the laptop camera. Dwell times of 1 second and normal-radius settings were used to make selections.

The phrase sets used were designed with slightly different objectives than what is common in text entry research and it was therefore not possible to use MacKenzie and Soukoreff's de facto standard phrase sets [20]. Two conditions had to be satisfied. First, the phases had to be in Norwegian, and second, the phases had to contain well-known long compound words. Moreover, the text entry sessions were kept short to simplify the recruiting of participants. As the task was unusual and quite demanding it was expected that participants would have a low tolerance for long sessions.

Simple Norwegian phases were constructed ranging from 32 to 63 characters with some longer, yet well-known high-frequency words. All characters were lower-case and there were no punctuation symbols. Phrases were presented in random order.

2.6 Procedure

Each participant was given a few minutes to try the given text entry technique and abbreviation before the experiment started. The participants were asked to perform a text copy task where the text to be copied was printed on a piece of paper. The abbreviation/non-abbreviation conditions were randomized. The users were tested individually. The physical keyboard sessions lasted from 10 seconds to 1.1 minute, while the longer scanning keyboard sessions lasted from 4.4 minutes to 10.2 minutes.

Inspired by SOUNDEX, the old phonetic method for composing compact telegrams [6] the participants were suggested to use an abbreviation approach where one simply inputs the consonants in a word, excluding double consonants. This abbreviation approach was easy to explain. It was assumed that this approach also worked quite well since testing with this approach revealed a reduction of around 50% in input characters. Note that this abbreviation approach was only a non-mandatory suggestion. Statistical analyses were performed using JASP version 0.8.6.0.

3. RESULTS

Figure 3 summarizes the results. As expected, the most productive text entry in terms of wpm was achieved with the traditional QWERTY keyboard without abbreviation (M = 38.8, SD = 14.9). The traditional QWERTY keyboard was also associated with the largest spread in observation reflecting the participants varying QWERTY text entry performance and skill.

The four input techniques (between-subjects factor) were significant different ($F(3, 32) = 65.7$; $p < .001$) as well as the within-subject effect of abbreviations ($F(1, 32) = 33.5$; $p < .001$). There was also a significant interaction between the input type and abbreviation ($F(3, 32) = 27.7$; $p < .001$).

Exploring the abbreviation specifically for each of the four participant groups it was found that head mouse was the only input device with no significant difference between using abbreviations and no abbreviations ($t(8) = 0.364$, $p = .725$), namely ($M = 4.1$, $SD = 0.9$) with abbreviations and ($M = 4.2$, $SD = 0.3$) without abbreviations. The head mouse was about twice as slow to use compared to the touchpad.

For physical keyboards the abbreviations resulted in significantly slower text entry rates ($M = 11.14$, $SD = 3.5$) than no abbreviations ($t(8) = 5.44$, $p < .001$). In fact, the abbreviation technique slowed down participants as the input rate was about one quarter of the keyboard use without abbreviation.

A similar pattern was also observed for the touch pad where abbreviations lead to slower text entry rates ($M = 5.7$, $SD = 1.6$) compared to not using abbreviations ($M = 8.1$, $SD = 1.3$) and this difference was significant ($t(8) = 3.58$, $p = .007$). Clearly, abbreviations were not beneficial to the text entry performance. As expected, the touchpad-based pointing-based text entry yielded the second highest text entry performance, yet much lower than the physical keyboard.

A totally different pattern was observed for keyboard scanning where the abbreviations led to faster text entry rates ($M = 2.2$, $SD = 0.5$) than without abbreviation ($M = 1.8$, $SD = 0.4$) and the difference was statistically significant ($t(8) = 3.6$, $p = .007$). However, the effect size (a difference of just 0.4 wpm) is small and in practical terms this difference has little real significance. The scanning keyboard was the least productive of the four input devices explored herein with about only half the speed of the head mouse.

By analyzing the between-subject observations of different input devices with abbreviations ($F(3, 32) = 32.6$, $p < .001$), Tukey post-hoc tests confirmed that the results obtained with the keyboard were significantly different from those obtained with the three other devices ($p < .001$). Moreover, the touchpad was also significantly different from the scanning keyboard ($p = .004$) but not significantly different to the head mouse ($p = .33$). The observable difference between the head mouse and the scanning keyboard was also not statistically significant ($p = .203$).

The observations without abbreviations exhibited a similar pattern ($F(3, 32) = 47.9$, $p < .001$) where Tukey post hoc tests revealed that the physical keyboard was significantly different from the other input techniques ($p < .001$), while none of the other pairs were significantly different.

Generally, the results indicate that abbreviations are not beneficial. Signs of advantages with automatic abbreviation expansion is only visible for keyboard scanning which is the slowest of the input methods addressed herein. Still, this result is noteworthy as the experiment is conducted with only novice participants during a very short time interval showing that they can adapt to, and exploit, the abbreviation technique. It would therefore be relevant to explore the effect of abbreviation in a longitudinal study with longer sessions.

The variances of the three slowest techniques are much smaller than the variance for the physical keyboard. This is probably because none of the participants had any substantial practice using the virtual keyboards, head mouse and scanning keyboards.

Although not explicitly measured, it was observed that users tended to write out words in full rather than rely on suggestions. This observation agrees with the findings in previous work [12] where users preferred to enter text without suggestions as the evaluation and selection of suggestions impaired performance. It is likely that there is even a lower preference for abbreviation expansion than prefix expansion since it involves more mental work. In addition, abbreviation expansion is an unfamiliar concept compared to prefix expansion, which has become a commonly used input mechanism. Moreover, a prefix is a natural part of a word. Future work should explicitly measure the degree with which users rely on the abbreviations or write out words in full.

4. LIMITATIONS

The observations in this study is of participants without reduced motor function. The participants thus use the same software as would users with reduced motor function. Indeed, the motor function of the participants is not the same as the actual motor function of disabled users. The human motor system is complex with individual segments automatically counterbalancing adverse effects such as momentum and balance of actions performed by other segments, in this way the system as a whole can provide a particular level of performance. For disabled users such performance may be unachievable if these counterbalancing mechanisms are absent. For example, the users in this experiment would use the head-mouse quite different than users with reduced motor function. Moreover, the participants were all new to the keyboard scanning and head mouse input techniques and abbreviations, and it is unlikely that their performances are comparable to those of users with experience using such input techniques. Disabled users may be more experienced and trained using some of these input techniques such as head-mouse and keyboard scanning and hence experiments with such participants may lead to higher text entry observations than was observed herein. It is unlikely to be any users well-trained in using automatic abbreviation expansion as there are currently no such commercial technologies available. Therefore, to make any reliable conclusion about whether abbreviation-based text entry is beneficial a longitudinal study, such as [41, 22], on users with various forms of reduced motor function is needed. The results herein can thus only be viewed as preliminary indicators.

The prototype software presented up to nine suggestions during text entry justified from the easy access of 9 digits on numeric keypads. It is possible that fewer suggestions may have been less cognitively demanding to process, for example six suggestions which is common on smartphones and web-based search such as Google. Another problem could be that these suggestions were displayed horizontally along one or two lines of text. Instead, by presenting the suggestions vertically as for instance is done in the Google search interface it is possible that the suggestions would be easier to process and hence produce more favorable results. However, all the experimental conditions involving abbreviations were conducted using the same presentation and the results are all thus affected equally.

Another potential weakness of the experiment is that the phrases to be copied was presented on paper, hence shifting focus between the sheet of paper and the display. This approach was adopted for practical reasons of simplicity although it is common practice in text entry experiments to display the phrases to be copied directly in the experiment interface. As the text entry tasks with abbreviations and scanning are quite time-consuming it is unlikely that this have affected the results much since most of the time is spent waiting for scans. With more rapid text entry schemes the visual switching between paper and display may become more of a bottleneck.

Moreover, the text entry sessions were short. Future work should therefore focus on longer text entry sessions, preferably across multiple sessions. This will allow for more robust and reliable observations.

Another issue was that participants were given a hint on how to abbreviate. It would be interesting to explore the effect of not providing the participants with a set abbreviation method, but rather allow the participants to explore and find their own approach to abbreviations. However, there is also a chance that by not making the participants aware of the practical use of the abbreviation functionality the participants may not have used it.

The Windows OSK scanning keyboard was used herein as it was easily available. However, there are several obvious shortcomings with the design of the Windows OSK scanning mode such as three scan levels and long scans paths. Previous research on keyboard scanning often rely on only two scan levels and shorter scan paths [10]. With such designs, less effort is needed to input text. Future research should therefore employ special purpose third-party keyboard scanning software.

Finally, the cost of making errors can be high with certain scanning layouts as the user will have to retrieve backspace via the scanning keyboard. Future work should also investigate errors, both the quantity of errors and the nature of the errors. The abbreviation strategies employed by the users should be investigated in more detail and the learning of the best abbreviations for commonly used words over time should be catalogued.

5. CONCLUSIONS

Preliminary experimental data with abbreviation-based text entry was collected. Three text entry mechanisms typically used by users with reduced motor function were explored in conjunction with abbreviations. The results based on very short initial sessions show that the abbreviations are non-beneficial to users unless for the text entry method is highly time-consuming to use, such as with keyboard scanning. The OSK in scanning mode was used, and this implementation requires both visual attention, waiting and mental effort to use since the user needs to make three decisions per character. One explanation for these initial results is that the mental load involved in creating abbreviations is higher than the physical effort and skill involved in using regular keyboards. Further work involves exploring if abbreviation-based text entry would be less beneficial for more efficient scanning keyboards. Moreover, observations should be made of users with reduced motor function. It is relevant to explore how users would adapt to both abbreviation and scanning over time. Also, it would be valuable to measure how users with extensive experience using scanning keyboards would respond to abbreviations. One would expect that such users may experience text entry performance improvements. However, such users are very hard to locate and recruit. The issue of abbreviation errors also deserves attention, as it was not addressed herein.

Acknowledgements

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