The Effects of Word Prediction on Communication Rate for AAC

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Abstract

Individuals using an Augmentative and Alternative Communication (AAC) device communicate at less than 10% of the speed of "traditional" speech, creating a large communication gap. In this user study, we compare the communication rate of pseudo-impaired individuals using two different word prediction algorithms and a system without word prediction. Our results show that word prediction can increase AAC communication rate and that more accurate predictions significantly improve communication rate.

1 Introduction

Communication is a significant quality-of-life issue for individuals with severe speech impairments. The field of Augmentative and Alternative Communication (AAC) is concerned with mitigating communication barriers that would otherwise isolate individuals from society. Most high-tech AAC devices provide the user with an electronic letter and word board to input messages which are output via speech synthesis. However, even with substantial user interface optimization, communication rate is often less than 10 words per minute (Newell et al., 1998) as compared to about 150-200 words per minute for unimpaired speech.

One way to improve communication rate is to decrease the number of keys entered to form a message. Word prediction is an application of language modeling to allowing the user to access words they may be spelling at a cost of one keystroke. Many commercial AAC devices use word prediction, such as PRC's Pathfinder™, Dynavox Technology's Dynavox 4™, and Saltillo's ChatPC™.

Although word prediction is used in AAC devices, researchers have questioned whether it actually increases communication rate (Venkatagiri, 1993; Koester and Levine, 1997; Anson et al., 2004). These works note the additional cognitive demands and cost of using word prediction in conjunction with a letter-by-letter interface, such as the need to shift the focus of attention to the prediction list, the time to scan the prediction list, and the cognitive effort required for making decisions about the predicted words. Obviously the design of the particular interface (e.g., the ease of using word prediction) will affect these results. In addition, these studies used a single, simplistic method of generating predictions, and this may also be responsible for some of their results.

In contrast, other researchers (Lesher and Higginbotham, 2005; Li and Hirst, 2005; Trnka et al., 2006) have continued to investigate various improvements to language modeling for word prediction in order to save the user more keystrokes. Newer methods such as topic modeling yield statistically significant keystroke savings over previous methods. However, the question remains as to whether improvements in prediction methods translate to an enhanced communication rate. We hypothesize that it will.

In this paper we study (1) whether a word prediction interface increases communication rate over

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letter-by-letter typing when a reasonable prediction method is employed and (2) whether an advanced word prediction method increases communication rate over a basic word prediction method to a degree greater than that afforded by the difference in theoretical keystroke savings between the two methods. We expect that the communication rate gain due to the better word prediction method will exceed the gains from the poorer system. Our reasons for this expectation has to do with not only users wasting time scanning lists that do not contain the desired word, but also the tendency for a user to give up on such a system (i.e., choosing to ignore the predictions) and thus missing the predicted word even if it does appear in the list. Validating these hypotheses will motivate continued improvements in word prediction methods for increased communication rate.

The target population of our research is adult AAC users without significant cognitive impairments. Including actual AAC users in the study poses several significant complications, perhaps the largest of which concerns the user interface. AAC devices vary significantly in the physical interfaces available, in accordance with the variety of physical abilities of AAC users. This diversity has caused different word prediction interfaces to be developed for each physical interface. Moreover, it would be impossible to mimic our word prediction layout in a consistent fashion on all of the major AAC devices used. Because of this, we conducted this pilot study using subjects that are pseudo-impaired: the subjects have no motor impairments but we have simulated a motor impairment by providing an interface that emulates the communication rate of a typical AAC user. Future work includes the verification of the results using a smaller number of actual AAC users.

2 Approach

The purpose of the study was to measure the effects of word prediction methods on communication rate. To this end, the interface used for text entry was optimized for ease-of-use and kept constant across trials. Subjects were asked to enter text on a touchscreen monitor using Wivik^{TM}, an on-screen keyboard. Because we wanted to simulate AAC users with motor impairments, we programmed a 1.5 second delay between a key press and its registration in the system. The artificial impairment gave the subjects the same incentive to use word prediction that AAC users face every day, whereas users with fine motor control tend to ignore word prediction (e.g., in common word processing software). The delay slows the input rate of our subjects down to a rate more typical of AAC users (about 8-10 words per minute).

Seventeen adult, native speakers of English with no visual, cognitive, or motor impairments participated in the study. These subjects were asked to type in three different excerpts from held-out data of the Switchboard corpus on three different days.[1] In each of these sessions, a different prediction method was used and the order of prediction methods was randomized across subjects. Keystrokes and predictions were logged and then post-processed to compute the words produced per minute, seconds per keystroke, and keystroke savings, among other statistics.

2.1 Independent variable: prediction methods

The independent variable in our study is the method of text entry used: (1) letter-by-letter typing using the Wivik keyboard with *no word prediction*, (2) letter-by-letter typing augmented with word predictions produced by a *basic prediction method*, (3) letter-by-letter typing augmented with word predictions produced by an *advanced prediction method*.

Basic prediction generates predictions from the combination of a recency model of the text entered so far in conjunction with a large word list. The recency model is given priority in generating predictions. This model is similar to language models used in AAC devices with the exception that many devices use a unigram model in lieu of a word list.

Advanced prediction generates predictions on the basis of a trigram model with backoff. A special unigram model is used for the first word in each sentence. This language model is constructed from the transcribed telephone conversations of the Switchboard corpus. If the prediction list isn't filled from this model's predictions, then predictions are selected from a recency model and then a word list, as in the basic prediction method.

[1] Switchboard was chosen because our prediction models were trained using another portion of the corpus. A copy task was chosen for more controlled experimental conditions.

	Adv. prediction	Basic prediction	No prediction
Words per minute (wpm)	8.09	5.50	5.06
Time (seconds)	1316s	1808s	2030s
Seconds per keystroke (spk)	2.92s	2.58s	2.28s
Keystroke savings (ks)	50.3%	18.2%	-
Potential keystroke savings (pks)	55.2%	25.0%	-
Prediction utilization (pru)	90.9%	73.3%	-

Figure 1: Average statistics for each method.

3 Results

Once the data was collected, we post-processed the logs and accumulated statistics. Average values for each method are shown in Figure 1 and comparative values are shown in Figure 2.

3.1 Communication rate (output rate)

The overall average words per minute and task completion time for each method is shown in Figure 1, and Figure 2 shows comparative data for the three methods. As hypothesized, advanced prediction was found to be significantly faster than basic prediction and basic prediction was found to be significantly faster than no prediction ($\alpha = 0.01$). For example, users produced 59.9% more words per minute using advanced prediction compared to no prediction. Advanced prediction was 44.4% faster than basic prediction but basic prediction was only 10.1% faster than no prediction.

Additionally, the relative task completion time is shown in Figure 2. The copy tasks with advanced prediction were completed in 64.5% of the time it took to complete without word prediction. The trend shown with relative task completion time reinforces the trends shown with words per minute – advanced prediction offers a large speedup over no prediction and basic prediction, but basic prediction offers a much smaller increase over no prediction.

Our results show that basic word prediction significantly boosts communication rate and that advanced word prediction substantially increases communication rate beyond basic prediction.

3.2 Input rate (seconds per keystroke)

Figures 1 and 2 indicate that there were significant differences (at $\alpha = 0.01$) in the methods in terms of the rate at which keys were pressed. In particular, while overall communication rate was significantly faster with advanced prediction, users took 0.641 seconds longer for each key press from using advanced prediction compared to entry without prediction. Similarly, users spent 0.345s longer to enter each key using advanced as opposed to basic prediction and basic prediction required more time per keystroke than no prediction. The slower input rate can be attributed to the additional demands of searching through a prediction list and making a decision about selecting a word from that list over continuing to type letters.

3.3 Keystroke savings / prediction utilization

The difference between the potential keystroke savings offered by advanced and basic prediction is substantial: 55.2% vs. 25.0%, as shown in Figure 1. Accordingly, the actual keystroke savings that users realized under each prediction method shows a wide separation: 50.3% for advanced and 18.2% for basic. The keystroke savings that users of basic prediction achieved seems quite a bit lower than the potential keystroke savings offered by the predictions. In other words, the prediction utilization of basic prediction was much lower than that of advanced prediction. Comparative analysis shows a 17.1% improvement in prediction utilization from advanced over basic prediction.

4 Discussion

The results show that communication rate increased despite the decreased input rate due to a large reduction in the amount of input required (high keystroke savings). In the past, researchers have noted that the cognitive load of using word prediction was considerable, so that the keystroke savings of word pre-

	Adv. over None	Adv. over Basic	Basic over None
Relative task completion time	0.645[1]	0.701[1]	0.919[1]
Words per minute (wpm)	59.9% faster[2]	44.4% faster[2]	10.1% faster[2]
Seconds per keystroke (spk)	0.641s[2]	0.345s[2]	0.286s[2]
Prediction utilization (pru)		17.1%[2]	

Figure 2: Average per-subject improvements. ([1] Significance not tested. [2] Significant at $\alpha = 0.01$.)

diction was outweighed by the overhead of using it. However, we have shown that despite significant cognitive load, the reduction in keystroke savings dominates the effect on output rate.

In contrast to earlier studies, our basic method showed a significantly improved communication rate over no prediction. One reason for this could be the intuitiveness of our user interface. A second reason could be related to the consistency of the basic prediction method. In particular, at least some subjects using the basic prediction method learned to scan the prediction list when the desired word was recently used and mentioned it in the exit survey. At other times they simply ignored the prediction list and proceeded with letter-by-letter typing. This behavior would also explain why the input was significantly slower with the advanced method over the basic method – users found that scanning the prediction list more often was worth the added effort. This also explains the significant difference in prediction utilization between the methods.

The relationship between keystroke savings and communication rate is a trend of increasing rate enhancement with increasingly accurate prediction methods. Improved prediction methods offer greater potential keystroke savings to users and users see increased keystroke savings in practice. Additionally, users rely on better predictions more and thus lose less of the potential keystroke savings offered by the method. We expect that keystroke savings will see substantial increases from improved potential keystroke savings until prediction utilization is closer to 100%.

5 Conclusions

Word prediction in an experimental AAC device with simulated AAC users significantly enhances communication rate. The difference between an advanced and basic prediction method demonstrates that further improvements in language modeling for word prediction are likely to appreciably increase communication rate. Therefore, further research in improving word prediction is likely to have an important impact on quality-of-life for AAC users. We plan to improve word prediction and validate these results using AAC users as future work.

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