Facilitating Gaze Interaction Using the Gap and Overlap Effects

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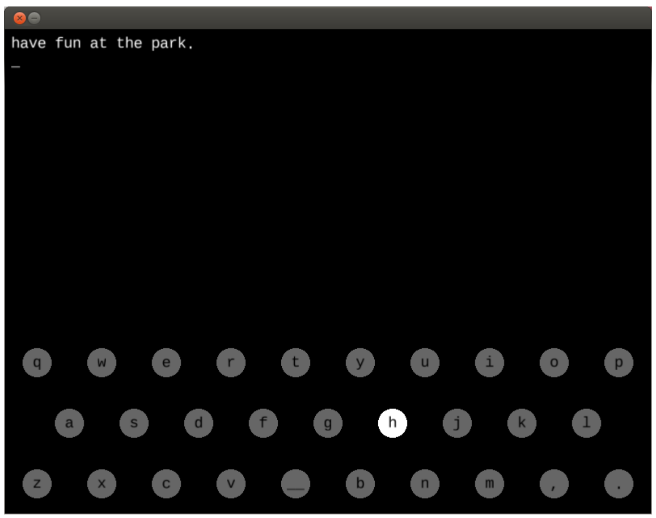

Figure 1: Virtual keyboard used in the experiment. The background has zero brightness, the keys' background have brightness 50%, and highlighted keys have brightness 100%.

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Abstract
Many results from psychophysics have indicated that the latency of saccadic eye movements is affected by how new visual stimuli is presented. In this paper we show how two such results, known as the gap effect (GE) and overlap condition (OC), can be used to improve gaze interaction. We have chosen a dwell time based eye typing application, since eye typing can be easily modeled as a sequence of eye movements from one key to the next. By modeling how dwell time selection is performed, we show how the GE and OC can be used to generate visual feedback that facilitates the eye movement to the next key. A pilot experiment was conducted in which participants had to type short phrases on a virtual keyboard using 2 different visual feedback methods, one traditional feedback based on animation and a new feedback scheme using the GE and OC. Results show that using a feedback that exploits these phenomena facilitates eye movements and can improve eye typing user experience and performance.

Author Keywords
Gap effect; overlap condition; eye typing; gaze interaction

ACM Classification Keywords
H.5.2. [User Interfaces]: Theory and methods—gaze interfaces, feedback; H.1.2. [Models and Principles]: Human factors—gap and overlap effects

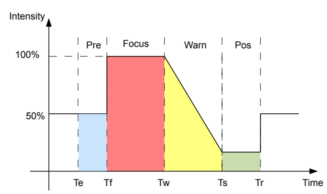

Figure 2: Visual feedback elements for dwell time gaze interaction.

Introduction

One of the main issues for gaze interaction is how to handle the Midas touch [4] problem that occurs when gaze is used for both pointing and selection. The most common solution is **dwell time**, where a selection is performed after the gaze fixates a target for a given period of time. Other competing solutions are eye blinks [1] and gaze gestures, that can be either discrete [3] or continuous [12]. When the user is not restricted to her gaze, other selection mechanisms can be applied, such as mechanical switches or keys and keyboards [11].

Though eye movements and perception have been long studied in psychophysics, this knowledge has been mostly ignored in the design of gaze based applications, as most of the literature only considers fixations and saccades. In this paper we show an example of how such knowledge can be applied to facilitate eye movements and, as a result, we expect to create a more fluid interaction, with benefits to speed, accuracy, and comfort, enhancing the whole user experience.

In the following sections we show how the gap effect (GE) and overlapping condition (OC) can be exploited to create a new feedback scheme for dwell time selection. A pilot experiment was designed to indicate the benefits of this new feedback scheme. A simple eye typing task was selected since it can be modeled as a sequence of key selections, which are easily mapped to eye movements. The experiment compares the performance of a traditional dwell time feedback using animation of the focused key with the new feedback scheme. In the next section the GE and OC are further explained.

Gap Effect and Overlap Condition

The gap effect consists of a reduction in the mean saccadic latency when the visual stimulus (called T for current target) at the current fixation point is removed before the presentation of a second stimulus (called N for next target) at a different location. Typically the gap between the presentation of N after the offset of T is about 200 ms [9]. When T is maintained after N is presented, the mean latency increases. This opposite effect is known as overlap condition.

One theory that might explain the gap-overlap effect (GOE) is that the disappearance of T helps the person to disengage her attention, so that the eyes can move faster to N once it is presented (the gap effect), and it is harder to move the eyes if T is maintained (the overlap condition). In this paper we will simply call these phenomena the gap and overlap effects.

Visual Feedback Using GOE

To exploit the GOE we first model the dwell time into 3 time slots, as shown in Figure 2, plus a 4th time slot corresponding to the post-selection period. We consider dwell time to be the sum of three feedback intervals: pre-focus, focus, and warning, i.e., $T_s - T_e$, that correspond to the actual time the gaze has to lie on a key before it is selected.

Eye contact occurs at T_e but no visual feedback is given until T_f (focused time) to filter eye tracker noisy measurements and avoid blinking keys (keys that receive focus for a very short time) during a saccade. After T_w a warning feedback is started to indicate that the key will soon be selected. A key is selected when the user fixates it until T_s. The system can give the user a post-selection feedback that lasts at least until T_r. This feedback can be

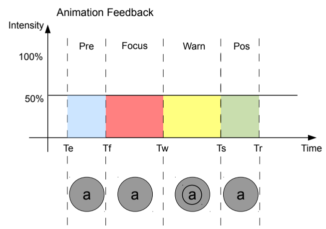

Figure 3: Visual feedback for the animation technique.

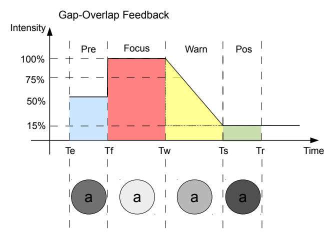

Figure 4: Visual feedback for the gap-overlap technique. The key is highlighted during focus, and its brightness is reduced for the warning feedback (shown at 75%), until it reaches 15% brightness. It remains at 15% after selection, until the key looses eye contact.

visual, or audible such as a clicking sound, or a combination of both [7].

The basic idea to use the warning feedback to create the GE is as follows: the key is initially highlighted for focus feedback and then its brightness is reduced until it practically disappears. The OC is used to keep the key dimmed (instead of returning it to its normal brightness) during post-selection so the eye can move away "with less friction" to the next key.

Eye Typing User Experiment

To show how evidence from research in psychophysics can help in the development of gaze based interfaces we have implemented a simple gaze controlled virtual keyboard that uses dwell time for key selection.

The keyboard, shown in Figure 1, uses a QWERTY layout. The area above the keyboard is used to display messages and the eye typed text. Because eye movement responses can be affected by color combinations, only gray levels were used to draw the whole interface.

One important feature of gaze interaction using dwell time is how to give the user a warning feedback about the time left before a key is selected. For example, animation of the character is commonly used. A shrinking effect can be animated, so when the character reaches a very small size the selection is about to occur [7].

The objective of the pilot user experiment is to compare the performance of two visual feedback techniques: a typical animation and the gap-overlap effect (GOE). The animation feedback used in the experiment is shown in Figure 3. A shrinking disk is drawn during the warning, similar to the shrinking box in ERICA [5]. There is no visual feedback during focus, and selection occurs when the disk disappears. Figure 4 illustrates the second technique, that exploits the GOE. A typicall dwell time of 500 ms [7] was used in the experiment, composed of 50 ms of pre-focus, 200 ms of focus and 250 ms of warning feedback. The key remained at its post-selection state for as long as the eye kept contact with the key. A very short audible "click" was used to indicate key selection in combination with both techniques, as suggested in [7], to make the moment of selection distinct and clear.

Experimental Design

A within-subject design was used, where each subject typed several small and easy to memorize sentences in their native language using each technique.

Different than previous typical eye typing user studies that use similar setups [7, 6], we use guided typing that highlights the next key to be typed. By using guided typing, the user just needs to follow the highlighted key with her gaze, reducing the cognitive load of the typing task (memorization), and leveling all users to "expert" typists. By reducing the expertise and cognitive load requirements, the effects of eye movement behavior should become more noticeable.

The performance of each technique is measured by typing speed and error rate. Typing speed is measured in words per minute (wpm), where a word is any sequence of 5 characters, including spaces.

Because we want to determine if the GOE can facilitate eye movements from key to key, we are not interested in the accuracy itself. Therefore, users were told to ignore any error and to keep following the highlighted key. We compute the error rate using the minimum string distance method [10], as a measure of difficulty of the task. The error rate was also used to filter out outliers, in general caused by noisy data from the eye tracker.

Setup and experimental procedure
A RED 500 eye tracker from SensoMotoric Instruments was used in the experiment. The RED 500 transmitted the gaze estimates at 500 Hz to the computer running the keyboard experiment using a dedicated socket connection.

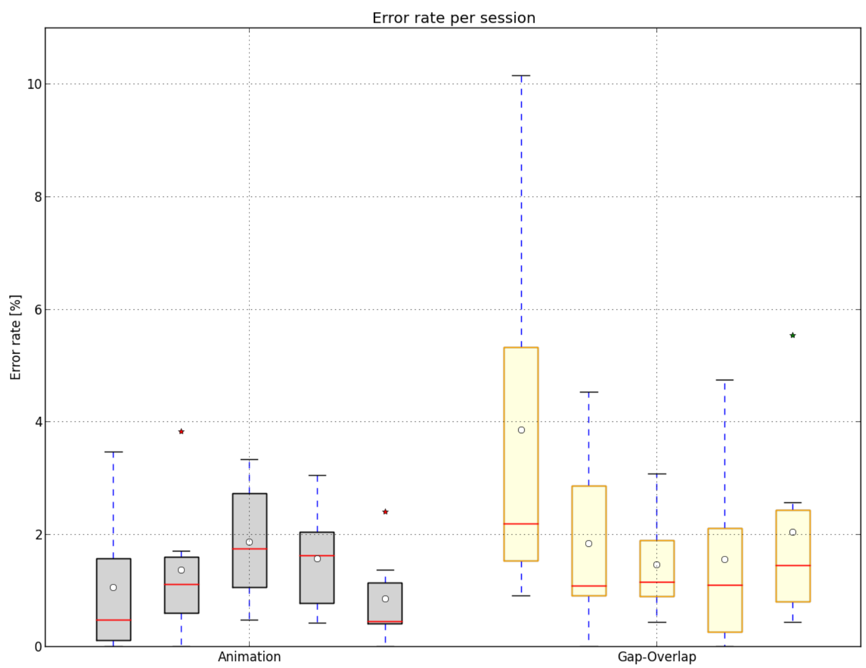

Figure 5: Error rate per session.

A total of 8 volunteers participated in the experiment (one female). Their ages range from 22 to 45 years old (average 28 years old). Though the RED 500 allows for some head motion, participants used a chin rest to help maintaining a good calibration during their sessions. The 22" monitor displaying a keyboard with width of 12 degrees of visual angle was placed about 60 cm from the participant.

The experiment constituted of 5 sessions. In each session, a volunteer typed short sentences using each feedback method. Volunteers were allowed to take short breaks between sentences and had to physically press the space bar on the experiment computer keyboard to display the next sentence. A session ended after 200 s of actual eye typing. Longer breaks were taken during the switch between methods and between sessions. The order of the methods in each session was balanced by a Latin square pattern.

After a volunteer was explained about the experiment and signed the informed consent form, he was allowed about 60 s of typing using each technique for practice before the first session. Volunteers were asked to be as fast and accurate as possible. After the completion of the experiment, each participant responded a short questionnaire about the perceived speed, ease of use, and comfort of each method.

Results
Two of the participants had considerable problems using the eye tracker, so their data was discarded before further analysis. Therefore, Figure 5 and 6 show the results of the remaining 6 volunteers.

Figure 5 shows the boxplot of the user error rate per session for the 2 feedback methods. Each column corresponds to the error rate per session, and shows the minimum and maximum error rates as the extremes of the dotted line, the 2nd and 3rd quantiles as the shaded box, the median as the red horizontal bar, and the white circle ('o') corresponds to the mean error rate of the sample. Outliers are shown as '*'. For both methods the error rate was quite low, under 2% in almost all sessions. A pairwise t-test for each participant over all sessions found no significant difference between error rates; $t(5)=0.898$, $p=0.41$, Cohen's $d=0.4$. Hence the two techniques had similar error rate performance.

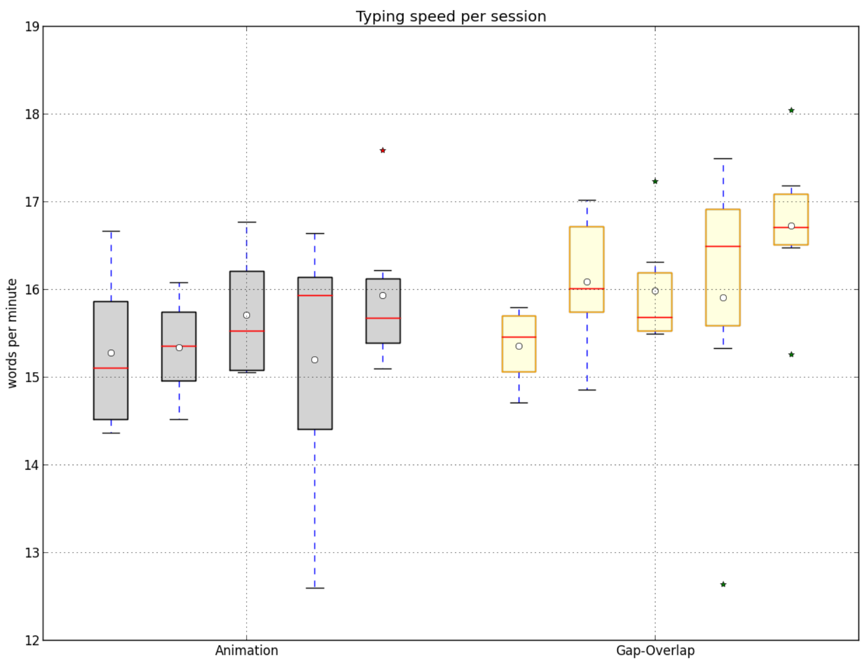

Figure 6: Typing speed per session.

Figure 6 shows the boxplot of the typing speed (in wpm) per session achieved by the volunteers using the 2 feedback methods. Each column shows the distributions of the typing speed in each session, similar to the error plots. There seems to be a learning effect for both methods, indicated by the increase of the median value.

A pairwise t-test for each participant over all sessions found that GOE ($M=16.01$, $SD=1.03$) was significantly faster than animation ($M=15.49$, $SD=0.96$); $t(5)=4.345$, $p=0.0074$, Cohen's $d=1.943$. These results suggest that GOE outperforms animation typing speed.

Qualitative results show that 5 out of 6 participants found the GOE feedback to be easier and more comfortable to use. From the 6 participants 3 perceived the GOE as the fastest feedback technique, 1 perceived animation as the fastest one and 2 did not notice any speed differences. One participant said that he "had the feeling that it (GOE) needed less effort, and it was easier for the eye to follow to the next key".

Discussions and Conclusion

This paper shows preliminary results that demonstrate how psychophysics can be exploited to improve gaze interaction. Using a dwell time based eye typing task, we describe how the GE and OC can be used to provide visual feedback that facilitates gaze interaction.

For the pilot experiment we have implemented a simple dwell time virtual keyboard with configurable pre-focus, focus, warning, and post-selection feedbacks, and tested another method to compare its performance against the GOE technique. The method for comparison uses animation (a simple shrinking disk) for the warning feedback.

As a result of the facilitation on gaze interaction the experiment shows an improvement in typing speed. But more relevant were the results of the questionnaires that show that most participants found GOE easier and more comfortable to use.

The facilitation of eye movements remains even when the user is not typing at full speed. It occurs because GOE disengagement mechanism also works for voluntary saccades and is largely independent of higher level cognitive processes [2]. Moreover the GE is still present when using complex stimulus [8] in multi-object environments, such as GUIs.

In future work we will further explore the impacts of the GOE in gaze interaction, applying the principle to paradigms other than dwell time, and applications other than eye typing. Also we will investigate other findings from psychophysics on natural eye movement behavior to further enhance gaze interaction.

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