論 文 内 容 の 要 旨

Text input on mobile devices is getting prevalent. Users of different levels of ability and expertise are starting to learn and use the soft keyboard. However, comparing with typing on a physical keyboard, users face more challenges on mobile devices in the perspective of eye and finger control. First, compared with physical keyboards, soft keyboards on mobile interfaces are generally smaller and built without any tactile feedback. Those features make users rely more on the visual guidance while moving their fingers towards key buttons. Adding that proofreading on the text input area is also required, attention shifts happen more frequently across the text input area and the keyboard, which takes time and cognitive resource. Second, as the keys are mostly smaller than fingertips, users are likely to commit more errors due to occlusion problems. Third, users have to adapt their operations to the constrains of mobile devices, and press keys with only one or two fingers on the touchscreen. Those constrains prevented smartphone typists from using the 10-finger touch-typing technique, which is a standardized way of typing on a physical keyboard. In order to achieve a relatively faster typing speed on mobile devices, users have to develop their own typing strategies. During the development of typing skills, users learn how to control their eye and finger movement to adapt to the constrains from the task and device.

Existing text input designs in mobile interfaces are mostly based on the qwerty layout from physical keyboards and design guidelines from studies of key-pressing logs and touchpoint distributions. However, it is still not clear how the touchpoints were made and how users managed to adapt to the mobile typing environment, specifically 1) how attention resource is allocated between tasks like key-searching and proofreading, 2) how fingers are guided to press the target keys with different level of typing proficiency, 3) how errors are made and corrected, and 4) how does the eye and finger behavior change from being novice to expert. Answering those questions can help us re-think about the current typing strategies and keyboard designs, and finally provide more in-depth guidelines for learning and designing text input. In order to understand the typing behavior in mobile interfaces, we conducted four studies, starting from basic pointing task to the learning process and expert typing performance, to gradually unveil the inner mechanism of the attention and movement control in typing.

As typing is composed of sequences of pointing operations, we first conducted a study on a pointing task on the smartphone, and summarized eye and finger movement patterns. The results confirmed that, finger pointing movement on mobile devices were guided by gaze, which moved in four patterns: 1) Finger following, 2) Finger guiding, 3) Locate and leave, and 4) Finger guidance with peripheral vision. These behaviors vary across different users. Findings of this study provided a basic understanding of the eye-hand coordination mechanism on mobile devices.

In the second study, we looked into the typing behavior through a transcription task on the smartphone, and captured finger and gaze movement in both two-thumb typing and index-finger typing conditions. We analyzed the typing behavior using both the basic matrixes (e.g. typing speed and error rate) and detailed measurements based on gaze and finger tracking data. Results showed that adaptive attention sharing strategies play a significant role in typing. Even though mobile devices are relatively small, one cannot monitor the keyboard and the text display at the same time. A strategy must be selected that determines which to give attention and when. Another aspect is about speed-accuracy tradeoff. Users have to decide a strategy which strikes a compromise between the cost of not correcting errors early and the time lost in glancing at the text display, when the fingers cannot be guided. The findings once again confirmed the importance of understanding the eye and finger movement for typing tasks. We summarized the characteristics of relatively faster typists, and compared them with those who are slow in typing. This study not only indicated how a faster typing speed can be achieved, but also supported further modeling and perdition of gaze and finger movement under different constrains of keyboard design by revealing the inner mechanism of attention sharing and movement control.

Understanding how user behavior differs from novice to skilled helps us find out the underlying learning mechanism and provide insight of how the typing performance can be improved. As it is hard to find users who are absolutely new to typing, in the third study, we controlled the level of typing proficiency by setting different levels of keyboard layout randomization. We captured the typing behavior under three conditions: static randomized keyboard and dynamically randomized keyboard, and compared those behaviors with the data captured on the qwerty layout in study 2. The qwerty layout refers to a standard qwerty layout on the mobile device. The static randomized keyboard refers to a keyboard with randomized letter keys. The keys were randomized once per participant. The dynamically randomized keyboard refers to a keyboard with randomized letter keys, which were re-randomized once the participant clicked on the keyboard. By controlling the keyboard randomization, we defined novice typist as someone who has no knowledge of where the keys are, intermediate typist as someone who has had some exposure to the layout, and skilled typist as someone who has had enough typing experience with the layout. Findings not only revealed the difference of behaviors between novice and skilled typist, but also showed the adaption of eye and finger movement throughout the learning process.

Despite the constraints we discussed about typing on a mobile device, there are still users who type twice as fast as average users, reaching an average typing speed of 80 WPM. In the fourth study, we invited fast typists selected from a web-based typing test and studied their typing strategies. In order to capture the natural typing behavior, we developed a web-based experiment application, and asked the participant do the transcription task on their own mobile devices. The findings of this study showed that fast typists focused on the text input area most of the time, which challenged the original understanding of how people type on mobile devices. Compared with touch typists on a physical keyboard who were trained to type with 10 fingers and focus on the monitor, the fast typist on mobile devices could also adapt their behavior to the constrains of the soft keyboard and apply a similar strategy. Thus, this raise a discussion of how the typing strategies could be shared among different devices and environments.

In summary, this dissertation looks into the typing behavior from the perspective of eye and finger movement, which revealed the overlooked details of typing on mobile devices. The contribution can be summarized as follows: 1) in-depth findings on eye and finger movement control during typing on mobile devices, which to our knowledge, has not been done before, 2) theoretical foundation of human skill learning by systematical investigation of the normal typist, fast typists and the transformation process from novice to skilled typist, from the perspective of eye and finger movement, 3) detailed dataset supporting the development of models for eye and finger movement which can further contribute to the ability-based keyboard optimization, and 4) guidelines not only for text input design, but also for learning and improving typing skills. The conclusions drawn in this dissertation provide insights not only on how to fully leverage human capabilities for better typing performance, but also on how to provide text input designs for supporting it.