Evaluation of Callout Design for Ultra-small Touch Screen Devices

Akira Ishii
University of Tsukuba
1-1-1 Tennodai, Tsukuba, Ibaraki
305-8573, Japan
ishii@iplab.cs.tsukuba.ac.jp

Buntarou Shizuki
University of Tsukuba
1-1-1 Tennodai, Tsukuba, Ibaraki
305-8573, Japan
shizuki@cs.tsukuba.ac.jp

Jiro Tanaka
University of Tsukuba
1-1-1 Tennodai, Tsukuba, Ibaraki
305-8573, Japan
jiro@cs.tsukuba.ac.jp

CHI'16 Extended Abstracts, May 07-12, 2016, San Jose, CA, USA
ACM 978-1-4503-4082-3/16/05.
http://dx.doi.org/10.1145/2851581.2892434

Abstract
Ultra-small touch screen devices tend to suffer from occlusion or the fat finger problem owing to their limited input area. Callout design, a design principle that involves the placement of a callout in a non-occluded area in order to display the occluded area, could eliminate occlusion. However, callout designs for ultra-small touch screen devices have not yet been explored. In this study, we conducted an experiment to examine eight callout designs for ultra-small touch screen devices. The results show that the selection speed was higher when the content of the callout was changed continuously, the error rate decreased when a pointer was displayed to indicate the touched position within the callout, and the workload decreased when the content was changed continuously. Further, the score that subjectively evaluates the performance decreased when the position of the callout was fixed.

Author Keywords
Interaction technique; occlusion; fat finger; small target acquisition; wearable devices; smartwatch.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces - Input devices and strategies, Interaction styles, Screen design; D.2.2 [Design Tools and Techniques]: User interfaces

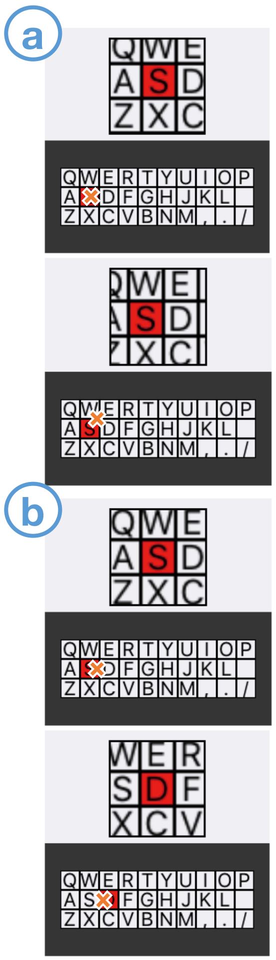

Figure 1: Presentation Method condition. a) Continuous, b) Discrete. The X mark indicates the position of the user's finger.

Introduction

Ultra-small touch screen devices (henceforth referred to as ultra-small devices), such as smartwatches, must be small because they are worn on the body; thus, the touch screen of these devices is ultra-small. Owing to their limited input area, ultra-small devices are more prone to occlusion or the fat finger problem [11] than smartphones or tablet devices. Therefore, the main application of these ultra-small devices is limited to the display of information. Hence, an improvement in the usability of these devices is desired.

A promising solution to the problem is the use of a callout. A callout has been used for a pull-quote or text extract that is typically set apart in a larger or contrasting font in an article. A callout has also been used for the selection task on a touch screen [12]. A callout is used to display a copy of the occluded area, thus eliminating the occlusion caused by the finger. However, callout designs on ultra-small devices have not yet been explored.

In this study, we examined eight callout designs, evaluated these designs on ultra-small devices, and analyzed the results in order to recommend design guidelines for callouts on ultra-small devices.

Related Work

Numerous studies have investigated small target acquisition and solutions to the finger occlusion problem. NanoStylus [13] uses a finger-mounted fine-tip stylus to reduce the occlusion problem. NanoTouch [1] addresses the problem of finger occlusion using touch input at the back of the device.

In ZoomBoard [8] and Swipeboard [2], touch gestures on the touch screen trigger iterative zooming (visual magnification) until a certain level of zoom is reached; thus, text can be entered using a QWERTY keyboard on ultra-small devices. SplitBoard [4] splits a QWERTY keyboard into two parts, and thus, increases the size of each key to enable text entry on ultra-small devices.

Occlusion and ambiguity in selection can be avoided with the Offset Cursor technique [9, 10]. In this technique, a pointer is displayed at a fixed distance above the touch point; this pointer serves as a software version of a stylus. Shift [12] is a target acquisition technique that uses a callout on a PDA. In order to eliminate occlusion caused by a finger, Shift uses a callout that shows a copy of the area occluded by the finger in a non-occluded area. However, this technique has not been evaluated on ultra-small devices. The study that is most similar to our research is [6]. Leiva et al. [6] use a callout to enable text entry from a QWERTY keyboard on ultra-small devices. The study has focused on proposing a technique for text entry and on comparing related techniques to determine the most appropriate one. In contrast to the research by Leiva et al., our study focused on the comparison between different callout designs to evaluate their effectiveness on ultra-small devices.

Callout Design

We explore the method of displaying a callout by considering a scenario in which a user selects a tiny target (e.g., keyboard or small icon) on an ultra-small device. We considered three factors of callout design: *Presentation Method*, *Presentation Position*, and *Pointer Existence*.

Presentation Method

Presentation Method is the factor that determines how the content of a callout changes in response to a user operation; it has two levels: Continuous and Discrete. In Continuous, the content of a callout is changed continuously in response to the current touch point, as shown in Figure 1a. The area occluded by a finger is directly displayed on the callout. Shift [12] and the standard copy and paste opera-

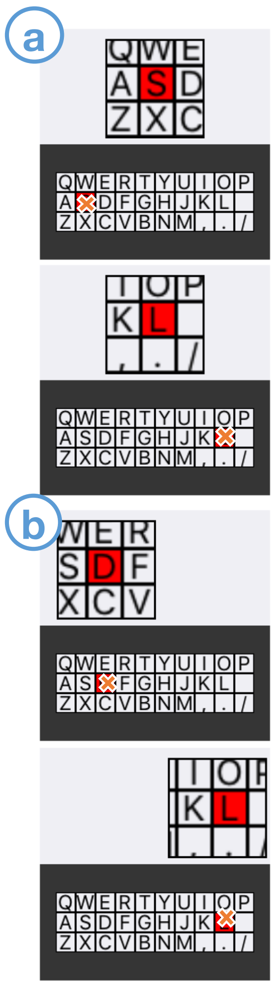

Figure 2: Presentation Position condition. a) Fixed, b) Following. The X mark indicates the position of the user's finger.

tion in iOS adopt this approach. In Discrete, the content of a callout is changed discretely in response to the current selection of an item by a finger, as shown in Figure 1b. Unlike Continuous, the content is not changed as long as the finger stays on the same item, even if the finger is moved. As the user moves the finger, when another item is selected, the content is changed to display the surrounding area of the newly selected item. This approach is similar to the callout of the software keyboard in iOS. The content is changed whenever an item is selected; therefore, the change can serve as visual feedback to the user.

Presentation Position

Presentation Position is the factor that determines how the position of a callout changes in response to a user operation; it has two levels: Fixed and Following. In Fixed, the position of the callout is fixed at the center, as shown in Figure 2a. The users must look at the same point for operation because the callout position is fixed. Therefore, this condition has the advantage of low gaze movement. In Following, the position of the callout follows the current finger position of the user, as shown in Figure 2b.

Pointer Existence

Pointer Existence is the factor that determines whether the actual touch point of the user is displayed on a callout as a pointer (Existing) or not (NotExisting), as shown in Figure 3. If the pointer is displayed, the user can determine the actual touched point.

Experimental Evaluation

We conducted an experiment to examine the usability of various combinations of the three factors of callout design. Participants performed target selection, i.e., the selection of tiny targets for each combination. We recorded participant operations during input and analyzed these operations according to the following three criteria: selection speed, error rate, and workload.

Participants

For the experiment, we recruited 8 participants (7 males, 1 female) aged between 22 and 23 years (M = 22.6, SD = 0.5). All the participants were right-handed, and 4 participants used a smartwatch (period of time: 3–15 months, M = 8, SD = 5.1). Each participant received JPY 1,640 after the completion of the experiment.

Apparatus

The target selection task was implemented on an iPhone 5 smartphone (iOS 9.1, 4 inch, 1,136 × 640 pixels, 326 ppi). The smartphone was used for the experiment because its touch screen is more accurate than the touch screen of existing smartwatches. A region of 18.0 × 18.0 mm (1.0 inch, 232 × 232 pixels) on the screen was used to simulate the smartwatch; the touch events outside this region were ignored. The input region was divided into 2 equal regions: the upper region was used to display a callout, and the lower region was used as the input area that displayed a tiny QWERTY keyboard. The dimension of each key was 1.6 × 1.6 mm. Similar to the approach in [6], the smartphone was attached in a landscape orientation to the non-dominant hand of the participant using a Velcro strap (D&M Co., Ltd.; knee wrap; 842XUD2786 BLK M), as shown in Figure 4.

Experimental Design

The experiment was designed as a repeated measures experiment. It had three independent variables: *Presentation Method* (Continuous and Discrete), *Presentation Position* (Fixed and Following), and *Pointer Existence* (NotExisting and Existing).

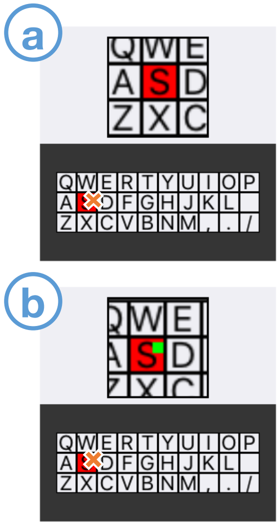

Figure 3: Pointer Existence condition. a) NotExisting, b) Existing. The green dot indicates the position of the touch point. The X mark indicates the position of the user's finger.

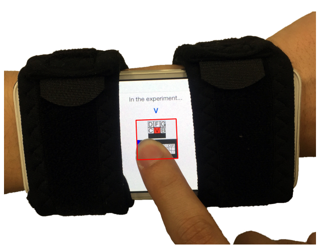

Figure 4: The smartphone attached in a landscape orientation to the non-dominant hand.

In order to examine only the effects of callout designs, we added two starting point conditions (Left or Right), as shown in Figure 5. Participants may select the target without using the callout; therefore, we presented the starting point on one side of the keyboard (left or right) as a blue bar. The participants were instructed to start a trial by touching the blue bar (touch down), dragging their finger toward the target, and selecting the target by lifting their finger (touch up). This design ensured the usage of the callout by making it necessary for the participants to touch the starting point in the beginning and forcing them to drag their finger toward the target. We presented the starting point in the order, left and right. Therefore, for each callout design, the participants performed the task twice–once for each starting point condition.

The callout designs were presented to the participants in a random order to counterbalance possible biases caused by the order of the conditions. One of the 26 targets (A to Z keys on the keyboard) was randomly presented. In summary, the experimental design involved: 2 Presentation Method (Continuous and Discrete) $\times$ 2 Presentation Position (Fixed and Following) $\times$ 2 Pointer Existence (NotExisting and Existing) $\times$ 2 Starting Points (Left and Right) $\times$ 26 Targets $=$ 416 trials per participant.

Procedure and Task

The experiment was conducted in a calm office environment. The purpose of the experiment was explained to the participants. In addition, we informed them that they could abort the experiment and take a break at any time. The participants were requested to sign a consent form and answer a demographics questionnaire. Then, we measured the width of the index finger of their dominant hand with a digital caliper; for the measurement, the digital caliper was aligned with the distal interphalangeal joint (Figure 6). The average width obtained was 14.9 mm (SD $=$ 0.8), which matches the standard size for the Japanese people [5].

First, a smartphone was attached to the non-dominant arm of each participant. Each callout design was presented and explained to the participants through a short demonstration. Then, the participants were asked to select targets 5 times using each callout design as training. They were advised to use only the index finger of the dominant hand for selecting targets during the entire experiment. This warm-up session took an average time of approximately 3–5 minutes. Then, the actual sessions began.

In the actual sessions, a target was displayed above the region simulating the smartwatch (Figure 5). During the experiment, the participants were instructed to select the presented target as quickly and accurately as possible and to think-aloud their thoughts to the researcher. After the participants selected the target, a new target was displayed. The next target was displayed immediately after participants succeeded or failed to select the target. When each callout design was complete, the participants were requested to respond to the NASA Task Load Index (TLX) questionnaires [3]. We used the Japanese version of NASA-TLX [7] because all the participants were Japanese. Then, the participants took a break of approximately 1–2 minutes.

After all the callout designs were complete, the participants were given a questionnaire related to the callout design. The duration of this experiment was approximately 70 minutes. The entire experiment was recorded by screen capture, and the comments of the participants were recorded by a voice recorder.

Measurement and Analysis Methodology

The selection time was measured as the time from the touch up event for the previous target to the touch up event

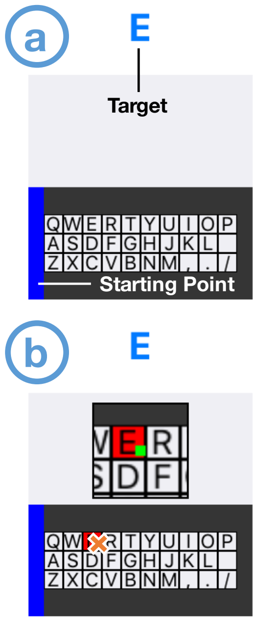

Figure 5: The application used in the experiment. a) The indications displayed to the participants at the start of a trial, b) Selection of a target. The X mark indicates the position of the user's finger.

Figure 6: Measurement position for the index finger.

for the current target. If the participants failed to select the target, we marked the selection as an error and did not include such scenarios in the calculation of the selection time.

Results

Selection Speed

The selection speed for each callout design is shown in Figure 7. It can be observed that Continuous-Following-NotExisting achieved the fastest selection speed; Discrete-Fixed-Existing showed the slowest selection speed.

We analyzed the results with a repeated measure ANOVA. We observed a significant main effect within *Presentation Method* ($p < 0.001$); Continuous had a significantly faster selection speed. No significant interaction effect was seen.

Error Rate

The error rate for each callout design is shown in Figure 8. The results show that Continuous-Following-Existing achieved the lowest error rate; Continuous-Fixed-NotExisting and Discrete-Fixed-NotExisting had the highest error rates.

We analyzed the results with a repeated measure ANOVA. We observed a significant main effect within *Pointer Existence* ($p < 0.05$); Existing had a significantly lower error rate. No significant interaction effect was seen.

Workload

The TLX score of each callout design is shown in Figure 9. The results show that Continuous-Fixed-Existing achieved the lowest score; Discrete-Following-NotExisting had the highest score.

We analyzed the overall TLX scores with a repeated measure ANOVA. We observed a significant main effect within *Presentation Method* ($p < 0.01$); Continuous had a significantly lower score. A significant interaction effect between *Presentation Method* and *Pointer Existence* ($p < 0.01$) was observed. A marginal interaction effect between *Presentation Position* and *Pointer Existence* ($p = 0.08$) was seen.

We also analyzed the TLX score of each evaluated category with a repeated measure ANOVA. Among the six scores that TLX evaluates from different perspectives, the Mental score demonstrated a significant main effect within *Presentation Method* ($p < 0.01$); Continuous had a significantly lower score. The Physical score yielded a significant main effect within *Presentation Method* ($p < 0.01$);

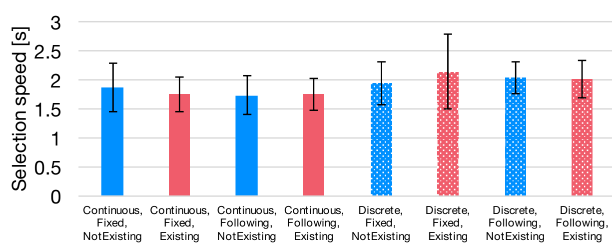

Figure 7: The average selection speed for each condition (lower is better).

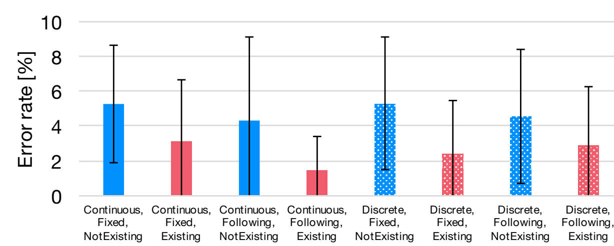

Figure 8: The average error rate for each condition (lower is better).

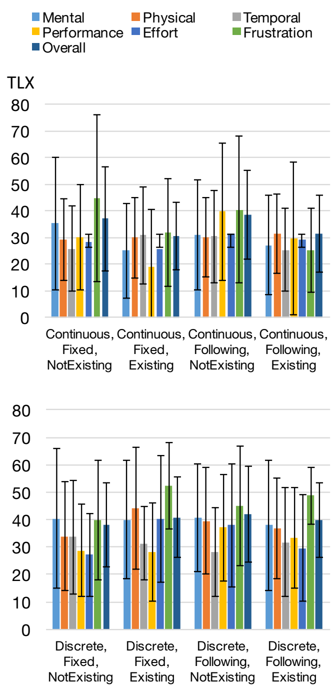

Figure 9: TLX scores (lower is better). They indicate the degree of difficulty in selecting a target.

Continuous had a significantly lower score. In the case of the Performance score, we observed a significant main effect within *Presentation Position* ($p < 0.01$); Fixed had a significantly lower score. In the case of the Effort score, a marginal interaction effect between *Presentation Position* and *Pointer Existence* ($p = 0.07$) was observed. The Frustration score generated a significant main effect within *Presentation Method* ($p < 0.05$); Continuous had a significantly lower score. Further, a significant interaction effect between *Presentation Method* and *Pointer Existence* ($p < 0.01$) was observed, and a marginal interaction effect within *Presentation Method* and *Presentation Position* ($p = 0.09$) was seen.

Qualitative Results

The question that we posed to the participants was, "*Which of the three methods was easier to use? Continuous or Discrete, Fixed or Following, and NotExisting or Existing?*" All the participants responded Continuous was easier to use than Discrete. Five participants indicated that Fixed was easier to use than Following, and 5 participants responded that Existing was easier to use than NotExisting.

Discussion

The above results suggest that Continuous was easier to use than Discrete; Continuous shows faster selection speed and lower TLX scores than Discrete. The reason for this result is that in Continuous, the finger movement of a user corresponds to the content of the callout. In the questionnaire, 5 participants stated that "*Continuous was more similar to the natural movement of the finger, and I was able to accomplish my operation better*" and that "*It was easier to adjust the exact position in Continuous*".

Further, the pointer improves the performance because the error rate decreased in Existing. In the questionnaire, 5 participants stated that "*In Existing, selection was easier because I was able to see the actual point that I was touching*" and that "*It was easier to aim at the target in Existing*".

With respect to Presentation Position, the participants felt that Fixed was better than Following; the TLX score, specifically, the Performance score, was lower in Fixed than in Following. The reason for this result is that in Fixed, the participants were able to observe the entire content on the screen in one trial because the screens used for wearable devices were very small. In the questionnaire, 4 participants stated that "*I had to follow the callout with my eyes in Following; however, I did not do so in Fixed*".

Conclusions and Future Work

We examined eight callout designs for ultra-small devices in order to determine the most optimized callout design. The results of our experiment showed that the selection speed was faster when the content of the callout was changed continuously, the error rate decreased when a pointer was displayed to indicate the position touched by the user within the callout, and the workload decreased when the content was changed continuously. Further, the score that evaluates the performance decreased when the position of the callout was fixed. These observations will help interaction and UI designers in designing interactions and UI on ultra-small devices.

We also observed an interesting comment in the questionnaire: 3 participants stated that they could not recognize the difference between Presentation Position and Pointer Existence. Therefore, in future work, we will conduct additional experiments with a larger number of participants to examine the reason for this perception. In addition, we will investigate the usability for various screen sizes to guarantee consistent usability for different screen sizes.

References

[1] Patrick Baudisch and Gerry Chu. 2009. Back-of-device Interaction Allows Creating Very Small Touch Devices. In *Proceedings of the 27th Annual ACM Conference on Human Factors in Computing Systems (CHI '09)*. ACM, New York, NY, USA, 1923–1932. DOI: http://dx.doi.org/10.1145/1518701.1518995

[2] Xiang 'Anthony' Chen, Tovi Grossman, and George Fitzmaurice. 2014. Swipeboard: A Text Entry Technique for Ultra-small Interfaces That Supports Novice to Expert Transitions. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology (UIST '14)*. ACM, New York, NY, USA, 615–620. DOI: http://dx.doi.org/10.1145/2642918.2647354

[3] Sandra G. Hart and Lowell E. Staveland. 1988. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Human mental workload* 1, 3 (1988), 139–183.

[4] Jonggi Hong, Seongkook Heo, Poika Isokoski, and Geehyuk Lee. 2015. SplitBoard: A Simple Split Soft Keyboard for Wristwatch-sized Touch Screens. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1233–1236. DOI: http://dx.doi.org/10.1145/2702123.2702273

[5] Makiko Kouchi. 2012. AIST The measurement data of the hands of the Japanese. https://www.dh.aist.go.jp/database/hand/index.html (In Japanese) Last accessed on February 10, 2016. (2012).

[6] Luis A. Leiva, Alireza Sahami, Alejandro Catala, Niels Henze, and Albrecht Schmidt. 2015. Text Entry on Tiny QWERTY Soft Keyboards. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 669–678. DOI: http://dx.doi.org/10.1145/2702123.2702388

[7] Shinji Miyake and Masaharu Kumashiro. 1993. Subjective mental workload assessment technique - An introduction to NASA-TLX and SWAT and a proposal of simple scoring methods -. *Human factors and ergonomics* 29, 6 (1993), 399–408. DOI: http://dx.doi.org/10.5100/jje.29.399 (In Japanese).

[8] Stephen Oney, Chris Harrison, Amy Ogan, and Jason Wiese. 2013. ZoomBoard: A Diminutive QWERTY Soft Keyboard using Iterative Zooming for Ultra-small Devices. In *Proceedings of the 31st Annual ACM Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 2799–2802. DOI: http://dx.doi.org/10.1145/2470654.2481387

[9] Richard L. Potter, Linda J. Weldon, and Ben Shneiderman. 1988. Improving the Accuracy of Touch Screens: An Experimental Evaluation of Three Strategies. In *Proceedings of the 6th Annual ACM Conference on Human Factors in Computing Systems (CHI '88)*. ACM, New York, NY, USA, 27–32. DOI: http://dx.doi.org/10.1145/57167.57171

[10] Andrew Sears and Ben Shneiderman. 1991. High Precision Touchscreens: Design Strategies and Comparisons with a Mouse. *International Journal of Man-Machine Studies* 34, 4 (April 1991), 593–613. DOI: http://dx.doi.org/10.1016/0020-7373(91)90037-8

[11] Katie A. Siek, Yvonne Rogers, and Kay H. Connelly. 2005. Fat Finger Worries: How Older and Younger Users Physically Interact with PDAs. In *Proceedings of the 2005 IFIP TC13 International Conference on Human-Computer Interaction (INTERACT'05)*. Springer-Verlag, Berlin, Heidelberg, 267–280. DOI: http://dx.doi.org/10.1007/11555261_24

[12] Daniel Vogel and Patrick Baudisch. 2007. Shift: A Technique for Operating Pen-based Interfaces using Touch. In *Proceedings of the 25th Annual ACM Conference on Human Factors in Computing Systems (CHI '07)*. ACM, New York, NY, USA, 657–666. DOI: http://dx.doi.org/10.1145/1240624.1240727

[13] Haijun Xia, Tovi Grossman, and George Fitzmaurice. 2015. NanoStylus: Enhancing Input on Ultra-Small Displays with a Finger-Mounted Stylus. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software and Technology (UIST '15)*. ACM, New York, NY, USA, 447–456. DOI: http://dx.doi.org/10.1145/2807442.2807500