PairRing: A Ring-Shaped Rotatable Smartwatch Controller

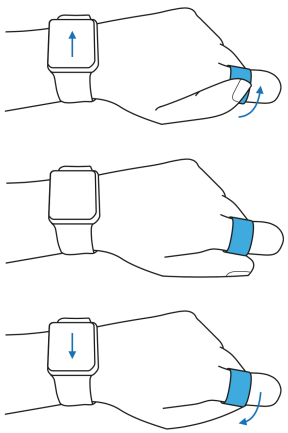

Figure 1: Conceptual design of PairRing system. A user wears PairRing on the index finger and put on the smartwatch on the same hand. By rotating PairRing with thumb, the user can control vertically aligned items on smartwatch.

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Abstract
Smartwatch users often report usability problems despite its handiness and convenience. Fingers often block the screen, and both hands are often required to operate the gadget. To address these issues, we present PairRing, a ring-shaped rotatable smartwatch controller. PairRing allows users to scroll up and down listed items by turning the ring on their index finger with their thumb. To determine the optimal ring shape and rotation speed, we designed and conducted a user study and report the results. We found that (1) users could perform tasks better with the angular ring prototype; (2) the rapid rotation speed was better suited for browsing ordered lists; and (3) overall, participants were positive about the feasibility of the prototype. We conclude with a discussion on the design implications of PairRing as well as its future applications.

Author Keywords
Smartwatch; Ring-shaped Controller; Wearables

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: User Interfaces-Input Devices and Strategies.

Introduction
Recently, smartwatches have become one of the most common electronic gadgets. However, the fact that the user

(a) Virtual Smartwatch Interface

(b) PairRing Prototypes

Figure 2: PairRing and Smartwatch system : (a) Virtual Smartwatch Interface and (b) PairRing Prototypes. The virtual smartwatch and additional information are depicted in the smartphone interface. Users fasten smartwatch on their wrist. And the users wear PairRing in their index finger of the same hand.

must wear the watch on one wrist and operate it with the other hand limits the ease of manipulation and accessibility of the device. This sets the smartwatch apart from other gadgets, such as smartphones and tablets, in terms of its unique interaction design. Many HCI researchers have addressed the issue and suggested employing various interaction techniques [3, 5, 4, 9, 11, 13].

Still, many smartwatch users report problems. The limited screen size of the smartwatch often causes control errors that interfere with user intent [2]. In addition, users must wear the watch on one wrist and operate it with the other hand, forcing them to use both hands. This could be a barrier not only for people with disabilities but also for average users who use their smartwatches while in transit or while carrying personal belongings.

To address the aforementioned issues, we present PairRing, a ring-shaped rotatable controller for operating smartwatches with one hand. Users can control PairRing by turning it with their thumb, which enables an intuitive interaction with the smartwatch (Figure 1).

In this work, we designed and evaluated the feasibility of the PairRing prototype. We explored the shape and the rotation speed of the ring prototype to determine the most appropriate conditions for easier and more convenient use. Users were presented with two different shapes (circular vs. angular) and two different rotation speeds (slow vs. rapid). They performed tasks where they were measured in terms of the time taken for item navigation. They evaluated the usability of the prototype in the survey and completed short interviews. Our key findings are as follows. (1) Users could manipulate their smartwatches more quickly and easily with the angular type of the PairRing prototype. (2) They performed better with the rapid rotation speed for the given tasks. (3) Participants were positive with the idea of using a ring-shaped device for controlling their smartwatch.

The contributions of our study are below:

- We designed and implemented PairRing, a novel ring-shaped controller for a smartwatch that can be operated with one hand that is wearing the watch.
- We evaluated the usability and feasibility of the PairRing prototype and suggested design considerations.
- From the interview, we identified that PairRing system could be applied to other devices and contexts.

Related Work

Various input methods for improving interactions with smartwatches have been studied, such as kinematic devices [11], built-in or additional sensors [5, 9], cameras [3], finger-mounted devices [10] and smartwatch's bezel [13]. Harrison et al. suggested an additional device that can be worn on a user's finger, enabling in-air control of the smartwatch [4]. Although these previous studies explored new ways of manipulating the smartwatch interface without blocking it, they still required users to use both hands.

Meanwhile, many researchers have studied using ring-shaped controllers as new input methods for smart devices, such as optical sensors [12] and cameras [7]. Some used infrared sensors to measure hand and finger movements [8], while others investigated the possibility of input using pressure sensors [6]. Notably, several studies used ring-shaped rotating devices as an input method. For example, Nenya [1] used magnets, and iRing [8] used skin strain and distance sensors. Although these have identified new possibilities in terms of using the ring as an input method with various sensors, they have not yet explored the rotating of the device to control the interfaces of smartwatches or other smart devices.

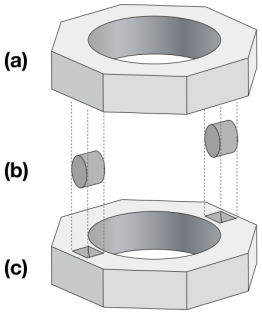

Figure 3: (a) The upper body of PairRing; (b) The magnets; and (c) The lower body of PairRing. The magnets fit in the upper and lower body of the prototype.

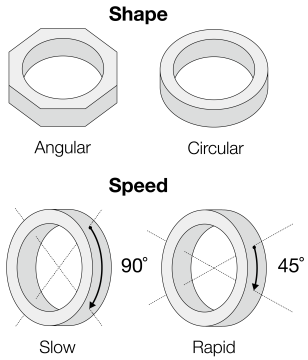

Figure 4: The shape of the PairRing and rotation per item movement speed. The ring has two types of shape: angular and circular. The users can move the cursor by rotating the ring 90 degree in slow and 45 degree in rapid.

PairRing

PairRing is a new way of controlling smartwatches. It is a ring-shaped, rotatable controller worn on the index finger of the same hand with which users can manipulate the smartwatch by turning it with their thumb. Figure 1 shows the research prototype of PairRing.

Design Prototype

The PairRing system operates on two parts: a virtual smartwatch user interface on a smartphone and a ring controller. (Figure 2)

PairRing has three components: the upper body, the lower body, and a pair of magnets between them (Figure 3). As users rotate the ring, the magnets change the magnetic field around the system, and then the movement of the ring is detected by a sensor in the paired smartphone. The bodies of the ring were made using a 3D printer, between which 3mm X 3mm size and N42-grade neodymium magnets were inserted. The prototype is diametrically magnetized.

The virtual smartwatch user interface was designed by simulating the smartwatch interface on the center of the screen of a smartphone (Figure 2). In the blank space of the screen, additional information (e.g. task type, operation speed, timer) is displayed as a dashboard. A Samsung Galaxy S7 was used as the apparatus for the experiment. When a user fastens the smartphone with a band on their wrist, it is almost as if the user is wearing a real smartwatch.

Ring Shape and Rotation Speed

In the process of designing the prototype, we considered two factors, ring shape and rotation speed, and devised two different styles for each factor (Figure 4).

- Ring Shape: There are two ring shapes: circular and angular. We chose an octagonal shape for the angular one, which helps to facilitate the user's holding of the ring's surface [6].
- Rotation Speed: There are two operation speeds: slow and rapid. With the slow speed, users could move the cursor one item up and down on the screen by rotating the ring for 90 degrees. On the other hand, with the fast speed, users could move the cursor up and down by rotating the ring for 45 degrees.

User Study

To evaluate the feasibility of PairRing and identify the most appropriate shape and rotation speed for operation, we designed and conducted a user study where users performed a given task and participated in a survey and an interview.

Task

We created an application that worked on the smartwatch (Figure 5) for the experiment. The application provided users a list of 26 words. Users could move the cursor and navigate the items by rotating PairRing with their thumb as shown in Figure 1. Participants were asked to find target items using the blue cursor (Figure 5) by rotating the ring controller. we measured the time taken for a user to locate each given target word appeared on the dashboard among a list of word items.

Participants and Procedure

A total of 16 participants performed the task (6 female). Their average age was 30.1 (SD=4.24). The participants performed 12 browsing trials (two shapes X two rotation speeds X three iterations). All trials were presented in a random order. Prior to trials, participants had enough time to familiarize themselves with the system. We also evaluated the usability of each condition by asking the partici-

Figure 5: Our smartwatch application. It consists of total 26 words, each of which is as easy noun starting with a letter from A to Z. All words are arranged in a hierarchical order. The blue highlight acts as a cursor that the user can move around. The cursor goes up and down by turning PairRing.

pants to answer the System Usability Scale (SUS) using the 7-point Likert scale. After completing all trials, participants were invited for a post-hoc interview.

Data Analysis
We conducted both quantitative and qualitative analyses on collected data. First, we conducted a 2X2 two-way RM ANOVA on the time and usability scores. We transcribed and reviewed the interviews by tagging them by keywords and employing a thematic analysis.

Quantitative Analysis

We have found statistically significant effects on time and usability of our PairRing system.

Time
A total of 192 observations (16 participants X 2 shapes X 2 rotate speeds X 3 trials) were analyzed. We conducted two-way RM ANOVA test and identified significant effects for shape ($F(1,188) = 3931.06$, $p < 0.01$) and rotation speed ($F(1,188) = 256.79$, $p < 0.01$) on time. We also found a significant two-way interaction between them ($F(1,188) = 33.72$, $p < 0.01$). This shows that the time consumed is shorter with angular shape and rapid rotation speed. (Figure 6(a))

Usability
We collected 64 user ratings (16 participants X 2 shapes X 2 rotate speeds). We found significant effects for shape ($F(1,60) = 303.43$, $p < 0.01$) and rotation speed ($F(1,60) = 47.30$, $p < 0.01$) on the usability of our system. However, there was no significant interaction effect between the two factors ($F(1,60) = 1.53$, $p = 0.22$). The result supports higher usability with angular shape and rapid rotation speed. (Figure 6(b))

Qualitative Analysis

Many users reported that the angular-shaped ring was easy to hold, while they had mixed opinions for speed preference. Overall, they found PairRing useful, intuitive, and applicable.

The Angular-shaped Ring is Easy to Hold
Participants said the angular-shaped ring offered better haptic feedback than the circular-shaped ring, as it had a flat surface. P3 said, “I like this flat surface. While rotating this device, it was more comfortable and I could rotate it better.” P7 also said, “The circular-shaped ring had no edge to pull or push on, so it was difficult for me to control.”

Speed Preference is Task-Dependent
Despite the findings from the statistical analysis, some users reported that they did not always preferred the rapid rotation speed. While the rapid speed was suitable for browsing a longer list of items, the slow speed was more appropriate when they tried to apply a fine change in locating the item on the screen. P12 said, “In the rapid condition, even if I only moved the device a little bit, the switching of the item occurred too quickly. So, if I had to control it precisely, I would prefer the slow mode to the rapid mode.” P2 said, “For tasks requiring a lengthy exploration, such as searching long lists, I think the rapid mode is better, but I would prefer the slow mode for tasks that require a smaller item selection.”

PairRing is Useful, Intuitive, and Applicable
Most participants said that PairRing was very useful and intuitive, and could be applied to other contexts. Some of them even considered PairRing a potential solution for fat finger problem. P6 said, “Because this interaction system can be controlled by only one hand, now I can see my smartwatch without blocking the screen.” P8 said, “I love this way of moving the cursor up and down. It is very in-

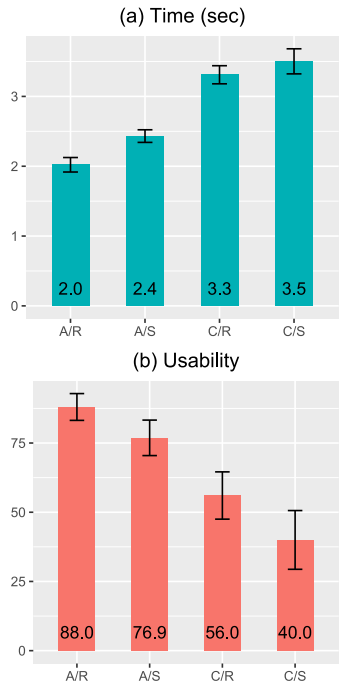

Figure 6: The mean of time taken (a) and usability scores (b) of participants in each shape and rotation speed condition. (a) shows the angular/rapid rotation speed condition required the shortest amount of time. Likewise, (b) indicates the same condition recorded the highest usability score.

tuitive." P9 also added, "I'd like to use PairRing for other devices and situations as well. I think it would be useful if I could connect it with my television. It would help me switch channels easily."

Design Considerations

Based on the findings from the user study, we discuss the design implications of PairRing.

Double-Sided Surface

Our study participants showed a strong preference for the angular-shaped prototype of PairRing. That the outer and inner sides of the ring are different can effectively serve two purposes. The inner side of the ring, which is circular as a usual ring is, conveniently suits the finger. The outer side of the ring, which is angular, provides a flat surface on which users can apply input in a more convenient manner. We believe this creates a novel interaction space for HCI researchers to employ yet to be explored input and control methods on a smart device.

Speed Adjustment

While we identified that users generally preferred the rapid rotation speed, they reported that the slow speed served the purpose better in some trials. We find that while users would naturally want to navigate items faster, they would also strongly prefer to avoid control errors. More specifically, in contexts where users explore a lengthy list of items, speed adjustment should be equipped in system settings so that users can serve their needs on their own.

Device Connectivity

Post-hoc interviews suggest that paired interaction can be applied to various smart device usage contexts. For example, users can use the ring-shaped device to control other devices in distance such as TV and smart screens. They can also make adjustments on wearable devices (e.g. modulate intensity of sunglasses or hearing aids), and authenticate themselves (e.g. substitute for car key).

Limitations and Future Work

Our work is not without limitations. First, we did not utilize a smartwatch for our experiment. Also, the task only pertained to item navigation, for which we are now considering other use case scenarios. In future work, we will implement the system on a smartwatch device paired with our prototype. We plan to make improvements on the system to better function as a controller. We will design various functions (e.g. click, swipe etc.) and applications such as controlling music playlists, locating on a map, etc. We aim to acquire a higher level of usability when employing a typical smartwatch interface, and compared with other ring shaped devices. Moreover, as more and more devices are connected (i.e. Smart Home), we will explore how a simple ring controller may be applied to a variety of smart devices and applications at home, office, and work settings.

Conclusion

We designed and implemented PairRing, a ring-shaped smartwatch controller. To gauge its feasibility, we conducted a user study consisting of a set of trials, a survey questionnaire, and a semi-structured interview with 16 participants. We found that users could potentially manipulate their smartwatch more accurately and quickly with the angular-shaped PairRing prototype than the circular one. They could perform the task better with the rapid rotation speed, albeit having mixed opinions on speed preference. They were positive about the idea of using PairRing for controlling their smartwatch and other smart devices. We present design suggestions for a ring-shaped controller for smart devices, which we hope to contribute to designing new interaction spaces and techniques for smartwatch controllers and improving usability of existing smart devices.

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