Interaction Techniques for Binding Smartphones:
A Desirability Evaluation

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Abstract. This paper reports on the use of guided interviews to evaluate the desirability of different interaction techniques for *binding* smartphones. We demonstrate five interaction techniques using storyboard sketches and cardboard prototypes of iPhones. The participants highlight five words from a list of adjectives that best describe their experience with each technique. For comparative evaluation, we group the highlighted adjectives for all techniques into a list of nouns and let the participants rank each technique on a 5-point Lickert scale with respect to these nouns. We discuss the implications of these results for the design of interaction techniques for smartphones.

Keywords: Ubiquitous computing, spontaneous connection, smartphone, co-located collaboration, desirability evaluation.

1 Introduction

Ubiquitous computing envisions the seamless and spontaneous connection amongst computing devices prevalent in everyday life [8, 11]. To establish a connection between mobile devices that do not have *a priori* knowledge of each other's network addresses remains a challenging issue [6-12]. For the purpose of this work, we define *binding* as a way of coupling two devices by explicitly or implicitly creating a software plus network connection between them. Binding can relieve the users of the hassle of selecting the addresses/names of the devices in situations such as exchanging files or sharing photographs. The emergence of smartphones [1] has created opportunities to develop interaction techniques that bind these devices by taking advantage of their advanced features such as RFID, Bluetooth, GPS, infrared, and accelerometers. The established techniques that enable binding of devices by using physical action on part of the user include shaking [6, 9], bumping [3], touching [7, 10], pen-based stitching [4], and simultaneous button-pressing [12]. We provide an overview of these techniques in section 2 of this paper.

To date, the literature does not cite any significant activities on evaluating user satisfaction [13] with mobile binding techniques. Instead, much of the evaluation has been focused on effectiveness (can people complete the task?) and efficiency (how long do people take to complete the task?) of the said techniques. In this paper, we report on two user studies that make use of guided interviews to investigate the desirability of different interaction techniques for binding mobile phones. The first case

study is aimed at evaluating desirability of individual techniques. It involves demonstration of techniques using storyboard sketches and paper prototypes of iPhones. For each technique, the participants highlight the top 5 adjectives in a word-list that best describe their experience with that technique. The results of this study are explained in section 3 of this paper.

As a follow-up to the first case study, we generate a list of nouns by grouping the top five adjectives selected by the participants for each technique. The participants rank each technique on a 5-point Lickert scale with respect to each noun in the list. The section 4 of the paper explains the results of this study focused on comparative desirability evaluation of these techniques. After discussing implications of our results for the design of mobile interaction techniques in section 5, we sum up our conclusions in section 6.

2 Related Work

Researchers have introduced interaction techniques to bind computing devices that do not recognize each other. Hickley et al. [3] explored the notion of *synchronous gestures* and introduced the technique of bumping two tablet computers equipped with touch sensors and two-axis linear accelerometers. Pen-based stitching [6] allows the users to couple pen-operated mobile devices with wireless networking by using pen gestures that span multiple displays. Holmquist et al. [6] implemented small embedded devices, called *Smart-It Friends*, that get connected when a user holds them together and shakes them. Expanding the idea of shaking further, Meryhofer [9] demonstrated the coupling of two mobile phones while holding and shaking them simultaneously. Reikimoto et al. [12] introduced the "SyncTap" technique of simultaneously pressing and releasing a button on each device. Hardy et al. [5] presented an interaction technique in which a mobile phone can be touched with a large display at any position in order to establish pairing between two devices. Park et al. [10] introduced the use of intra-body communication signal [15] for touching and pairing devices.

Much of the effort in this domain has been focused on system design and implementation. On the other hand, usability evaluation of interaction techniques has received relatively little attention. Formal usability tests offer excellent tools to evaluate whether users can complete tasks (effectiveness) and how long they take to complete tasks (efficiency). However, such tests fail to measure intangible aspects of user experience (satisfaction) as often positive ratings for each question make it difficult to elicit candid or negative feedback [2, 13]. Desirability Toolkit [2] is an approach to measure satisfaction that requires the participants to sort through a series of 118 "product reaction cards" and select five cards that most closely describe their personal reaction to the system in use. The five selected cards then become the basis of a post-test guided interview. This approach has been shown to help elicit negative and critical comments from the participants and provide a better measure of desirability of the interface in test. An alternative implementation of this method is to use a simple paper checklist of adjectives [13] instead of a set of product reaction cards. This is the

method we employ in our case study as it simplifies the process of sorting out the relevant words for the users.

3   Desirability Evaluation of Individual Techniques

The first part of the study deals with evaluating desirability of individual interaction techniques for binding smartphones. We included five techniques i.e. bumping, stitching, shaking, touching and simultaneous button-pressing (SBP) in this study. To give the participants an overview of the underlying mechanisms, we demonstrated these interaction techniques using cardboard prototypes of iPhones and storyboard sketches as shown in Fig. 1. We also showed them the storyboard sketches of usage scenarios that involve bindings between smartphones. With respect to each interaction technique, the participants selected a number of adjectives from a list of adjectives [13] and highlighted the top five of the selected adjectives that best described their experience. The study was conducted with 17 participants, 12 of them postgraduate students and 5 post-doctoral researchers, all in the Computer Science department. The participants comprised 14 males and 3 females in the age range of 20-35. On average, each participant spent 20-25 minutes on this part of the study. Each of them was given a small gratuity as thanks.

Fig. 1. a) Shaking b) Bumping c) Simultaneous Button Pressing d) Stitching e) Touching

3.1   Storyboard Sketching

The participants were shown storyboard sketches illustrating usage scenarios where spontaneous binding of smartphones may facilitate collocated collaboration, as follows:

Sharing. In this scenario, two users exchange digital business cards, files and photos from one mobile phone to the other, as shown in Fig. 2.

Control. There is a slave-master relationship between two mobile phones and the master mobile phone can be used to control the functions of slave mobile phone. For instance, a user can click a place on the map shown on master device and get its zoomed-in view on the slave device.

Pairing. Before coupling, each mobile phone shows a single-player map of Pacman game. After being coupled, the multi-player map of Pacman game appears on each mobile phone and the users can play game in multi-player mode on their respective phones.

Fig. 2. a) Before binding b) After binding

3.2 Guided Interviews

With respect to each interaction technique, each participant selected 5 words out of a list of 105 words. A subset of the word-list is shown in Table 1. Words selection was followed by a guided interview in which the participants explained their reasons to their selection of the words. The results of these guided interviews are explained here.

Table 1. Selected words from a list of 105 words

Accessible	Advanced	Ambiguous	Appealing	Awkward	Boring
Busy	Clean	Creative	Convenient	Efficient	Easy to Use
Frustrating	Fun	Hard to Use	Ineffective	Insecure	Misleading
New	Powerful	Professional	Reliable	Secure	Simple
Slow	Stable	Unrefined	Useful	Usable	Vague

Bumping. Bumping [3] involves striking the devices together just as clinking glasses together for a toast as shown in Fig. 1(b). With respect to bumping, the user responses are shown in Table 2.

Table 2. User responses with respect to bumping technique

Top 5 words	Selectors	Comments
Easy-to-Use	65% (11/17)	Handy approach, no complications
Fast	41% (7/17)	Ensures instant connection
Effortless	35% (6/17)	No hassle for configuring devices
Time-saving	30% (5/17)	Less time spent on connecting devices
Non-standard	24% (4/17)	Un-usual way of connecting

During the interview, many participants described bumping as a straightforward way of establishing instant connection between mobile devices. Some of them expressed their reservations about any possible physical damage to the mobile phones while using this technique. They were ambiguous about the extent of force that needs to be applied to accomplish coupling.

Stitching. Stitching [4] establishes connection between pen-operated mobile devices by using pen gestures that span multiple displays as shown in Fig. 1(d). This

interaction technique recognizes devices within an arm's research and can support connection between the users sitting shoulder-to-shoulder. With respect to stitching, the user responses are shown in Table 3.

Table 3. User responses with respect to stitching technique

Top 5 words	Selectors	Comments
Difficult	35% (6/17)	Hard to use, hard to distinguish sender and receiver
Advanced	30% (5/17)	Innovative technique
Effortless	30% (5/17)	Easy to connect devices
Frustrating	30% (5/17)	Annoying, wearisome
Insecure	24% (4/17)	Prone to intrusion

During post-test interview, many participants expressed their security concerns about using this technique for spontaneous connections. They also found it cumbersome to draw pen strokes along two devices for data exchange.

Shaking. Shaking [9] is an interaction technique that enables connection between devices by holding and shaking them together as shown in Fig. 1(a). With respect to shaking, the user responses are shown in Table 4.

Table 4. User responses with respect to shaking technique

Top 5 words	Selectors	Comments
Simple	35% (6/17)	Does not require much learning
Creative	30% (5/17)	Innovative
Fun	30% (5/17)	Enjoyable, like shaking cocktail
Unattractive	24% (4/17)	Does not fascinate me
Awkward	20% (3/17)	Does not look an elegant way

Some participants find it a fun and innovative way of binding phones as it resembles to the act of shaking drinks for cocktail. However, others were apprehensive that the shaking can be unpredictable in certain situations such as two phones in a backpack may accidently get connected based on their accelerometer readings.

Touching. This technique [10] involves touching two devices and using the person's body as a medium for the signals between two devices, as shown in Fig. 1(e). It is based on Zimmerman's idea of intrabody signalling module [15] to connect devices. Table 5 shows the user responses with respect to touching technique.

Table 5. User responses with respect to touching technique

Top 5 words	Selectors	Comments
Simple	30% (5/17)	Does not require much learning
Effortless	30% (5/17)	Easy to connect devices
Time-saving	30% (5/17)	Saves time from manual configuration
Appealing	24% (4/17)	It is fascinating, I like the idea
Useful	24% (4/17)	Handy, Makes data exchange smooth and easy

Most participants find the idea of using human body as a medium for connecting two devices very appealing. They also considered it more professional-looking. However, there were some security concerns that such technique may be prone to undesirable intrusion.

Simultaneous Button Pressing (SBP). This technique involves simultaneous press and release of a button on each device [12] to establish connection as shown in Fig. 1(c). Table 6 shows the user responses with respect to SBP technique.

Table 6. User responses with respect to SBP technique

Top 5 words	Selectors	Comments
Awkward	35% (6/17)	Not an elegant way of connecting
Hard-to-Use	24% (4/17)	Difficult to synchronize
Slow	20% (3/17)	Take time to synchronize
Time-consuming	20% (3/17)	Take lot of time before making a correct choice
Dull	20% (3/17)	Not fun, no excitement

Some participants described it as awkward as both buttons need to be pressed simultaneously and it can be a big hassle to attain synchronicity between these actions. On the other hand, this technique was considered to be highly secure as the risk of intrusion seemed minimal.

4   Comparative Evaluation of Interaction Techniques

The guided interviews helped us elicit the factors that determine the desirability of interaction techniques for binding mobile devices. To conduct a comparative evaluation of interaction techniques, we grouped all the adjectives highlighted with respect to all techniques into a set of nouns. Taking assistance from the online "The Free Dictionary" (http://www.thefreedictionary.com/), we generated a list of nouns corresponding to the selected adjectives as shown in Table 7.

Table 7. Selected adjectives and corresponding nouns

Selected Adjectives	Corresponding Nouns
Easy to Use, Hard to Use, Effortless, Simple, Difficult	Ease of Use
Time-saving, Fast, Slow	Promptness
Appealing, Dull, Fun, Unattractive, Awkward, Frustrating, Useful	Appeal/Attractiveness
Advanced, Creative	Originality
Unpredictable	Reliability
Insecure	Security

We implemented a Wizard-of-Oz [14] application on the iPhone 3G, using the iPhone SDK that gives the impression of establishing a Wi-Fi connection between two iPhone devices when subjected to any of the aforementioned interaction techniques. The

participants were asked to rate each of the interaction techniques with respect to the nouns (shown in Table 7) on a 5-point Lickert scale, with 5 being the highest and 1 being the lowest. Out of 17 users who participated in the first case study, 11 agreed to volunteer for the follow up study. The results of this study are shown in Table 8.

Table 8. Comparative Desirability of different interaction techniques

Features Techniques	Ease of Use	Security	Promptness	Appeal	Originality	Reliablity
Bumping	3	4	4	3	4	3
Stitching	3	3	3	2	3	3
Shaking	4	3	3	3	3	3
Touching	4	3	4	4	4	3
SBP	2	4	3	2	2	2

As shown in the table above, shaking and touching rank highest as far as ease of use is concerned. Bumping and SBP score highest in matter of security. Promptness is considered best realized in bumping and touching. As the techniques that score low in ease of use and promptness score high in security column, satisfying these apparently conflicting demands poses a key challenge for designers. Overall, touching technique receives the highest score amongst all techniques.

5   Design Implications

Based on our case study results, we believe certain safeguards should be provided while designing interaction techniques for binding smartpones. Although our participants represent a limited sample of smartphone users and, hence, we are not in a position to generalize the results and come up with an exhaustive list of implications. However, we can still deduce some useful guidelines for the design of mobile binding techniques.

5.1   Purpose of Binding

The desirability of a particular interaction technique may vary depending on the purpose of binding the mobile devices. We presented to the participants storyboard sketches showing different usage scenarios of file exchange, map zoom-in, and multi-player games. Although most participants rated each technique considering its all-purpose utility, some of them opted to select different adjectives for the same technique in different usage scenarios. For instance, they particularly preferred the touching technique for multi-player games and stitching for exchanging files. This underlines the need to assess the intended purposes of binding as well as to allow support for multiple binding techniques in a smartphone.

5.2   Social Context

Some participants mentioned social context as an important determinant for their preference for a particular technique. While exchanging business cards with a

stranger, one may opt for SBP technique but while sending a photograph of wedding anniversary to one's spouse on a candle-light dinner, touching or shaking may be more attractive. This also raises the significance of considering cultural norms and social protocols (e.g. corporate events vs. social events), in addition to interpersonal relationships, while designing techniques for spontaneous device connection.

5.3 Privacy

Since mobile phones are very personal devices, containing lot of personal information and contacts, most users express their serious concerns about risks of undesired intrusions while making spontaneous connections. As shown in Table 8, interaction techniques that lead in the matters of ease of use, appeal and promptness lag behind in terms of security. To balance security with the quality of human experience is one of the key challenges in the design of these techniques.

6 Conclusions

In this paper, we described the use of guided interview method for evaluating user satisfaction with different interaction techniques for binding smartphones. We went through an exploratory phase of collecting the top 5 adjectives that best express the users experience with respect to each of the interaction techniques i.e. bumping, stitching, shaking, touching and simultaneous button pressing. After the evaluation of individual interaction techniques, we summed up the criteria for comparative evaluation by grouping all the highlighted adjectives into a list of nouns and going through guided interviews with the participants again. As shown by our study, the ease of use, security, promptness, appeal, originality and reliability are the key factors that determine the desirability of any binding technique. We also discussed the implications of purpose of binding, social context and privacy concerns on the design of interaction techniques.

In future work, we plan to build and evaluate collaborative applications on mobile phones that utilize these interaction techniques. We are also interested in exploring the social and cultural aspects that affect the desirability of interaction techniques.

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