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Erstveröffentlichung in / First published in:

MUM '19: Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia, Pisa, 2019. ACM Digital Library, Artikel-Nr. 43. ISBN 978-1-4503-7624-2

DOI: <https://doi.org/10.1145/3365610.3368412>

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User Strategies for Mobile Device-Based Interactions to Prevent Shoulder Surfing

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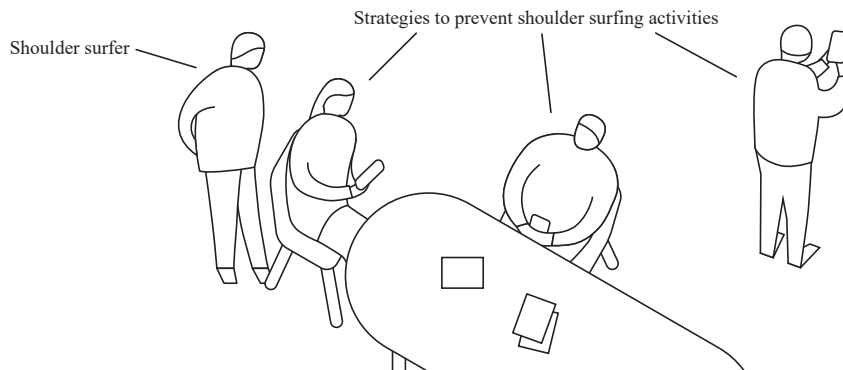


Figure 1: Shoulder surfing in a collocated collaboration scenario and some examples of user strategies to prevent it.

ABSTRACT

Shoulder surfing, also known as visual hacking, is the activity of obtaining information from or about others by observing visual content of displays that actually should be kept secret, such as PINs, passwords, or private text messages. Approaches that address shoulder surfing on mobile devices mainly focus on ways to recognize observers or to complicate visual presentations for them from the system's perspective. However, users also have developed their own strategies to keep their input secret. With this work, we contribute an investigation of strategies to prevent shoulder surfing from the users' perspective. We performed a user study and observed 32 participants while interacting with smartphones using different kinds of eyes-free device-based interaction techniques. We identified several strategies that users had to prevent shoulder surfing. These strategies help us to develop effective ways to design useful interactions that overcome shoulder surfing issues.

CCS CONCEPTS

• **Human-centered computing** → *Computer supported cooperative work.*

KEYWORDS

Shoulder Surfing; Mobile Devices; Collocated Collaboration.

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MUM 2019, November 26–29, 2019, Pisa, Italy
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ACM ISBN 978-1-4503-7624-2/19/11.
<https://doi.org/10.1145/3365610.3368412>

ACM Reference Format:

Romina Kühn, Mandy Korzetz, and Thomas Schlegel. 2019. User Strategies for Mobile Device-Based Interactions to Prevent Shoulder Surfing. In *MUM 2019: 18th International Conference on Mobile and Ubiquitous Multimedia (MUM 2019), November 26–29, 2019, Pisa, Italy*. ACM, New York, NY, USA, 5 pages. <https://doi.org/10.1145/3365610.3368412>

1 INTRODUCTION

Shoulder surfing is a common issue in public space, for example, while using the mobile device in a bus but also in work settings, for example, in open-plan offices. Even in several collaborative activities [17] in group work shoulder surfing occurs [12, 16]. While the observation mainly concerns the visual content of a display, such as PINs, passwords, or private text messages, also the way of entering content can be observed. This includes input patterns, e.g. for unlocking the smartphone screen, as well as mobile-based interactions, e.g. touching devices with each other for connecting [11] or bumping devices to expand the view area [9]. Mobile-based interactions, as described by Korzetz et al. [14], are becoming more and more usual for concrete smartphone functionality, e.g. switching between front and rear camera of a Google Pixel device by twisting the phone twice or placing the smartphone face down on a flat surface to mute an incoming call. They do not need a look at the screen. However, such kinds of interactions are often very exposed and can be recognized and hence interpreted easily by observers.

With an increasing number of such mobile-based interaction techniques, we investigate ways to support users in avoiding shoulder surfing activities on their mobile devices, especially smartphones. On the system's side, there are several ways to obstruct observers from recognizing the input. Either mobile-based interactions need to be unobtrusive themselves, e.g. squeezing the device

as introduced with the Google Pixel 2 phone, or they need to provide mechanisms to keep an input secret, e.g. back-of-device interactions [5, 6, 19]. Furthermore, there are recognition options using the front camera of the smartphone to detect observers [3].

However, there are also different user strategies to avoid shoulder surfing that users apply naturally. We investigated these strategies by performing a user study with 32 participants. With the results, we contribute a new perspective on shoulder surfing avoidance. In the following sections, we briefly describe related work that addresses different approaches to avoid or detect shoulder surfing activities. Further on, we present the user study we performed and the derived results. We conclude with highlighting the most important findings that can be used for further design of shoulder surfer prevented technology.

2 RELATED WORK

There is a wide range of contributions that address shoulder surfing on mobile devices (e.g. [2, 4, 12, 18, 21, 24]) and various strategies to overcome this problem. The majority of approaches focuses on password or PIN input and provides visual representations that are difficult to interpret as external person. For example, von Zezschwitz et al. [23] describe their approach *SwiPIN* where each number of a password or PIN is represented by a certain swipe gesture. Instead of tapping a button, users need to swipe in a given direction that represents a concrete number. Thus, shoulder surfers could not identify the particular number as easy as before. Gugenheimer et al. [8] present *ColorSnake*, a visual representation of PINs. To enter a PIN, users trace one given path out of several paths. Although, the path can be observed it is very difficult for an observer to identify the right path. Chen et al. [3] do not only focus on password or PIN input but they also address the visual presentation of a mobile device's screen. They use knowledge of human vision and optical systems to change the screen content by blending it into the background to hide it from shoulder surfers.

Some approaches use particularly innovative or unobtrusive interaction techniques to make it more difficult for observers to recognize input. De Luca et al. [5] present a back-of-device interaction for mobile device authentication. Because the input occurs at the backside of the device, shoulder surfers standing behind a user cannot see the input (see Fig. 1). Tafreshi et al. [22] present *TiltPass*, a gesture-based interaction technique that uses a tilt gesture as a shoulder surfer resistant password input for mobile devices. The password consists of different tilt gestures in different directions. Kühn et al. [15, 16] provide several device-based interactions for anonymous voting and rating that are eyes-free to perform.

There are also approaches that raise awareness for being observed. For example, Ali et al. [1] investigated shoulder surfing on mobile devices in public space. They provide an Android app (*iAlert*) that captures the surrounding of mobile phone users and detects people that are looking at the user's screen. The application alerts the user in case another person is looking at the screen of the mobile device. While they focus on the technology side of the detection, Saad et al. [20] evaluated different ways of communicating current shoulder surfing activities to the users.

Eiband et al. [7] investigated shoulder surfing in the wild and performed a user study where shoulder surfing reported on their

motivation and feelings to observe other people. Additionally, users described their feelings and their acting when they realized they were observed. Although, Eiband et al. list different kinds of user actions after they realized they were observed, concrete user strategies to prevent shoulder surfing in the first place are not mentioned. Khan et al. [13] evaluated defense and attacker strategies and found that the most common defense strategy is to face away the display from the attackers sight. Again, the defense strategy was applied after the user was observed. We aim at closing this gap with our research by investigating proactive user strategies that aim at preventing shoulder surfing before it occurs.

3 USER STUDY

To investigate user strategies to prevent shoulder surfing, we utilized four concrete types of mobile-based interaction techniques that meet the definition of Korzetz et al. [14]: *Tilt to Vote* as a movement-based interaction, *Fingerprint* as back-of-device interaction, *Draw to Vote* as touch-based interaction, and *Multitouch* as multitouch interaction [15]. All four interaction techniques address collocated collaborative settings. Using these different types of mobile device-based interactions, we wanted to find out how users avoid shoulder surfing especially when there is no need to look at the screen of a mobile device [14]. Furthermore, we wanted to see what users do and how they reflect on their own explicit strategies. We therefore decided to use questionnaires as well as video records for further analysis. We performed the following user study.

3.1 Participants

We asked 32 participants (12 female) from age 18 to 51 ($M = 31.2$, $SD = 6.4$) personally or via e-mail to participate in our user study. About two third of the participants were academics recruited from the university. All users were familiar with smartphone usage. We had 8 groups with 4 people each. Each participant was asked to act as shoulder surfer to trigger such activities within a group.

3.2 Apparatus

We provided a mobile Android application that included the four above-mentioned interaction techniques and a draw function. The participants received the task to draw small images for a fictional exhibition, share them with the other group members, and assess all created images. With this task, the participants should be motivated to keep their input secret as they did not want to show how they assessed. Consequently, they had to avoid the shoulder surfing activities of other group members. The four interaction techniques were used either to vote on the images whether they should be included in the fictional exhibition or to rate them on a scale from one to five. The movement-based interaction *Tilt to Vote* was triggered by tilting the mobile device along the x- or y-axis. *Draw to Vote* as touch-based interaction used sequential touch inputs (one or two strokes) on the display, whereas *Multitouch* detected one to five synchronous touch inputs on the multitouch display. Finally, *Fingerprint* worked as back-of-device interaction where each recognized fingerprint in a short time period was counted as one rating point. Additionally, the Android application included a questionnaire which the participants had to complete after using the different device-based interaction techniques.

Interaction \ User strategy	Tilt to Vote	Draw to Vote	Fingerprint	Multitouch	Σ
Do nothing specific	12	12	14	11	49
Hide device	17	13	15	15	60
Observe surrounding	1	0	1	2	4
Distract observer	0	0	1	1	2
Vary way of entering	2	7	1	3	13

Figure 2: Total number of mentions of user strategies coming from the questionnaire.

3.3 Procedure

The study sessions were performed in a lab environment. After the participants arrived in the lab, they received detailed information concerning the global procedure of the study. We emphasized the focus on shoulder surfing activities and encouraged the participants to keep their input secret. We prepared the mobile application on four mobile phones which the participants could choose. Furthermore, we prepared a square table where the participants were allowed to take a seat but did not have to. They were explicitly allowed to walk freely within the lab. Additionally, a study leader was present the whole time and each session was recorded for retrospective analysis. First, the participants started with an introduction to become familiar with the four interaction techniques. Then, they performed the given task and shared their created images digitally. The images were assessed four times in total because participants were asked to use each interaction. After each interaction the participants completed a questionnaire concerning their own reflection on the strategies they used to avoid shoulder surfers. To conclude a session, we asked for final feedback in a semi-structured interview.

4 FINDINGS AND DISCUSSION

We analyzed the results from the questionnaires and the recorded videos. Furthermore, we interpreted the data and gained interesting insights into the strategies of users to prevent shoulder surfing.

4.1 Results from Questionnaires

After using each interaction techniques, we asked the participants what they did to keep their vote or rate secret. Participants answered with short descriptions of what they did. Then, we categorized the results in 5 categories. The first category is that participants *did nothing specific*. Participants stated clearly that it was sometimes not necessary to do something against shoulder surfing because they had the feeling that interactions were unobtrusive enough. As second category, we identified users *hid the device*. Participants mainly used the table to hid the device but also body parts such as hands or legs. Ten times, participants did not specify how they hid their device. The third category comprises that participants *observed the surrounding* to find out whether they were observed or not. If not, then they rated or voted. Participants also *distracted observers*

Interaction \ User strategy	Tilt to Vote	Draw to Vote	Fingerprint	Multitouch	$M_{Strategy}$
Do nothing specific	2.7	4.3	3.7	2.7	3.4
Hide device	1.9	4.0	3.1	3.5	3.1
Observe surrounding	3.0	-	3.0	3.0	3.0
Distract observer	-	-	1.0	3.0	2.0
Vary way of entering	1.5	3.9	2.0	4.3	2.9
$M_{Interaction}$	2.3	4.1	2.6	3.3	

Figure 3: Mean values (M) from the 5-point Likert scale concerning the effort of keeping input secret (5 = little effort).

by making noises or movements so that it was not clear to observers how users rated. We identified the distraction as fourth category. That participants *varied the way of entering* is the fifth category. This category mainly comprises the speed of the input which was increased or decreased by the users to disguise the real input. Figure 2 shows the total numbers of strategies the participants used.

We further asked the participants to state how much effort it was for them to keep the input secret on a 5-point Likert scale (5 = best). From the questionnaire, we found that the effort depended both on the interaction technique as well as the user strategy. Figure 3 presents the mean values of the questionnaires' results. Both touch interactions (*Draw to Vote* and *Multitouch*) were rated as overall effortless in keeping input secret. In contrast, the movement-based interaction *Tilt to Vote* was rated with higher effort of keeping input secret. The back-of-device interaction *Fingerprint* received good ratings when hiding the device, doing nothing, and observing the surrounding but worse ratings for varying the way of entering and distracting observers. When comparing the different user strategies, *hide device*, *observe*, and *vary entering* received similar ratings for the mean values. In contrast, *distracting* required higher effort. Overall, as expected, *doing nothing specific* was rated with least effort ($M = 3.4$). However, from the questionnaires we could not find reasons that led to the devaluation of this category. Therefore, we continued to evaluate the observations we made.

4.2 Results from Observations and Interviews

After analyzing the questionnaires, we took the video records for further analysis. Overall, we investigated about 240 minutes of data. Our aim was to validate the findings from the questionnaires. Moreover, we wanted to substantiate the category *do nothing specific*.

First of all, we observed that the participants sat closely to each other around the table while performing the task. When it came to voting and rating they increased the distance to other participants by reclining on the chairs. At the same time, they pulled the devices towards the body to decrease the distance and started observing the surrounding. On the one hand, this behavior led to higher focus of the participants on the devices and their individual task. In terms of collaboration, the participants switched from close collaboration to

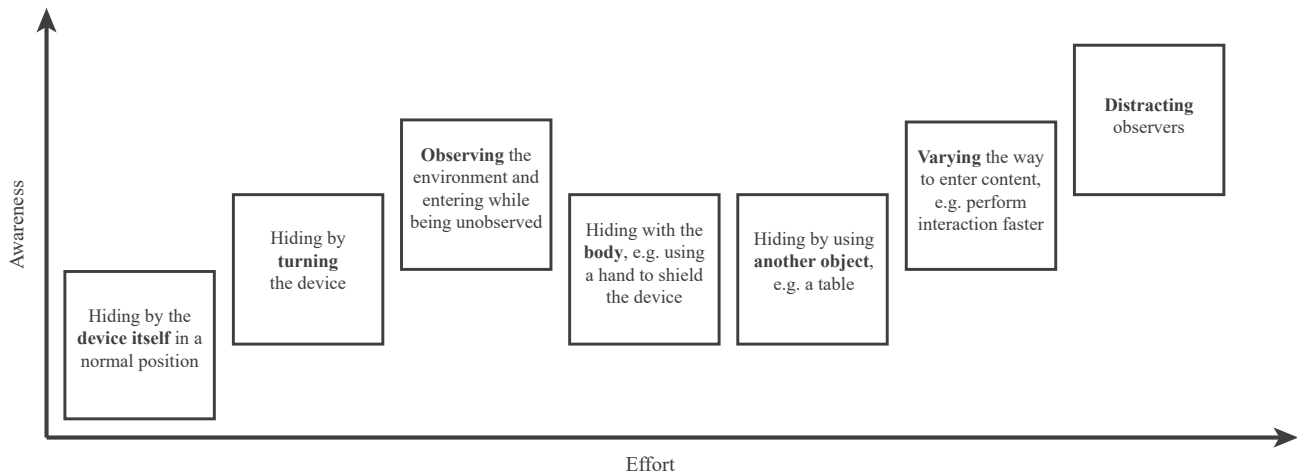


Figure 4: User strategies to prevent shoulder surfing.

loose collaboration [10]. On the other hand, shoulder surfers were triggered to observe because of the obvious movement.

We had a closer look at participants that stated to *do nothing specific* for avoiding shoulder surfers. We found that these participants often acted unconsciously with different strategies that we already described. Most commonly, they observed the surrounding while interacting with the device. They also changed their position to hide the device with their own body. According to these observations, both strategies (*observing* and *hiding*) seem to be very intuitive.

Furthermore, we identified four hiding strategies within the user study. The first strategy was hiding by the device itself, e.g. by using a back-of-device interaction. Participants used this strategy both consciously and unconsciously. Turning the device was the second way of hiding and was mainly used similarly to a back-of-device interaction. As a third way, participants shielded the device with their own body, e.g. a hand or the forearm. Lastly, participants hid their device with an object. In our study, participants often held their device under the table to hide it.

4.3 Discussion

From the results of our user study, we derived several concrete user strategies to prevent shoulder surfing as presented in Figure 4. We classified the user strategies into two dimensions: the effort of keeping input secret and the awareness of different strategies. Effort includes the need of moving as well as the need of changing focus from the task or interaction to, for example, observing the surrounding or distracting observers. Awareness is about user intention, intuitiveness, and concreteness of actions that need to be performed to keep an input secret. We arranged the observed strategies within these dimensions building on the recordings and interviews. The types of hiding devices with the device itself were the most intuitive and effortless strategies as we found from the results. Also observing the surrounding was identified as intuitive and effortless. However, from the questionnaires we assess them a little worse than hiding due to the number of times it was mentioned. Varying the way of entering content generated more effort

depending on the variation. Similarly, distracting observers produced higher effort and needed conscious handling. Comparing our results with the results of Eiband et al. [7], we found that hiding and varying the way of entering were also proactive reactions after being observed not only to prevent shoulder surfing.

4.4 Limitations and Future Work

The user strategies we observed are based on mobile device-based interaction techniques. When investigating user strategies for conventional multitouch interactions the results could vary, especially, because device-based interactions do not need the display as visual representation of content. Therefore, we expect higher effort and greater need for awareness for user strategies to prevent shoulder surfing. Furthermore, we investigated four out of several more device-based interactions according to Korzetz et al. [14]. Although we suspect similar results and strategies for other mobile device-based interactions, further investigations should be made.

5 CONCLUSION

In this paper, we described several user strategies to prevent shoulder surfing activities while using mobile device-based interactions in group settings. We identified seven strategies by conducting a user study with 32 participants. They comprise observing the surrounding while interacting, distracting observers, varying the way to interact, and hiding the device in different ways. Furthermore, we classified the identified strategies by the effort it takes and by the user awareness it needs. Hiding by the device itself and observing the surrounding were assessed best. The study results are the basis for further investigations concerning ways to prevent shoulder surfing on mobile devices. Our findings contribute to the open research gap of strategies from a user's perspective.

ACKNOWLEDGMENTS

The European Social Fund (ESF) and the Free State of Saxony have funded this work within the project CyPhyMan (100268299).

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