Performance of Eyes-Free Mobile Authentication
Work in Progress

Flynn Wolf
University of Maryland, Baltimore County
flynn.wolf@umbc.edu

Adam J. Aviv
United States Naval Academy
aviv@usna.edu

Ravi Kuber
University of Maryland, Baltimore County
rkuber@umbc.edu

***Abstract*—Mobile device users avoiding observational attacks and coping with situational impairments may employ techniques for eyes-free mobile unlock authentication, where a user enters his/her passcode without looking at the device. This study supplies an initial description of user accuracy in performing this authentication behavior with PIN and pattern passcodes, with varying lengths and visual characteristics. Additionally, we inquire if tactile-only feedback can provide assistive spatialization to support users when interacting with the mobile interface, finding that orientation cues prior to unlocking do not help. A within-group, randomized study was conducted with 26 participants. 1,021 passcode entry gestures were performed under eyes-free conditions. Edit distance measurements were then calculated. Gesture traces and subjective feedback were recorded for subsequent analysis. We found that users who focused on orienting themselves to position the first digit of the passcode using the tactile feedback performed better in the task. These results could be applied to better define eyes-free behavior in further research, and to design better and more secure methods for eyes-free authentication.**

I. Introduction

Smartphone users, particularly those dealing with situational impairments or under threat of observational attacks in shared or public spaces, may have to unlock their devices without looking at the screen. This type of real-world eyes-free authentication behavior, whether motivated by user distraction (e.g needing to look elsewhere while unlocking), or the screen being out of view (e.g. screen glare, or interacting with the device under the table [12]), or deliberate obfuscation by the user (e.g., attempting to hide the screen in a bag [18] or a pocket [1] from a shoulder surfing attack), is not well understood. While eyes-free interactions for different types of users and mobile devices have been studied by researchers in the past [3], [4], [7], [8], [11], [15], [16], [19], [20], [24], [29], studies have yet to investigate the performance with common authentication mechanisms when the phone is out-of-view, and user coping strategies to enter passcodes in an eyes-free manner.

To address this knowledge gap, we conducted a randomized, multi-factor study with 26 participants entering PINs and patterns. Participants entered passcodes under both in-view and eyes-free conditions, as well as eyes-free using an additional training module for spatialization based on tactile feedback. The tactile channel was chosen to discreetly offer cues directly to the user's hand, without drawing attention during interaction, as would likely occur with auditory or visual cues. Existing assistive aids aid to eyes-free PIN authentication, such as iOS VoiceOver, rely on audio feedback (audio readout of PIN number buttons when touched, allowing selection). However, audio cues impose usability and security penalties in shared and public spaces. Biometric authentication such as fingerprint identification can greatly expedite this task for many users. However, fingerprint identification remains only a secondary means of authentication, which is generally tied to a PIN passcode for screen unlocking. Essentially, even biometric authentication users must necessarily enter conventional passcodes on a semi-regular basis, and eyes-free conditions may apply in some instances. With this in mind, tactile-only feedback was designed for this study as a research device for understanding authentication performance with strictly eyes-free interaction. Its functionality, and our evaluation of its performance, is not intended to propose a workable real-world tool in the present form. Instead, we tried to capture how users develop techniques that use additional spatial cues to locate key screen features. This spatialization might then assist the accuracy and precision of eyes-free authentication gestures.

Given these assumptions, we have undertaken these research questions:

- **RQ1**: How well are users able to perform eyes-free authentication (without tactile feedback) with common methods, such as PIN and pattern entry, and how is this affected by passcodes' length and visual features?
- **RQ2**: Will spatial cues to screen features (e.g. position of buttons), presented by tactile interaction, support users' performance when authenticating eyes-free?
- **RQ3**: When tactile feedback is presented, what approaches will users develop for using it?

To address the first two of these questions, we recorded and analyzed movement traces of all participants' on-screen touch-based gestures during each authentication attempt, totaling 1021 eyes-free traces. We further evaluated participants' performance in the eyes-free setting in terms of accuracy, using the edit-distance (or *Levenshtein distance*) between the input passcode and the true passcode. The edit-distance considers the number of additions or removals to transform one string sequence into another. We also collected participants' post hoc subjective descriptions of how they approached the task.

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Analysis of this material is on-going, and will be used in future work to address RQ3.

Based on this initial analysis, we found that participants in eyes-free settings were more accurate using patterns than PINs. Additional tactile training was found generally to not improve participants' accuracy. These results firstly contribute an initial baseline of performance results for eyes-free authentication. This will help further research on eyes-free interaction make accurate comparisons and descriptions regarding performance in this condition. Additionally, these insights will help iterate the design of targeted training aids for users who need to authenticate frequently in eyes-free settings, such as blind mobile technology users who rely on secure ubiquitous computing for privacy-sensitive tasks in shared spaces. Informing users of effective techniques will enable users to enter unlock authentication more confidently, securely, and accurately, away from adversarial observation. While the tactile aid adopted for this study produced a mostly negative result from accuracy and edit distance measures, we assert several important contributions from this investigation:

1) A novel characterization of HCI and security performance in eyes-free authentication conditions.
2) A systematic inquiry of input accuracy in eyes-free settings.
3) Establishing the unequivocal performance gap between eyes-free PIN and pattern entry (although unsurprising, this is the first time this has been shown empirically).
4) Identifying passcodes features for which accuracy significantly deviated from average (e.g. self-crossing pattern 743521).

II. Related Work

A. Eyes-Free Interaction Techniques

Mobile technologies rely primarily on visual attention to guide interaction for a broad and increasing array of on-the-go tasks. Research has described a number of ways this interaction can be interrupted. For example, Yi et al. describes several types of situational impairments, including environmental factors (e.g. glare or distraction), social factors, interface design, and deliberate disregard by the user [28]. More specifically, the threat of observer attacks may motivate users to hide the screen from view and interact from memory, either shielded by the hand [18] or placed within a garment or accessory [1]. Without visual feedback, conventional input processes are often inaccurate and frustrating for users. Eyes-free interaction techniques have been studied to reduce the impact of these interaction problems and allow easier visual multi-tasking. To better support users, a range of techniques have been developed involving gestural input (e.g. [3], [7], [8], [11], [20], [26], [29]), or voice input (e.g. [4], [19]), along with accessible forms of output to provide feedback to the user (e.g. audio [7], [8], [16], [26], [29], and/or tactile output [15], [26] either to the user's hand via the mobile device or via a separate wearable. Similar technologies have also been designed to support users for whom the visual channel is restricted or blocked (i.e., individuals who are blind and visually-impaired [5], [13], [14], [17], [21]). These approaches complement or replace visual feedback with assistive technologies (e.g. screen readers) and other forms of accessible information [23]. Examples of these non-visual augmentations include tactile feedback and overlays [24], [22], and voice or auditory cues [8].

Eyes-Free		In-View	
A) w/o tactile aid		B) w/o tactile aid	
A1) 4-digit PIN	A3) 4-len Pattern	B1) 4-digit PIN	B3) 4-len Pattern
A2) 6-digit PIN	A4) 6-len Pattern	B2) 6-digit PIN	B4) 6-len Pattern
C) w/ tactile aid		D) w/ tactile aid	
C1) 4-digit PIN	C3) 4-len Pattern	D1) 4-digit PIN	D3) 4-len Pattern
C2) 6-digit PIN	C4) 6-len Pattern	D2) 6-digit PIN	D4) 6-len Pattern

TABLE I: Conditions for study.

B. Device and Interaction Modifications for Mobile Authentication

Although not designed to improve eyes-free accessibility, research has also explored interaction and hardware concepts intended to reduce vulnerability to adversarial observation attacks [9], [6], [10]. Shoulder surfing was combated by obscuring by methods such as haptic encoding and hardware redesigned to allow easier out-of-view gestures. Performance was compared by measures such as user unlocking performance and simulated adversary's success in copying down passcodes as they are entered. For example, Ali et al. proposed H4Plock [2], where the user is required to enter a sequence of up to four pre-selected on-screen gestures while responding to tactile prompts signaling whether stimuli from a primary or secondary passcode should be entered. The solution proved to be secure against 76.5% of participants, who carried out attacks immediately after watching a set of videos. Participants were able to express strong levels of confidence in using the system.

Limited work has been conducted exploring existing common mobile authentication mechanisms and their use when the user is visually-distracted. In this paper, we describe a study investigating PIN and graphical pattern entry using tactile feedback, when the device is out of view, with the aim to unlocking entry. While auditory feedback appears to be an appealing solution to this scenario, it may be impractical. Auditory content from a screen reader may be insecure or an unacceptable distraction, or it may be masked by ambient noise. Tactile feedback may offer a solution to directing users to make accurate entry gestures (e.g. finding the start position of their passcode). A tactile aid to support orientation has also been evaluated, as part of this research. To better understand user behaviors, we aim to focus on input techniques, and methods of classifying these.

III. Study Design and Procedure

We designed a within-subjects, multi-factor study where participants were asked to enter authentication sequences under four primary conditions (performed in- and out-of-view, with and without tactile feedback). Performance in these conditions addresses RQ1 and RQ2. Within each condition, the participants were assigned a sequence of 10 PINs or patterns to enter, evenly divided between passcodes of 4 and 6-digit length (Table II).

Passcodes were sourced from real world data (the RockYou dataset) for validity, and selected to include visual characteristics for analysis (e.g. left vs. right side shift, and self-crossing patterns). For all experiments, we used a Nexus 5x phone,

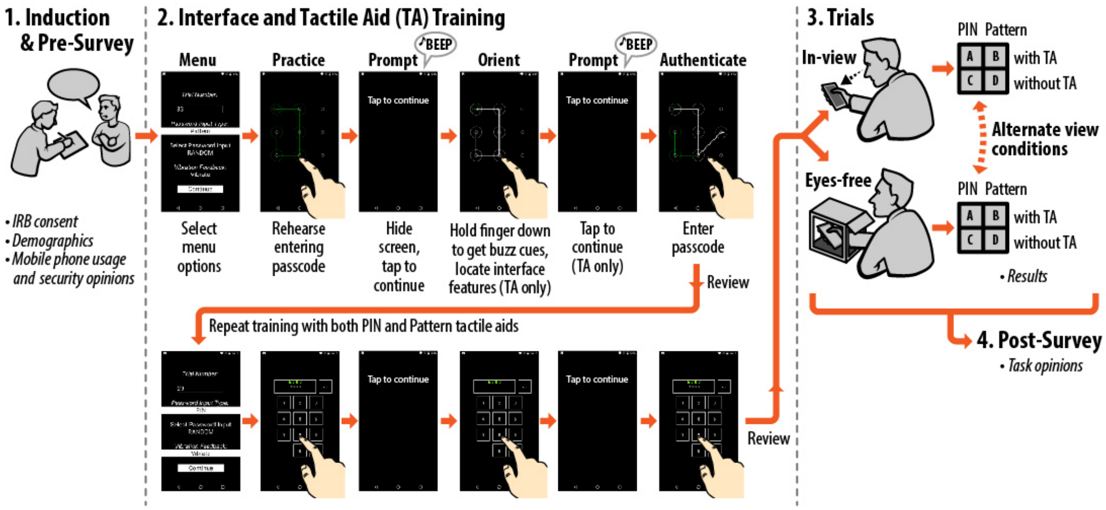

Fig. 1: Study procedure: Participants are informed of the make-up of the experiment, and basic demographic and usage data is collected in step (1). In step (2), participants are trained on the application interface for data collection for both PINs and patterns, and spent time interacting with the training aid (the first prompt/orient phase). Without the training aid, participants in trial A and B proceed directly to the next phase. After completing the training stage, step (3) the trials begin alternating between the conditions as presented in Table I.

Fig. 2: Participant holding the LG Nexus 5x test phone inside the eyes-free observation box.

	PINs	Patterns
4-length	1328	0145
	1955	1346
	5962	3157
	6702	4572
	7272	6745
6-length	153525	014763
	159428	136785
	366792	642580
	441791	743521
	458090	841257

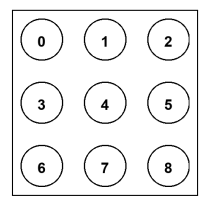

TABLE II: PINs and patterns used in experiments, and reference for labeling pattern contact points. See the Appendix and Supplementary Materials for graphical depictions of the authentication.

which has a common 5.79"x 2.86" form factor, 5.2" display, 1080x1920 resolution. The procedure and study design are similar to that presented in related work [25], [27]. The steps of the study are illustrated in Figure 1.

A web-based application was developed using HTML5 to collect data for the study. This application ran full-screen in a browser, and closely simulated the layout and interaction of typical mobile authentication screens, while collecting input and gesture traces (x-y coordinates of the finger's position on the phone's touchscreen, over time). The application also provided tactile feedback using the phone's actuators for the appropriate conditions. For eyes-free conditions, we used an open-sided cardboard shielding box. This box was placed on a table in front of the seated participant, allowing them to comfortably hold and interact with the phone inside, out of their own view. Researchers could easily observe their actions through cut-out windows in the sides (Figure 2).

26 participants were recruited from university mailing lists, 12 male and 14 female, between the ages of 18-34. Participants were fully sighted mobile users, evenly divided between using iOS and Android (Table III). After an IRB consent form and demographic questionnaire were completed, participants were trained with using the features of the application, particularly the tactile feedback for eyes free trials. A laptop was used to show the current passcode to be entered, so the task did not require any memorization of the passcodes. Once comfortable with the interface, trials were conducted for the four main conditions in randomized order using a Latin Square. A post-trial interview collected subjective responses regarding the tasks and conditions. Each participant took approximately 40 minutes each to complete the experiment.

A. Limitations

In terms of limitations, passcodes were presented in the same order to all participants under each condition. Although pass-codes did not necessarily increase in complexity during each condition, it is acknowledged that this may have

		Male	Female	Total
	total	12	14	26
age	18-24	7	7	14
	24-34	5	7	12
OS	Android	8	5	13
	iOs	4	9	13
Unlock Choice	Fingerprint	5	10	15
	PIN-6	2	7	9
	PIN-4	5	4	9
	Pattern	4	2	9
	No-Lock	1	1	2
Level of Confidence (1-5 Likert)	Phone Security	3.75	3.79	3.77
		(STD: 1.42)	(STD: 0.7)	(STD: 1.07)
	Shoulder Surfing	3.08	3.79	3.46
		(STD: 1.24)	(STD: 0.97)	(STD: 1.140

TABLE III: Demographics of participants

contributed to an effect. Additionally, in order to provide a baseline control, participants were asked to perform in-view PIN and pattern conditions, with/without the presence of a tactile aid. Due to the randomization of conditions, half of the group of participants performed this condition after the eyes-free condition. This was conducted to minimize the likelihood of an order effect. It was acknowledged that this may have led to a slight performance disadvantage for users performing eyes-free first, as the in-view conditions may be considered equivalent to a small amount of extra training.

IV. Results

In this section, we present the participants' performance results. We begin with a description of the metrics applied, followed by the results.

A. Performance Metrics

Accuracy. A crucial and informative metric to determine effectiveness is simply how accurately participants performed the tasks in eyes-free settings. Of course, authentication is a binary response: either participants entered the passcodes correctly or not. As we are also interested in granularity of performance, we also considered the *edit distance*, normalized to the distance of each passcode. More precisely, we considered accuracy as a fraction calculated for a passcode p and entered code p'

$$acc = \frac{len(p) - d(p, p')}{len(p)}$$

where $len(p)$ is the length of the passcode and $d(p, p')$ is the edit distance between the entered and expected passcode. The edit distance (or Levenshtein distance) computes the number of additions, subtractions, or replacements needed to transform one sequence into another. For example, if the task requires entering the passcode 123456, and the participant entered 12356 (or any passcode off by one in some dimension), then the accuracy would be $(6-1)/6$ or 0.83 as the edit distance is 1. This is a generous accuracy measure in the sense that the edit distance is a greedy algorithm and tries to aggressively match strings. However, given the nature of the task, eyes-free entry, we feel that this provides a better reflection on participant effort and performance than a binary yes/no.

B. Performance Results

The primary performance results are presented in Table IV, with per-passcode breakdowns in Table V and Table VI. We applied the accuracy metric to conditions that considered the use or non-use of the tactile aid with the two unlock authentications, PINs and patterns. Additionally, we considered the time (in milliseconds) of entering the authentication in the eyes-free setting.

As observed in Table IV, the impact of the tactile aid is rather limited. There were small effects for patterns, as compared to no effect in PINs, and the effect was most notable when it comes to the start point in the pattern. Using the aid showed a significant improvement in starting accuracy as compared to not using the tactile aid. This is reasonable given that the tactile aid performed different vibration feedback for the first point/digit in the passcode. As the t-test performed is two-tailed, one can consider the significance for the accuracy measure is somewhat intriguing, $p = 0.243/2 = 0.1215$. While this effect is not-significant as a one-tailed result, it is encouraging for tactile aids in the eyes-free setting, perhaps a better design based on feedback from this study, could improve the accuracy of entry.

The performance of the tactile aid for PINs can only be explained as detrimental. The eyes-free task for PINs is already significantly harder, in all conditions, but the addition of the aid showed no effect on accuracy (maybe even hurting accuracy). The time increase of using the aid is also striking and much larger than the time increase for patterns. We can speculate as to the reason for this disparity from participants' post hoc responses regarding eyes-free PIN entry. It may be that the task is already challenging enough (concentrating on a series of discrete gestures hitting PIN digits) that the cognitive burden of integrating the aid's tactile feedback only decreased the participants' abilities. This is an area of future investigation, suggesting that different kinds of tactile aids may be needed for different authentication systems in the eyes-free setting.

When observing performance impacts of the tactile aid on a per-passcode basis, see Tables V and VI, there is no noticeable effect for accuracy. In only one case, for pattern 743521, was there a significant difference gained from using the tactile aid for accuracy. This pattern required doubling-back, (see the Supplemental Material for a graphical depiction) and the tactile aid may have provided some reference points for that process which improved performance. This is further evidence that introducing aids for the eyes-free setting needs further investigation.

V. Conclusion and Future Work

This study was conducted to examine interaction techniques developed by users when they entered different types of passcodes on a mobile touchscreen device under eyes-free conditions. We also inquired if tactile-only spatial feedback would effectively assist users with this type of screen unlocking. We documented a picture of eyes-free authentication performance for common passcode entry methods. Looking at accuracy measures in particular, we can say regarding RQ1 that eyes-free unlocking overall (without tactile feedback) is understandably very challenging. PIN authentication is harder to perform accurately, likely because of the numerous jumps the pointing finger must make. Looking at these measures for

	Tactile Aid	Pattern	PIN	t-test
acc.	w/o	($\mu = 0.80$, $\sigma = 0.28$, $n = 250$)	($\mu = 0.72$, $\sigma = 0.30$, $n = 260$)	$t = 3.08, p < 0.05*$
	w/	($\mu = 0.83$, $\sigma = 0.27$, $n = 253$)	($\mu = 0.71$, $\sigma = 0.30$, $n = 258$)	$t = 4.78, p < 0.001 **$
	t-test	$t = 1.17, p = 0.243$	$t = -0.49, p = 0.628$	
start	w/o	($\mu = 80.51$, $\sigma = 67.62$, $n = 250$)	($\mu = 96.56$, $\sigma = 109.79$, $n = 260$)	$t = -1.98, p < 0.05*$
	w/	($\mu = 68.35$, $\sigma = 61.96$, $n = 253$)	($\mu = 91.77$, $\sigma = 86.46$, $n = 258$)	$t = -3.51, p < 0.001 **$
	t-test	$t = -2.10, p < 0.05*$	$t = -0.55, p = 0.582$	
time (ms)	w/o	($\mu = 7134.86$, $\sigma = 6672.95$, $n = 250$)	($\mu = 8597.35$, $\sigma = 6314.62$, $n = 260$)	$t = -2.54, p < 0.05*$
	w/	($\mu = 7500.12$, $\sigma = 5359.63$, $n = 253$)	($\mu = 10227.07$, $\sigma = 8236.91$, $n = 258$)	$t = -4.43, p < 0.001 **$
	t-test	$t = 0.68, p = 0.499$	$t = 2.53, p < 0.05*$	

TABLE IV: Performance results: *acc.* is the accuracy using the edit-distance measure, `start` is the Euclidian distance of the start point, and `time` refers to the number of milliseconds. As the data was normal, we used a two-tailed t-test. Horizontally, the t-test compared Pattern vs. PIN results, and vertically, the t-test compared w/ and w/o the tactile aid. Effect size of $\alpha = 0.05$ was considered significant. Only traces that were complete and collected without errors were considered.

Pattern	Metric	w/o Tactile Aid	w/ Tactile Aid	t-test
0145	*acc*	($\mu = 0.81$, $\sigma = 0.27$, $n = 25$)	($\mu = 0.86$, $\sigma = 0.27$, $n = 25$)	$t = -0.66$, $p = 0.510$
1346	*acc*	($\mu = 0.88$, $\sigma = 0.19$, $n = 25$)	($\mu = 0.87$, $\sigma = 0.22$, $n = 26$)	$t = 0.25$, $p = 0.801$
3157	*acc*	($\mu = 0.78$, $\sigma = 0.31$, $n = 25$)	($\mu = 0.75$, $\sigma = 0.28$, $n = 26$)	$t = 0.36$, $p = 0.717$
4572	*acc*	($\mu = 0.92$, $\sigma = 0.14$, $n = 25$)	($\mu = 0.80$, $\sigma = 0.29$, $n = 25$)	$t = 1.86$, $p = 0.068$
6745	*acc*	($\mu = 0.68$, $\sigma = 0.38$, $n = 25$)	($\mu = 0.74$, $\sigma = 0.42$, $n = 25$)	$t = -0.53$, $p = 0.595$
014763	*acc*	($\mu = 0.81$, $\sigma = 0.26$, $n = 25$)	($\mu = 0.87$, $\sigma = 0.24$, $n = 26$)	$t = -0.74$, $p = 0.461$
136785	*acc*	($\mu = 0.80$, $\sigma = 0.23$, $n = 25$)	($\mu = 0.86$, $\sigma = 0.22$, $n = 25$)	$t = -0.93$, $p = 0.356$
642580	*acc*	($\mu = 0.78$, $\sigma = 0.25$, $n = 25$)	($\mu = 0.79$, $\sigma = 0.23$, $n = 25$)	$t = -0.20$, $p = 0.844$
743521	*acc*	($\mu = 0.77$, $\sigma = 0.27$, $n = 25$)	($\mu = 0.92$, $\sigma = 0.17$, $n = 26$)	$t = -2.34$, $p = 0.024*$
841257	*acc*	($\mu = 0.80$, $\sigma = 0.31$, $n = 25$)	($\mu = 0.86$, $\sigma = 0.22$, $n = 24$)	$t = -0.79$, $p = 0.434$

TABLE V: Performance Metrics per-Pattern: Comparisons were made with-out (w/o) and with (w/) the tactile aid, and a t-test is used as the data is normal. Note that not all participants provided valid traces, and invalid traces were excluded.

PIN	Metric	w/o Tactile Aid	w/ Tactile Aid	t-test
1328	*acc*	($\mu = 0.73$, $\sigma = 0.32$, $n = 26$)	($\mu = 0.69$, $\sigma = 0.33$, $n = 26$)	$t = 0.43$, $p = 0.672$
1935	*acc*	($\mu = 0.73$, $\sigma = 0.36$, $n = 26$)	($\mu = 0.62$, $\sigma = 0.36$, $n = 26$)	$t = 1.06$, $p = 0.296$
5962	*acc*	($\mu = 0.82$, $\sigma = 0.20$, $n = 26$)	($\mu = 0.72$, $\sigma = 0.40$, $n = 26$)	$t = 1.09$, $p = 0.280$
6702	*acc*	($\mu = 0.65$, $\sigma = 0.29$, $n = 26$)	($\mu = 0.63$, $\sigma = 0.28$, $n = 26$)	$t = 0.24$, $p = 0.810$
7272	*acc*	($\mu = 0.81$, $\sigma = 0.31$, $n = 26$)	($\mu = 0.67$, $\sigma = 0.31$, $n = 26$)	$t = 1.56$, $p = 0.124$
153525	*acc*	($\mu = 0.78$, $\sigma = 0.28$, $n = 26$)	($\mu = 0.82$, $\sigma = 0.21$, $n = 26$)	$t = -0.66$, $p = 0.515$
159428	*acc*	($\mu = 0.69$, $\sigma = 0.26$, $n = 26$)	($\mu = 0.72$, $\sigma = 0.25$, $n = 26$)	$t = -0.45$, $p = 0.654$
366792	*acc*	($\mu = 0.66$, $\sigma = 0.32$, $n = 26$)	($\mu = 0.71$, $\sigma = 0.24$, $n = 26$)	$t = -0.65$, $p = 0.517$
441791	*acc*	($\mu = 0.72$, $\sigma = 0.27$, $n = 26$)	($\mu = 0.81$, $\sigma = 0.17$, $n = 24$)	$t = -1.46$, $p = 0.151$
458090	*acc*	($\mu = 0.65$, $\sigma = 0.32$, $n = 26$)	($\mu = 0.71$, $\sigma = 0.28$, $n = 26$)	$t = -0.62$, $p = 0.540$

TABLE VI: Performance Metrics per-PIN: Comparisons were made with-out (w/o) and with (w/) the tactile aid, and a t-test is used as the data is normal. Note that not all participants provided valid traces, and invalid traces were excluded.

gestures that were aided by tactile feedback, as addressed by RQ2, we see a small positive effect on start point accuracy, for pattern unlocking. Otherwise, the tactile only feedback employed in this study is not helpful to eyes-free authentication in terms of accuracy and time taken to unlock.

Future work in this study will analyze additional features of the collected data. We will use a classification process on the gesture traces to identify and describe strategies undertaken for unlocking and using tactile feedback, per RQ3. Findings reported here regarding accuracy will also be compared to a precision measure based on dynamic time warping, which will compare the movement traces to an ideal entry gesture. We will also review the subjective perceptions reported post trial by participants, and compare those strategies with accuracy and precision measures. These insights about user strategies, event and error types should support the design of targeted authentication training aids for users who may frequently encounter similar eyes-free conditions.

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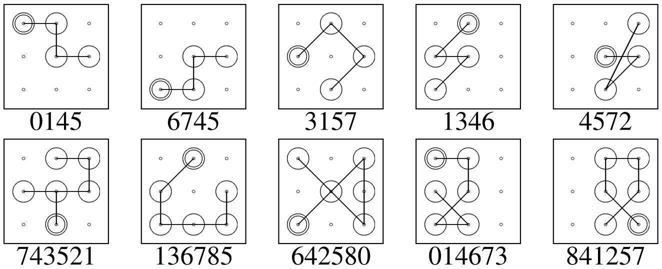
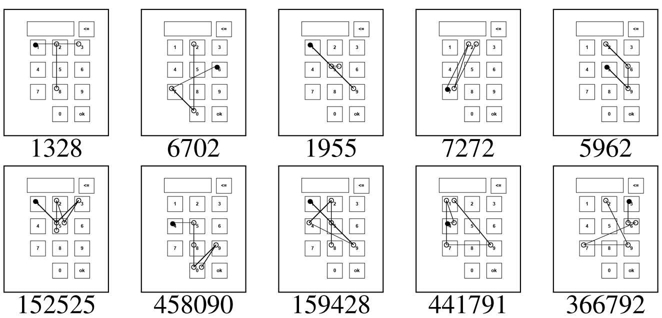
Appendix

A. Patterns and PINs Visualized

1) Patterns: The double circle indicates a start point, single circles is a point included in the pattern. Note that labeling of patterns begins in the upper left with 0, incrementing across each row, ending in the lower right with 8. All visuals also provided in `images/patterns` sub-directory.



2) PINs: The filled circle • indicates the start point, and unfilled circle ∘ indicates an intermediate point. Line traces are provided to show expected shape and directionality of a trace, but users do not drag/maintain contact during entry. Rather, users enter the PIN as normally would be expected by clicking/pressing the buttons. All visuals also provided in `images/pins` sub-directory.



B. *Pre-Survey Questions*

- What is your age (18-24, 25-34, 35-44, 45-54, +65, NA)?
- What is your identified gender?
- Do you have any physical conditions that might affect your ability to enter authentication passcodes on a mobile phone?
- Do you use a smartphone currently? What is its operating system? Why did you select that phone?
- Do you use an authentication method to lock your phone, and if so which method, and why (i.e. PIN, grid, TouchID, etc.)?
- Without telling me your current passcode, how do you select the passcodes you use to lock your phone (i.e. familiar number, or visual pattern)?
- How concerned are you with keeping your phone secure (1, not at all concerned, to 5, highly concerned)? item What experiences can you recall involving people either trying to steal or use your phone without permission?
- What experiences can you recall involving people trying to observe your passcodes without permission?
- How concerned are you, typically, in a public space, with the threat of someone watching you authenticate and collecting your passcodes (1, not at all concerned, to 5, highly concerned)?
- If you had any of these experiences, how did it affect your behavior?
- Have any other experiences or concerns indirectly affected your authentication behavior (news articles, stories about friends, etc.)?
- If you do authentication, how do you typically hold your phone for that?

C. *Post-Survey Questions*

- On a scale from 1-5, how difficult was entering passcode this way (1, very easy, to 5, very hard)? How so?
- On a scale from 1-5, how easy was the grid pattern tactile app to learn (1, very easy, to 5, very hard)? How so?
- On a scale from 1-5, how easy was the grid pattern tactile app to use (1, very easy, to 5, very hard)? How so?
- On a scale from 1-5, how easy was the PIN tactile app to learn (1, very easy, to 5, very hard)? How so?
- On a scale from 1-5, how easy was the PIN tactile app to use (1, very easy, to 5, very hard)? How so?
- Can you see yourself using the grid pattern tactile aid to help authenticate on your phone in your actual daily life? Why or why not?
- Can you see yourself using the PIN tactile aid to help authenticate on your phone in your actual daily life? Why or why not?
- How is this approach similar or different from how you enter passcodes on your phone now?
- Do you think the grid tactile aid would help protect you from someone shoulder surfing you? Why or why not?
- Do you think the PIN tactile aid would help protect you from someone shoulder surfing you? Why or why not?