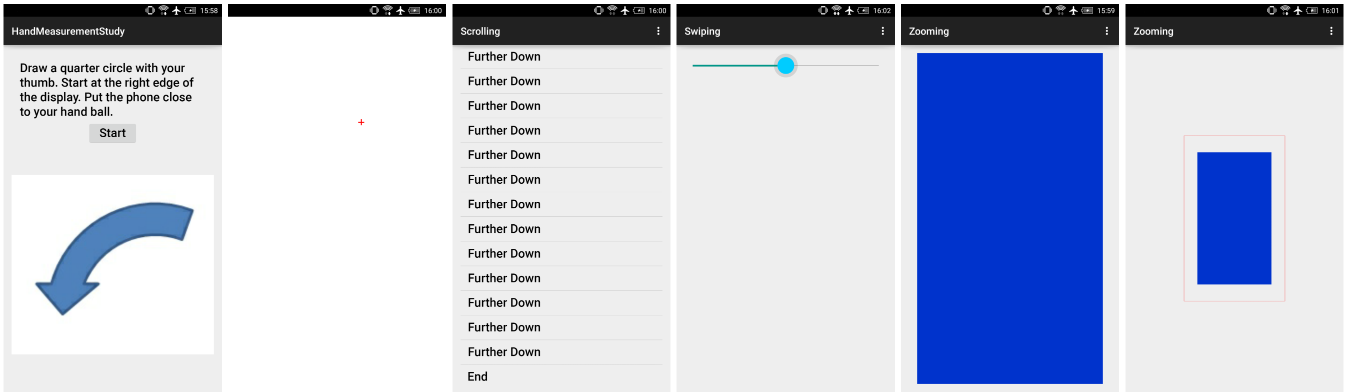
An Exploratory Study on Correlations of Hand Size and Mobile Touch Interactions

Sarah Prange[1,2], **Daniel Buschek**[2], **Florian Alt**[1,2,3]
[1]University of Applied Sciences Munich, Germany, {firstname.lastname}@hm.edu
[2]LMU Munich, Germany, {firstname.lastname}@ifi.lmu.de
[3]Bundeswehr University Munich, Germany, {firstname.lastname}@unibw.de



Draw a quarter circle with your thumb. Start at the right edge of the display. Put the phone close to your hand ball.

1. Radius 2. Tapping 3. Scrolling 4. Swiping 5. Maximum Zooming 6. Frame Zooming

Figure 1: We contribute an exploratory study (N=62) of hand size and touch features in six common interaction tasks on a mobile touchscreen device. We analysed correlations among the touch data and participants' hand sizes.

ABSTRACT

We report on an exploratory study investigating the relationship of users' hand sizes and aspects of their mobile touch interactions. Estimating hand size from interaction could inform, for example, UI adaptation, occlusion-aware UIs, and biometrics. We recorded touch data from 62 participants performing six touch tasks on a smartphone. Our results reveal considerable correlations between hand size and aspects of touch interaction, both for tasks with unrestricted "natural" postures and restricted hand locations. We discuss implications for applications and ideas for future work.

CCS Concepts

•**Human-centered computing** → **Touch screens;** *Mobile devices;* User studies;

Author Keywords

Touch; Hand Size; Correlation; Scrolling; Swiping; Targeting.

MUM'18, Nov 25–28, 2018, Cairo, Egypt

ISBN 978-1-4503-6594-9/18/11...$15.00
DOI: https://doi.org/10.1145/3282894.3282924

INTRODUCTION

Hand size matters when operating a mobile touch screen device. Depending on the current interaction (i.e. typing, scrolling, swiping, zooming), the size of the device, and the context (i.e., sitting vs being on-the-go), interaction requires one or both hands and different levels of effort. People may be forced to adjust their hand posture when trying to reach certain UI elements.

Previous research on mobile touch interaction considered hand size or related factors in several ways:

Modelling touch targeting behaviour, Buschek and Alt found that small-handed users had larger vertical errors in the upper left screen corner, but were more accurate in the lower area of the screen [4]. Bergstrom-Lehtovirta and Oulasvirta modelled the thumb's "functional area" on a mobile touchscreen, depending on the finger location on the back of the device. Thus, the functional area covers a smaller ratio of the screen for larger displays and smaller hand sizes [2]. Karlson et al. showed that mobile devices are often used with only one hand and that reachability degrades with increasing device size. Thus, mid-device regions are easier to reach in one-hand operation while reaching the corners is more time consuming [9]. For a fixed device size, different hand sizes might thus influence these effects.

Another focus in research is on revealing user characteristics from their mobile touch interaction. As an example, Bevan et al. investigated revealing a user's thumb length from how they complete swipe gestures (though restricting their hand posture). From this characteristic, further assumptions about the user's gender or standing height can be made [3].

Further related work studied factors like finger posture in touch input [7], the detection of hand postures to adapt keyboards [6], multitouch gestures for authentication on tablets [13], one-handed phone use while holding other objects [12], and full-body ergonomics when using touchscreens [1]. These and further projects implicitly deal with hand size in various ways (e.g. it likely influences the gestures in [13]), but never explicitly consider hand size as a predictor or prediction target. This motivates our research.

Overall, from the presented research we learn that certain user characteristics can be modelled based on mobile touch interaction with some restrictions (e.g., fixed hand postures), and that assessing hand size could be useful as a relevant factor in HCI studies and in interactions in practice. As a first step towards embedding this assessment into touch interaction itself, we thus investigate how "revealing" fundamental touch interactions are with respect to hand size.

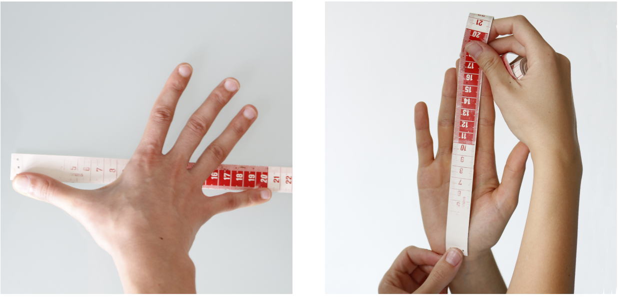
We contribute: 1) an exploratory study (N=62) and correlation analyses of hand size and touch features in six touch interaction tasks; and 2) a discussion and pointers for future research and applications.

STUDY: INVESTIGATING HAND SIZE

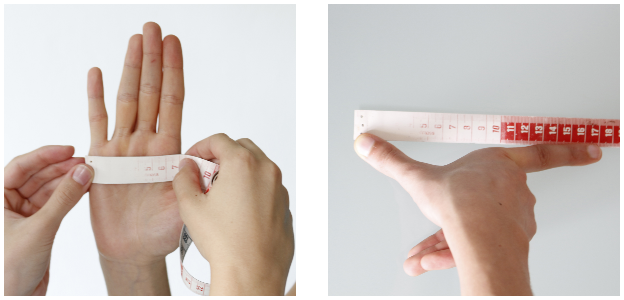
We conducted an exploratory study to investigate correlations between users' hand sizes and their mobile touch interactions. We used six interaction tasks (refer to Figure 1), based on common interactions in casual use of mobile devices. One task had a predetermined fixed hand position (Fig. 1: 1. Radius), while posture was not controlled in the other tasks. We measured hand dimensions (refer to Figure 2) and recorded touch data for the different tasks. The tasks were:

1. *Radius*: Drawing a quarter circle from the right edge of the screen to the lower left, holding the radius as large as possible (predetermined hand position).
2. *Tapping*: Tapping on 144 cross-hairs, shown one at a time in random order across the screen (as in [4]).
3. *Scrolling*: Scrolling a list from top to bottom.
4. *Swiping*: Swiping sliders from left to right; at four different locations (top, middle, bottom, diagonal).
5. *Maximum Zooming*: Scaling a rectangle as far as possible with a single pinch gesture.
6. *Frame Zooming*: Scaling a rectangle to fit into a fixed frame (small, medium and large) using multiple pinch gestures (if necessary).

The order of tasks was randomised with a Latin Square, except for the task with the predetermined hand position, which came first and serves as an "optimistic" or "baseline" task since it requires participants to stretch their thumbs as far as possible while restricting their hand posture.



(a) Total Span (b) Hand Length



(c) Hand Width (d) Zooming Span

Figure 2: Measurement procedure to acquire hand dimensions.

Apparatus

We implemented the tasks as an Android app running on a smartphone (HTC One Max, 5.9 inches screen size). We used measuring tape to measure hand size. For the measures of spans (refer to Fig. 2 a) and d)), we asked participants to perform the respective finger span on a table, while we measured length and width (refer to Fig. 2 b) and c)) directly on the hand.

Participants

We recruited 62 participants, 36 male and 26 female. They had an average age of 24 years (range: 18 to 36 years). The smallest hand was 152mm in length, the largest 224mm (see Table 1 for mean and standard deviation). People were compensated with either a € 5 gift voucher or study credits.

Procedure

Participants were invited to our lab for 15 minute sessions. We first measured hand length and width, total span from thumb to pinky finger, as well as the "zooming span" from thumb to index finger (see Figure 2). Afterwards, participants completed the six tasks using our Android application. Participants sat at a desk with unconstrained body posture. They were free to choose their exact hand posture, (e.g. location along device edge), except for the first task. However, they always had to use their right hand only.

Study Limitations

Our sample is biased towards men and young people. Thus, our results might not represent the general population. Moreover, more precise hand measures might be obtained, for example, with medical measuring devices and methods.

	length	width	zooming span	total span
mean	186.5	84	185	211
std	14.5	7.32	18.58	20.34

Table 1: Participants' hand dimensions, mean and standard deviation.

		Hand Dimension			
Notes	Value	Total Span	Zooming Span	Length	Width
Radius					
start-end	distance	0.26	0.45	0.35	0.25
	Min X	-0.5	-0.57	-0.52	-0.48
	Min Y	-0.1	-0.22	-0.16	-0.08
Tapping					
1/4 screen	av. time difference	-0.1	-0.02	0.15	-0.08
whole screen	"	-0.1	0.04	0.17	-0.06
1/4 screen	av. X-deviation	-0.23	-0.09	-0.17	-0.2
whole screen	"	-0.21	-0.1	-0.2	-0.17
1/4 screen	av. Y-deviation	-0.16	0	-0.11	-0.16
whole screen	"	-0.05	0.04	-0.06	0.07
1/4 screen	pressure	0.21	0.14	0.07	0.19
whole screen	"	0.29	0.2	0.14	0.22
1/4 screen	orientation X	-0.5	-0.21	-0.13	-0.32
whole screen	"	-0.2	-0.2	-0.11	-0.27
1/4 screen	orientation Y	-0.04	-0.06	0.15	-0.02
whole screen	"	-0.06	-0.11	0.09	-0.05
1/4 screen	touch size	0.21	0.17	0.1	0.24
whole screen	"	0.24	0.14	0.13	0.26
Scrolling					
	scroll count	-0.31	-0.29	-0.35	-0.43
	av. distance	0.13	0.04	0.05	0.11
	start X	0.04	0.08	0.07	0.09
	start Y	0	-0.05	-0.04	0.01
Swiping					
top	end X	-0.13	-0.17	-0.1	-0.02
middle	"	0.13	0.09	0.06	0.06
bottom	"	0.26	0.16	0.17	0.22
diagonal	"	0.09	-0.04	0.04	0.1
top	Y difference	0.08	-0.06	0.18	0.25
middle	"	0.03	0.07	0.08	0.01
bottom	"	0.3	0.25	0.23	0.19
diagonal	"	0.11	0.17	0.08	0.16
Zooming					
span	variance	0.21	0.12	0.28	0.2
span	maximum	0.29	0.16	0.18	0.36

Table 2: Correlations by tasks (and "subtasks" for tapping and swiping). Highest correlations are highlighted.

RESULTS

Next, we report correlations between the hand measures and the most promising touch interaction features (refer to Table 2):

1. Radius: distance from start to end; minimum X, Y. Minimum X refers to the leftmost point.
2. Tapping: average time difference, average deviation in X and Y, pressure, orientation X, Y, touch size. We evaluated both the correlation for the whole screen and for the top left quarter (i.e. the part that is hardest to reach).
3. Scrolling: scroll count, mean distance, start X, Y.
4. Swiping: For each of the sliders (top, middle, bottom, diagonal), we compared total distances of sliding interactions along X and Y axis.
5. Zooming (Maximum & Frame): variance and maximum of current distance between thumb and index finger (i.e., width of zooming gesture).

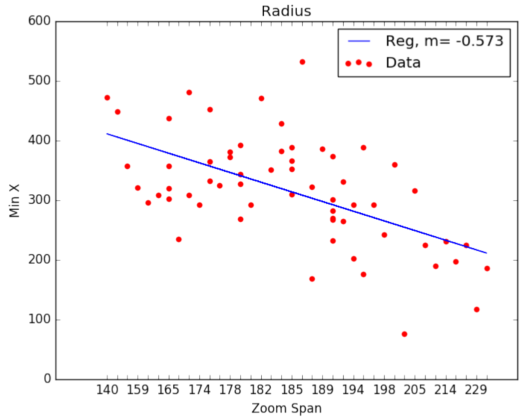


Figure 3: Radius Task: Minimal x value to zooming span.

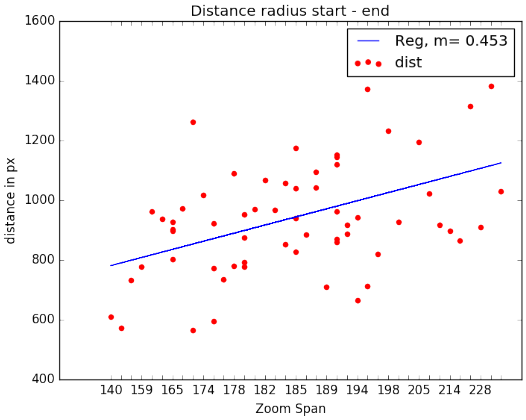


Figure 4: Radius Task: Distance to zooming span.

Note that this is an exploratory study, not a confirmatory one. We are interested in finding possible relationships between hand size and interactions. Thus, we do not compute and interpret the significance of these correlations (see e.g. [8]). This should be done in confirmatory follow-up work, with hypotheses informed by our exploratory results.

We observed highest correlation for the radius task, which required a fixed posture. Looking at the minimal x-value, people with a bigger "zooming span" (referring to the measured hand dimension), were able to reach a smaller x-value (i.e. they could reach further to the left edge of the screen, Figure 3). Also, participants with a higher "zooming span" covered a larger distance with their arcs (Figure 4).

Another interesting correlation is observed for the number of scrolls, which correlated most with hand width (i.e., participants with a wider hand needed less scrolls). Observations revealed that most participants flicked the list and then waited a short moment until the list slowed down spinning. Other participants just dragged the list and did not flick it at all, which explains the top "outliers" (refer to Figure 5).

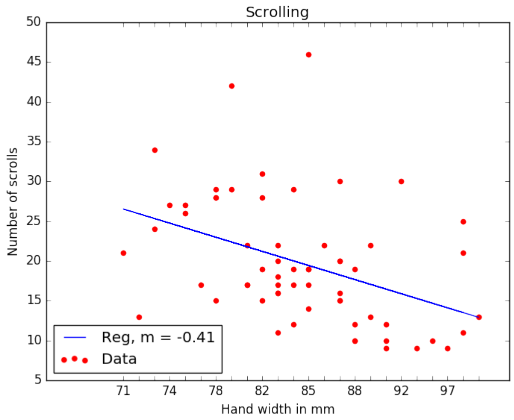


Figure 5: Scrolling Task: Number of scrolls to hand width.

DISCUSSION

Using Common Interactions to Infer Hand Size

In our study, we focused on casual interactions (i.e. scrolling, swiping, zooming, tapping) without controlled postures. Given this setup, our results reveal interesting correlations with regard to future inference in applications.

Comparing the tasks, the radius task showed most promising correlations (though it does not occur "naturally" and requires a fixed hand posture). Number of scrolls and maximum zooming span also showed high correlations. Tapping has smaller ones and requires more interactions (i.e. 144 taps across the whole screen). Swiping also shows several considerable correlations. In addition, for practical applications, we propose to investigate using a combination of the interaction tasks we tested.

Restricting Hand Posture to Investigate Hand Size

Participants' hand posture was often restricted in related work (e.g., [2, 3]). In our tasks with free hand locations, people applied their own habits when interacting with the large "foreign" device. Based on our observations and participants' comments during the study, people with large hands had no troubles to reach every task stimuli on the screen. In contrast, people with small hand dimensions tended to compensate by adapting their hand posture. Moving their hand across the device, they were equally able to reach the far corners. This makes it challenging to see differences of hand sizes in touch data alone. Future work might thus include other data, such as grip sensing around the device (e.g. [10, 11]).

Artificial vs Natural Tasks

Though trying to keep our study as natural as possible, the most promising correlation we received was related to our Radius Task, which required a fixed hand posture. Executing an artificial task with fixed hand posture might distract the user, but it also presents a promising (first) approach for assessing hand size via a touchscreen (e.g. as part of an enrolment for an adaptive UI).

Using Hand Size Information

Assuming that estimates of hand size are available via touch interactions, what might systems do with this information? We discuss potential use cases as follows:

Informing Adaptation for Reachability

Similar to work on one-handed mobile interaction, hand size estimates could be used to inform user interface adaptation, for example to improve reachability. In contrast to mapping sensor data and behaviour features directly to such adaptations, first inferring hand size could contribute to a more explainable user model for adaptation.

Informing Occlusion-Aware UIs

Estimates of hand and finger dimensions might also inform occlusion-aware user interfaces [14], possibly combined with data indicating the current grip and finger location (e.g. last touch location, around device sensors [10, 11]).

Biometrics

Conceptually, estimating hand size from touch behaviour links behavioural and physiological biometrics. In this view, inferred hand size could contribute to future biometric systems (among other information sources), following the idea of "soft biometrics" [5].

Device Sharing

Consider a device shared among a small group of users, such as a "family tablet". Here, inferring hand size from touch interactions might be used to automatically change user-specific settings (e.g. apps shown on homescreen). Related, hand size might be used as a feature to distinguish children and adult users and adapt presentation styles and access to content accordingly.

Practical Integration with Device Unlock

As we found a promising correlation from our swiping task, the "measurement" of the user's hand could be included into tasks such as swipe-to-unlock, which are performed by many users in causal use. This could allow for estimating hand size without the need for an artificial task.

CONCLUSION

We explored the relationship of users' hand sizes and aspects of their mobile touch interaction. We found promising correlations between touch features and hand dimensions for several touch interaction tasks. In future work, we plan to study more features and interactions, and prototype systems using machine learning to estimate hand sizes in the discussed use cases.

ACKNOWLEDGEMENTS

We thank Iris Figalist and Jonas Mattes for their help with the app and study. Work on this project was partially funded by the Bavarian State Ministry of Education, Science and the Arts in the framework of the Centre Digitisation.Bavaria (ZD.B). This research was supported by the Deutsche Forschungsgemeinschaft (DFG), Grant No. AL 1899/2-1.

REFERENCES

1. Myroslav Bachynskyi, Gregorio Palmas, Antti Oulasvirta, Jürgen Steimle, and Tino Weinkauf. 2015. Performance and Ergonomics of Touch Surfaces: A Comparative Study Using Biomechanical Simulation. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1817–1826. DOI: http://dx.doi.org/10.1145/2702123.2702607
2. Joanna Bergstrom-Lehtovirta and Antti Oulasvirta. 2014. Modeling the functional area of the thumb on mobile touchscreen surfaces. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*. ACM Press. DOI: http://dx.doi.org/10.1145/2556288.2557354
3. Chris Bevan and Danaë Stanton Fraser. 2016. Different strokes for different folks? Revealing the physical characteristics of smartphone users from their swipe gestures. *International Journal of Human-Computer Studies* 88 (apr 2016), 51–61. DOI: http://dx.doi.org/10.1016/j.ijhcs.2016.01.001
4. Daniel Buschek and Florian Alt. 2015. TouchML. In *Proceedings of the 20th International Conference on Intelligent User Interfaces - IUI '15*. ACM Press. DOI: http://dx.doi.org/10.1145/2678025.2701381
5. Antitza Dantcheva, Petros Elia, and Arun Ross. 2016. What Else Does Your Biometric Data Reveal? A Survey on Soft Biometrics. *IEEE Transactions on Information Forensics and Security* 11, 3 (2016), 441–467. DOI: http://dx.doi.org/10.1109/TIFS.2015.2480381
6. Mayank Goel, Jacob Wobbrock, and Shwetak Patel. 2012. GripSense: Using Built-in Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones. In *Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology (UIST '12)*. ACM, New York, NY, USA, 545–554. DOI: http://dx.doi.org/10.1145/2380116.2380184
7. Christian Holz and Patrick Baudisch. 2011. Understanding Touch. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 2501–2510. DOI: http://dx.doi.org/10.1145/1978942.1979308
8. Robert G. Jaeger and Tim R. Halliday. 1998. On Confirmatory versus Exploratory Research. *Herpetologica* 54 (June 1998), S64–S66. http://www.jstor.org/stable/3893289
9. Amy K Karlson, Benjamin B Bederson, and Jose L Contreras-Vidal. 2006. Studies in one-handed mobile design: Habit, desire and agility. In *Proc. 4th ERCIM Workshop User Interfaces All (UI4ALL)*. 1–10.
10. Huy Viet Le, Sven Mayer, Patrick Bader, and Niels Henze. 2017. A smartphone prototype for touch interaction on the whole device surface. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services*. ACM Press. DOI: http://dx.doi.org/10.1145/3098279.3122143
11. Mohammad Faizuddin Mohd Noor, Andrew Ramsay, Stephen Hughes, Simon Rogers, John Williamson, and Roderick Murray-Smith. 2014. 28 Frames Later: Predicting Screen Touches from Back-of-device Grip Changes. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2005–2008. DOI: http://dx.doi.org/10.1145/2556288.2557148
12. Antti Oulasvirta and Joanna Bergstrom-Lehtovirta. 2011. Ease of Juggling: Studying the Effects of Manual Multitasking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 3103–3112. DOI: http://dx.doi.org/10.1145/1978942.1979402
13. Napa Sae-Bae, Kowsar Ahmed, Katherine Isbister, and Nasir Memon. 2012. Biometric-rich Gestures: A Novel Approach to Authentication on Multi-touch Devices. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 977–986. DOI: http://dx.doi.org/10.1145/2207676.2208543
14. Daniel Vogel and Ravin Balakrishnan. 2010. Occlusion-aware interfaces. In *Proceedings of the 28th international conference on Human factors in computing systems*. ACM Press, New York, New York, USA, 263. DOI: http://dx.doi.org/10.1145/1753326.1753365