# Investigating the Effect of Orientation and Visual Style on Touchscreen Slider Performance

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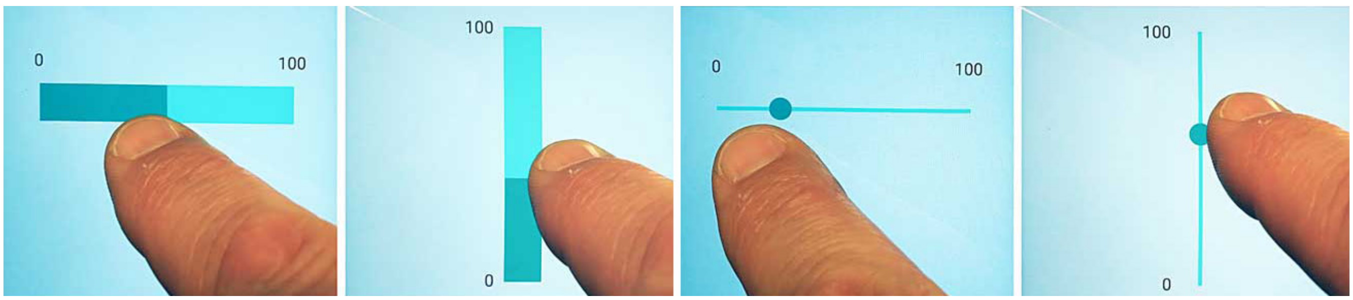


**Figure 1: The four variants of touchscreen slider evaluated in the study.**

## ABSTRACT

Sliders are one of the most fundamental components used in touchscreen user interfaces (UIs). When entering data using a slider, errors occur due e.g. to visual perception, resulting in inputs not matching what is intended by the user. However, it is unclear if the errors occur uniformly across the full range of the slider or if there are systematic offsets. We conducted a study to assess the errors occurring when entering values with horizontal and vertical sliders as well as two common visual styles. Our results reveal significant effects of slider orientation and style on the precision of the entered values. Furthermore, we identify systematic offsets that depend on the visual style and the target value. As the errors are partially systematic, they can be compensated to improve users' precision. Our findings provide UI designers with data to optimize user experiences in the wide variety of application areas where slider based touchscreen input is used.


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## CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

## KEYWORDS

Slider, input, touchscreen, mobile device, visual analogue scale.

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## 1 INTRODUCTION

The proliferation of touchscreen devices is continuing to increase, with a variety of application cases reaching far beyond the nowadays omnipresent smartphone. Whilst the UIs of touchscreen-based applications are typically highly individual, they are built on a core set of basic components, which are generally available for all UIs platforms. One of the fundamental components in such UIs toolkits is the slider.

The slider component is available in both desktop-style mouse driven and touchscreen based environments. While sliders are omnipresent on smartphones, they are used for an even larger number of tasks, e.g., as a visual analogue scale (VAS) for collecting survey results, filtering data [1], controlling machinery in factory settings, and as a pain rating scale in hospitals. In general, sliders are not optimal for inputting specific values, as highlighted in Nielsen Norman Group's rather negative assessment of the component[1]. However, sliders are an excellent solution for enabling users to quickly select a value along a subjective range. Particularly, sliders visually represent the current state of the parameter they are controlling. This visual nature of sliders, and the tangibility of dragging the slider thumb to select a value make them particularly suited for touchscreen interaction.

Since the introduction of Apple's first iPhone in 2007, touchscreens have become the de facto interface for mobile devices. The use of skeuomorphism in the early iPhone UIs, by which the affordance of the touchscreen interface was made intuitive though real-world analogy, has been cited as an enabler for the wide adoption of touchscreens. Nowadays, a truly large number of users, from young children to the elderly, have learned how to interact with touchscreens, and there is now the general expectation among users that everything on a screen can be tapped, dragged or pinched. This has reduced the need for highlighting affordances in touchscreen UIs, which is apparent through later releases of Android and iOS, which focus more on presenting "clean" UIs, rather than optimizing for affordance. Early UIs utilized grip-like textures and drop shadows to highlight the affordance of the slider component's draggable thumb, which have now been replaced with flat graphical styles (see Figure 1 right side). We hypothesize that in the next evolutionary step, the thumb of the slider itself may become redundant, with users simply directly manipulating the marker-bar within the slider (see Figure 1 left side).

Matejka et al. [13] investigated the effect of visual appearance on the performance of continuous sliders and visual analogue scales for desktop UI. The authors found considerable bias in the distribution of responses received. It is therefore likely that values entered with touchscreen sliders are also biased. Operating touchscreen sliders might even be more challenging as the area where a finger first touches the slider is obscured by the finger itself. Furthermore, touchscreen sliders come in different visual styles and orientations, the effects of which are similarly unknown.

In this paper we follow the approach used by Matejka et al. [13] for desktop UIs to investigate how perceptual judgment and objective precision of interacting with a touchscreen slider are affected by its visual design. We conducted a study comparing four different visual presentations of a touchscreen slider on a smartphone, both with and without a thumb, and in horizontal and vertical orientations. We found that both the visual style and the orientation of a touchscreen slider affect the precision with which values are entered. Further, we discovered a systematic pattern of error across the range of the slider's input.

[1] https://www.nngroup.com/articles/gui-slider-controls/

The contribution of this paper is three-fold:

(1) Quantifying the accuracy with which users can input data on touchscreen sliders
(2) Identifying performance differences between horizontal and vertical sliders
(3) Describing the effect of two common visual styles on users' performance

## 2 RELATED WORK

Our work is inspired by previous work in different domains. In the following, we first provide an overview of sliders and the terminology we use. Afterwards, we discuss work on touchscreen interaction and on sliders in non-touchscreen interfaces. Finally, we discuss the use of sliders for touchscreens.

### Slider Functionality and Terminology

The terminology applied to the visual elements that form a slider is generally the following, see Figure 2:

- Track, showing the range available for user selection. The track may run horizontally or vertically and the smallest value is located on the left (for left-to-right language settings) or bottom of the track respectively. In this paper we refer to sliders with an inclusive range of range 0 to 100.
- Thumb, which moves along the track, indicating the selected value through its position.
- Optional additional visual elements, such as tick marks on the track or a value label, numerically indicating the current position of the thumb.
- Touch area - the area that must be pressed such that the slider captures the touch event - once captured, the dragging finger can freely move anywhere on the touchscreen whilst moving the slider thumb.

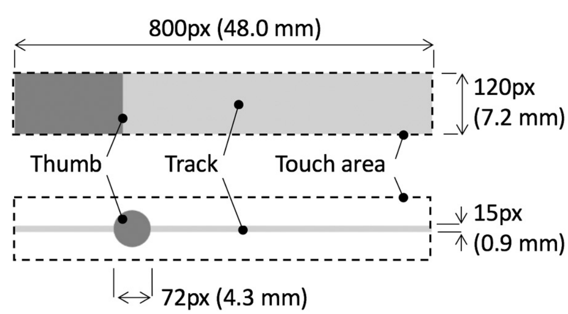



**Figure 2: The two styles of slider compared in the study. Pixel dimensions indicate those when used on the study device Nexus 5X. Moreover, the dimensions used for the study match the stock Android component dimensions.**

Touchscreen sliders offer two interaction approaches, press-drag and press-jump. In the former, the user presses the slider component at the thumb and drags it to the desired release point. In the latter the user directly taps (presses and releases) the slider track at the desired value point. In both cases the thumb immediately jumps to the position of the press event.

### Touchscreen Performance

Whilst there is a significant amount of prior work covering touchscreen interaction, Holz and Baudish's *Understanding Touch* [11] is perhaps the seminal work on the topic for HCI research. The authors focus primarily on tapping type interactions with touchscreens i.e. press and then directly release in the same position. They discuss that target selection is challenging because the area where a finger touches a screen is obscured by the finger itself. However, in the drag based interaction of the touchscreen slider, where, once the component has captured the touch event, the drag gesture can move anywhere on the screen, such masking may not present an issue. Other works have identified systematic offsets in touch input across the area of the touchscreen, particularly in the vertical direction e.g. Henze et al. [9]. Such systematic offsets may produce distortion the input values of sliders, that stretch in length e.g. over 5 cm of screen. Additionally, ergonomic constraints can further impact the accuracy of interaction with touchscreen devices [14, 15].

Considering touchscreen sliders, prior work has looked at enhancing touchscreen sliders with physical overlays, to provide tangible feedback during operation [6, 22]. Here, both works reporting only marginal improvements in operation. The individual nuances of sliding a finger on a touchscreen, e.g. when operating a slider, have been investigated as a way of continuously authenticating the device user by Xu et al. [25]. Since the early days of touchscreen interaction there has been much focus on the visualization of touchscreen buttons, ranging from Parhi et al.'s [16], to more recent use context specific evaluations [21]. Similarly, many works have evaluated the use of free-form sliding gestures on touchscreens e.g. Bragdon et al.'s work [4] looking at the influence of the screen bezel. To the best of our knowledge, there has not been any prior work specifically aiming to characterize interaction with touchscreen sliders.

### Sliders in Non-Touchscreen Interfaces

Studies on non-touchscreen sliders or VAS have generally been applied to the input of subjective data, e.g. in general survey tools or in clinical research. Considering paper-based VAS scales, primarily in the clinical domain, prior work comparing horizontal and vertical orientations has generally reported correlation between the two orientations [17, 19]. However, studies in this area have been based on the input of subjective data and employed small study groups, and thus were likely not sensitive enough to observe small offset effects. However, some differences have been noted. Scott and Huskisson [19] report that values entered in horizontal orientation were slightly lower than vertical, whilst Dauphin et al. [17] report end-of-scale and orientation effects. In a small sample (n = 21) comparative study using the VAS in the Short-Form McGill Pain Questionnaire, a vertical format has been reported as more closely matching a more accurate method of pain assessment [20]. In the same domain, works have highlighted the better visibility of a vertical scale for patients with a narrowed field of vision due to stress as a reason to favor vertical orientation [7]. Considering physical sliders, Lischke et al. [12] demonstrate accuracy improvements achieved through the use of variable movement resistance. A slider with a thumb that extends to reach the track ends more ergonomically, has been evaluated by Rosso et al. [18]. Here, although the final target was a physical slider, initial evaluations of the concept were made on a touchscreen.

In on-screen HCI implementations various application specific visualizations for slider inputs have been demonstrated. For example, Betella et al.'s Affective Slider [2] places bipolar emoticons at the track ends and two triangles under the track, extending from the center point, to visualize intensity level. Looking at use in online surveys, van Schaik and Ling [23] provide a summary of earlier works reporting end-of-scale distortions in VAS. The use of a slider thumb visualized with a gradient, to imply that the value has ambiguity, has been investigated by Greis et al. [8]. Here, in some evaluated configurations, the participant was also able to change the width of the thumb to indicate the confidence level of the value being set.

The closest work to ours is that by Matejka et al. [13] who investigate the impact of placing scale markers on the track of a non-touchscreen slider, highlighting the distortion in input caused by certain visual approaches. Following a similar method to Matejka et al. [13], we apply the approach to look at so far unresearched aspects of sliders - touchscreen sliders, slider orientation and thumb visualization. As a further note of comparison, Matejka et al. [13] report that in their study participants were only able to directly click to select a point on the slider track, rather than dragging the slider to the desired value, which is the typical usage mode. In our test implementation we enable both modes of interaction, and aim to provide data on their relative usage.

### Summary

Touchscreens have become one of most important input devices. Sliders are widely in desktop UIs but are even more pervasive in UIs for touchscreens. Previous work found considerable bias in the distribution of responses received for sliders in desktop UIs. It is, however, unclear if similar biases also occur for touchscreen sliders. This would be critical as touchscreen sliders are even used in applications, such as clinical trials [24], where understanding systematic distortions in the data caused by the collection method is critical. As touchscreen sliders come in horizontal and vertical orientations as well as different visual styles, potential effects of these factors need to be investigated.

## 3 HYPOTHESES

Our study investigates the influence of the visual appearance of sliders on their accuracy. We approach this through three hypotheses:

H1 As prior works on touchscreen interaction [9, 11] have identified the propensity for visualization affecting interaction, we set Hypothesis 1 (**H1**): The visual appearance of the slider thumb will influence slider performance.

H2 For paper-based VAS there has been much work investigating the influence of orientation e.g., [17, 19, 20]. Thus it is of interest to examine if similar effects are visible in touchscreen implementations. Additionally, Matejka et al.'s [13] work on visualization effects, whilst limited to horizontal orientation, highlights the need to investigate vertical orientations. Hence we set Hypothesis 2 (**H2**): The orientation of the slider, horizontal or vertical, influences slider performance.

H3 Prior work, for example Matejka et al. [13] have identified systematic distortions across the input range of sliders. Aiming to validate this for touchscreen implementations we set Hypothesis 3 (**H3**): There is a systematic error in slider input across the range of input targets.

## 4 METHOD

To investigate the three hypothesis, we conducted a study with two independent variables, Style and Orientation, both with two levels. For Orientation we choose the *Horizontal* placement of the slider as seen in all major operation systems as well as the *Vertical* placement, which is less common. For Style we used two approaches, a thin visual track with a circular thumb (*Thumb*), and a version with a thick track with an overlaid bar indicating the current selected value (*Bar*), see Figure 3.

### Apparatus

To compare the four conditions, we implemented an Android application, running on a Nexus 5X smartphone. Each of the sliders had an identically sized touch area, and responded identically to touch inputs. Thus, the conditions only differed in their visualization. Each of the sliders had a range of 0 to 100 (inclusive), indicated with numbers situated at the track ends. The dimensions of the sliders used in the study is shown in Figure 2. In particular, the size of the circular thumb was set to be the same size as that of the screen brightness setting slider of the Nexus 5X. The dimensions of the vertical sliders were identical. As we aimed to first quantify the performance of the basic slider component, no additional visual guides (such as scale tick marks), audio or haptic feedback were provided.

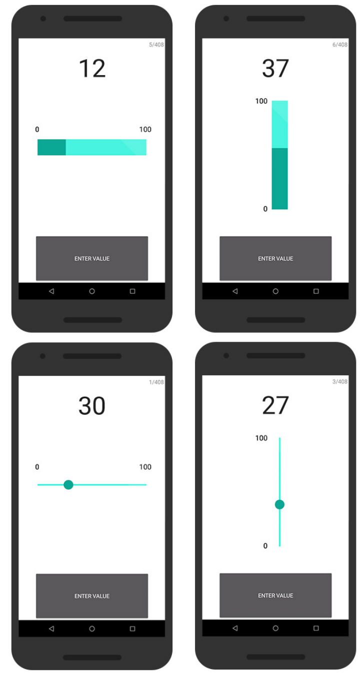



**Figure 3: Screen shots from the study application showing the two levels for each of the independent variables Style (top row: *bar*, bottom row: *Thumb*) and Orientation (left column:Horizontal, right column: Vertical).**

Our method followed that of Matejka et al. [13]. However, as we felt it essential that all tests used identical hardware, we applied a within-subject experiment design with a smaller sample. Our test application presented numeric values between 0 and 100 (inclusive), to which the participant was required to set the slider. The slider position could be adjusted as many times as required, after which an enter button on the display was pressed to record the value and continue to the next trial in the series. For each of the four sliders, all the integers between 0 and 100 (inclusive) were presented as test trials. The order of the sliders was randomized. Within each condition, the order of the trials was also randomized. Thus, each participant entered a total of 404 values. In addition, two training trials were added to the beginning of the study. After each set of 101 values the application offered the participant a chance to pause, to reduce the effects of loss of concentration or physical strain.

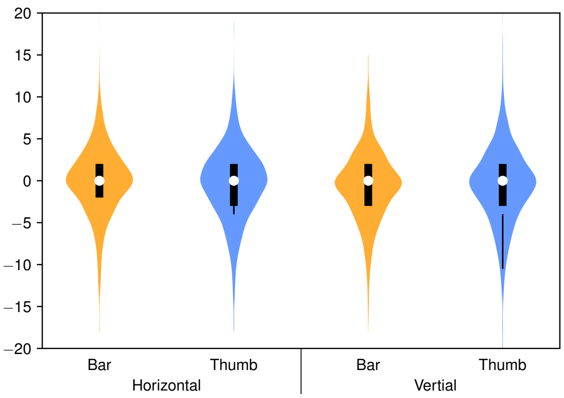



**Figure 4: Violin plots showing the spread of input errors for each slider type.**

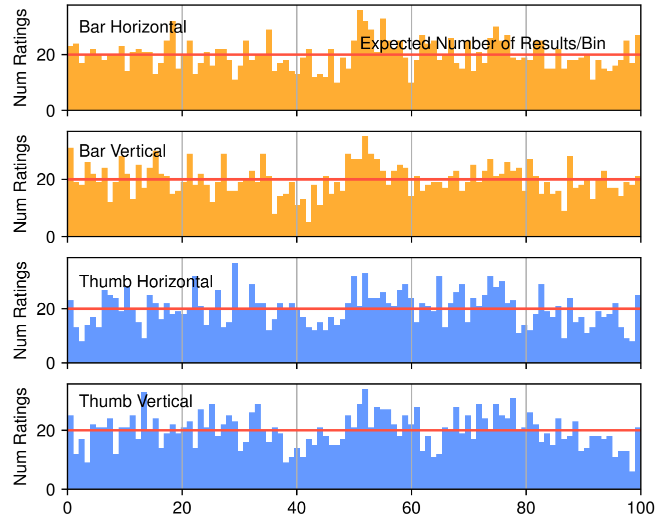



**Figure 5: Histogram of the number of entered values per target for each of the four slider conditions.**

To ensure that the difficulty of all trials was similar, the initial position of the slider was set to a random distance between 30 and 50 scale points from the target value, in either direction. The application recorded the target value, the entered value, the number of touch events, and the total time to enter the value. To guide participants to focus on our core research question of accurate input, e.g. rather than trying to balance accuracy with time, a gamification element was added. A popup *perfect!* was shown when the participant entered the exact value and *great!* when the entered value was within ±3 of the target. The feedback did not inform if the entered value was too high or too low, and was set so broadly that the majority of trials produced the response *great!* Thus, it was a minimum threshold, and did not guide the participants to change their behavior.

### Procedure

After welcoming a participant, we explained the purpose and the procedure of the study. Following this, participants completed a consent form. The participants were seated on a chair during the study, and were asked to select one hand to hold the phone, whilst interacting with the touch screen using the other hand. We handed the Nexus 5X to the participants, on which they first answered a demographics questionnaire and then started with the main study procedure. After completing the initial two warm-up trials, they completed the 404 trials.

### Participants

We recruited 20 participants (14 male, and 6 female) between the ages of 18 and 37 ($M = 25.2$, $SD = 5.1$) from our mailing list. Participants were free to operate the phone as they liked. All held the phone in their left hand and operated it with their right hand index finger.

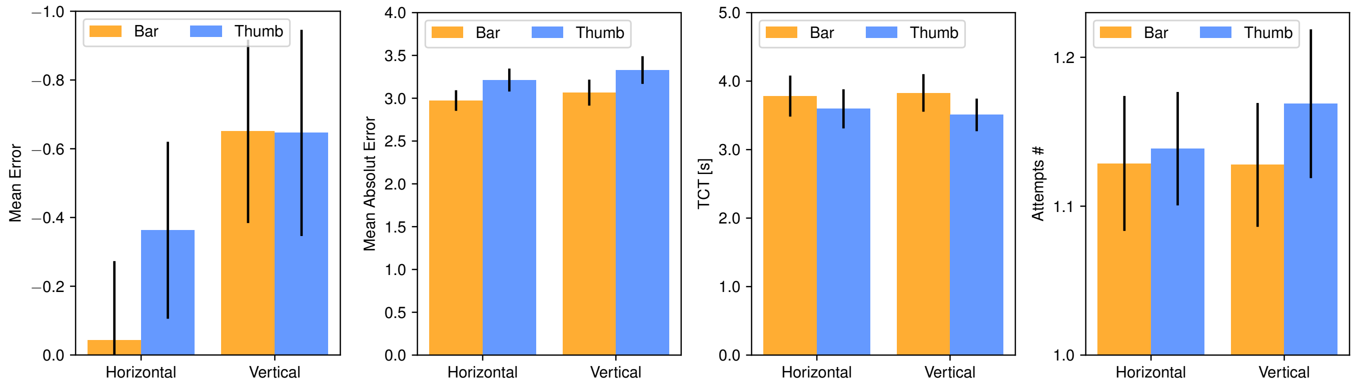
## 5 RESULTS

In total, the 20 participants performed 8080 slider selections. The mean time to complete the 404 trials was 28 minutes ($SD = 8.2$), including the self-regulated rest periods. The average time to enter a value with one of the sliders was $3.7s$ ($SD = 2.3$). Although the test sequence was long, many participants noted that the gamification aspect maintained their interest. Altogether, in 13.4% of the trials participants set the slider to the exact value, with the best performing participant managing this in 19.1% of the trials. Looking at the overall distribution of input errors (Figure 4), the four conditions appear generally similar. Thus, we continued with more a detailed analysis. In the following analysis, whenever Mauchly's test showed that the sphericity assumption was violated in the repeated measures analysis of variance (RM-ANOVA), we report Greenhouse-Geisser (GG) or Huynh-Feldt (HF) corrected degree of freedoms and p-values.

### Setting Error and Bias

To determine the accuracy in setting values, we analyzed both the error and the absolute error. The error is the distance between the target and the selected value, including the direction. When the selection is closer to 0 than the target value the error is negative, and when the selection is closer to one hundred than the target value the error is positive. The absolute error is the unsigned distance between target and selection, without direction.

We conducted a three-way RM-ANOVA to determine whether Style, Orientation and Target have an effect on the distance between the target value and selected value (error), see




**(a) Error** **(b) Absolute Error** **(c) TCT** **(d) Attempts**

**Figure 6: Error, TCT and number of setting attempts.**

Figure 6a. We used TARGET as the independent variable to investigate **H3**. The RM-ANOVA revealed a significant main effect for TARGET, STYLE, and ORIENTATION ( $F_{1,19} = 10.695$, $p < .005$; $F_{1,19} = 4.414$; $p < .05$, $F_{1,19} = 7.171$, $p < .015$; respectively). Moreover, we found significant two-way interaction effects for TARGET *times* STYLE and TARGET *times* ORIENTATION ($F_{1,19} = 44.458$; $p < .001$, $F_{1,19} = 6.939$, $p < .017$; respectively). However, we found no interaction effects for ORIENTATION *times* STYLE ($F_{1,19} = 4.319$, $p = .051$). Finally, the analysis did not reveal a significant three-way interaction effect ($F_{1,19} = .094$, $p = .763$).

We conducted a second three-way RM-ANOVA to determine whether STYLE, ORIENTATION and TARGET have an effect on the absolute distance between the target value and selected value (absolute error), see Figure 6b. This second RM-ANOVA confirmed the results of the first RM-ANOVA. We found a significant main effect for STYLE ($F_{1,19} = 7.940$, $p < .011$) as well as a significant two-way interaction effects for TARGET *times* STYLE ($F_{1,19} = 9.384$, $p < .007$). However, all other effects were not significant (all $p > .22$).

Looking at the currently most commonly used *Horizontal* orientation, the *Bar* outperforms *Thumb* in the mean error which is important for typical slider usage applications. Here the *Bar* is 88% more accurate (*Bar*: $M = -0.04$, $SD = 1.03$ and *Thumb*: $M = -0.36$, $SD = 1.15$).

To investigate if the thumb movement direction impacted the error, we utilized data from target values in the center of the slider (between 40 and 60), which were approached equally from both directions. With this dataset, we re-ran the ANOVAs with Direction as an additional independent variable, finding no significant effect for Error: $F_{1,19} = .581$, $p > .446$. To examine if there is a bias towards specific input values, we plotted histograms of the number of input values at each position on the slider (Figure 5). This also enables comparison with work on desktop UIs [13], noting that our study had far fewer samples. Based on visual examination, no specific effects are apparent.

## Task Completion Time

We conducted a two-way RM-ANOVA to determine whether STYLE (*Thumb*, and *Bar*) and ORIENTATION have significant effects on the TCT, see Figure 6c. The RM-ANOVA revealed a significant main effect for STYLE, $F_{1,19} = 14.246$, $p < .002$. Hence, participants used less time to enter values with *thumb* than with *bar*. However, we found no significant main effect for ORIENTATION, $F_{1,19} = .127$, $p > .725$. We also fount no significant interaction effect, $F_{1,19} = 2.145$, $p < .159$. We found that *Thumb Vertical* was the fastest with $M = 3.5s$ ($SD = 2.$), followed by *Thumb Horizontal* with $M = 3.6s$ ($SD = 2.3$), next was *Bar Vertical* with $M = 3.8s$ ($SD = 2.3$), and last was *Bar Horizontal* with $M = 3.8s$ ($SD = 2.6$).

We further analyzed the TCT by comparing the number of attempts (number of corrections) participants made with the four conditions. Therefore, we conducted a two-way RM-ANOVA to determine whether STYLE and ORIENTATION have significant effects on the number of attempts, see Figure 6c. The RM-ANOVA revealed a significant main effect for STYLE, $F_{1,19} = 6.567$, $p < .019$. Thus, participants used significantly more attempts operating the *thumb* slider than the *bar* slider. However, we found no significant main effect for ORIENTATION, $F_{1,19} = .155$, $p > .698$. We also found no significant interaction effect, $F_{1,19} = 2.284$, $p < .147$.

## Interaction Style

To examine whether participants pressed the slider at the thumb and dragged it (*press-drag*) or immediately pressed the slider track at the target point (*press-jump*), we examined the proximity of first press events to the initial position of the thumb.

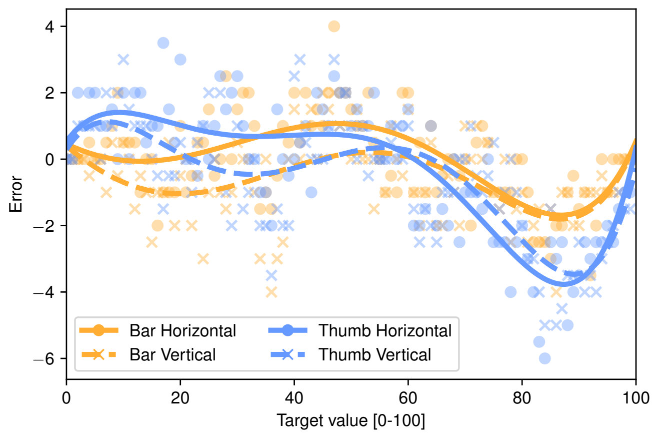



**Figure 7: Average error across all participants for each condition per target as well as the underling error function for each.**

We deemed that presses within an 8.6 mm wide area from the center of the thumb were aiming to press the thumb and continue to drag it to the target position. An 8.6 mm wide area as been reported as encompassing 95% presses to a small visual target [10]. Here, only 13.2% (*SD*= 2.1%) of presses lay outside the thumb's target area, indicating that the majority of interactions are *press-drag*. Further analysis revealed that almost half of the *press-jump* events were from a single user, who applied this approach in 400 of the 404 test cases.

### Error Trend Estimation

By confirming **H3**, we showed that the setting error depends on the target, and hence proceeded to better understand the correlation between error and target. We performed a gird search in combination with a leave-4-participants-out-cross-validation to find the best fitting polynomial. We used orthogonal distance regression minimizes as cost function to fit the polynomial. We found that a polynomial of degree 5 (quintic function) best describes the data. We use Equation (1) to predict the mean error per target. Here $x$ is the target value of which to predict the error.

$$f(x) = ax^5 + bx^4 + cx^3 + dx^2 + ex + f \quad (1)$$

We found that Equation (1) can model the trend of the *Thumb* slider better then the *Bar* slider. Moreover we found that the *Horizontal* orientation can be better modeled then the *Vertical* orientation. With $R^2 = .25$ we found the lowest fit for the *Bar Vertical* slider, followed by *Bar Horizontal* slider with $R^2 = .41$, the *Thumb Horizontal* slider with $R^2 = .54$, and finally the highest value for the *Thumb Horizontal* slider with $R^2 = .72$, see Figure 7. All coefficients for the error trend estimation are presented in Table 1.

## 6 DISCUSSION

Based on the results of our study we now return to our original 3 hypotheses. Our results validate our hypothesis (**H1**): that the visual appearance of the slider thumb will influence performance. In this respect the *thumb* visualization style including a $\sim 4mm$ diameter circular thumb, introduces more offset in the input that the thumbless *bar* visualization. The size of the thumb causes an overestimate for lower target values and an underestimate for higher target values. Here, we speculate this is caused by the user evaluating the position of the slider based on the edge of the thumb nearest the track end point. For example, when setting a value of 88, the distance between the rightmost edge of the thumb and the end of the track at 100 is the basis for positioning the slider. As the *bar* slider effectively has a zero width thumb, it behaves more similarly at both end of the range. Although the *bar* slider still exhibits underestimation in the high target values range (70 - 95) this is less so than the *thumb* condition, see Figure 7.

The *thumb* slider was significantly faster to use than the *bar* slider. We consider there are two possible causes for this. Firstly, due to the higher affordance offered by the visible thumb and the preferred mode of slider interaction that users first press the thumb before starting to drag it. Here, the larger visual target area presented by the thumb in the *thumb* condition compared to that in the *bar* condition will result in faster initial presses, see e.g. Henze et al. [9]. A second contributory factor may be that the larger thumb introduces the perception of ambiguity in the setting, encouraging the user to settle for a 'close enough' value. This is generally supported by the findings of Greis et al. [8], in their study of sliders to enter uncertain data.

We were also able to validate our second hypothesis (**H2**): that slider orientation influences performance. Here we report that the vertical orientation introduced more offset distortion to the input than the horizontal. No difference in the interaction times between the two orientations was found.

We found noticeable differences in the offset error at different positions across the range of the slider, validating our

**Table 1: The coefficients for the four functions (in $10^{-5}$). The coefficients are rounded with in the 95% confidence bounds.**

| | Bar H. | Bar V. | Thumb H. | Thumb V. |
|---|---|---|---|---|
| $a$ | 0.000102 | 0.000138 | 0.000373 | 0.000465 |
| $b$ | −0.015050 | −0.023822 | −0.081822 | −0.107254 |
| $c$ | 0.262044 | 0.891208 | 6.182070 | 8.487389 |
| $d$ | 30.315521 | 24.922813 | −196.255907 | −268.521395 |
| $e$ | −808.521266 | −1404.275994 | 2285.235518 | 2695.568356 |
| $f$ | 4572.188397 | 3926.439119 | 5415.562625 | 2890.283450 |

hypothesis (**H3**). As noted in our discussion around (**H1**) this is likely due to participants positioning the slider thumb relative to reference points such as the track ends or track midpoint. The participants' left-to right reading direction may present one explanation for the larger error in the 70 to 95 range [5], with participants being less precise in estimating backwards from the 100 track end point.

Whilst the level offsets identified (less than 4%) may be considered small and inconsequential in some applications, there may be other use cases where such distortions are important. For example, prior work on VAS e.g. for use in clinical trials has been motivated to evaluate such effects. As noted in our review of related work, there are now industry proposals to adopt smartphone based solutions as the standard tool for clinical trials.

Based on our findings, we conclude that where low-distortion of input is required the optimal slider format is *bar* style in *horizontal* orientation. However, if speed, and likely ease of use, are the drivers then the currently dominant slider with a visible *thumb* is recommended. As an interesting side note, the latest version of Apple's iOS operating system implement a new thumbless bar type of slider slider[2], which they do not further specify in their guidelines. Interestingly, the current applications of the slider place it in a vertical position.

We acknowledge that our work is limited by the sample size in our study. However given the relatively narrow distribution of our test task of entering numerical values, our sample was sufficient to identify statistically significant effects. If input tasks with a larger spread of subjectivity are used, such as Borg and Borg's scale of blackness [3] then a far larger sample size would be required.

As future work, we plan to investigate the effect of slider track length and further develop the visually design of our *bar* slider with the aim to promote the affordance of the tap-jump mode of interaction, which we believe may offer benefits in some applications.

## 7 CONCLUSION

The visual design and orientation of touchscreen sliders affects the offset errors when users input data. Overall a slider design without a thumb and placed in horizontal orientation was found to perform best and introduce less offset to inputted values. However, whilst introducing slightly more offset, a slider with a visible circular thumb was faster to set. A systematic distortion of input values vs. target value was identified with largest impact in the range 70% to 95% of the slider's track.

[2]https://support.apple.com/en-gb/HT202769

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