POSTER

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Motor Accessibility of Smartwatch Touch and Bezel Input

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ABSTRACT
Smartwatches present inherent input difficulties due to the small touchscreen. In a controlled experiment with 14 participants with upper body motor impairments, we compared smartwatch touchscreen input to input on the bezel of the watch, the latter of which should at least theoretically stabilize user input due to its hard edge. Results demonstrate a speed-accuracy tradeoff whereby the touchscreen is faster but the bezel is more accurate.

Author Keywords
Smartwatch; motor impairment; touchscreen; accessibility.

ACM Classification Keywords
• **Human-centered computing~Accessibility systems and tools**.

INTRODUCTION AND BACKGROUND
Smartwatches present an inherent accessibility challenge: the small screen, often only ~4 cm in width, requires precise input and can be difficult for people with upper body motor impairments to use [6]. Touchscreen accessibility work, however, has largely focused on smartphones and tablets, showing, for example, that people with motor impairments encounter higher error rates [2, 8] and exhibit longer dwell times than people without motor impairments [4]. Multi-touch gestures and text entry can also be particularly difficult [1, 5, 10].

One strategy to address these challenges is to stabilize the user's finger by utilizing the hard edges of the screen [3, 12]. While modern smartwatches do not have the same hard screen edges as older mobile devices, taps or swipes on the bezel (Figure 1) rather than the touchscreen may provide similar benefits while also mitigating the fat-finger problem (a common issue with small screens [9]). Indeed, a study by Malu et al. [6] showed that users with motor impairments were open to the idea of bezel gestures and preferred them to other non-touchscreen input options (skin or wristband input). However, that qualitative study did not measure users' input performance with the bezel.

We report on a controlled lab study comparing touchscreen and bezel input with 14 participants with upper body motor impairments. Our findings reveal a speed-accuracy tradeoff: the bezel significantly lowered error rates with small targets, but the touchscreen was significantly faster. We discuss the implications of these findings and subjective feedback, and outline next steps to build on this research.

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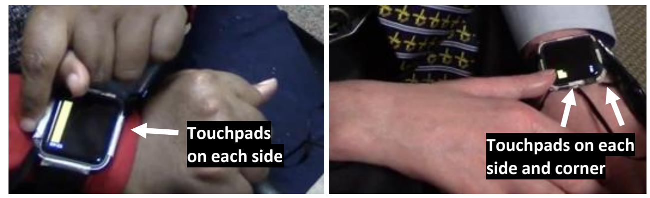

Figure 1. Bezel input: four (left) or eight (right) conductive fabric touchpads were affixed to a smartwatch case.

METHOD
Our controlled experiment compared bezel and touchscreen input performance for two target layouts (4 and 8 targets).

Participants
Fourteen participants (6 women, 8 men) with upper body motor impairments were recruited. They were on average 36.9 years old (*SD*=13.6) and their most common diagnosed medical conditions were cerebral palsy (*N*=5), muscular dystrophy (*N*=2), and spinal muscular atrophy (*N*=2). On a standardized Box-and-Block test of gross manual dexterity, scores ranged from 0–48 (adults without motor impairments score ~80 [7]). All owned a smartphone, two owned a smartwatch, and one owned a wrist-worn fitness tracker.

Apparatus and Procedure
We built a testbed in Swift for a 42mm Apple Watch 1 (Figure 2). While the screen was 24x27mm, we restricted the active area to 24x24mm so the vertical and horizontal spans were equal. For touchscreen input, this area was divided into a 2x2 grid for the 4-target layout and a 4x2 grid for the 8-target condition (mimicking common layouts in watchOS). For bezel input, we affixed conductive fabric to a smartwatch case (Figure 1). These touchpads were wired to an Arduino Uno that connected via Bluetooth to an iPhone 5s paired to the watch. For the 4-target condition, we centered a 24mm-long target along each side of the case (this length was chosen to match the active touchscreen size rather than the full watch bezel); touchpads were 5mm in height. For the 8-target layout, eight 12mm-long touchpads were centered on the sides and corners of the case.

Study sessions were 90 minutes and began with background questions and the Box-and-Block test. Then, the four experimental conditions were presented in counterbalanced order using a balanced Latin Square. For each condition,

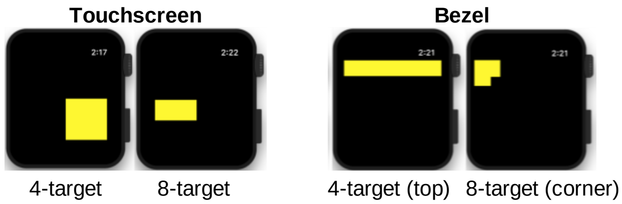

Figure 2. Visual cues. Participants tapped directly on the touchscreen target (left) or on the closest bezel target (right).

participants completed a practice block (8 tapping trials) followed by three test blocks (16 trials each) with brief rests between blocks. Within each block, each target location was presented the same number of times (e.g., 2 times for the 8-target layout and 4 times for the 4-target layout), and trials were randomly ordered such that a single target would not be appear twice in a row. For each trial, a visual cue was shown (Figure 2) and an audio cue played. A trial ended upon successfully tapping the target or after a 10-second timeout (indicating substantial difficulty). The session concluded with semi-structured questions.

Study Design, Data and Analysis

We used a 2×2 within-subjects design: *technique* (bezel *vs*. touchscreen) × *layout* (4- *vs*. 8-target). We hypothesized that bezel input would be faster (H1) and more accurate (H2) than touchscreen input. The dependent variables of time and error rate violated the normality assumption of ANOVAs (shown by Q-Q plots and Shapiro-Wilk's W tests), so we used 2×2 repeated measures (*technique* × *layout*) ANOVAs with Aligned Rank Transform—a non-parametric alternative [11]. Posthoc pairwise comparisons used Bonferroni-adjusted Wilcoxon signed rank tests.

RESULTS

Overall, we found a speed-accuracy tradeoff, as shown in Figure 3. The touchscreen was significantly faster (M = 1.2s, SD = 0.2) than the bezel (M = 1.7s, SD = 0.2) (main effect of *technique*: $F_{1,13} = 22.60$, $p < .001$, $\eta_p^2 = .63$). Reflecting differences in target size, the 4-target layout was significantly faster than the 8-target layout, at on average 1.3s (SD = 0.4) versus 1.6s (SD = 0.4) (main effect of *layout*: $F_{1,13} = 50.50$, $p < .001$, $\eta_p^2 = .79$). The *layout* x *technique* interaction effect was not significant for time.

In contrast, the bezel yielded a significantly lower error rate (M = 3.5%, SD = 1.0) than the touchscreen (M = 10.0%, SD = 11.3) (main effect of *technique*: $F_{1,13} = 18.62$, $p < .001$, $\eta_p^2 = .58$). As expected again, the 4-target layout resulted in a significantly lower error rate (M = 2.5%, SD = 0.5) than the 8-target layout (M = 11.1%, SD = 9.79) (main effect of *layout*: $F_{1,13} = 26.54$, $p < .001$, $\eta_p^2 = .67$). However, there was also a significant *technique* × *layout* interaction effect ($F_{1,13} = 37.20$, $p < .001$, $\eta_p^2 = .74$). Posthoc pairwise comparisons showed that the touchscreen was particularly error prone with the small targets in the 8-target layout compared to the bezel ($p < .05$), but that the two types of input were not different for the 4-target layout ($p > .05$).

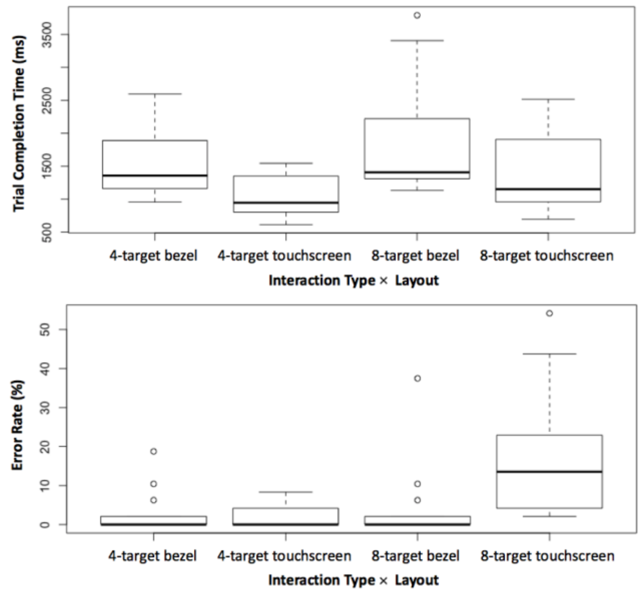

Figure 3. Boxplots of average trial completion time (top) and error rate (bottom). Lower values are better in both graphs.

Subjectively, participants largely favored the touchscreen despite its higher error rate. For example, all but one participant felt the touchscreen was more comfortable (e.g., due to familiarity, did not require twisting the wrist) and easier to use (e.g., due to the flat surface and combined input/output space). However, participants also identified advantages to bezel input, such as the ability to use multiple fingers (*"I found myself using only the index finger for the touchscreen but for the bezel I was using multiple fingers"*, P8), and different finger orientations (*"different sides of my finger"*, P5). Four participants also felt the bezel could be useful for quick tasks (e.g., stopwatch start/stop, P9), three thought it could be useful when occlusion is a problem (e.g., manipulating a map), and one participant (P6) suggested the bezel could be a more accessible alternative to the physical buttons on the side of the watch.

DISCUSSION AND FUTURE WORK

Our findings reveal a speed-accuracy tradeoff that supports hypothesis H2 but not H1: the touchscreen is faster but the bezel is more accurate, particularly for small targets. While participants largely preferred the touchscreen for general input, the bezel could be useful for specific scenarios, such as when needing to limit visual occlusion, performing quick shortcut gestures, or as an alternative to small physical buttons. Several possibilities exist to improve the bezel input, such as increasing the size of the touchpads, adding physical guides (e.g., notches) to stabilize input, only using the watch sides that are within easiest reach, and exploring swiping as well as tapping. Ultimately, while the bezel had previously shown promise for accessible off-screen input [6], we recommend using it as a complement to the touchscreen and focusing on further design tweaks.

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