Age-Related Differences in Performance with Touchscreens Compared to Traditional Mouse Input

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ABSTRACT
Despite the apparent popularity of touchscreens for older adults, little is known about the psychomotor performance of these devices. We compared performance between older adults and younger adults on four desktop and touchscreen tasks: pointing, dragging, crossing and steering. On the touchscreen, we also examined pinch-to-zoom. Our results show that while older adults were significantly slower than younger adults in general, the touchscreen reduced this performance gap relative to the desktop and mouse. Indeed, the touchscreen resulted in a significant movement time reduction of 35% over the mouse for older adults, compared to only 16% for younger adults. Error rates also decreased.

Author Keywords
Older adults; input; touchscreens; accessibility.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User interfaces - *input devices & strategies*.

INTRODUCTION
The potential of touchscreen devices for older adults has been explored in research applications from health information [12] to social networking [9]. Their universal ease and intuitiveness has also been lauded by abundant anecdotes and media attention. Despite this apparent popularity, little is known about the psychomotor performance benefits of touchscreens for older adults, especially in comparison to younger adults and traditional computing setups (*e.g.,* mouse and desktop). Put simply, *do* touchscreens reduce the performance gap between younger and older adults as compared to desktop computers?

Although limited, previous work suggests that touchscreens may be especially beneficial for older adults: Schneider *et al.* [14] showed that a touchscreen reduced the performance difference between adults aged 60-75 and a middle-aged group (40-59) compared to mouse input. For a dragging task, however, Wood *et al.* [19] found that a touchscreen was slower and *more* difficult than the mouse for older adults. These mixed findings suggest a need for more

comprehensive examinations of touchscreens versus traditional desktop input. While we acknowledge that motor performance is only one aspect of usability, it is the fundamental basis for all interactions and thus has significant influence over a device's overall ease-of-use.

We report on a study with 20 older and 20 younger adults, comparing mouse and touchscreen performance across four tasks: *pointing*, *dragging*, *crossing*, and *steering*. On the touchscreen, we also evaluate *pinch-to-zoom*. Our results show that, while older adults were significantly slower than younger adults in general, the touchscreen reduced this performance gap relative to the desktop and mouse. Indeed, the touchscreen resulted in a significant movement time reduction of 35% over the mouse for the older adults, compared to only 16% for the younger adults. Error rates also decreased. Steering, which was particularly problematic for older adults on the desktop, achieved the greatest improvement. Finally, touchscreen dragging was relatively slow, extending previous work [3] to older adults.

RELATED WORK
Few studies have evaluated touchscreen input performance for older adults beyond pointing and dragging. Rogers *et al.* [13] found that older adults were slower than younger adults for pointing and sliding (scrolling) tasks on a touchscreen, and that small button sizes were particularly problematic for the older adults. Piper *et al.* [12] showed that older adults can complete a range of touchscreen gestures with little difficulty, although no detailed performance comparison was provided. Stößel *et al.* [17] compared older *vs.* younger adults' abilities to draw a large set of gestures, finding that the older adults were slower but not more error-prone than younger adults. Finally, Kobayashi *et al.* [8] studied older adults' abilities to point, drag, and pinch/zoom on a touchscreen, but neither a younger control group nor an alternative input device was included. Even combined, these studies do not offer a systematic and complete understanding of age-related differences across a range of touchscreen interactions.

With a traditional mouse, older adults consistently perform less well than younger adults (*e.g.*, [1, 2, 7, 16, 18]). Chaparro *et al.* [1] showed that older adults were slower for pointing and dragging tasks with a trackball and a mouse. Movement analyses show that older adults have a higher noise-to-force ratio [18] and do not travel as far in their primary movement or reach the same peak velocity as
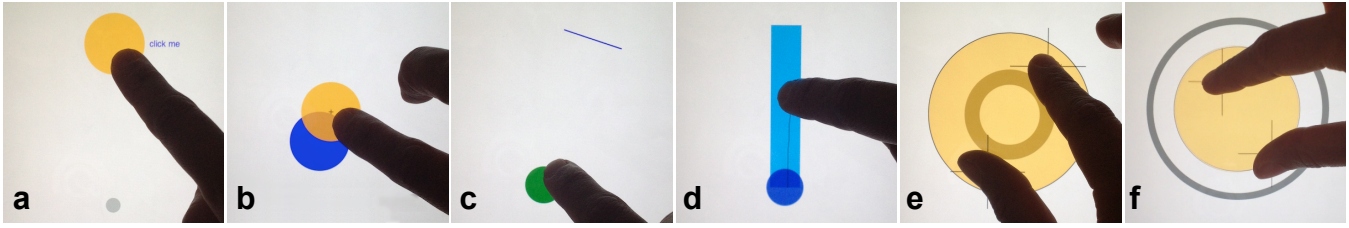
Figure 1. The six tasks: (a) *pointing* **to a circle (next target is also shown in light gray); (b)** *dragging* **one circle and dropping it on another; (c) from a start circle,** *crossing* **over a target line; (d) from a start circle,** *steering* **through a rectangle; (e)** *zooming out* **and (f)** *zooming in* **using two touch points to resize a circle to fit within a gray ring. Only tasks (a)-(d) were completed on the desktop.**

younger adults [7]. Older adults also have more difficulty clicking and double-clicking than younger adults [16]. For the general population, mouse versus touchscreen interaction has received more attention, *e.g.*, examining target size [15], bimanual tasks [4], and dragging [3]. The lattermost paper highlights the surprisingly small amount of comparative work on touchscreens beyond pointing.

STUDY METHOD

Participants
We recruited 20 adults aged 19–51 ($M = 27.7$, $SD = 8.9$) and 20 adults aged 61–86 ($M = 74.3$, $SD = 6.6$). The younger and older groups contained 8 and 14 females, respectively. All but four participants reported daily computer use, while 12 younger and 9 older adults reported daily touchscreen use. Very few (1 younger; 3 older) had never or almost never used touchscreen devices. Three participants were left-handed and 2 were ambidextrous.

Apparatus
The experimental testbed was built in JavaScript, HTML5 and PHP. It ran on Apple iPad 3's in the Safari browser and Apple laptops (Mac OS X 10.7) in the Chrome browser. The laptops were connected to identical external monitors set to a resolution of 1152×870 and to Logitech M310 optical mice with identical mouse gain settings. Chrome was put in full-screen mode before the desktop tasks began. For the touchscreen, the iPad lay flat on the table.

Care was taken to ensure the iPad and desktop setups were equivalent. Pointing, dragging, crossing, and steering were implemented based on the ISO 9241-9 circle 2-D Fitts' law task [6]. Figure 1 shows the touchscreen tasks; Table 1 shows distances to target, that is *amplitudes* (*A*), and target *widths* (*W*). For pointing, dragging, crossing and steering, *A* was 344 px based on the size of the iPad (1024×768 px). The minimum target width for the touchscreen had to be much larger than for the desktop: 9.2 mm (48 px), which was based on our own pilot studies and previous literature [11]. Since *A* was held constant across devices, *W*'s of 64 and 96 resulted in the same Fitts' law *index of difficulty* (*ID*) regardless of device. *ID* is the ratio between distance to a target and the target's width, which determines how "difficult" the target is to acquire: $ID = \log_2(A/W+1)$. Thus, trials with the same *ID* should be equivalently difficult across devices, allowing us to isolate the effect of the input device itself (mouse *vs*. touchscreen). Zooming was implemented for touchscreen only and required two touch

points to resize a circle to fit within a ring. The *A* parameter was the difference between the original circle's radius and the ring's radius, while *W*, the width of the ring, varied.

Task	A (px)	W (px)	
		Desktop	*Touchscreen*
Pointing, steering, crossing, dragging	344	16, 32, **64**, **96**	48, **64**, **96**, 128
Zooming out and in	128	not tested	16, 32, 64, 96

Table 1. Tested amplitudes (*A*) and target widths (*W*). Widths representing overlapping *ID*s between the devices are in bold.

Procedure
The procedure fit in a single session: one hour for younger adults and up to two hours for older adults. Participants first completed a background survey, which included previous technology experience. Participants then used the touchscreen and desktop presented in counterbalanced order, with the four tasks (pointing, dragging, crossing, steering) in randomized order within each device. Since the zooming tasks were secondary, they appeared (randomized) at the end of the touchscreen phase of the study.

For each task, instructions were presented on screen in text and video form. Then, a set of 8 practice trials was given, with the option to repeat the set once before starting the test trials in earnest. Target sizes were presented in random order, with 10 test trials per size. Spatial outliers were automatically redone by appending them to the end of the current set of trials. Based on prior work [10], outliers occurred when: (i) the movement was less than half the distance of *A*, or (ii) the end of the trial (*e.g.*, mouse click) occurred more than twice the target width *W* from the ideal endpoint (*e.g.*, target center). Finally, subjective task difficulty ratings were collected using 7-point Likert scales.

Movement time calculations per trial were specific to each task. *Pointing*: last click or touch up of previous trial to last click or touch up of this trial. *Dragging* and *Zooming*: time from initiating the movement (mouse button or touch down) to ending it (mouse button or touch up). For *Steering* and *Crossing*, the mouse cursor or finger needed to first come to rest in a circular "start" area, at which point timing started; end of timing occurred when the cursor or finger crossed over or near (in the case of an error) the target line for crossing, or end of the column for steering (Figure 1c, d).

Design and Analysis
In total, 16,000 trials were completed: 40 participants ×10 trials × 4 target widths × 10 tasks. Trials flagged as spatial

outliers accounted for 1.2% of all trials. Our main analysis compared the devices for trials with equivalent *IDs*, where *W* was 64 or 96 pixels. We selected *only* these trials for each input device and ran a 3-way repeated measures ANOVA with movement time as the dependent variable: *Group* (2 levels; between-subjects) × *Device* (2 levels; within-subjects) × *Task* (4 levels; within-subjects). For zooming, we ran a 2-way ANOVA with movement time as the dependent variable: *Group* (2 levels; within-subjects) × *Task* (2 levels; within-subjects). Since error rate and Likert scale data often violate the normality assumption of ANOVA, we ran non-parametric Friedman tests to compare tasks within each device (touchscreen *vs.* desktop) and participant group. *Post hoc* pairwise comparisons for ANOVAs and Friedman tests, the latter using Wilcoxon signed ranks tests, were protected against Type I error using a Holm's sequential Bonferroni adjustment [5]. For the ANOVAs, we tested sphericity using Mauchly's test and used a Greenhouse-Geisser adjustment when the Mauchly's test was significant; this adjustment can result in fractional degrees of freedom. One younger participant was removed because her trial completion times were on average over 4 standard deviations away from the mean for that group.

RESULTS
We focus on comparing the mouse and touchscreen for the subset of trials with overlapping indexes of difficulty.

Movement Time
Movement time results are shown in Figure 2. All main and interaction effects were significant. As expected, older adults were slower than younger adults, completing trials on average in 1.34 seconds versus 0.72 seconds (main effect of *Group*: $F_{1,37} = 42.23$, $p < .001$, $\eta^2 = .53$). A main effect of *Device* also showed that the desktop was significantly slower than the touchscreen ($F_{1,37} = 44.46$, $p < .001$, $\eta^2 = .55$). Finally, a main effect of *Task* revealed the tasks impacted movement time differently ($F_{3,111} = 33.29$, $p < .001$, $\eta^2 = .47$).

Our main hypothesis was that the touchscreen would be relatively easier compared to the desktop for older adults than for younger adults. The devices did have a differential effect on the participant groups: a *Group × Device* interaction was significant ($F_{1,37} = 16.87$, $p < .001$, $\eta^2 = .31$). Older adults' movement time decreased by 35% when moving from desktop trials ($M = 1.62$ seconds) to touchscreen trials ($M = 1.06$ seconds); *post hoc* pairwise comparisons revealed this was a significant improvement ($p < .001$). For the younger adults, an improvement of 16% from the desktop to the touchscreen (0.79 to 0.66 seconds) was only a trend ($p = .082$).

While older adults improved more than younger adults from the desktop to the touchscreen, the degree of change was different for some tasks more than others (*Group × Device × Task* interaction: $F_{1.62,59.88} = 6.91$, $p = .004$, $\eta^2 = .16$). For older adults, *post hoc* pairwise comparisons revealed that crossing and pointing were the
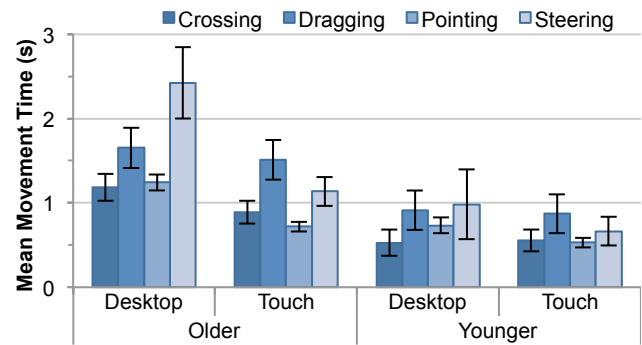

Figure 2. Mean movement time per trial for Desktop and Touch devices. While older adults were generally slower than younger adults, steering on the desktop was particularly slow. (*N* = 39; error bars show 95% confidence intervals.)

fastest tasks on the desktop, followed by dragging, with steering the slowest. As can be seen in Figure 2, however, the relative movement times for each task were different for the touchscreen. On the touchscreen, older adults were slowest with *dragging*, followed by steering. Crossing and pointing were fastest and not significantly different from each other. For younger adults, the only significant differences were dragging *vs.* crossing on the desktop and dragging *vs.* pointing and crossing on the touchscreen. Reported *post hoc* pairwise comparisons: $p < .05$.

The remaining significant interaction effects on movement time were *Task × Group* ($F_{2.36,87.20} = 7.64$, $p < .001$, $\eta^2 = .17$) and *Device × Task* ($F_{1.17,59.89} = 20.83$, $p < .001$, $\eta^2 = .26$). We did not conduct *post hoc* pairwise comparisons on these interaction effects because they did not contain both of our primary factors of interest (*Group* and *Device*).

Error Rate
Error rates were higher for the desktop than for the touchscreen for both groups. For older adults, error rates were on average 4.18% ($SD = 4.71\%$) for the desktop versus 0.75% ($SD = 1.02\%$) for the touchscreen. Younger adults made 2.89% errors on average on the desktop ($SD = 2.36\%$), compared to 0.26% ($SD = 0.67\%$) on the touchscreen. The difference between desktop and touchscreen was significant with both participant groups using a Wilcoxon signed rank test (older: $Z = -3.42$, $p = .001$; younger: $Z = -3.35$, $p = .001$). When comparing the error rates of older versus younger adults, no significant differences were found with Mann-Whitney U tests for either the desktop or the touchscreen.

Subjective Difficulty
Figure 3 shows perceived difficulty ratings. While we analyzed performance only for only a subset of trials (those with overlapping IDs) subjective difficulty ratings were collected based on *all* trials. It is thus not fair to compare subjective ratings between the touchscreen and desktop because the desktop had higher overall IDs. Instead, we examine ratings within each group and input device. The touchscreen tasks were all perceived to be relatively easy for participants in both groups, with an average rating of 1.62 ($SD = 0.97$) on a scale from 1 (easy) to 7 (difficult).
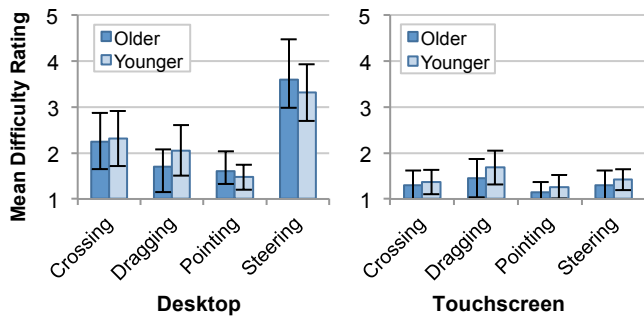
Figure 3. Perceived difficulty ratings: 1 (easy) to 7 (difficult). Desktop steering was deemed particularly difficult. ($N = 39$; error bars show 95% confidence intervals.)

No significant effects of task on subjective difficulty rating were found for the touchscreen. For the desktop, however, some tasks were perceived to be more difficult than others, with significant main effects of *Task* on perceived difficulty for both older ($\chi^2_{(3,N=20)} = 30.93$, $p < .001$) and younger ($\chi^2_{(3,N=19)} = 28.74$, $p < .001$) adults. Steering was hardest for the older adults, followed by dragging; no difference was found between pointing and crossing. For the younger adults, steering was more difficult than pointing and crossing. Reported *post hoc* pairwise comparisons: $p < .05$.

Zooming Out and In (Pinch-to-zoom)
For our secondary analysis on zooming, older adults were again slower than younger adults: on average 1.88 seconds per trial versus 1.13 seconds (main effect of *Group*: $F_{1,36} = 32.11$, $p < .001$, $\eta^2 = .47$). Counter to Kobayashi *et al.* [8], zooming out was slower than zooming in (main effect of *Task*: $F_{1,36} = 11.76$, $p = .002$, $\eta^2 = .25$); however, Kobayashi *et al.* did not report a significance level for this comparison. No significant interaction effect was found between *Group* and *Task*. Finally, error rates were uniformly low. Older adults made on average 1.58% ($SD = 2.92$) errors for zooming out and 2.00% ($SD = 4.97$) for zooming in. On average younger adults made 0.26% ($SD = 1.14\%$) errors for zooming out and no errors for zooming in.

CONCLUSION
This study showed that the touchscreen did reduce the performance gap between older and younger adults compared to a traditional desktop setup. Across dragging, pointing, steering and crossing, older adults' movement times decreased by 35% when moving from the desktop to the touchscreen; younger adults only saw a 16% reduction. Interestingly, while the steering task was most difficult on the desktop, the dragging task was slowest on the touchscreen. This finding expands on previous work showing a similar tradeoff between pointing and dragging for younger adults [3]. Future work is needed to uncover whether the negative impact of the touchscreen on dragging performance has to do with occlusion by the finger, or perhaps extra friction as users press hard to keep "hold" of the dragging target. Finally, while motor performance is only one component of overall usability, it is a fundamental and critical base for all interactions. Our findings strengthen the case that touchscreens are easy to use for older adults.

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