ORIGINAL INVESTIGATION

Comparing Haptic Pattern Matching on Tablets and Phones: Large Screens Are Not Necessarily Better

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SIGNIFICANCE: Touchscreen-based, multimodal graphics represent an area of increasing research in digital access for individuals with blindness or visual impairments; yet, little empirical research on the effects of screen size on graphical exploration exists. This work probes if and when more screen area is necessary in supporting a pattern-matching task.

PURPOSE: Larger touchscreens are thought to have distinct benefit over smaller touchscreens for the amount of space available to convey graphical information nonvisually. The current study investigates two questions: (1) Do screen size and grid density impact a user's accuracy on pattern-matching tasks? (2) Do screen size and grid density impact a user's time on task?

METHODS: Fourteen blind and visually impaired individuals were given a pattern-matching task to complete on either a 10.5-in tablet or a 5.1-in phone. The patterns consisted of five vibrating targets imposed on sonified grids that varied in density (higher density = more grid squares). At test, participants compared the touchscreen pattern with a group of physical, embossed patterns and selected the matching pattern. Participants were evaluated on time exploring the pattern on the device and their pattern-matching accuracy. Multiple and logistic regressions were performed on the data.

RESULTS: Device size, grid density, and age had no statistically significant effects on the model of pattern-matching accuracy. However, device size, grid density, and age had significant effects on the model for grid exploration. Using the phone, exploring low-density grids, and being older were indicative of faster exploration time.

CONCLUSIONS: A trade-off of time and accuracy exists between devices that seems to be task dependent. Users may find a tablet most useful in situations where the accuracy of graphic interpretation is important and is not limited by time. Smaller screen sizes afforded comparable accuracy performance to tablets and were faster to explore overall.

Optom Vis Sci 2018;95:720–726. doi:10.1097/OPX.0000000000001274
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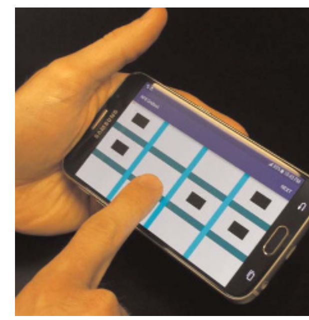

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Touchscreen-based devices, such as smartphones and tablets, are changing the way that users access and manipulate information. Recent research has demonstrated that the inclusion of multimodal information and universal design in the native interface of this technology makes it especially beneficial as an information-access device for people who are blind or visually impaired.[1–4]

Although text-to-speech software, via Apple's VoiceOver (Apple Inc, Cupertino, CA) and Google's TalkBack (Google, Mountain View, CA), is widely available for making textual information accessible in the digital world, there remains no comparable access solution for digital graphical material. This lack of access to graphical content represents a large challenge to blind and visually impaired individuals because it directly affects their educational, vocational, and social progress as well as individual independence.[5,6] Access to graphics is currently limited to verbalized textual descriptions of images, sonification-based graphics, refreshable pin arrays, and force-feedback devices.[3,7] These devices and rendering solutions are often expensive, lack portability, or are not fully multimodal, contributing to infrequent usage and limited adoption by blind and visually impaired people. A more recent approach to accessible graphics focuses on using the vibration, audio, and visual displays built within commercially available touchscreen smart devices, which are relatively inexpensive, portable, and already adopted within the blind and visually impaired community.[8] It is important to note, however, that touchscreen interfaces introduce a different tactile paradigm that is rooted in vibration-based feedback, which differs from traditional, physical tactile graphics. Extant literature on tactile thresholds for physical stimuli,[9,10] the effect of aging on tactile ability,[11] and the underlying tactile science of braille reading and pattern recognition inform our understanding of tactile abilities in the physical space.[12] We note, however, that vibrations provide different stimuli and target different receptors. For instance, vibrotactile perception is governed by the rapidly adapting and Pacinian corpuscle channels of touch sensing. The absolute thresholds of vibrotactile stimuli strongly depend on the frequency of the vibration.[13] The Pacinian corpuscle channel has a frequency range of 10 to 500 Hz and is the primary perceiving channel for vibration. The rapidly adapting channel has a smaller frequency range from 3 to 100 Hz and is most commonly associated with perceiving flutter.[14–16] The smallest detectable displacement can be less than 0.1 μm, which is usually observed between 150 and 300 Hz, although this threshold is affected by a number of factors including contact area, stimulus properties, age, and others.[13] Subjectively, if a vibration is less than 3 Hz, it tends to be perceived as a slow kinesthetic motion. If it is between 10 and 70 Hz, it tends to be perceived as a fluttering motion, and if it is between 100 and

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300 Hz, as is used here, it tends to be perceived as smooth vibration.[17] The perceived intensity of the vibration signal, governed by Steven's power law, is a function of both amplitude and frequency of vibration.[18,19] Our tactile sensitivity, which enables discrimination of pulses with time gaps as small as 5 milliseconds, is better than that for vision but worse than that for audition.[13] By temporally varying the vibration amplitude over time, the perception of rhythm is elicited, which tends to be highly discriminable and recognizable, enabling designers to create a multitude of meaningful vibration signals for real-world applications, for instance, differentiating aspects of graphics to make them more accessible to nonvisual users.[20,21]

Recent studies have illustrated the potential of conveying a myriad of graphics on touchscreens, including simple stimuli from lines and points to more complicated shapes, graphs, and maps.[1,2,4,22] However, most of these investigations and recent new touchscreen-based solutions (e.g., See ColOR, Feelif, and ViTAL)[23–25] rely on the use of larger screens, such as tablets, despite the significant prevalence and preference of smaller, handheld mobile devices being used by blind and visually impaired people for everyday tasks.[8,26]

This study addresses the anecdotal belief that larger touchscreens offer distinct benefits for graphical exploration to users over smaller screens and thus may equate to better user experience and performance. However, there is a distinct lack of empirical research regarding the assumption that larger screens are a better medium for supporting graphical exploration. This study aims to provide empirical evidence regarding the trade-off between performance and device size to better understand whether screen real estate is indeed a key factor in the interpretation and navigation of multisensory content, especially graphical concepts that are rendered on touchscreens. Specifically, we seek to understand if and how target identification and pattern-matching performance, two relatively simple tasks in the graphical domain, compared across two devices with different screen sizes—a tablet and a phone.

Matching of nonvisual grid-based target patterns was chosen because this represents a fundamental graphical task that requires little prior knowledge of graphical information, unlike more complex tasks such as shape identification and graph interpretation. Using targets avoids the semantic retrieval failure associated with trying to name discrete shapes,[27,28] thus enabling us to focus specifically on task performance. Second, we are interested in the impact of screen size on perception and retention of important stimuli for which the pattern-matching task is well suited. Our interest is not in the recognition of shapes or two-dimensional objects or the interpretation of complex spatial entities such as graphs or charts, which have been explored in prior studies[1,2,4,22] and involve extra processes such as integrating features (e.g., size and surface) to determine distinct objects.[28] Finally, grids benefit this specific task because they discretize the screen area, dividing it into smaller, functional units that can be evaluated on a continuous scale. Performance on the target identification and pattern-matching tasks in this work will provide initial insight into when and where the use of tablets is actually necessary over more commonly accepted and prevalent smaller mobile platforms in the context of simple graphics.

Research Questions

To investigate the role of screen size in conveying simple graphics using vibratory feedback on a touchscreen, we pose two research questions:

1. Do screen size and grid density impact a user's accuracy on pattern-matching tasks?
2. Do screen size and grid density impact a user's time on task?

Grid density refers to the number of grid rectangles that are presented on the screen, with a higher number of rectangles representing high grid density and a lower number of rectangles representing low grid density (Fig. 1).

METHODS

This study was approved by the Saint Louis University Institutional Review Board.

Demographics

Fourteen individuals (age, 19 to 74 years; mean, 42 years) with blindness or visual impairment were recruited (with permission) at the 2017 National Federation of the Blind Conference (Table 1). Of the 14 participants, the majority was female (57%). Participants were randomly assigned to use either a tablet or a phone during the study. A postanalysis of the demographics of the two groups revealed that the tablet group average age was 48 years (23 to 74 years), and the phone group average age was 37 years (19 to 58 years). All tablet users were right-hand dominant (n = 7), whereas four of seven phones users were right-hand dominant.

To participate, individuals were required to use some form of access technology (e.g., braille or screen readers). The range of

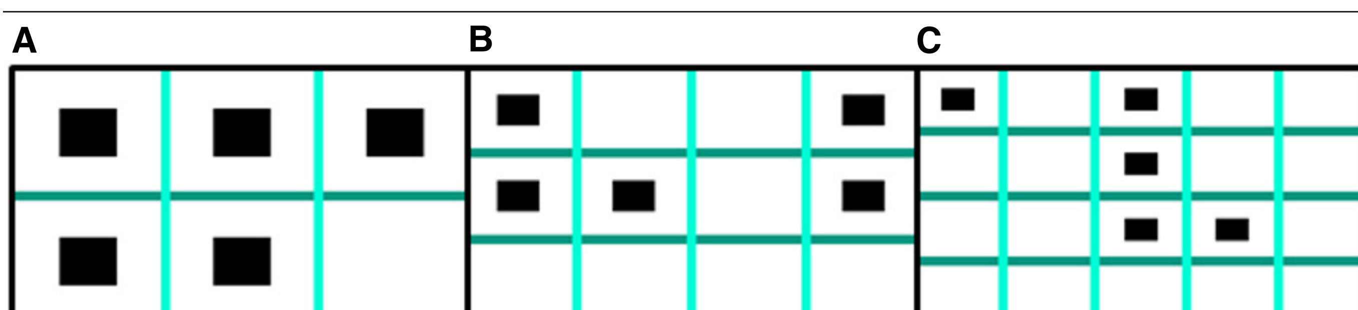

FIGURE 1. Examples of the vibrating targets imposed inside each grid size. (A) Low-density grid. (B) Medium-density grid. (C) High-density grid. Green lines (light green for vertical lines and dark green for horizontal lines) play tones, whereas black rectangles vibrate.

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TABLE 1. Participant summary

No.	Age (y)	Sex	Impairment	Group
1	31	F	Retinopathy of prematurity	Tablet
2	58	F	Glaucoma	Phone
3	23	F	Leber congenital amaurosis	Tablet
4	19	M	Detached retinas	Phone
5	59	M	Congenital microphthalmia	Tablet
6	52	M	Glaucoma	Phone
7	41	M	Unknown	Tablet
8	29	F	Optic nerve hypoplasia	Phone
9	56	F	Retinopathy of prematurity	Tablet
10	48	F	Optic neuritis	Phone
11	49	M	Retinoblastoma	Tablet
12	25	F	Optic nerve atrophy	Phone
13	74	M	Leber congenital amaurosis	Tablet
14	27	F	Pathological myopia	Phone

F = female; M = male.

diagnoses of the participants is listed in Table 1. All individuals gave informed consent and received a $25 gift card for participation.

Materials

Demographics Questionnaire

Participants were administered a short demographics questionnaire at the beginning of the study. This questionnaire collected participants' age, sex, visual impairment, onset of impairment, and any touchscreen/computer aids used (Table 1).

Tablet and Phone

The tablet and phone chosen for this study have a 2:1 ratio in both resolution and physical size, providing a straightforward comparison of screen size. A 10.5-in Samsung Galaxy Tab S (Samsung, Seoul, South Korea) (288 pixels per inch resolution) with a 9-in active area was used for the tablet condition. A 5.1-in Samsung Galaxy S6 phone (577 pixels per inch resolution) with a 4.4-in active area was used for the phone condition. The devices were outfitted with rubber bands around the active screen area to create a physical boundary that prevented accidental pressing of “soft buttons” on the screen.

Grid Layouts

Twelve grids were explored, with grids divided into three groups with four grids in each group. Regardless of device, grid groups consisted of (1) 6 rectangles (2 × 3, low density), (2) 12 rectangles (3 × 4, medium density), and (3) 20 rectangles (4 × 5, high density). Grid lines provided auditory tones and grid targets vibrated, as shown in Fig. 2 and elaborated hereinafter. Five grid rectangles contained targets (vibrating rectangles), and those targets occupied 16% of the space in the rectangles in which they appeared. This ratio was maintained across devices and across all grid sizes.

Sixteen percent occupancy of targets was determined to be a reasonable ratio of stimuli versus no feedback for promoting target identification while not overstimulating the user. Five targets allowed for pattern flexibility across all grid sizes without having excessive empty space containing no feedback in low-density grids. The same number of targets (five) was kept constant across grid groups for consistency in the complexity of the pattern-matching task.

The target vibration pattern (SHORT_BUZZ_100) was chosen from Immersion's Universal Haptic Layer library for the strength of its signal and the regularity of its vibrational pattern.[29] Grid lines played an auditory tone when touched by the participant's finger. Targets vibrated when a participant's finger made contact with them. Grid lines played an auditory tone from Android's native tone library (DTMF_A for horizontal gridlines, DTMF_D for vertical gridlines) when touched by the participant's finger. These tones were dual-tone multifrequency tones for keys A (1633 Hz, 697 Hz, continuous) and D (1633 Hz, 941 Hz, continuous) and are within the midrange of normal human hearing.[30] Two tones were chosen to convey the horizontal and vertical grid lines to reduce the chance of participants confusing one gridline with another. All grid lines were rendered at approximately 4 mm thick on both devices, which was determined from pilot studies[31] to be sufficient feedback for determining the presence of a grid line.

We note that the touch resolution is limited by the user's finger pad, which has an average width of 16 to 20 mm.[32] The center-to-center target separation distances for neighboring cells on the low, medium, and high densities are 80, 59, and 48 mm (tablet) and 40, 30, and 24 mm (phone). The vertical center-to-center target separations are 75, 49, and 37 mm (tablet) and 27, 18, and 13 mm (phone; Fig. 2).

In the instances when a user's finger pad may happen to bridge two elements (e.g., a grid line and a grid target), only one element's feedback would play, corresponding to whichever element was closest to the centroid of the finger. When the participant moved

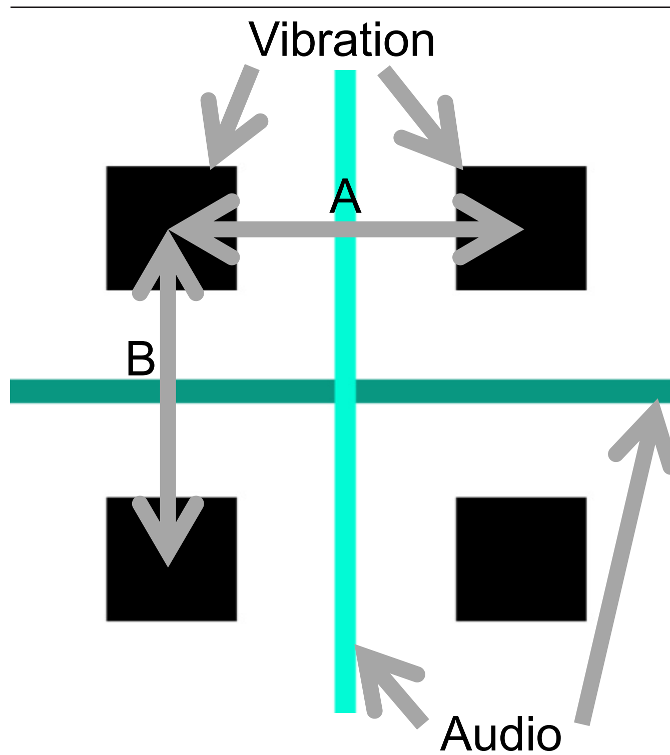

FIGURE 2. The targets were conveyed via vibrations, with a horizontal center-to-center distance (A) and vertical center-to-center distance (B). Each target was separated by auditory gridlines.

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from this point, the first element's feedback would stop triggering, and the second element's feedback would begin. This ensured that a user would not miss one or the other element.

The separation distances for the grid lines and grid targets were chosen with both the hardware size and the average fingertip width in mind. All targets, even adjacent targets separated by distances smaller than 16 to 20 mm, are separated by an auditory gridline. Participants were given directions to move at a constant speed and to keep their finger on the screen while moving, which reduced the likelihood of participants erroneously interpreting targets that were close together as being one target.

An example of a grid from each of the three groups can be found in Fig. 1. Corresponding tactile embossed versions of these digital grids were prepared using a ViewPlus Emprint Embosser (ViewPlus, Covallis, OR) for the pattern-matching task. Embossed versions were as close to the same size as the device screen as the embosser would allow while still retaining the embossed integrity of the grid features.

Pattern-matching Task

A program to display the grids in a random order per grid group was created to run on Android 5.0 (Google, Mountain View, CA). This program allowed participants to explore the digital grid at their own pace until they self-reported that they could identify a physical, tactually embossed printout of the graphic among four alternative options. In this task, participants were asked to choose the tactile grid that matched the pattern they had just felt without access to the digital pattern on the touchscreen. Of the four alternatives in the multiple-choice embossed assessment, only one image was the correct grid. The remaining three grids included a grid from the same density group of which they may have already explored and two grids of the same density that the participants would have never explored on their device. This task is further described in the context of the study hereinafter.

Procedures

A repeated-measures between-subject design was used. Participants were assigned to a device group upon arrival according to their participant number (odd numbers received only the tablet; even numbers received only the phone). Each session took approximately one hour to complete. After obtaining consent, a demographic questionnaire was completed by verbally asking participants for general information on themselves, including their age, sex, and information on their visual impairment(s) and their familiarity with tactile images. Although we note that all of our participants used their dominant hand on the phone or tablet, we did not measure hand dexterity or tactile ability in our participants. After the short intake session, participants were introduced to either a phone or a tablet for use during the study.

Participants began with a short training period before administering each group of experimental trials with the three grids. During training, the physical device was described, and participants practiced with an exemplar grid. These grids were not subsequently used during the study. During practice, participants were able to ask questions of the experimenter and were given corrective feedback about their responses. We opted not to dictate specific exploration strategies to participants, as our previous studies have illustrated that each individual prefers (and interprets) information differently, which tends to manifest through his/her use of personal and preferred exploration strategies. Participants were told that targets vibrated and that the grid lines played different sounds depending on if they were oriented horizontally or vertically. The experimenter did not note any participants who seemed to struggle with hearing or feeling the experimental stimuli. All questions were answered before commencing with the experimental trials.

During the experimental trials, participants were asked to explore a pattern. For each grid, they were told the size of the grid (e.g., 2 × 3) and were reminded of the number of targets to find (five). Participants were instructed to finish exploring each digital grid as quickly as possible, but no time limit was imposed. Their goal was to find all of the vibrating targets on the touchscreen and after exploration, to match the pattern formed in memory from the five-target configuration with an embossed hardcopy analog chosen from four possible alternatives (as described previously in the Materials section).

Participants explored 12 grids in total, comprising four grids per each of the three grid-size groups. Each grid group was presented in the same order, with large (low density) grids (6 rectangles) presented first, medium density grids (12 rectangles) presented second, and small (high density) grids (20 rectangles) presented last. This fixed order was imposed to convey a progression of difficulty to the participants as they explored less condensed to more condensed grid sizes. Because of this design, a learning effect may have occurred and was taken into account in the interpretation of analyses in the Results section.

RESULTS

Data collected in this study included time to explore the digital grids across the two sizes of touchscreens (phone vs. tablet) as well as matching accuracy on the multiple-choice pattern-matching test. Analyses were conducted using IBM SPSS Statistics 2015 (Armonk, NY).

To determine if the larger screen size of the tablet is advantageous (e.g., faster and more accurate than the phone), performance during the study was examined in two ways: (1) the correct identification of the pattern on the grid given a choice of four embossed versions and (2) the time participants spent identifying a digital grid on a touchscreen device (see Fig. 1 and Table 2 for a summary of participant correctness performance).

Pattern Identification

Participant identification accuracies were recorded as dichotomous variables (1 if correct) for each of the 12 grids administered. To avoid summarizing each participant's performance with percent scores, a regression model was chosen to analyze accuracy. A logistic regression was performed to determine the effects of device type, grid density, sex, and age on the likelihood that participants obtain better accuracy on grid matching. The logistic regression model was statistically significant ($\chi^2_5 = 12.372$, $P < .05$). For a complete description of the model, see Table 3.

The model explained 15.2% (Nagelkerke R^2) of the variance in grid matching accuracy and correctly classified 79.5% of cases. Grid density, device type, and age had no significant effects on the likelihood of matching digital grids to their tactile counterpart ($P > .05$). However, sex effects were observed ($P = .01$; $\beta = -1.293$), with an odds ratio of 0.274 (95% confidence interval, 0.098 to 0.773). The odds that women matched a digital grid with the correct tactile grid were 0.274 times higher than those for men.

Grid Exploration Time

A multiple regression was run to determine the effects of device type, grid density, sex, and age on exploration time. The model was statistically significant ($F_4 = 17.669$, $P < .001$, $R^2 = 0.389$

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TABLE 2. Participant summary of identification accuracy performance, including the number of grids received (N), the total correct (sum), and the mean for each grid density

	Low density			Medium density			High density		
No.	**n**	**Sum**	**Mean**	**n**	**Sum**	**Mean**	**n**	**Sum**	**Mean**
Tablet									
1	3	1	0.333	2	1	0.500	3	3	1
2	3	3	1	3	3	1	3	3	1
3	2	1	0.500	3	3	1	2	2	1
4	3	1	0.333	3	3	1	—	—	—
5	3	3	1	4	4	1	2	2	2
6	4	3	0.750	3	3	1	2	2	2
7	4	4	1	4	4	1	3	3	3
Phone									
1	4	4	1	4	4	1	3	3	1
2	3	3	1	3	3	1	3	2	0.667
3	4	1	0.250	2	0	0	3	0	0
4	3	3	1	3	3	1	3	3	1
5	3	2	0.667	3	3	1	3	3	1
6	4	3	0.750	3	2	0.667	3	1	0.333
7	4	3	0.750	4	3	0.750	3	3	1

[adjusted $R^2 = 0.367$]). Device type, grid density, and age added significantly to the prediction ($P < .005$). A full description of this model can be found in Table 3.

From the model, we observed the following: (1) phone users explored grids faster than did tablet users ($\beta = -58.357$); (2) participants finished faster when exploring lower-density grids ($\beta = 49.748$); and (3) as participants' age increased, grid exploration time decreased ($\beta = -1.315$).

DISCUSSION

This study sought to investigate how screen size affects graphical information extraction in terms of exploration time and pattern identification accuracy. Our findings illustrate that participants were able to match the digital grid with the correct embossed grid, with an overall score of 81.889% across both devices, 88.136% for tablet users, and 76.471% for phone users. One participant in the phone group (no. 3 in Table 2, phone group) was able to answer only one grid correctly during their session but was not deemed to be an outlier because they were still within 3 standard deviations of the phone group mean. See Table 2 for a summary of participant grid matching performance.

From our logistic regression model, we determined that device type was not a significant contributing factor to accuracy. Although we acknowledge that our sample size is relatively low, this finding suggests that performance was not impacted by the phone or the tablet. In addition, we found no evidence of density- or age-related effects within our sample cohort. This suggests that, despite the broad age range included in the analysis, age of the participants was not a key indicator for performance. We did, however, observe sex effects in the model. The odds of matching a digital grid with the tactile grid were 0.274 times higher for a woman than for a man. It is possible that this effect is observed owing to the study having more female participants (two more than male participants). A study with a larger sample size would be needed to further investigate this sex effect.

There was also no evidence that grid density had a significant effect on the model. This is interesting because it was expected a priori that participants would perform the worst on the phone with the high density grid, as the grid rectangles were only about the size of the average adult finger pad. However, participants were still able to correctly identify the 20-rectangle grid pattern 71.4% of the time. This suggests that the task was still feasible and that even higher information densities (up to a limit) are usable on smaller screen sizes. Future investigations probing what this upper limit is are necessary toward quantifying this information density limit in the context of graphics. It is also worth noting that participant performance on the task would likely benefit from a longer training period, an effect that has been demonstrated for similar tasks.[1] This finding is promising, given that phone platforms are more commonly used than tablet platforms and are likely preferred for supporting everyday tasks.

The regression model for exploration time revealed more significant effects compared with the model for accuracy. From the model, we observed faster exploration times on the phone. This is unsurprising because the phone is almost twice as small as the tablet and the distances between targets are much smaller, allowing participants to travel from one target to the next quickly. Although future studies should explore this in the context of tasks beyond pattern matching, this work suggests that phone-sized devices may be a very viable choice for viewing simple graphics because phone exploration is faster and accuracy seems to be unaffected by device type.

It is also interesting to note the effect of grid density on exploration time. Lower-density grids tended to be explored faster than higher-density grids. This was expected, as having more information condensed on the screen is likely to require participants to investigate a certain area of the screen either more often or for longer periods to garner the information required and to detect the

TABLE 3. Regression analysis for identification accuracy and exploration time

Identification accuracy				**95% CI**	
Variable	**β**	**Sig.**	**OR**	**Lower**	**Upper**
Age	0.011	.49	1.011	0.979	1.045
Sex	−1.293	.01	0.274	0.098	0.773
Device	1.105	.06	3.019	0.956	9.533
Density (1)	−0.598	.31	0.550	0.174	1.741
Density (2)	0.396	.56	1.485	0.392	5.624
Constant	1.330	.08	3.782		
Exploration time				**95% CI**	
Variable	**β**	**Sig.**	***t***	**Lower**	**Upper**
Age	203.671	.001	−3.506	−2.058	−572
Sex	−1.315	.32	−1.006	−38.241	12.493
Device	−12.874	<.001	−4.658	−83.184	−33.530
Density	−58.357	<.001	6.876	35.410	64.086
Constant	49.748	<.001	6.658	143.056	264.286

β = unstandardized β; CI = confidence interval; OR = odds ratio.

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pattern. We note that, although participants explore higher-density grids slower, this is not necessarily detrimental to their accuracy performance because grid density had no effect on determining accuracy in the regression model.

We also observed age effects on the model for exploration time. As the ages of the participants increased, grid exploration time decreased, which is surprising. This may be due to the possibility that older participants could have more familiarity with traditional tactile graphics, have more experience using a touchscreen device, or have developed more effective strategies to navigate a touchscreen device. Future investigations are necessary to parse out if and how this age effect stands across a variety of tasks.

The findings from these models seem to indicate that more screen real estate is not always better and that for simpler graphics the trade-off for smaller screen sizes may be reasonable without sacrificing accuracy. Furthermore, smaller screen sizes seem to have an advantage when it comes to exploration time. However, the findings of this study also imply that exploration time is impacted by density. As the graphical information density increases on the screen, exploration time increases. This is worth noting because it illustrates the trade-off between information density and exploration time, which are competing factors on both the phone and the tablet platform.

Although we note that our findings are interesting, we acknowledge some limitations to this study. Because of the participants' handling of the screen, data were sometimes lost for a particular grid or grid density. Although the active area of the screen was marked with thick, fitted rubber bands, the bands would sometimes be moved slightly because of the participants' exploration of the screen edges and would cause participants to accidentally close the program. As such, our future software will ensure that all tablet buttons, even the soft keys outside the active screen area, are disabled to prevent accidental touches.

We also acknowledge concerns regarding the statistical power of our analyses. Our sample size was low but indicative of other psychophysical studies with blind and visually impaired individuals. In regard to the logistic regression done to determine effects on pattern-matching accuracy, we note that the odds ratios (Table 3) are low, although the 95% confidence interval (0.098 to 0.773) is quite small for the odds ratio of the significant effect (sex). We also acknowledge that the 95% confidence intervals for the exploration time β values are wide. However, the unstandardized β values (as seen in Table 3) reveal more information on the magnitude of the effect of each variable. For age in particular, the magnitude of β is quite large.

In addition, because of time constraints, we were unable to conduct preliminary hearing, tactile ability, or hand dexterity measures, such as the Purdue Pegboard.[33] Without a measure of dexterity, which is especially relevant to the blind and visually impaired population, we note that dexterity deficits may have affected the participant's ability to search the grid patterns, especially for older individuals.[33–35] However, no participant brought to the experimenter's attention any difficulty completing the task, and best practices for promoting participant performance were followed.

In sum, although there were some limitations to the study, our findings suggest that both large and small touchscreen devices have benefits and drawbacks that are highlighted by this study. The most important finding is that device size had no difference in accurately determining a simple pattern on a touchscreen, but phone users completed the task faster. There seem to be a trade-off of time and accuracy between device sizes that are task dependent, but this work illustrates that smaller screen sizes are not necessarily worse for simple tasks, such as pattern matching.

CONCLUSIONS

This study extends the current state of research on multimodal touchscreen interfaces by providing data-driven insights on whether large screen sizes are necessary for successful interpretation of graphical information. We present empirical results from a pattern-matching task conducted across multiple information density grids on both a tablet and a mobile phone, representing approximately 2:1 screen real estate difference. Phone exploration time is faster than tablet exploration time, but accuracy did not seem to be impacted by screen size within our sample cohort. Although more research needs to be done to specifically explore the limits of each platform, these initial results demonstrate the utility of smaller-sized devices in displaying simple multimodal graphics. This research informs future work in the display of accessible graphics serving blind and visually impaired individuals and mobile phone users at large.

ARTICLE INFORMATION

Submitted: February 1, 2018

Accepted: June 28, 2018

Funding/Support: National Science Foundation (1644538; to JLG).

Conflict of Interest Disclosure: None of the authors have reported a financial conflict of interest.

Author Contributions and Acknowledgments: Conceptualization: JLT, NAG, JLG; Data Curation: JLT, ZSC; Formal Analysis: JLT, ZSC, JLG; Funding Acquisition: JLG; Investigation: JLT; Methodology: JLT, NAG, JLG; Project Administration: JLT; Software: JLT, ZSC; Supervision: NAG, JLG; Validation: JLT; Visualization: JLT; Writing – Original Draft: JLT; Writing – Review & Editing: JLT, ZSC, NAG, JLG.

The authors thank their participants from the 2017 National Federation of the Blind conference and Derrick Smith and Kathryn Nichols (University of Alabama in Huntsville) for their assistance in conducting the user studies.

The authors also thank Steven Rigdon (Saint Louis University) for his expertise and assistance in analyzing the data.

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