Comparing Search of Tactile and Visual Graphics

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Abstract. Speed and accuracy in searching tactile and visual graphics were compared. Process measures of search behaviours indicated both sensory mode and display complexity influenced performance. Implications for improving comprehension of tactile graphics and suggested future research directions are discussed.

Keywords: tactile graphics; visual graphics; search processes; comprehension; complexity.

Introduction

Tactile graphics are depictions made up of raised lines and textures that can be explored via the sense of touch. They are widely used to provide vision impaired learners with accessible alternatives to standard visual depictions. However, tactile graphics too often pose comprehension difficulties. Given education's increasing reliance on graphic representations, it is important that the conversion of visual learning materials into their tactile counterparts produces depictions that are readily comprehensible. Currently, educational tactile graphics are typically produced by applying various rules of thumb to existing visual graphics (e.g. Purdue Research Foundation, 2002). These rules are used to simplify depictions and make different regions haptically distinguishable in order that the graphic's information is accessible. Unfortunately, information accessibility does not guarantee comprehension. What really matters is the extraction of task-relevant information that provides the raw material from which mental models of the referent content can be built. With visual depictions, such extraction can be derailed when search processes are inappropriately directed to information of high perceptual salience but low thematic relevance (Schnotz & Lowe, 2008). However, relatively little is known about how people search tactile graphics and how these processes may influence their comprehensibility.

Haptic versus Visual Search

Because current approaches to the design of tactile graphics use visual graphics as their starting point, it is important to determine the similarities and differences in learner processing of these two depiction types. Although both sight and touch operate across space and time, they pick up information in distinctive ways. For example, (i) visual resolution is much finer than haptic resolution (hence the need to 'rework' visuals when producing tactile graphics), (ii) direct physical contact with the stimulus is required for haptic but not visual exploration, (iii) there is no haptic analogue of peripheral vision, (iv) touch-based exploration involves both haptic and kinaesthetic components, and (v) our two eyes typically act together whereas our two hands can act independently. Such differences are likely to affect how readily learners can comprehend information presented via these two forms of graphic display. The study reported here investigated the fundamental search processes upon which comprehension of tactile and visual graphics relies. It was expected that visual graphics would favour some performance measures, such as search efficiency (i.e., processing speed). However, it was less clear whether and how search effectiveness (i.e., accuracy) would differ between the two modalities, since many factors can influence this aspect in different ways. For example, the complexity of a display would likely influence the approach used to search it and the success of the search process, irrespective of modality-specific considerations. Nevertheless, details of the processing activities would be expected to reflect the particular modality concerned.

Method

Design and Participants

Thirty-two Teaching Education students with normal vision voluntarily participated in the study. Each participant performed both a visual and a tactile search task.

Materials

Two presentation display designs were used, each consisting of eight assorted graphic entities arranged in two rows. The graphic entities varied in size, shape and surface rendering. In one of these designs, the entities in both rows were vertically aligned, while in the other design, they were offset. The set of entities in the aligned design was different from that in the offset design. Visual and tactile versions of the aligned and offset designs were produced with variations in levels of grey or texture respectively. Figures 1a and 1b show the aligned design. Each presentation display was surmounted by a test display made up of four tiles each containing two graphic entities. Only one of these test pairs (see ringed 'correct pair') corresponded exactly to a target pair in the presentation display.

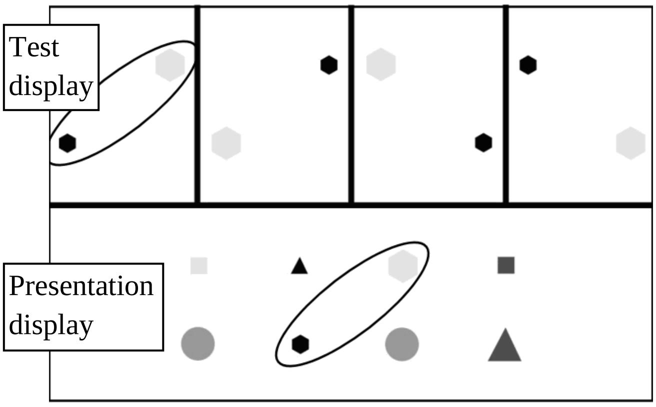

Figure 1a. Visual aligned display

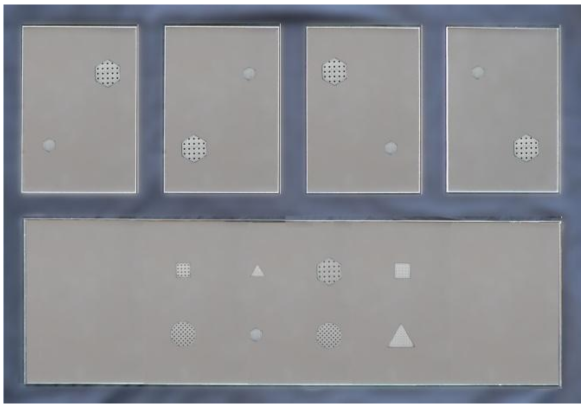

Figure 1b. Tactile aligned display

Procedure

The participants' task was to search the displays to identify the correct pair. Each participant performed a visual and a tactile search task (orders counter-balanced). One task involved the aligned visual or haptic display (trial A) and the other involved the offset visual or haptic display (trial O). Participants were instructed to use all characteristics of the entities to help them perform the task. Although no time limit was imposed, task completion times were recorded (from when the array was first presented until the participant indicated the chosen item either verbally or by pointing). Participants scored 1 point for identifying the correct item.

Fixation coding. Visual search data were collected using eye tracking. Foveations within areas of interest that corresponded with the functional visual field (see Murata, 2004) were deemed visual fixations. Haptic search data were collected by video recording hand movements from beneath a glass-topped table. Direct finger contacts with a display entity were deemed 'haptic fixations'.

Results

For both aligned (A) and offset (O) displays, visual search (M_A = 12.90, SD_A = 8.91; M_O= 8.06, SD_O = 4.21) was significantly faster than tactile search (M_A = 161.99, SD_A = 89.34; M_O = 75.26, SD_O = 46.05), F (1, 30) = 44.18, $p < .001$, η^2 .60; F (1, 30) = 33.86, $p < .001$, η^2 .54.

In display A, visual search (N = 15; M = 1.0, SD = 0.0) was more accurate than tactile search (N = 15; M = .60, SD = .51); F (1, 29) = 9.33, p = .005, η^2 = .25. In display O, there was no significant difference in accuracy between visual search (N = 16; M = 1.0, SD = 0.0) and tactile search (N = 15; M

= .87, *SD* = .35), *p* > .05. Only one participant did not correctly identify the target pair. Table 1 presents fixations data for test and presentation displays (aligned and offset).

Table 1: Visual and Haptic Fixations.

	M_{visual}	SD_{visual}	M_{haptic}	SD_{haptic}	p	η^2
Test Display A	22.27	14.09	35.13	24.48	.09	-
Test Display O	12.63	5.98	16.73	11.52	.22	-
Presentation Display A	21.33	18.00	58.53	36.69	.001	.31
Presentation Display O	11.31	5.47	25.80	11.28	.000	.42

Discussion

There are probably several reasons why visual search was many times faster than haptic search. These include differences in the resolution of the two sensory systems, the opportunities offered by peripheral vision, and the greater automaticity of visual search. Further, with participants using around twice as many haptic as visual fixations for corresponding tasks, haptic search appears to involve a more intensive form of processing. This may partly reflect two-handed exploration. Nevertheless, video records of the haptic search indicate that participants typically used multiple touch contacts to characterise a graphic entity's attributes and establish its positioning relative to other entities. While haptic and visual search produced broadly similar levels of accuracy, speed of search in the two modalities differed dramatically. This raises the question of whether greater experience with tactile representations (as possessed by vision impaired learners) could reduce this search speed difference to any significant extent. The somewhat less accurate haptic performance with aligned display might be due to differences in the complexity of the two displays. This seems to be supported by the fixation data, where the values for both haptic and visual forms of the aligned display were around twice those for the corresponding versions of the offset display.

If the comprehensibility of tactile graphics is to be improved, they must be designed and used in ways that are consistent with how they are processed by learners. Rather than merely applying rules of thumb to convert existing visual graphics, the design and use of tactile graphics should be approached on their own terms (c.f. Jehoel, McCallum, Rowell, & Ungar, 2006). A possible implication of the extremely slow rate of haptic search found in this study is that vision impaired learners should be given plenty of time to interpret tactile graphics. The reading of Braille is around three times slower than reading of visual text (Daneman, 1988) so it would be interesting to know if the much greater haptic-visual differences found in the present study apply to tactile graphics more generally. Further research is also needed to explore the effect of graphic complexity on the comprehension of both visual and tactile graphics. The technique used in the present study for comparing eye-tracking data from visual search with data about haptic search offers a way to evaluate these effects.

References

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