Comparison of Haptic and Non-Speech Audio Feedback

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Abstract. We report a usability study which investigated the use of haptic versus non-speech audio interface to identify different geometric shapes. The study used simple graphics containing one to three geometric shapes (line, triangle, rectangle and circle). We presented the graphics to 11 participants in two different modes, audio and haptic, in a counterbalanced design. The participants were asked to identify the number and the types of the shapes. Error rates with audio and haptic feedback were very similar. The time to answer the overview task was generally faster with audio feedback, however it was generally faster with haptic feedback for detailed view task. These results need to be considered with some care because they were not statistically significant because of the small number of participants.

Keywords: graphics, usability, accessibility, haptic, audio, multi-touch

1 Introduction

There have been many assistive technologies which use different human sensory systems. Among these systems haptic and aural systems are the most preferred ones to present graphical information because of their characteristics.

The haptic subsystem is specialised to process tactual and kinesthetic stimuli. It has sensors that receive stimuli about touch, temperature and motion [1], so it can provide information about shape, size, texture and position of an object [2].

The aural subsystem has sensors that receive aural information such as speech and non-speech audio [1]. It is more effective in acquiring sequential stimulus than the haptic subsystem [2]. The aural subsystem provides binaural hearing in which time and position differences in sound occurring due to the natural spacing of the head and the ears, enables a person to locate the source of a stimulus [5].

As a result of their characteristics, these sensory systems have been used in many different assistive technologies, such as [3, 4] which use haptic, and [6, 7] which use aural. Both of these approaches have successfully demonstrated that they work on some graphics. However, it was not clear for us to decide which one to use in the GraVVITAS system [8] that we have been developing. Therefore, we want to compare these two different approaches.

This paper reports a usability study which investigates the use of haptic versus non-speech audio interface modes to identify different geometric shapes. We provide the preference, time and number of errors for participants in each of the modes, as well as the strategies that they use.

2 Comparison of Haptic and Non-Speech Audio Feedback

In our first trials we experimented with the number of fingers that we attached the vibrating motors to. We tried (i) only the right index finger, (ii) the left and right index fingers, and (iii) the left and right index and middle fingers.

Our experience, corroborated by feedback from blind participants in pilot studies was that it was beneficial to use fingers on both hands but that it was difficult to distinguish between vibration of the index and middle finger on the same hand. We first tried attaching the vibrating devices to the underside and then to the top of the finger but this made little difference. Our experience is that, with sufficient practice, one can distinguish between vibration on all four fingers but this takes many hours of use. We therefore decided to use the tool with two fingers—the left and right index fingers—as we would not be able to give the participants the necessary time to learn to use four fingers before conducting the user study.

Given that we decided only to provide haptic feedback for the left and right index finger, a natural question to investigate was whether stereo audio feedback might be better. To determine this we implemented an audio feedback mode as an alternative to haptic feedback. This mode was restricted to the use of one finger or two fingers on different hands. In audio mode if the user touches an object on the screen then they will hear a sound from the headphones. If they use one finger they will hear a sound coming from both headphones while if they use two fingers then they will hear a sound on the left/right headphone if their left/right finger is on an element. The sounds associated with objects were short tones from different instruments played in a loop.

We conducted a usability study to investigate whether audio or haptic feedback was better for determining the geometric properties (specifically position and shape) of graphic elements. The study used simple graphics containing one to three geometric shapes (line, triangle, rectangle and circle). Each shape had a low intensity interior colour and a thick black boundary around it. This meant that the intensity of the haptic or audio feedback was greater when the finger was on the boundary.

We used 5 different training graphics in total; 4 of which included different types of shapes (line, triangle, rectangle and circle) — see Figure 1. The last one included all of the shapes. For each shape we used a different audio. We changed the audio files to be sure that no kind of shape always has the same audio associated.

We used 6 graphics for the experiment whose complexity varied in the number of shapes: easy (1 shape), medium (2 shapes), and hard (3 shapes) — see Figures 2 to 4.

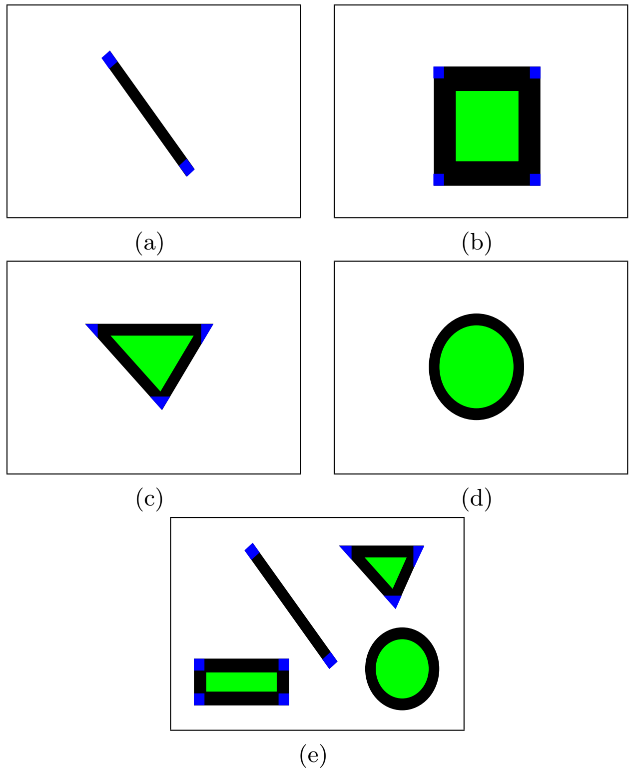
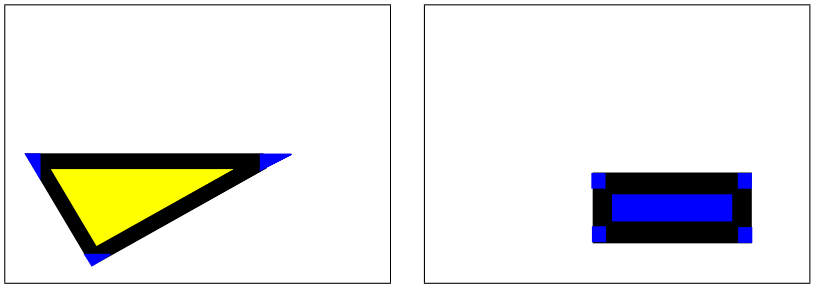


Fig. 1: Training graphics used in comparison of audio and haptic feedback.

We presented the graphics to each participant in the two different modes—*audio and haptic*—in a counterbalanced design. For each mode the following two-step procedure was carried out. First we presented the participant with one training graphic that contained all of the different shapes. In this step we told them what shapes were on the screen and helped them to trace the boundaries by suggesting techniques for doing so and then letting them explore the graphic by themselves. Second, the participant was shown three graphics, one at a time, and asked to explore the graphic and let us know when they were ready to answer the questions. They were then asked to answer two questions about the objects in the graphic:

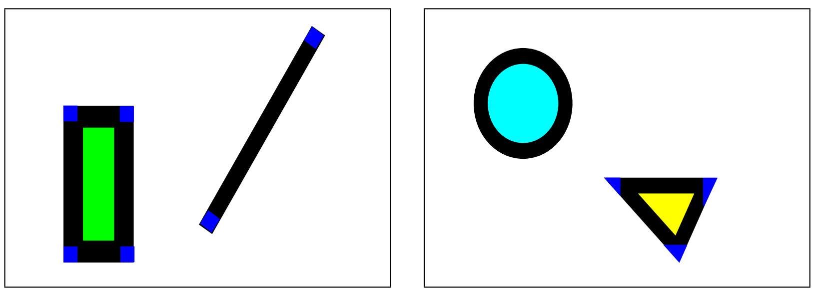
1. How many objects are there in the graphic?
2. What kind of geometric shape is each object?

The times taken to explore the graphic and then answer each question were recorded as well as their answers. After viewing and answering questions about the graphics presented with the audio and haptic interaction modes, the participants were asked which interaction they preferred and invited to give comments and explain the features that influenced their preference.



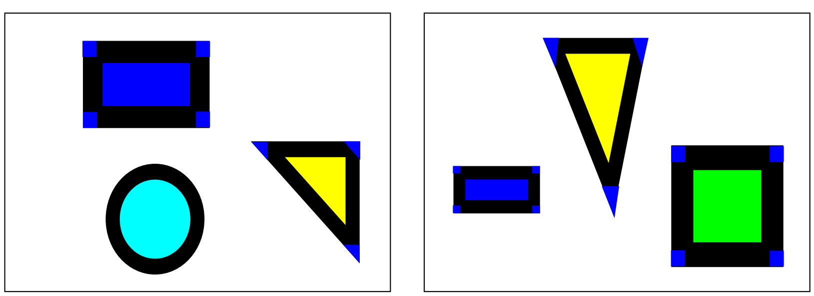
(a) (b)

Fig. 2: Simple graphics used in comparison of audio and haptic feedback.



(a) (b)

Fig. 3: Medium hard graphics used in comparison of audio and haptic feedback.



(a) (b)

Fig. 4: Hard graphics used in comparison of audio and haptic feedback.

A caveat is that we slightly modified the presentation midway through the usability study. This was because the first three participants had difficulty identifying the geometric shapes. The reason was that they found it difficult to determine the position and number of vertices on the shape. To overcome this in subsequent experiments object vertices were given a different colour so that the audio and haptic feedback when touching a vertex differed from that for the boundary and the interior of the shape. This reduced the error count to almost zero in the subsequent participants.

Another source of annoyance to the first three participants was a delay in response from the haptic feedback due to latencies in the touch screen, Arduino circuit board, and the inertia in the vibrating motor. It was at this point that we added a predictive component to the tool which provided haptic feedback based on the expected position of the finger.

3 Data analysis and results

We recruited 11 participants, 6 born blind and 5 late blind for the study. They were aged between 17 and 63. They all had previously read a tactile graphic. 3 of the participants could not complete the experiment because of hearing and sensing problems. 8 participants completed the usability study. We found that 6 out of 8 participants preferred haptic feedback, and 2 of the 3 excluded participants also preferred haptic feedback. Error rates with audio and haptic feedback were very similar. The time to answer the question 1 (overview task) was generally faster with audio feedback, however it was generally faster with haptic feedback for question 2 (detailed view task). These results need to be considered with some care because they were not statistically significant because of the small number of participants.

In Table 1 and Figure 5 we give the preference, time and number of errors for each participant in each of the two modes.

There were 14 errors out of 48 diagrams which included 96 shapes. However, as we discussed earlier the first 3 participants had difficulty identifying the geometric shape. To overcome this we added vertices with a different colour on the shapes so that the intensity of audio and haptic feedback for a vertex differed from the boundary and the interior of the shape. This reduced the error count significantly in the remaining 5 participants.

We observed that participants used two quite different strategies to identify shapes. The first strategy was to find the corners of the shapes, and then to carefully *trace* the boundary of the object using one or two fingers. This was the strategy we had expected.

The second strategy was to use a single finger to repeatedly perform a quick horizontal and/or vertical *scan* across the shape, moving the starting point of the finger between scans slightly in the converse direction to that of the scan. Scanning like this gives rise to a different audio or haptic pattern for different shapes. For instance, when scanning a rectangle, the duration of a loud sound on an edge, a soft sound inside the shape, and another loud sound on the other

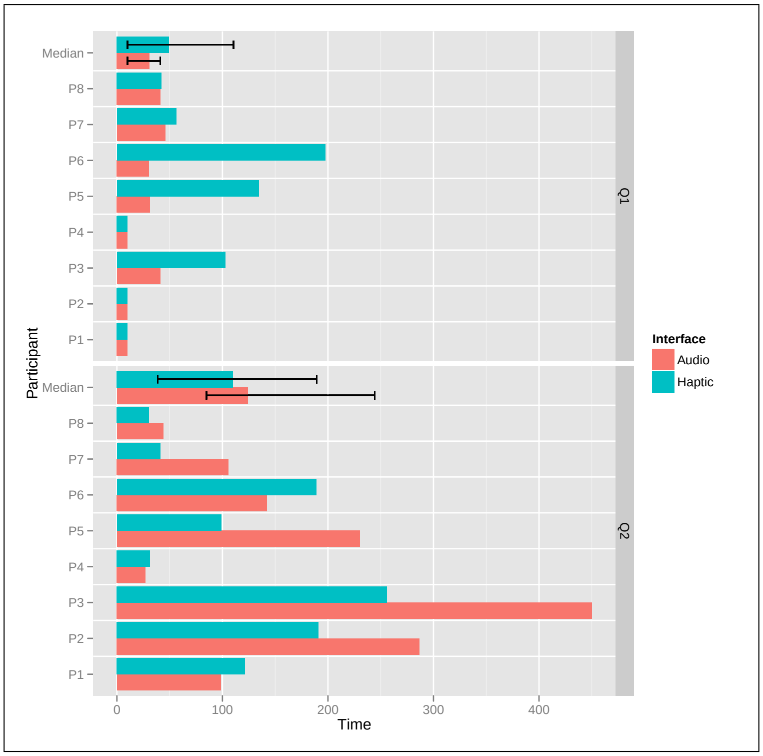


Fig. 5: Experiment 1 time results, and first and third quartiles for the median time.

Table 1: Experiment 1 results which shows the preferences, times (in seconds) and error numbers for haptic versus audio interface comparison. Since each graphic has multiple shapes, the times given are the average times for one shape.

Participant	Preference	Audio				Haptic			
		Q1		Q2		Q1		Q2	
		Error	Time	Error	Time	Error	Time	Error	Time
P1	Audio	0	10.00	3	98.50	0	10.00	1	121.33
P2	Haptic	0	10.00	2	286.83	0	10.00	2	191.00
P3	Haptic	0	41.00	2	450.17	0	102.67	3	256.00
P4	Audio	0	10.00	0	27.17	0	10.00	0	31.33
P5	Haptic	0	31.33	0	230.17	0	134.33	1	98.83
P6	Haptic	0	30.33	0	142.17	0	197.33	1	188.83
P7	Haptic	0	45.67	0	105.83	0	56.33	0	41.17
P8	Haptic	0	41.33	1	43.83	0	42.33	0	30.50
Median		0	30.83	1	124	0	49.33	1	110.08

edge are all equal as you move down the shape. But, for a triangle, the duration of the soft sound will either increase or decrease as you scan down the shape. Moreover, users could increase the speed of scanning so that they could finish the whole process quicker. However, this was harder with the tracing because the users had to adjust the direction by using the audio and the haptic feedback. With the scan strategy it was important to use the same speed for the scan, otherwise it might be confusing.

We thought that this might be a problem, but surprisingly all the participants used this strategy without any problems. The scan strategy was quite effective and those participants who used it were faster than those using the boundary tracing strategy.

4 Conclusion

As a result of this usability study we decided to provide haptic feedback (through the vibrating motors) rather than audio feedback to indicate when the user was touching a graphic element. Our study showed that this was quite effective, allowing the users to determine geometric properties of graphic elements (position and shape). The decision was due to user preferences, the slight performance advantage for haptic feedback in the detailed view task, haptic feedback being more readily generalised to more than two fingers, and because it allowed audio feedback to be used for other purposes.

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