Evaluation and User Testing of a Simple Two-Dimensional Screen Reader System

This is a report on a project submitted in part requirement for the degree of MSc. Information Processing in the Department of Computer Science at the University of York.

John McLean
30th September 1998

Abstract

This report is based on a project undertaken to evaluate, through user testing, a simple two-dimensional screen-reader system. The associated hardware and software was installed in a 486 IBM compatible PC operating under Windows 95.

A test of four sections was devised and ten subjects took part in the testing procedure. Their results were noted and they form the basis of this report. A questionnaire was devised and distributed to those who took part in the testing. Their responses are contained in this report.

Two subjects took part in the system testing a second time in a bid to determine if familiarity with the system would affect the users' abilities to use the system successfully.

Conclusions are drawn from the results obtained and suggestions are made for further research into this topic. The report begins with a brief review of the literature in the general field of study.

Contents

Introduction

This project investigates a two-dimensional screen reader system by means of a purposefully designed test. Ten subjects took part in this test and two of them took the test a second time, although the second test was slightly different to the first.

The system represents shapes sonically through four speakers positioned in from of the user, positioned as though in the four corners of a square. The test required the users to identify the shapes and objects represented sonically by the system and, in one section, specifically to identify the positioning of the sounds with reference to a computer screen displaying the images.

The report begins with a brief literature review concerning screen-reader systems and different types of sound reproduction. The system under investigation is then briefly described. The description is purposefully brief as a full description of the system may be obtained elsewhere and the purpose of this study is to investigate the system through user testing.

A description is given of how the system was set-up using preliminary testing procedures to help identify the optimum positioning of the speakers and a break-down of the actual test is given. A more detailed analysis of the test is given in the appendix section along with the document which was read out to the subjects at the start of the system testing procedure.

The results of the four sections of the test are presented and analysed and conclusions are drawn from them. The results of the questionnaire given to the subjects are reported and the questionnaire, in the form presented to the subjects, is given in the appendix section.

The results from the tests on the two subjects who took the test a second time are presented and analysed and conclusions are drawn from them.

The conclusion to the project summarises the results of the project, discusses the possible practical implementations of the system and suggests the direction of future research in the subject area.

Brief Literature Review and Introduction to the Subject Area

In recent years Graphical User Interfaces have become more and more prevalent in the world of computing, making it even more difficult for the visually impaired to make use of standard computer systems. With this in mind, research into sound as a reliable source of information given to the user by the computer has been undertaken.

To compensate for a lack of vision, screen readers for the blind must transform the graphical representations into a form accessible to the sensory modalities available to the user, touch and hearing. This report does not address the issue of touch but instead focuses on sound.

Clearly, there are many problems inherent in trying to represent with sound the wealth of information which may be on a screen at any given time. In order to try to address this problem combinations of synthesised speech, non-speech sounds and representations of spatialisation are used.

The use of non-speech sounds is gaining more and more importance in standard multimedia applications and this is particularly true of those designed for use by the visually impaired. There a two basic 'types' of such sound.

One, which was proposed by W. Gaver[1,2] is based on the *ecological* approach to the study of psychological phenomena, as developed by J. Gibson [3,4]. Gaver's approach takes sounds from 'the real world' and uses them metaphorically in computer interfaces. Examples of such sounds were used by Crispien and Petrie[5] in their Graphical User Interface for the Blind system where they used the sound of a door opening to represent a window pop-up and the sound of footsteps to represent the mouse tracking around the screen.

The other approach, as developed by M. Blattner and colleagues[6] and Brewster and colleagues[7] suggests the use of relatively simple tones which should be combined to create musical 'motives' to provide information to the blind user.

A combination of the two types of sound listed above can be used to try to achieve the objective of conveying reliable information to a blind user and these sounds can, of course, be combined with synthesised speech.

Burgess[8] and Crispien and Petrie[9] tested applications of spatial sound, used to try to allow blind persons to navigate their way around a Graphical User Interface. Crispien and Petrie's system can be used with either a multiple loudspeaker system or with a headphone-based 3D sound system. The sounds created by the system were spatialised according to the position on the computer screen by a two-dimensional auditory display (azimuth and elevation).

Spatialised Sound

To properly describe the notion of spatialised sound, distinction should be made between monaural, stereo and binaural sound from 3D sound. A monaural sound recording, made using

only one microphone, contains no sense of sound positioning. Stereo sound is recorded using two microphones, generally a few feet apart and separated by empty space. When such a recording is played back, the recording from one microphone goes into one ear and the recording from the other microphone into the other ear, through two speakers. This produces a sense of the positioning of the sound as recorded by the two microphones. Humans listening to stereo sound often report the sensation of perceiving the sound sources to be located at a position inside their own head. This is considered to be due to the fact that humans do not normally experience sounds in the same way as they are recorded in stereo, separated by empty space, as the human head essentially acts as a filter to incoming sounds.

Humans generally perceive binaural recordings as being more realistic in their representation of real world sounds as the manner in which they are recorded resembles the human acoustic system more closely than that of monaural recording. The standard method of achieving binaural recording is to embed recording microphones in the head of a dummy. Due to the fact that the dummy head filters sound in a manner similar to the human head, binaural sounds sound closer to what humans hear in the real world.

As part of attempts to synthesise accurate 3D sound, binaural recordings have been taken a step further in an effort to better model the human acoustic system by recording sounds registered by miniature microphones placed in the ears of humans. The recordings registered in such a manner are then compared with the original sounds in order to compute the individual's head-related transfer function (HRTF). The HRTF is a linear function based on the position of the sound source. It takes account of many of the variables humans take account of in localising sounds. The HRTF may then be used to develop finite impulse response (FIR) filters for specific sound positions. Two filters are required for each sound position, one for the right ear and one for the left. Therefore, in order to place a sound in a given position in virtual space, that set of FIR filters which corresponds the specified position is applied to the incoming sound, resulting in spatialised sound.

Convolving sound signals from a particular point in virtual space requires highly demanding computation, as detailed in Burgess (1992), and they are so demanding that they are currently unable to be processed in real-time without specialised hardware.

In an effort to meet the real-time challenges of 3D sound synthesis, strategically placed speakers have been used to simulate spatial sound. Rather than try to simulate many of the variables used by humans to form perceptions of localisation, this approach focuses instead on attaching sampled sounds to objects in 3D space. This approach has been adopted by Visual Synthesis Incorporated[10] with their Audio Image Sound Cube which has eight speakers to simulate spatial sound. The speakers may be arranged to form a cube of any dimensions with two speakers located in each corner of the cube, one low down and the other high up. Sound location is simulated by manipulation of the pitch and volume of the sampled sounds. The volume is channelled through the speakers to create the perception of a sound source's spatial location. This approach speeds up processing by neglecting the requirement for such high-level computation as required in the HRTF approach. Whilst this allows for the provision of much less expensive real-time spatial sound it is not as accurate as methods which convolve sound.

Problems with the simulation of spatial sound

The most pervasive problems with the generation of spatial sound are front-to-back reversals, intracranially heard sounds and HRTF measurement difficulties. Front-to-back reversals refers to a subject's perception that a sound which is really located in front of them is coming from behind them, and vice-versa. This problem may be lessened by accurately taking account of the subject's pinnae response and head movements. Burgess (1992) showed that another method of lessening the problem is to include a first order echo response to aid front-to-back differentiation.

The sound which is heard inside a subject's head when the sound source is actually located externally to the subject's head is referred to as intracranially heard sound. The problems created by such perceptions of sound may be diminished through the addition of reverberation cues to the sound signals.

Additional problems are associated with the generation of the HRTF's themselves. Problems arise particularly with the measurements collected by the small microphones placed in the ear canal as such microphones are susceptible to noise and linearity problems. In addition, Begault (1990) notes that speakers which are used to generate sounds are sometimes ineffective in the reproduction of low-frequency sounds.

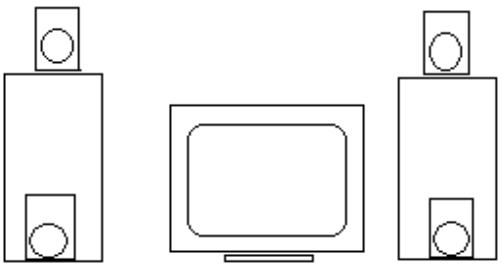
The system undergoing evaluation in this report

A full technical report on the system under test is not relevant here as this project is concerned with the user testing of the system. Full information on the system may be obtained in:

Grigori Evreinov, "Objects' Relative Displacement, Perception of Motion and Formation of the Planar Virtual Acoustic Objects", Specvuzavtimatika Design Bureau, Rostov-on-Don, Russia.

To avoid unnecessary duplication of the information contained in the above paper a simple, brief description of the system will be given here.

This system uses four speakers, placed in front of the user around the computer monitor, as shown in the crude diagram below:



Sounds which are produced by the lower speakers are of a lower pitch than sounds produced by the two speakers which are placed higher up, shown here above the height of the monitor. Thus a

straight line drawn along the top of the screen will be represented sonically by the system with a sound of a higher pitch than a straight line drawn across the bottom of the screen. Intermediate points between these two lines are represented by variations in the level of pitch between the lowest and the highest pitches used by the system.

In order to represent shapes the strength of the sound signal, as well as its pitch, varies between speakers. For example, the straight line drawn left-to-right across the screen would be represented sonically in the following way:
The sound would begin, in a low pitch in the bottom left speaker at a volume predetermined by the system administrator. To represent the movement of the sound leftwards across the screen the speaker on the bottom right would produce a sound, initially of lesser volume than the sound omitted by the bottom right speaker. As the line moved across the screen the balance of volume between the two speakers would change gradually with the bottom left speaker gradually becoming dominant and the bottom right speaker eventually becoming dormant. A similar system works when representing a line drawn from between the top and the bottom of the screen.

As another example, consider the case of a large circle drawn across the entire screen. All four speakers will be involved in sonically representing this shape as the line describing it moves from its initial point around the screen and then back to where it started.

If a smaller circle is drawn in one of the corners of the screen, however, then only the speaker placed in the corresponding corner of the screen will produce sound (providing the circle, or other shape, is sufficiently small).

Smaller objects are sonically represented by the system with a sound source of a lesser temporal duration than larger objects. Thus the smaller circle just discussed would be represented very quickly in comparison to the circle which was drawn across the entire screen.

The software which controls the system operates under Windows 95 and is written in Visual Basic with a Graphical User Interface. The interface displays a square window, which represents the computer screen, on which objects and shapes can be drawn before instructing the system to convert them into sound signals.

The interface has a number of drawing tools to enable the user to quickly and efficiently construct shapes in the form of straight lines and composite shapes constructed from them, rectangles, square, circle, arcs and ellipses. There is also a drawing tool allowing the mouse cursor to act as the tip of a pencil so that the user can construct any required shape. The interesting point is that shapes drawn using the pencil tool are represented sonically extremely quickly by the system, regardless of their size, in comparison with a shape constructed using any of the other drawing tools.

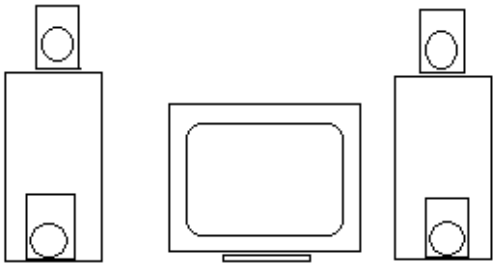
The software allows a number of manipulations of the images and their subsequent sonic transformations to be made for example, changing the direction and pitch of the sound.

Setting-Up The System

Having been moved between various machines, the sound card finally was fitted to a PC running Windows 95 and two pairs of speakers were connected to its outputs. It soon became apparent that identical speakers should be used in order to avoid the subtle differences between the outputs of different speakers which might adversely affect the testing procedure.

The speakers were initially arranged by placing the two bottom speakers on the desk, on either side of the monitor, and the two top speakers on either side of the top of the monitor. A number of subjects were involved in preliminary testing to determine the significance of the speaker positioning.

On conducting preliminary testing with one subject it immediately became apparent that she was ill at ease with the positioning of the four speakers and much time was spent in positioning the speakers in the place considered by the subject to be optimum. This involved acquiring two identical cardboard boxes, on the suggestion of the subject, to aid in the speaker placement. On each side of the monitor an empty box was placed on its side with one speaker being placed on its top and one speaker being placed inside it on its bottom wall. All four speakers were then facing the subject with the bottom two just above the height of the desk, as they were resting on the inside of the boxes, and the top two about 70 cm above the desk. The diagram below gives an idea of how the system was arranged:



On playing the subject numerous sounds it became clear that she felt most comfortable when sitting directly in the middle of the two sets of speakers, as expected. What also became clear was that the subject found it most important that her head be positioned in the middle of all four speakers. Indeed, the subject voluntarily adopted a slouching posture in her chair so that her head was positioned where she perceived the centre of the four speakers to be and she remained in this position for the duration of the trial test. Observations made of preliminary testing on further subjects suggested that the speakers were in the optimal position possible and these subjects were also noted to change their seating position in order to place themselves where they perceived the middle of the speakers to be. It should be noted at this point that the subjects all had visual awareness of the system they were using and so were able to use their sight to position themselves in the middle of the speakers.

It was also found to be of great importance that all four speakers be operating at the same level of volume. Subjects also found it important that the overall level of volume be at a comfortable level of loudness. Although the testing was conducted in an electronics workshop with people

and machines making noise in the background, some subjects requested that the volume be lowered from the initial level which greeted them. It is not certain if the subjects simply found the volume too loud to be comfortable or offensive due to the actual sounds being produced or if the subjects were simply keen to avoid disturbing the others in the room (or to avoid drawing attention to themselves). In any case, there was unfortunately no alternative to conducting the tests in a busy, noisy room. However, at least this provided a realistic setting in which to conduct the tests as opposed to doing it in an unrealistically sterile environment.

A further problem was that access to the system was only permitted during office hours with the result that a fewer number of people could be tested than would have been preferable. This also meant that the test had to be kept short as asking subjects to take part in the test essentially involved disturbing them from their own work.

Devising a test from preliminary testing

Some subjects taking part in the preliminary testing were allowed to view a shape on screen as the system represented it sonically. This allowed them to gain immediate understanding of how the sounds related to the lines on screen. Other subjects were not allowed to see the screen at any time.

It was explained to some subjects, but not to others, that certain sounds were standard when two lines in a shape met and the significance between sounds coming from the different speakers.

The idea behind the system was explained to the subjects and the system then played a number of sounds to them. They were told in advance of hearing each sound exactly what shape that sound was supposed to represent. Following this, a number of shapes were then played to the subjects and they were asked to state what shapes they thought the sounds represented.

It was immediately clear that those subjects who had originally been permitted to watch the screen whilst listening to a sonic representation of what they were viewing were far more able to correctly identify the shapes being sonically represented. However, the differences between the number of correct responses returning from the two groups became less marked as the test proceeded.

It was also similarly clear that those subjects to whom various 'hints' as to how shapes could be recognised were suggested were far better at returning the correct answer than those to whom no 'hints' had been offered. It was found that, as the test proceeded, there was still a marked difference between the two groups. This highlighted the significance of teaching before subjects started using the system and further research into the effects of teaching would no doubt prove very interesting and informative.

Choosing the test format

The test was split into four sections with the total time taken to complete the full test approximately 30 minutes. Before the test begins, the subject is explained some details about the system and is then given some example sounds to listen to and is told which shapes these sounds are supposed to represent. Subjects were not allowed to see the objects on screen as some subjects were in the preliminary testing stage. The details about the system and the introduction to it are detailed in Appendix 2 which is the document that was read aloud to subjects at the beginning of the test.

Following this, Section 1 of the test requires the subjects to listen to five different sounds and to write down the name of the shape which they believe is being described by each sound. The subject may request that each sound is repeated as many times as they desire before writing down their answer. After each answer is given, the subject is informed of whether or not they correctly identified the shape.

This first section is very short and is designed to test if subjects are able to recognise simple shapes, some of which they had previously heard in the examples given to them before the start of the test. The purpose of this section is simply to test if the subjects can recognise simple shapes before progressing to the further stages. The fact that the subjects are given feedback on their responses in this section allows them to learn more about the system and the correlation between their own responses, the sounds they heard and the actual shapes the sounds were supposed to represent.

In section 2, subjects are requested to draw the shapes they believe the sounds played to them represent, rather than to simply write down the name of the shape. Subjects are also requested to draw each shape they hear in a small box drawn on paper, which is intended to represent the shape of a computer screen. Subjects are requested to draw each shape in the box to correspond to the position on the computer screen they believe the shape to be drawn.

This section further tests the subject's ability to correctly recognise the shapes output by the system as well as testing their spatial awareness with regards to the relative positioning of shapes on the computer screen. In this section the shapes are not as large as in the previous section and there sonic representation is therefore quicker than in the previous section. This makes the shapes somewhat harder to recognise and so this section forms a logical progression from the first section.

Asking the subjects to draw the shapes in the box which represents the screen tests the system's ability to convey reliable information to the subject on both the graphic's form and its positioning. This was considered interesting as a real-world application of the information gathered from the system testing might be that of applying similar technology to aiding a blind person in recognising icons in various parts of the screen operating under a Graphical User Interface system.

Again in this section the subjects are allowed to request that each sound is repeated as many times as they desire before they give their response. They are not given any feedback on their responses, however.

In Section 3, the subjects are again requested to draw what they hear in boxes which represent the screen. This time, however, the subjects are informed that the sounds they hear may or may not correspond to recognisable, standard shapes.

The shapes in this section are, in fact, a mixture of standard shapes (letters of the alphabet) and random shapes generated from single or multiple straight lines. The subjects are again requested to draw the shapes in the box which corresponds to that part of the screen they believe the actual shape to be drawn.

The purpose of using non-standard shapes is two-fold. Firstly, it reduces the risk that the subjects are merely guessing or have simply remembered shape patterns from Section 1 or the introduction they were given to the system. Secondly, the shapes made of lines can be thought of as representing the tracks left behind a cursor moving around the screen. Subjects draw the shapes from the point at which they started on the screen through to the point at which they terminated. Because of this, it can be considered that the subjects are following a pattern around the screen as it is generated and this, by extension, could be considered to be analogous to a real-world application of the movement of a cursor around the screen, where the point of the cursor is that part of the shape which has just been drawn.

In Section 3 the subjects are allowed to request that each sound is repeated as many times as they desire before they give their response. They are not given any feedback on their responses, however.

Section 4 is much shorter than the previous two sections but again requires that the subjects draw their responses in boxes which represent the screen. The subjects are told that this section is designed to test if the system can produce sound which is accurate enough to allow distinction to be made between different versions of the same shape...i.e. square/rectangle and equilateral/isosceles/scalene triangle. This is considered important as a measure to determine just how accurate and reliable might be information conveyed to a user in a real-world application based on a system such as the one under investigation.

Three of the shapes in this section are triangles and two are variants of the square. A kite, parallelogram and rhombus are also included in the test as they contain a number of angled lines and were considered to be difficult to recognise in preliminary testing and it was thought appropriate that some more advanced shapes be included in this section. Including these shapes also helped to prevent the subjects from making guesses based on the false assumption that the following sound would simply represent a variant of the previous sound.

Again in this section the subjects are allowed to request that each sound is repeated as many times as they desire before they give their response and no feedback is given.

A more detatailed description of the test is given in 3 which also shows the shapes used in the test.

Questionnaire

A questionnaire was distributed to the subjects after the testing had been completed.
This questionnaire is reproduced in 4.

The results from the questionnaire are reported later in this paper.

The questionnaire was include in order to gain some feedback from the subjects to gauge their general feelings regarding the system and to enquire as to what they felt about their own use of the system.

Reporting and Analysis of Results from the System Testing

This section reports and then analyses the results from each section of the test in turn. An overall analysis is then conducted for each individual subject before a conclusion is drawn.

Results from Section 1 of the System Testing

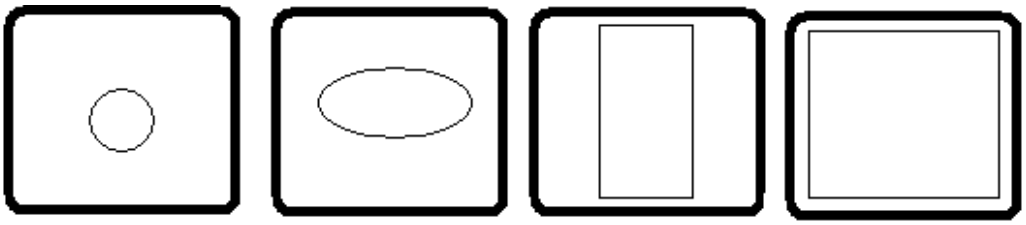
The table below gives the results of Section 1 of the System Testing. S1...S10 refer to Subjects 1 to 10. Each subject's response (YES or NO) to each sound is listed under the heading for each shape, 1 to 5. Also listed for each subject for each shape is the number of times the subject listened to the shape corresponding to that sound before giving a response.

The final column of the table lists, firstly for each subject in turn, the number of shapes correctly identified, the average number of times a shape was listened to before a response was given, and the modal number of times a shape was listened to before a response was given.

The final row of the table details, firstly for each shape in turn, the number of times the shape was correctly identified, the total number of times the shape was listened to, the average number of times each subject listened to the shape and the modal number of times each subject listened to the shape.

The final cell of the table, in the last column of the last row, gives the total number of times a shape was correctly identified and shows this as a percentage. Also given is the overall average number of times each shape was listened to and the overall modal number of times each shape was listened to. The shapes are shown below:

Shape 1, ection 1 Shape 2, Section 1 Shape 3, Section 1 Shape 4, Section 1



Shape 5, Section 1

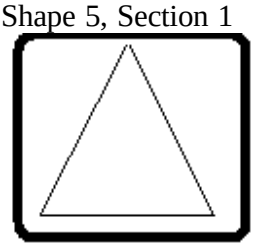


Table 1. Results of Section 1 of the System Test

For each subject S1 to S10, Shapes 1 to 5. Data on no. of times each shape heard and whether it was correctly identified. Totals column/row give aggregate statistics.

	SHAPE 1 (circle)		SHAPE 2 (ellipse)		SHAPE 3 (rectangle)		SHAPE 4 (square)		SHAPE 5 (triangle)		TOTALS
	correct	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**Number correct/ average times heard /modal times heard**
S1	YES	1	YES	2	YES	2	YES	2	YES	1	5 , 1.6 , 2
S2	NO	2	YES	2	YES	1	YES	2	YES	2	4 , 1.8 , 2
S3	NO	2	YES	2	NO	3	YES	2	YES	2	3 , 2.2 , 2
S4	YES	3	YES	2	YES	2	YES	2	YES	2	5 , 2.2 , 2
S5	YES	1	YES	1	YES	4	YES	3	NO	2	4 , 2.2 , 1
S6	NO	2	NO	3	NO	3	NO	3	NO	2	0 , 2.6 , 3
S7	YES	1	YES	1	YES	3	YES	5	YES	3	5 , 2.6 , 2
S8	YES	2	YES	2	YES	2	YES	1	YES	1	5 , 1.6 , 2
S9	NO	2	NO	4	YES	2	YES	4	YES	2	3 , 2.8 , 2
S10	YES	2	YES	1	NO	2	NO	3	YES	1	3 , 1.8 , 1.5
TOTALS	6 correct	Total times heard: 18 Average: 1.8 Mode: 2	8 correct	Total times heard: 20 Average: 2 Mode: 2	7 correct	Total times heard: 23 Average: 2.3 Mode: 2	8 correct	Total times heard: 26 Average: 2.6 Mode: 2	8 correct	Total times heard: 18 Average: 1.8 Mode: 2	Total number correct: 37 (74%) Overall average time each shape heard: 2.1 Overall modal time each shape heard: 2

From the table it can be seen that Subjects 1, 4, 7, and 8 correctly identified all five of the shapes played to them by the system. The average and modal values for the amount of times shapes were listened to are the same for Subjects 1 and 8. Subject 4 has the same modal value of 2 as Subjects 1 and 8 but has a higher average value of 2.2 as compared to the average value of 1.6 of Subjects 1 and 8. Subject 7 has a higher average value again, that of 2.6 and has a modal value of 2.

Subjects 2 and 5 both correctly identified four of the five shapes. Subject 2 incorrectly identified Shape 1 whereas Subject 5 incorrectly identified Shape 5. With regards to the number of times shapes were listened to, Subject 2 has a lower average value than Subject 5, 1.8 compared to 2.2, but has a higher modal value, 2 compared to 1.

Subjects 3, 9 and 10 all correctly identified three of the five shapes. Subject 3 did not correctly identify Shapes 1 and 3, Subject 9 did not correctly identify Shapes 1 and 2 and Subject 10 did not correctly identify Shapes 3 and 4. Subject 10 has the lowest average value of the number of times a shape was listened to of 1.8 compared to 2.2 for Subject 3 and 2.8 for Subject 9. Subjects 3 and 9 have the same modal values of 2 whilst Subject 10 has a modal value of 1.5.

Subject 6 did not correctly identify any of the five shapes. With regards to the number of times shapes were listened to, Subject 6's average value is 2.8 and modal value is 3.

Shape 1 was correctly identified 6 times and was listened to 18 times during the test. The modal number of times it was listened to by the subjects is 2 and the average number of times it was listened to is 1.8. Shape 3 was correctly identified 7 times and was listened to 23 times. The average number of times it was listened to is 2.3 and the mode is 2.

Shapes 2, 4 and 5 were all correctly identified 8 times. Shape 5 was listened to 18 times, giving an average of 1.8. Shape 2 was listened to 20 times, giving an average of 2.0. Shape 4 was listened to 2.6 times with and average number of times it was listened to of 2.6. However, the modal number of times Shapes 2, 4 and 5 were listened to is the same for all three shapes, which is 2.

Overall, shapes were correctly identified 37 times out of a possible 50, giving a success rate of 74%. On average, each shape was listened to 2.1 times and the modal number of times a shape was listened to is 2.

Interpretation of the results from Section 1 of the System Testing

Four of the ten subjects correctly identified all five of the shapes. From these four subjects, two of the subjects' average number of times of listening per shape was below the overall average and two of the subjects had an average above the overall average. This would suggest, along with further evidence from the table of results, that the amount of times a shape was heard does not have a particularly strong bearing on the subjects' perceived or actual abilities to correctly identify the shape.

Two subjects correctly identified four of the five shapes and the shape that each incorrectly identified was not the same (Subject 2 incorrectly identified Shape 2 whilst Subject 5 incorrectly identified Shape 5). One subject's average was lower than the overall average and the other's was higher, again supporting the contention that the number of times shapes were heard did not affect the level of identification.

Three subjects correctly identified three shapes. One of the subjects had an average value below that of the overall average and the other two had average values above that of the overall average.

One subject did not correctly identify any of the shapes and had the highest average value out of any of the subjects, and therefore above the overall average.

These results suggest that listening to the shapes more often does not lead to an increased ability to successfully recognise them. Indeed, two of the three subjects who correctly identified all five of the shapes each had an average of 1.6, the lowest average recorded. This, and the other results, suggest that successful recognition is significantly more dependent on the natural abilities of an individual to recognise a shape as it is presented to them than on the amount of times the shape is heard. To further support this contention it can be noted that the modal number of times each shape was listened to is 2 for almost all of the subjects in the test. One of the subjects, with the highest modal value, and also one of the highest average values, was the subject who failed to correctly identify any of the shapes. It should also be noted here, however, that one of the subjects who correctly identified all of the shapes had a high average value.

There is no evidence from the individual results to suggest that listening to a shape more often will necessarily lead to an increased likelihood of it being identified. For example Subject 9 listened to Shape 2 four times before returning the wrong answer but listened to Shape 4 four times before returning the correct answer. Shape 4 was correctly identified eight times and its average number of times heard (2.6) was greater than the overall average (2.1). However, Shapes 2 and 5 were also correctly identified eight times and their averages are below the overall average.

In order to ascertain if listening to sounds an increased number of times leads to an increase in the ability to successfully recognise the shapes the sounds represent, specific tests would have to be devised. However, from the results of Section 1 of the system testing under discussion it can be concluded, at least, that listening to shapes an increased number of times does not necessarily lead to an increased ability to correctly identify them. It may be the case, of course, that some subjects are simply more confident than others in giving their answers after hearing the shape only a very few number of times and that the abilities of these confident subjects to successfully recognise shapes would increase were they to listen to the shapes a greater number of times before returning their answer. However, it does not seem unreasonable to suggest, from these preliminary data, that an individual's immediate ability to recognise a shape is based on personal ability rather than another factor.

Three of the five shapes were correctly identified eight times, one was correctly identified seven times and the remaining shape was identified six times correctly. This gives a success rate of 75%, which would seem quite high. However, a number of factors must be taken into consideration in analysing the results from this section.

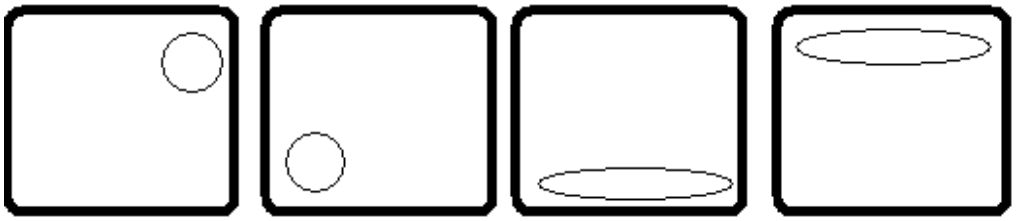
Firstly, subjects were informed that the shapes would be of a standard nature, e.g. circle, square, ellipse, etc., so they had an idea of what to expect. They were also given feedback on their responses. After they had given an answer they were told what the correct answer should have been. This could have influenced their future answers in this section. for example, after hearing that Shape 1 was a circle, subjects may have then thought it unlikely that another circle would be included in the test and so this may have helped them to identify the second shape, an ellipse.

Secondly, Section 1 was preceded by an introduction to the system and subjects heard a square and a circle prior to beginning the test which may have influenced their recognition of these shapes during the test(although they were of different size than those in the test).

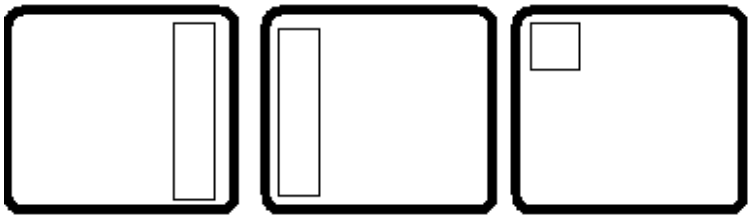
Results from Section 2 of the System Testing

Below are the shapes which were used in this section of the system testing:

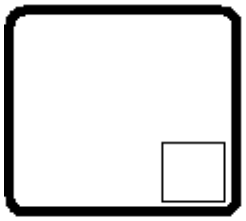
Shape 1, Section 2 Shape 2, Section 2 Shape 3, Section 2 Shape 4, Section 2



Shape 5, Section 2 Shape 6, Section 2 Shape 7, Section 2



Shape 8, Section 2



The table below, Table 2, contains the results of Section 2 of the System Testing. S1...S10 refers to Subjects 1 to 10. The table lists, for each subject and each shape, whether or not the subject correctly identified the shape (YES or NO), the number of times the subject listened to the shape before giving a response and whether or not the subject correctly identified the position of the shape (YES or NO). Due to its overall size, the table is shown in two parts below.

Table 2 (part 1). Results of Section 2 of the System Test

For each subject S1 to S10, Shapes 1 to 8. Data on no. of times each shape heard and whether it was correctly identified and positioned.

	SHAPE 1			SHAPE 2			SHAPE 3			SHAPE 4		
	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position
S1	YES	1	YES	YES	2	YES	YES	3	YES	NO	2	NO
S2	YES	1	YES	YES	2	YES	YES	2	YES	YES	3	YES
S3	YES	2	YES	YES	2	NO	NO	3	NO	YES	2	YES
S4	YES	3	YES	YES	2	YES	YES	3	YES	YES	4	YES
S5	YES	2	NO	YES	2	NO	NO	1	YES	NO	1	NO
S6	YES	2	YES	NO	3	YES	YES	2	YES	YES	1	YES
S7	NO	2	NO	YES	1	YES	YES	1	NO	NO	1	NO
S8	YES	1	YES	YES	2	YES	YES	1	NO	YES	2	YES
S9	YES	2	YES	YES	2	YES	YES	2	YES	YES	3	YES
S10	YES	3	YES	YES	1	YES	NO	1	YES	NO	2	YES

Table 2 (part 2). Results of Section 2 of the System Testing

	SHAPE 5			SHAPE 6			SHAPE 7			SHAPE 8		
	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position
S1	YES	3	YES	YES	4	YES	NO	3	YES	YES	3	YES
S2	YES	3	YES	YES	3	YES	YES	2	YES	NO	4	YES
S3	NO	3	NO	NO	1	NO	YES	2	YES	YES	2	NO
S4	YES	2	YES	YES	3	YES	NO	2	YES	NO	6	YES
S5	NO	1	NO	YES	2	NO	YES	1	YES	NO	1	YES
S6	NO	2	NO	NO	3	YES	NO	4	YES	YES	3	YES
S7	YES	2	NO	YES	4	YES	NO	1	NO	NO	2	YES
S8	NO	1	NO	YES	2	NO	YES	2	YES	NO	3	NO
S9	NO	5	YES	NO	2	YES	YES	1	YES	YES	3	YES
S10	YES	2	YES	NO	2	YES	NO	1	YES	NO	3	YES

The tables below, Tables 3 and 4, detail a number of statistics associated with the data represented in Table 2. Table 3 details for each shape the number of times the shape was correctly identified (and expresses this as a percentage), the number of times the correct position of the shape was identified (and expresses this as a percentage), the number of times both the correct shape and the correct position were identified together (and expresses this as a percentage), the overall number of times each shape was listened to, the average number of times the shape was listened to by a Subject and the modal number of times a shape was listened to by a Subject.

The final row of Table 3 gives the total number of times a shape was correctly identified in Section 2 of the System Testing (and expresses this as a percentage), the total number of times a shape's position was correctly identified (and expresses this as a percentage), the total number of times both a shape and its position were correctly identified (and expresses this as a percentage), the total number of times shapes were listened to, the overall average number of listens per shape and the overall modal number of listens to each shape.

Table 3. Results of Section 2 of the System Test

For each Shape 1 to 8. Data on no. of times each shape correctly identified, positioned and correctly identified and positioned simultaneously. Data on no. of times each shape heard and averages, percentages and modal values.

	No. of times correct shape identified, (%)	**No. of times correct position identified, (%)**	**No. of times both correct shape and position identified (%)**	**Overall total number of times shapes listened to**	**Average number of listens per shape by a Subject**	**Modal number of listens per shape by a Subject**
Shape 1	9, (90%)	8, (80%)	8, (80%)	19	1.9	2
Shape 2	9, (90%)	8, (80%)	7, (70%)	19	1.9	2
Shape 3	7, (70%)	7, (70%)	5, (50%)	19	1.9	1
Shape 4	6, (60%)	7, (70%)	6, (60%)	21	2.1	2
Shape 5	5, (50%)	5, (50%)	4, (40%)	24	2.5	2
Shape 6	6, (60%)	7, (70%)	4, (40%)	26	2.6	2
Shape 7	5, (50%)	9, (90%)	5, (50%)	19	1.9	1.5
Shape 8	4, (40%)	8, (80%)	3, (30%)	30	3.0	3
	Total number of times a shape correctly identified (%): 51, (63.75%)	Total number of times a position correctly identified (%): 59, (73.75%)	Total number of times both shape and position correctly identified (%): 42, (52.50%)	Total number of listens to shapes: 177	Overall average number of listens to each shape: 2.21	Overall modal number of listens to each shape: 2

Table 4 lists, for each subject, the number of shapes correctly identified (and expresses this as a percentage), the number of times the position on screen was correctly identified (and expresses this as a percentage), the number of times both the shape and its position were correctly identified (and expresses this as a percentage), the total number of times shapes were listened to, the average number of listens to each shape, and the modal number of listens to each shape.

Table 4. Results of Section 2 of the System Test

For each Subject 1 to 10. Data on no. of times a shape correctly identified, positioned and correctly identified and positioned simultaneously. Data on no. of times shapes heard and averages, percentages and modal values.

	No. of shapes correctly identified, (%)	**No. of times position correctly identified, (%)**	**No. of times both shape and position correctly identified, (%)**	**Total number of listens for each Subject**	**Average number of listens per shape**	**Modal number of listens**
Subject 1	6, (75.00%)	7, (87.50%)	6, (75.00%)	21	2.63	3
Subject 2	7, (87.50%)	8, (100%)	7, (87.50%)	20	2.50	2.5
Subject 3	5, (62.50%)	3, (37.50%)	3, (37.50%)	17	2.13	2
Subject 4	6, (75.00%)	8, (100%)	6, (75.00%)	25	3.13	2.5
Subject 5	4, (50.00%)	3, (37.50%)	1, (12.50%)	11	1.38	1
Subject 6	4, (50.00%)	7, (87.50%)	4, (50.00%)	20	2.50	2.5
Subject 7	4, (50.00%)	3, (37.50%)	2, (25.00%)	14	1.75	1
Subject 8	6, (75.00%)	4, (50.00%)	4, (50.00%)	14	1.75	2
Subject 9	6, (75.00%)	8, (100%)	6, (75.00%)	20	2.50	2
Subject 10	3, (37.50%)	8, (100%)	3, (37.50%)	15	1.88	1.5

Subject 2 correctly identified seven of the shapes, a success rate of 87.50%, and correctly identified eight of the positions, a success rate of 100%. Subject 2 correctly identified both the shape and positioning of a sound six times, a success rate of 75%. The total number of listens to the sounds by Subject 1 was twenty-one (average 2.63, mode 3).

Subjects 1, 4, 8 and 9 all correctly identified six of the eight shapes, giving a success rate of 75%. Subjects 9 and 4 correctly identified the position of a shape eight times, a success rate of 100%. Subject 1 correctly identified the positions seven times, a success rate of 87.50% and Subject 8 correctly identified four of the positions, a success rated of 50.00%.

Subjects 1, 4 and 9 correctly identified both the shape and positioning of a sound six times, a success rate of 75%. Subject 8 recognised correctly both the shape and positioning four times, a success rate of 50.00%.

Subject 8 listened to the shapes a total of fourteen times (average 1.75, mode 2), Subject 9 listened a total of twenty times (average 2.50, mode 2), Subject 1 listened a total of twenty-one times (average 2.63, mode 3) and Subject 4 listened a total of twenty five times (average 3.13, mode 2.5).

Subject 3 correctly identified five of the shapes, a success rate of 62.50% and successfully identified three of the positions, a success rate of 37.50%. This subject correctly identified both the shape and positioning of a sound three times, a success rate of 37.50%. The total number of times this subject listened to the sounds was seventeen (average 2.13, mode 2).

Subjects 5, 6 and 7 all correctly identified four of the shapes, a success rate of 50.00%. Subject 6 correctly identified the positioning seven times, a success rate of 87.50%, Subjects 5 and 7 correctly identified the positioning three times, a success rate of 37.50%.

Subject 6 correctly identified both the shape and position of a sound four times, a success rate of 50%. Subject 7 correctly identified both the shape and position twice, a success rate of 25.00% and Subject 5 correctly identified both the position and shape once, a success rate of 12.50%.

Subject 5 listened to shapes a total of eleven times (average 1.38, mode 1), Subject 7 listened a total of fourteen times (average 1.75, mode 1) and Subject 6 listened a total of twenty times (average 2.50, mode 2.5).

Subject 10 correctly identified three of the shapes, a success rate of 37.50% and correctly identified eight of the positions, a success rate of 100%. This subject correctly identified both the shape and position of a sound three times, a success rate of 37.50%. The total number of times Subject 10 listened to sounds was fifteen (average 1.88, mode 1.5).

Shapes 1 and 2 were correctly identified nine times, a success rate of 90%. The correct position of both Shapes 1 and 2 were identified on eight occasions, a success rate of 80%. Shape 1 and its position were correctly identified simultaneously on eight occasions, a success rate of 80%. Shape 2 and its position were correctly identified simultaneously on seven occasions, a success rate of 70%.

Shapes 1 and 2 were each listened to a total of nineteen times (average listens per subject 1.9, modal number of listens per subject 2).

Shape 3 was correctly identified on seven occasions, a success rate of 70%, and its position was correctly identified on seven occasions, a success rate of 70%. Shape 3 and its position were correctly identified simultaneously on five occasions, a success rate of 50%. This shape was listened to a total of nineteen times (average listens per subject 1.9, modal number of listens per subject 1).

Shapes 4 and 6 were correctly identified six times, a success rate of 60% and the positions of their sounds were correctly identified seven times, a success rate of 70%. Shape 4 and its position were correctly identified simultaneously on six occasions, a success rate of 60%. Shape 6 and its position were correctly identified simultaneously on four occasions, a success rate of 40%.

Shape 4 was listened to a total of twenty-one times (average listens per subject 2.1, modal number of listens per subject 2). Shape 6 was listened to a total of twenty six times (average listens per subject 2.6, modal number of listens per subject 2).

Shapes 5 and 7 were correctly identified five times, a success rate of 50%. Shape 7's position was correctly identified nine times, a success rate of 90% and Shape 5's position was correctly identified five times, a success rate of 50%. Shape 5 and its position were correctly identified simultaneously on four occasions, a success rate of 40% and Shape 7 and its position were correctly identified simultaneously on five occasions, a success rate of 50%. Shape 7 was listened to a total of nineteen times (average listens per subject 1.9, modal number of listens per subject 1.5). Shape 5 was listened to a total of twenty five times (average listens per subject 2.5 modal number of listens per subject 2).

Shape 8 was correctly identified four times, a success rate of 40% and its position was correctly identified eight times, a success rate of 80%. Shape 8 and its position were correctly identified simultaneously on three occasions, a success rate of 30%. The total number of times this shape was listened to was thirty (average listens per subject 3, modal number of listens per subject 3).

In total, shapes were correctly recognised fifty-one times, a success rate of 63.75%. The total number of times a position was correctly identified was fifty nine, a success rate of 73.75%. On forty two occasions, both a shape and its position were correctly identified simultaneously, a success rate of 52.50%.

In total, shapes were listened to 178 times with an average of 2.23 listens per shape and a modal number of listens to each shape of two.

Interpretation of the results from Section 2 of the System Testing

Subject 2 was the most successful in this section of the system testing and correctly identified seven of the shapes and all eight of the positions with an average number of listens per shape (2.5) above that of the overall average (2.21). The next two most successful subjects, Subjects 4 and 9 also had averages above the overall average (3.13 and 2.50 respectively).

Subject 1, who correctly identified six shapes and seven positions also had an average (2.63) above the overall average. The remaining subjects, those that were less successful in returning the correct answers all had, with the exception of Subject 6, an average number of listens per shape below the overall average number of listens per shape (2.21).

This would suggest that an important factor in identifying shapes is the number of times the corresponding sounds are listened to. This is in contrast to the suggestions made from the results of Section 1 of the system testing. However, there is no 'sliding-scale' which suggests that correct results will be fewer the lower the number of times a sound is listened to.

Also of interest here is that whilst no-one managed to correctly identify all of the shapes, four of the subjects successfully identified all eight of the positions. In fact the person who recognised the least amount of shapes, Subject 10, was one of those who recognised all of the positions. However, the mixed results suggest that it cannot be concluded that the position was easier to recognise than the shape. Four of the subjects recognised more shapes correctly than they did positions. This suggests that individual characteristics are an important factor in an individual's ability to use the system successfully as four of the subjects are better at recognising the shapes rather than the position whilst the others are more successful at recognising the position rather than the shape.

It is interesting to note, although not for those who recognised all eight positions correctly, that those subjects who recognised more positions than shapes all recognised both the shape and its position simultaneously the same number of times as they recognised the shape successfully (for example, Subject 1 recognised six shapes correctly and seven positions correctly and recognised both the shape and its position simultaneously six times).

Those subjects who recognised more shapes than positions did not exhibit a uniform trend. One of these four subjects (Subject 3) recognised five shapes and three positions correctly and correctly recognised both a shape and its position three times. Subject 8 exhibited a similar pattern. However, the remaining two of these four subjects (Subjects 5 and 7) did not follow this trend and correctly identified a higher number of positions than of shape and positions simultaneously.

It can be noted again that much of the variance in results might only be explicable through reference to the individual characteristics and abilities of the individual subjects. However, this time there is some warrant for suggesting that an increase in the number of times a sound is listened to may lead to a corresponding increase in its recognition success rate.

Analysing the data for individual shapes, however, turns up some very interesting statistics. The two shapes which were recognised the most often, which had both their position and shape recognised simultaneously the most often and which had their position recognised eight times, Shapes 1 and 2, were listened to among the least number of times, nineteen times.

The shape which was recognised the least often, but which interestingly had its position recognised eight times, was listened to the most often , thirty times.

These and other results which can be read from Table 3 may be interpreted to some extent as suggesting that those shapes which are listened to most often are perceived as being the most difficult to recognise. This interpretation would help explain why those subjects who, as noted in previous discussions, have scored highly in their recognition of shapes and positions did so having listened to the sounds an average number of times below the overall average. It may simply be that these subjects did not find the sounds so hard to decipher as the other subjects and did therefore not require to hear them so often, once again suggesting that the overriding factor involved in using the system successfully is personal characteristics and abilities.

In this section the two circles were each recognised nine times, a success rate of 90%. This is in some contrast to Section 1 where the circle was identified only 60% of the time.

The two ellipses were recognised seven and six times, a 65% success rate for the ellipses taken together. In section 1 the success rate for recognising the ellipse was 80%. This might lend credence to the argument suggested in the analysis of the results of Section 1 which was that perhaps the reason the ellipse was recognised so often was because subjects were told that the shape that immediately preceded it was a circle, thus leaving them perhaps less likely to believe that a circle was to appear next.

The rectangles were recognised 55% of the time in this section, as opposed to a 70% recognition rate in Section 1. This reduction in the recognition rate may be due to the way the system represents different sizes of the same shape. The rectangle in Section 1 was large and therefore took the system longer to represent sonically than was taken for the smaller rectangles in Section 2. The smaller the shape, the shorter is the duration of the sound that represents it and some subjects were very surprised at how quickly the sound was completed.

The square's recognition rate was the lowest of all of the shapes at 45%. This is compared to an 80% recognition rate in Section 1. This may be due to similar arguments as apply to the rectangle, as discussed above. The squares were very small, but not particularly small compared to the circles which had a relatively high recognition rate. The low recognition rate may be due to the way in which the system represents shapes with small side and corners. The sound is required to change direction very quickly, as opposed to the sound representing the circle which effectively is always changing but at a constant rate, and this rapid change of direction and the sometimes extremely brief representation of a short side of a shape appeared to confuse many subjects.

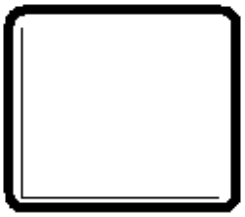
The squares and the circles in this test were located in the four corners of the screen. From Table 3 it can be seen that the number of times the correct position for these shapes was identified is

higher than that of the other shapes. This is particularly interesting in light of the fact that the squares, Shapes 7 and 8, had a low rate of recognition which obviously did not affect the subjects' abilities to recognise its positioning. The ellipses, Shapes 3 and 4, which were positioned at the bottom and top of the screen respectively, had their positions recognised less often than the positioning of the squares and circles which were in the corners of the screen. The positioning of the rectangles, Shapes 5 and 6, were correctly identified the fewest number of times. These shapes were positioned down the sides of the screen.

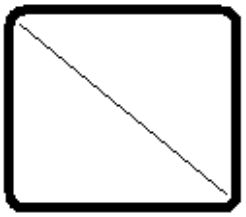
Results from Section 3 of the System Testing

The shapes below are those used in this section of the system testing:

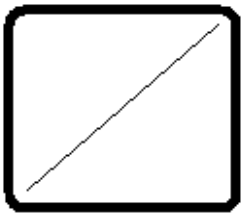
Shape 1, Section 3



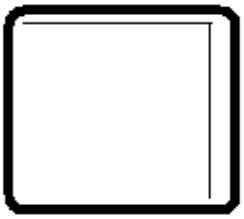
Shape 2, Section 3



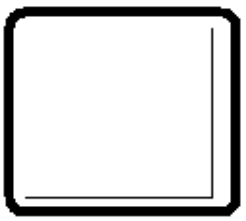
Shape 3, Section 3



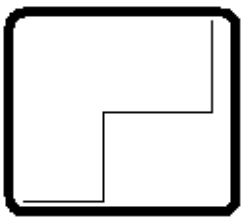
Shape 4, Section 3



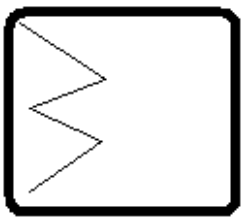
Shape 5, Section 3



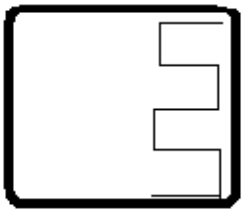
Shape 6, Section 3



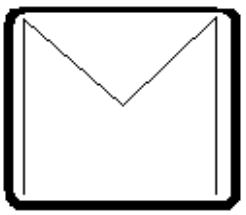
Shape 7, Section 3



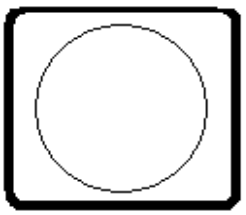
Shape 8, Section 3



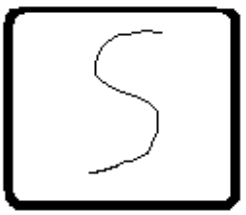
Shape 9, Section 3



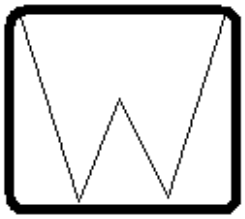
Shape 10, Section 3



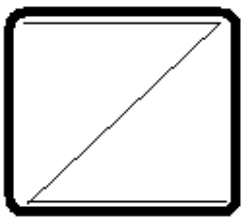
Shape 11, Section 3



Shape 12, Section 3



Shape 13, Section 3



The table below, Table 5, gives the results of Section 3 of the System Testing. The table is shown in two parts due to its large size. S1...S10 refers to Subjects 1 to 10.

The table shows, for each subject and each shape, the level of identification achieved. Each response to each shape, drawn on paper by each subject, was evaluated as to how closely it matched the image being represented by the system according to the following criteria:

> If the response showed no resemblance to the system representation then the grading '0' was awarded.
>
> If the response showed basic resemblance to the system representation then the grading '1' was awarded.
>
> If the response showed a good resemblance to the system representation then the grading '2' was awarded.
>
> If the response closely resembled the system representation of the image then the grading '3' was awarded.

The table also shows, for each subject, the number of times each shape was listened to before a response was given.

The final row of the table gives, for each shape, a summary of the gradings awarded for that shape (e.g. how many subjects were awarded '2' and how many were awarded 1'). This final row also lists, for each shape, the total number of times the shape was listened to, the average number of times it was listened to and the modal number of times it was listened to.

Table 5 (part 1). Results of Section 3 of the System Test
For each Subject S1 to S10 and each Shape 1 to 8. Data on no. of times each shape heard and the level of identification achieved (Grades 0, 1, 2, 3). Totals, averages and modal values.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5		SHAPE 6		SHAPE 7	
	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times
S1	3	2	3	1	3	1	3	2	2	3	3	4	3	3
S2	3	1	3	2	2	2	3	3	3	2	1	3	3	3
S3	0	2	3	1	3	1	3	2	1	2	2	2	3	2
S4	3	1	3	2	1	2	3	2	3	1	3	2	1	2
S5	0	2	2	1	0	1	1	1	1	1	1	1	1	1
S6	1	2	2	3	2	2	3	2	0	3	0	3	2	3
S7	0	4	0	3	0	1	3	1	0	1	0	2	3	3
S8	3	1	3	1	3	1	3	1	3	1	1	4	3	3
S9	2	1	3	1	2	2	3	1	2	4	0	3	1	4
S10	3	2	1	2	2	1	3	1	3	3	3	3	3	1
	answers 2 '0' 1 '1' 1 '2 5 '3'	Total times heard: 18 Ave: 1.8 Mode: 2	answers 1 '0' 1 '1' 2 '2' 6 '3'	Total times heard: 17 Ave: 1.7 Mode: 1	answers 2 '0' 1 '1' 4 '2' 3 '3'	Total times heard: 14 Ave: 1.4 Mode: 1	answers 0 '0' 1 '1' 0 '2' 9 '3'	Total times heard: 16 Ave: 1.6 Mode: 1	answers 2 '0' 2 '1' 2 '2' 4 '3'	Total times heard: 21 Ave: 2.1 Mode: 1	answers 3 '0' 3 '1' 1 '2' 3 '3'	Total times heard: 27 Ave: 2.7 Mode: 2.5	answers 0 '0' 3 '1' 1 '2' 6 '3'	Total times heard: 25 Ave: 2.5 Mode: 3

Table 5 (part 2).

	SHAPE 8		SHAPE 9		SHAPE 10		SHAPE 11		SHAPE 12		SHAPE 13	
	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times	identif-ication	no. of times
S1	1	4	3	2	3	2	3	2	2	2	3	3
S2	3	3	3	3	2	3	3	3	3	2	3	2
S3	1	3	3	2	3	1	3	3	3	3	3	2
S4	1	3	1	2	3	3	1	3	3	3	3	2
S5	0	1	1	2	1	1	0	2	1	2	0	1
S6	1	3	1	2	0	4	1	3	1	1	3	3
S7	1	10	3	2	3	2	3	3	3	4	3	3
S8	1	1	3	1	3	1	1	3	1	1	3	1
S9	1	4	3	2	0	1	0	5	3	3	3	1
S10	1	3	0	2	0	1	1	2	1	2	3	1
	answers 1 '0' 8 '1' 0 '2' 1 '3'	Total times heard: 35 Ave: 3.5 Mode: 3	answers 1 '0' 3 '1' 0 '2' 6 '3'	Total times heard: 20 Ave: 2 Mode: 2	answers 3 '0' 1 '1' 1 '2' 5 '3'	Total times heard: 19 Ave: 1.9 Mode: 1	answers 2 '0' 4 '1' 0 '2' 4 '3'	Total times heard: 29 Ave: 2.9 Mode: 3	answers 0 '0' 4 '1' 1 '2' 5 '3'	Total times heard: 23 Ave: 2.3 Mode: 2	answers 1 '0' 0 '1' 0 '2' 9 '3'	Total times heard: 19 Ave: 1.9 Mode: 1

The table below, Table 6, shows further results of this section of the System Testing. For each subject it shows the number of each type of grading awarded (0, 1, 2, 3). It also shows the total number of each grade awarded and expresses these figures as percentages of the total number of gradings awarded.

Table 6 Results of Section 3 of the System Test
For each Subject S1 to S10. Data on the level of identification achieved (Grades 0, 1, 2, 3). Totals and percentage values.

	grade 0	grade 1	grade 2	grade 3
Subject 1	0	1	2	10
Subject 2	0	1	2	10
Subject 3	1	2	1	9
Subject 4	0	5	0	8
Subject 5	5	7	1	0
Subject 6	3	5	3	2
Subject 7	5	1	0	7
Subject 8	0	4	0	9
Subject 9	3	2	3	5
Subject 10	2	4	1	6
totals (%)	19, (14.62%)	32, (24.62%)	13, (10%)	66, (50.77)%

Additional data from this section of the System Testing are shown below, in Table 7. The table shows, for each subject, the aggregate number of times shapes were listened to, and expresses this as a percentage of the overall number of times shapes were listened to in this section. The average number of times a subject listened to each shape is also given, as is the modal number of times each subject listened to a shape.

The final row of the table lists the overall number of times shapes were listened to, the overall average number of times a shape was listened to and the overall modal number of times a shape was listened to.

Table 7. Results of Section 3 of the System Test
For each Subject S1 to S10. Data on no. of times shapes heard, totals, percentages, averages and modal values.

	Amount of times listened to (as a percentage of total times listened to)	**Average number of times heard per shape**	**Modal number of times heard per shape**
Subject 1	31, (10.95%)	2.38	2
Subject 2	32, (11.31%)	2.46	3
Subject 3	26, (9.19%)	2.00	2
Subject 4	28, (9.89%)	2.15	2
Subject 5	17, (6.01%)	1.31	1
Subject 6	34, (12.01%)	2.62	3
Subject 7	39, (13.78%)	3.00	3
Subject 8	20, (7.07%)	1.54	1
Subject 9	32, (9.19%)	2.46	1
Subject 10	24, (8.48%)	1.85	2
	Total number of times sounds listened to: 283	Overall average number of times a shape listened to: 2.18	Overall modal number of times a shape listened to: 2

Interpretation of the results from Section 3 of the System Testing

The highest number of Grade 3 grades achieved was ten and this was achieved by two of the ten subjects, Subjects 1 and 2. It is interesting to note that neither of these two subjects received the lowest grade of 0 and that they each received only one Grade 1 in addition to two Grade 2 awards. This raises the question that an individual may either possess the required skills to competently use the system or may simply not possess such skills. In other words, a user may either be very competent at using the system or quite the opposite.

This contention is borne out somewhat by the results of Subjects 3, 4 and 8. Subjects 3 and 8 each received nine Grade 3 awards and Subject 4 received eight. Subject 3 received only one Grade 1 and Subjects 4 and 8 received none, echoing the results above.

Subject 5 received no Grade 3 awards and only one Grade 2 award. Five Grade 0 awards and seven Grade 1 awards were achieved. Again this would support the contention that a subject's ability to use the system tends to be either one extreme or the other.

However, this contention is not supported by the results from the remaining four subjects whose results are spread across the range of marks from one extreme to the other. The results from Subject 7 are particularly interesting as they fall almost entirely at one of the two extremes.

Overall, Grade 3 awards were achieved sixty six times, giving a success rate of 50.77%. Grade 2 grades, which represent the fact that a subject's efforts at recognising a shape were 'good' as opposed to 'very good' in the case of Grade 3 awards, were awarded only thirteen times (10%). At the other extreme to Grade 3, Grade 1 was only awarded nineteen times, a rate of 14.62%.

The percentage results would appear to dispute the earlier contention that candidates would either fall at one extreme or the other as although 50.77% of the responses were awarded a Grade 3, the remaining 49.33% were split between the other three grades with the extreme Grade 0 accounting for only 14.62% of the overall grading awards.

From the above analysis it would seem that the results are inconclusive and it is correct only to say that some individuals perform quite exceptionally well compared to some others in their use of the system.

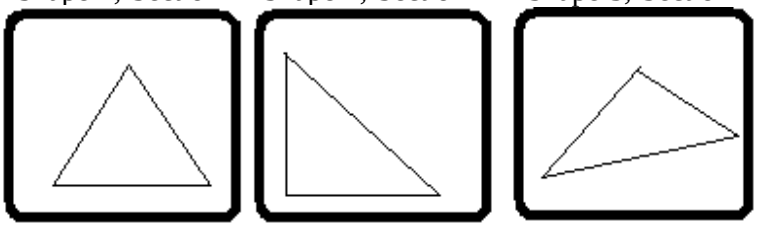
In this section there does not appear to be any correlation between the number of times subjects listened to a shape and the success rate for the identification of that shape. Subjects 1 and 2, who returned the best performances in this test had an average number of times of listening to the shapes above the overall average. However, Subjects 2 and 8, who also performed very well had averages below the overall average. Subject 5 performed very badly and had an average below that of the overall average but Subject 6 also performed badly but with an average above that of the overall average.

On the whole, the shapes which were in the form of recognizable letters were not recognised more often than shapes which were just randomly created. It is interesting that Shape 4, which is an 'L' shape spun around an axis, was recognised very competently four more times than the normal 'L' shape of Shape 1. Also of interest is the fact that Shape 7, which was a random pattern down the left side of the screen, was recognised competently more times than many of the letter shapes. It is also interesting to note that Shape 2 was recognised far more easily than Shape 3 which is very similar to it. As expected, however, Shape 8 proved to be the most difficult to recognise. This shape was included as it contains many corners and short sides which requires the sound to change direction rapidly, in the same way as it did when representing small squares in Section 2. Shape 6, which is composed of a number of lines which change direction at corners also proved difficult to recognise competently.

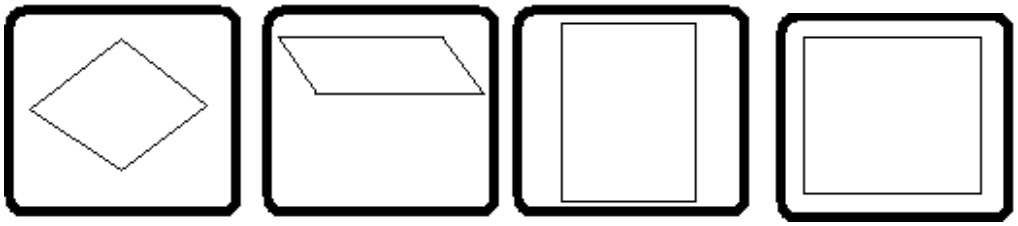
Results from Section 4 of the System Testing

The shapes used in this section of the system testing are shown below:

Shape 1, Section 4 Shape 2, Section 4 Shape 3, Section 4



Shape 5, Section 4 Shape 6, Section 4 Shape 7, Section 4 Shape 8, Section 4



The table below, Table 8, details the results of Section 4 of the System Testing. S1...S2 refers to Subjects 1 to 10. The table shows, for each subject and each shape, the level of identification achieved. Each response to each shape, drawn on paper by each subject, was evaluated as to how closely it matched the image being represented by the system according to the following criteria:

> If the response showed no resemblance to the system representation then the grading '0' was awarded.
>
> If the response showed basic resemblance to the system representation then the grading '1' was awarded.
>
> If the response showed a good resemblance to the system representation then the grading '2' was awarded.
>
> If the response closely resembled the system representation of the image then the grading '3' was awarded.

The table also shows, for each subject, the number of times each shape was listened to before a response was given.

The final row of the table gives, for each shape, a summary of the gradings awarded for that shape (e.g. how many subjects were awarded '2' and how many were awarded 1'). This final row also lists, for each shape, the total number of times the shape was listened to, the average number of times it was listened to and the modal number of times it was listened to.

Table 8. Results of Section 4 of the System Test
For each Subject S1 to S10 and each Shape 1 to 7. Data on no. of times each shape heard and the level of identification achieved (Grades 0, 1, 2, 3). Totals, averages and modal values.

	SHAPE 1 (triangle)		SHAPE 2 (triangle)		SHAPE 3 (triangle)		SHAPE 4 (rhombus)		SHAPE 5 (parallelogram)		SHAPE 6 (rectangle)		SHAPE 7 (square)	
	correct	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**	**correct**	**no. of times**
S1	1	2	3	2	1	2	3	2	1	3	1	2	3	1
S2	1	1	3	2	1	3	0	4	1	3	0	3	3	1
S3	1	2	3	2	1	3	0	2	1	4	1	2	3	2
S4	3	2	3	2	1	2	3	4	1	3	1	3	3	3
S5	0	2	1	1	1	2	0	2	0	1	1	1	3	1
S6	1	2	3	2	0	3	0	2	0	3	1	1	3	2
S7	1	10	2	2	2	7	3	5	3	5	1	4	0	2
S8	1	2	0	2	1	3	0	1	0	3	1	3	1	2
S9	3	4	3	3	3	3	1	6	0	7	1	2	0	2
S10	1	2	3	2	1	2	3	3	1	2	3	2	3	1
	answers: 1 '0' 7 '1' 0 '2' 2 '3'	Total times heard: 29 Ave: 2.9 Mode: 2	answers: 1 '0' 1 '1' 1 '2' 7 '3'	Total times heard: 20 Ave: 2 Mode: 2	answers: 1 '0' 7 '1' 1 '2' 1 '3'	Total times heard: 30 Ave: 2 Mode: 3	answers: 5 '0' 1 '1' 0 '2' 4 '3'	Total times heard: 31 Ave: 3.1 Mode: 2	answers: 4 '0' 5 '1' 0 '2' 1 '3'	Total times heard: 34 Ave: 3.4 Mode: 3	answers: 1 '0' 8 '1' 0 '2' 1 '3'	Total times heard: 23 Ave: 2.2 Mode: 2	answers: 2 '0' 1 '1' 0 '2' 7 '3'	Total times heard: 17 Ave: 1.7 Mode: 1.5

The table below, Table 9, shows further results of this section of the System Testing. For each subject it shows the number of each type of grading awarded (0, 1, 2 ,3). It also shows the total number of each grade awarded and expresses these figures as percentages of the total number of gradings awarded.

Table 9. Results of Section 4 of the System Test
For each Subject S1 to S10. Data on the level of identification achieved (Grades 0, 1, 2, 3). Totals and percentage values.

	grade 0	**grade 1**	**grade 2**	**grade 3**
Subject 1	0	4	0	3
Subject 2	2	3	0	2
Subject 3	1	4	0	2
Subject 4	1	4	0	2
Subject 5	3	3	0	1
Subject 6	3	2	0	2
Subject 7	1	2	2	2
Subject 8	3	4	0	0
Subject 9	2	2	0	3
Subject 10	0	3	0	4
totals (%)	16, (22.85%)	31, (44.29%)	2, (2.86%)	21, (30%)

Additional data from this section of the System Testing are shown below, in Table 10. The table shows, for each subject, the aggregate number of times shapes were listened to, and expresses this as a percentage of the overall number of times shapes were listened to in this section. The average number of times a subject listened to each shape is also given, as is the modal number of times each subject listened to a shape.

The final row of the table lists the overall number of times shapes were listened to, the overall average number of times a shape was listened to and the overall modal number of times a shape was listened to.

Table 10. Results of Section 4 of the System Test
For each Subject S1 to S10. Data on no. of times shapes heard, totals, percentages, averages and modal values.

	Amount of times listened to (as a percentage of total times listened to)	**Average number of times heard per shape**	**Modal number of times heard per shape**
Subject 1	14, (7.61%)	2.00	2
Subject 2	17, (9.24%)	2.43	3
Subject 3	17, (9.24%)	2.43	2
Subject 4	19, (10.33%)	2.71	2.5
Subject 5	10, (5.43%)	1.43	1
Subject 6	15, (8.15%)	2.14	2
Subject 7	35, (19.02%)	5.00	5
Subject 8	16, (8.70%)	2.29	2.5
Subject 9	27, (14.67%)	3.86	2.5
Subject 10	14, (7.61%)	2.00	2
	Total number of times sounds listened to: 184	Overall average number of times a shape listened to: 2.63	Overall modal number of times a shape listened to: 2

Interpretation of the results from Section 4 of the System Testing

The results from this section of the test are immediately striking due to the relatively low number of Grade 3 grades awarded. Subject 10, who had performed relatively badly in the previous section obtained four Grade 3 awards and Subjects 1 and 9 both obtained three.

Another immediately apparent point is that only two Grade 2 grades were awarded in this section of the test. This may be as a result of the failure of the subjective judging procedure used in the awarding of the grades. It may however, be a consequence of the fact that the shapes in this section were definite recognisable shapes, unlike many of those in the previous section, so there was less scope for having varying degrees of correctness as regards the drawing of the shape on paper.

In this section it does not appear to be the case that subjects either identified the shape well or identified it badly. The percentages shown in Table 4 show that most grades awarded were Grade 1, awarded when a subject had a basic recognition of the shape. However, the distribution of percentages is reasonably well spread across the different grades, with the exception of Grade 2, as already noted.

In this section, the two best-performing subjects, Subjects 10 and 1, had an average number of times of listening to each shape below that of the overall average. Subject 9, however, who performed next best, had an average of 3.86 which is significantly higher than the overall average of 2.63.

Subject 7, who performed relatively well had an average number of times of listening to a shape of 5. Given the disproportionately high average result of Subject 7, only three subjects (including Subject 7) have averages higher than the overall average. It is therefore not possible to state clearly if there is any correlation between the number of times a shape is listened to and the success rate of correct identification for that shape. However, cursory inspection would again suggest that there is no clear evidence that listening to a shape more often will lead to an increased likelihood of it being correctly identified.

Some interesting results are shown in Table 8 which reports figures regarding each individual shape. Shapes 1, 2 and 3 are all triangles of a different nature.

Many subjects were unable to tell much difference between the three shapes and drew a right-angled triangle as an answer to all of Shapes 1, 2 and 3. This accounts for the seven Grade 1 grades awarded for both Shapes 1 and 2 and the seven Grade 3 awards for Shape 2. Only two subjects were awarded a Grade 3 for their identification of Shape 1 and there was only one Grade 3 for Shape 3. Interestingly, Subject 9 achieved a Grade 3 on all of the triangles.

Another interesting point to note is that only one Subject was awarded a Grade 3 for the identification of the rectangle of Shape 6. The rectangle proved extremely difficult to identify, in marked contrast to the square of Shape 7. It is interesting to note here that many subjects thought that Shape 6 was a square and many subjects mistook the parallelogram of Shape 5 to be a rectangle.

Overall Interpretation of results

Subject 1

In the first section of the test Subject 1 correctly identified all of the shapes and did so with an average number of times of hearing each shape lower than that of the overall average.

In Section 2 Subject 1 correctly identified six of the eight shapes, a success rate of 75%. The subject correctly identified seven of the eight positions in Section 2 of the test, a success rate of 87.50% and correctly identified both a shape and its position six times, a success rate of 75%. This time, however, the subject's average number of times each shape was listened to was higher than that of the overall average. These results maintain Subject 1's position as one of the better subjects.

In Section 3 of the test this subject again did extremely well and was joint top with Subject 2. Ten maximum Grade 3's were achieved and no minimum Grade 0's. As in Section 2, this subject's average number of times of listening to each shape was higher than the overall average in this section.

In Section 4 this subject again performed very well in comparison to most of the other subjects. However, the overall results from this section were lower than from the other section and Subject 1's results were also lower than in previous sections. It is interesting to note that in this section, as in Section 1, the subject's average number of times of listening to a shape was lower than the overall average.

The questionnaire responses show that this subject believed that she was able to use the system competently, as indeed she was compared to most other subjects.

Subject 2

In Section 1 Subject 2 correctly identified four of the five shapes, a success rate of 80%. The average number of times Subject 2 listened to each shape was lower than the overall average. In Section 2 the subject correctly identified seven of the shapes, eight of the positions and a shape and its position simultaneously seven times, a success rate of 87.50%, 100% and 87.50% respectively. The subject performed better than any other in this section.

Contrary to the situation in the first section, in this section the subject's average number of times of listening to each shape was higher than the overall average figure.

In Section 3 this subject was joint best performer, gaining ten Grade 3 results. Again the subject's average number of times of listening to each shape was higher than the overall average figure.

The subject's performance in the final section, Section 4, placed the subject in roughly in the middle of all subjects, rated on performance. Again the subject's average number of times of listening to each shape was higher than the overall average figure.

One interesting point to note from the questionnaire results is that this subject reported that the system was not difficult to use, even when first to exposed to it. However, the subject also commented that:

"[the system] is extremely dependant on [the] position of [the] user and [the] speakers".

Subject 3

Subject 3 correctly identified three of the five shapes in Section 1 representing a success rate of 60%. The subject's average number of times of listening to each shape was very slightly higher than the overall average figure.

In Section 2 the subject correctly identified five of the shapes, three of the positions and three shapes and its position simultaneously, giving success rates of 62.50%, 37.50% and 37.50% respectively. In comparison with the other subjects these are not high results on the whole but this subject does score reasonably highly on the number of shapes correctly identified. It is interesting that this subject correctly identified more shapes than she did positions, a situation echoed by three other subjects. The subject's average number of times of listening to each shape was lower than the overall average figure.

It is interesting to note that, in Section 1, the subject did not correctly identify the rectangle. In Section 2, two of the three incorrectly identified shapes were rectangles.

In Section 3 this subject was one of the best performers, gaining nine Grade 3 results. Her average number of times of listening to each shape was lower than the overall average figure, as it was in Section 2.

This subject's results for Section 4 were above average, in comparison with the other subjects. Her average number of times of listening to each shape was lower than the overall average figure, as it was in Sections 2 and 3.

Subject 4

In the first section this subject correctly identified all of the shapes and did so with an average number of times of listening to each shape only very slightly above the overall average figure.

In Section 2 this subject performed second-best out of all the subjects with six shapes, eight positions and six shapes and positions simultaneously correctly identified. This gives a success rate of 75%, 100% and 75% respectively. The subject's average number of times of listening to

each shape was significantly higher than the overall average and was the highest of any of the subjects in this section of the test.

In the third section this subject performed fifth best with eight Grade 3 results and no Grade 0 results. The subject's average number of times of listening to each shape was slightly lower than that of the overall figure, in contrast to this subject's position in the first two sections of the test.

In the fourth section of the test this subject's performance was average. The average number of times the subject listened to each shape was higher than the overall average figure.

Subject 5

In Section 1 Subject 5 correctly identified four of the five shapes, a success rate of 80%, and had an average number of times of listening to each shape very slightly higher than the overall average figure.

In Section 2 this subject correctly identified four shapes, three positions, and one shape and its position simultaneously implying success rates of 50%, 37.50% and 12.50% respectively. This subject correctly identified more shapes than positions and correctly identified only one shape and its position simultaneously. This was the worst performance in this section of the test. The subject's average number of times of listening to each shape was lower than the overall average figure, the opposite of the situation in Section 1.

In Section 3 this subject again returned the worst performance, receiving no Grade 3 results and only one Grade 2. Again the subject's average number of times of listening to each shape was lower than the overall average figure.

In the final section this subject returned an average performance in a section in which the overall results were relatively low. As in the previous two sections, in this section the subject's average number of times of listening to each shape was lower than the overall average figure.

There are a number of interesting points to note from the questionnaire. The subject commented that he found the positioning of the sound on screen most difficult to determine and his results did show that he fared badly compared to the other subjects in his answers to Section 2 on the question of identifying positioning.

The subject claimed that he did not find the system difficult to use on first using it and that he did not feel that his ability to identify shapes increased as he progressed further into the test. He also claimed that he felt he had to concentrate hard to use the system and that he found it fatiguing.

Subject 6

In the first section Subject 6 did not correctly identify any of the shapes, the only subject in this position. The subject's average number of times of listening to each shape was higher than the overall figure.

In Section 2 the subject correctly identified four shapes, seven positions and four shapes and positions simultaneously, implying respective success rates of 50%, 87.50% and 50%. These were slightly below average results for this section. As in the last section the subject's average number of times of listening to each shape was higher than the overall figure.

In the third Section this subject's results were second worst overall and only two Grade 3's were achieved. Again the subject's average number of times of listening to each shape was higher than the overall figure.

In Section 4 the subject's results were average and this time the subject's average number of times of listening to each shape was lower than the overall average figure.

Subject 7

In the first section Subject 7 correctly identified all five of the shapes and had an average number of times of listening to the shapes greater than the overall average.

In Section 2 this subject identified four shapes, three positions and two shapes and positions simultaneously giving a success rate of 50%, 37.50% and 25% respectively. This was the second worst result in this section of the test and is a marked contrast from this subject's 100% success rate performance in Section 1. This time, it is interesting to note, the subject's average number of times of listening to a shape was lower than that of the overall average figure. A further point of interest is that this subject was one of the four who correctly identified less positions than shapes.

In the third section this subject attained seven Grade 7 results, placing him ahead of four other subjects, a significant improvement on the results of the previous section. As with Section 1, in this section the subject's average number of times of listening to each shape was greater than the overall average.

In the final section the subject was placed fourth overall with an average number of times of listening to a shape significantly greater than (in fact almost double) the overall average.

On the whole, this subject performed quite well and it is interesting to note that the only section in which this subject did not perform well was the one in which the average number of times he listened to a shape was lower than the overall average for that section (Section 2).

In Section 2 the subject correctly identified only three positions, a lesser amount than the number of shapes correctly identified, and it is interesting to note that in the questionnaire response this subject stated that he believed he could identify shapes "Quite Well" but positions "Not Well".

Subject 8

Subject 8 correctly identified all five of the shapes in the first section with an average number of times of listening to shapes lower than the overall average.

In Section 2 the subject correctly identified six shapes, four positions and four shapes and positions simultaneously, implying respective success rates of 75%, 50% and 50%. This subject was one of the four who correctly identified a greater number of shapes than positions. The subject listened to each shape on average a lesser amount of times than the overall average figure. The subject's performance in this section was average compared to the other subjects.

This subject was fourth top in Section 3 of the test with nine Grade 3 results. This time the subject's average number of times of listening to the shapes was lower than the overall average figure.

In the final section, Section 4, the subject was the worst performer with no Grade 3 or Grade 2 results. The subject's average number of times of listening to the shapes was again lower than the overall average figure.

Subject 9

In Section 1 Subject 9 correctly identified only three of the five shapes and had an average number of times of listening to the shapes higher than the overall average number.

In Section 2 the Subject correctly identified six shapes, eight positions and six shapes and positions simultaneously, a success rate of 75%, 100% and 75% respectively. This was the second best performance in this section of the test, a considerable improvement on this subject's results from the first section of the test. Again this subject's average number of times of listening to the shapes was higher than the overall average figure. It is interesting to note that the two shapes the subject did not correctly identify were the rectangles. She correctly identified the rectangle in Section 1.

In the third section this subject gave the third worst performance in marked contrast to her standing in the previous section. As in the previous two sections this subject's average number of times of listening to the shapes was higher than the overall average figure.

In the final section this subject came third overall, again a turnaround from her pos ition in the previous section. As in the previous three sections this subject's average number of times of listening to the shapes was higher than the overall average figure.

This subject was the only one to gain a Grade 3 score for recognition of Shape 3, one of the triangles. She was one of only two subjects to gain a Grade 3 for recognition of Shape 1, also a triangle. In fact, she was awarded Grade 3's for recognition of all three of the triangles. In section

1 of the test she correctly identified the triangle but also successfully identified both the rectangle and the square. In Section 4, however, she was awarded only a Grade 1 (basic) for her recognition of the rectangle and a Grade 0 for her recognition of the square.

In her comments following the questionnaire this subject wrote:

"I found it much easier, I think, to follow the line around the screen than to necessarily recognise shapes."

This is interesting as, in fact, her results show quite the opposite.

Subject 10

Subject 10 correctly identified three shapes in Section 1 and the number of times she listened to the shapes on average was lower than the overall average number of times.

In Section 2 this subject correctly identified three shapes, eight positions and three shapes and their positions simultaneously, implying respective success rates of 37.50%, 100% and 37.50%. As in the first section, the average number of times of listening to shapes was lower than the overall average figure.

It is interesting to note the contrast between the small number of shapes recognised and the 100% recognition rate for the positioning. This subject correctly identified fewer shapes than anyone else in this section but was one of only three to correctly identify all of the positions.

In Section 1 this subject correctly identified the ellipse but failed to identify either ellipse in Section 2. In Section 1 the subject did not identify either the square or the rectangle and identified neither square in Section 2 but did identify one of the rectangles.

In Section three Subject 10's results were below average and, as in the first two sections, the average number of times she listened to shapes was lower than the overall average figure.

In Section 4 Subject 10 scored the best results of any subject with four Grade 3's and three Grade 1's. It is interesting to note that, in this section, she correctly identified both the rectangle and the square at Grade 3 standard. Again, the average number of times she listened to shapes was lower than the overall average figure.

Conclusion of the Results Analysis

The overall results do not suggest that any shapes are easier to identify than others. In fact, it is very interesting to note that the recognition rates of some shapes varied widely from section to section of the test. However, the marked contrast between some of the results in Section 1 and Section 2 suggest that the smaller the shape the more difficult it is to recognise successfully. This is particularly so of shapes which have corners and small side lengths such as the rectangles used. It is also interesting to note here that the patterns in Section 3 which had corners and required the sound to change direction rapidly were found difficult to recognise. However, the shapes used in Section 4 were quite large and the results of Section 4 were very poor in comparison with the results of other sections.

In Section 1 the circle was recognised 60% of the time but this recognition rate increased to 90% in Section 2. The recognition rate for the ellipse was 80% in Section 1 but only 70% in Section 2. The rectangle's recognition rate in Section 1 was 70% but dropped to only 55% in Section 2 and to only 10% in Section 4. In Section 1 the recognition rate for the square was 80% but this dropped to only 45% in Section 2 but rose to 70% in Section 4. The triangle of Section 1 was very similar to the first triangle of Section 4. However, the triangle in Section 1 was correctly identified 80% of the time but the similar triangle in Section 4 was recognised at Grade 3 standard by only two subjects.

Of course, in Section 1 the subjects were required simply to say the name of the shape in order to identify it. In the other sections they were required to draw the shape. As already mentioned, feedback was given in Section 1 which may have resulted in the high successful recognition rate of shapes as subjects often made verbal comments at the time such as,

"if the last shape was a rectangle this one probably won't be, so it must be a square".

And so it is difficult to draw any firm conclusions as to the widely different results between sections. Seven subjects commented that they thought they would find the system difficult to use for extended periods of time. Perhaps this would help explain why the results of Section 4, the final section, were comparatively poor.

There was no evidence to suggest that individual subjects were more suited to recognising some types of shapes than others. There was also no evidence to suggest that there was a correlation between the number of times a sound was heard and the rate of success in correctly identifying shapes.

As regards the positioning of objects on screen, Section 2 produced some interesting results. Some subjects found it easier to identify the position of a shape on screen than the shape itself whilst others found the opposite. The circles were recognised in the same number of times, nine times, in their two different positions. The other shapes, however, were not recognised the same number of times in both of their positions. The ellipse at the bottom of the screen, for example, was recognised one more time than the ellipse at the top of the screen.

The squares and the circles, which were positioned in the extreme corners of the screen, had their positions recognised correclty most often. The ellipses located at the top and bottom of the screen had their positions correctly identified less often than the squares and the circles but more often then the rectangles which were located down the sides of the screen

Overall, the results are generally inconclusive. The only firm conclusions which may be drawn are that the abilities of individual subjects vary extensively, that an individual's own performances can vary significantly from one situation to the next and that there is definitely a case for claiming that some subjects are quite simply better at using the system than others. The reasons for this would no doubt prove very interesting and informative to investigate.

Results of the Questionnaire

The table below, Table 11, shows the results from the questionnaire given to the subjects who took part in the system testing. S1...S10 refers to Subjects 1 to 10. Q1...Q11 refers to Questions 1 to 11, from the Questionnaire, as listed below:

Question 1
Did you immediately find the system difficult to use (did you feel that you were unable to identify any of the shapes being represented in sound form)?

YES/NO

Question 2
Did you find that your ability to recognise shapes increased the further into the test you got?

YES/NO/NOT SURE

Question 3
Did you find that you had to concentrate hard in order to use the system?

YES/NO

Question 4
Did you find the test fatiguing?

YES/NO

Question 5
Do you think that you would find the system difficult to use for extended periods of time?

YES/NO

Question 6
Did background noise disturb you whilst you were using the system?

YES/NO

Question 7
Were you wary of others working around you being disturbed by the noise of the system as you were using it?

YES/NO

Question 8
Do you think that you would have found the system easier to use (you would have been more able to identify shapes correctly) if you had been given more examples/training before the testing began?

YES/NO/NOT SURE

Question 9
How well do you think you were able to identify the shapes represented sonically by the system?
quite well/very well/not well/not sure/not at all

Question 10
How well do you think you were able to recognise the positioning on the screen of the shapes represented by the sounds produced by the system?
quite well/very well/not well/not sure/not at all

Question 11
Do you think that the system could be used to provide reliable/accurate information to a non-sighted computer user?
YES/NO/DON'T KNOW

Table 11. Results of the Questionnaire for Subject S1 to S10 and Questions Q1 to Q10

	S 1	**S 2**	**S 3**	**S 4**	**S 5**	**S 6**	**S 7**	**S 8**	**S 9**	**S 10**
Q 1	Yes	No	No	No	No	No	No	Yes	Yes	Yes
Q 2	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Q 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q 4	No	Yes	No	No	Yes	Yes	No	No	Yes	No
Q 5	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Q 6	No	No	Yes	No	Yes	No	No	Yes	No	No
Q 7	Yes	Yes	No	No	Yes	No	Yes	No	No	No
Q 8	Yes	Yes	Yes	Yes	Yes	Yes	Not Sure	Yes	Yes	Yes
Q 9	Quite Well	Quite Well	Quite Well	Quite Well	Quite Well	Not Well	Quite Well	Not Well	Quite Well	Not Sure
Q 10	Quite Well	Quite Well	Not Well	Quite Well	Not Well	Quite Well	Not Well	Not Well	Quite Well	Very Well
Q 11	Yes	No	Don't Know	Don't Know	Yes	No	Yes	Don't Know	Yes	No

From the table it can be seen that four of the ten subjects immediately felt that the system was difficult to use. Eight subjects felt that their ability to recognise shapes improved the further into the test they got, whilst two did not.

All ten subjects found that they had to concentrate hard to use the system and four of them found the test fatiguing. Seven subjects expressed the view that they believed they would find the system difficult to use for extended periods of time.

Three subjects found that background noise disturbed them whilst they were taking part in the system testing and four claimed that they their use of the system could be disturbing to others working in the same room.

Nine of the subjects expressed the opinion that they believed that they might have been more able to successfully use the system had they been given more examples/training before taking

part in the test. The remaining subject was unsure whether or not extra training/examples would have aided in using the system.

Seven subjects thought that they performed 'quite well' in their abilities to recognise the shapes represented sonically by the system. Two subjects felt that they performed 'not well' whilst the remaining subject was 'no sure'.

Five subjects thought that they were able to recognise the positioning of the shapes 'quite well' whilst four thought that they performed 'not well'. The reaming subject thought that she performed 'very well'.

Four subjects expressed the opinion that the system could be used to provide reliable/accurate information to a non-sighted computer user. Two disagreed with this and three expressed the opinion that they did not know if the system could perform such a task.

Subject 1 commented:

> "To begin with the sounds seemed to represent no shapes at all and it was difficult to see how they could. However, on repeating the sounds it became easier to recognise the shapes. By the end of the test it had become quite easy to recognise the shapes and their relative positions on the screen. Through further training it would, presumably, become easier to use the system, which could then be useful for use by non-sighted people."

Subject 2 commented:

> "[the system is] extremely dependent on [the] position of [the] user and [the] speakers."

Subject 3 commented:

> "Perhaps it would be easier if the speakers were slightly further apart? Also, some of the shapes were performed too quickly."

Subject 4 commented:

> "Wouldn't it be easier for a voice to say 'square', 'circle', etc?."

Subject 5 commented:

> "I found identifying the shapes with corners in them (e.g. squares etc.) far easier than those without (e.g. circles). Deciding the size of shapes was difficult and the positioning of them on the screen most difficult of all. I think problems would also occur in relating complex shapes or like structures as it is difficult to remember long sequences of sounds."

Subject 9 commented:

> "definitely need more training to identify shapes. I found it much easier, I think, to follow the line around the screen than to necessarily recognise shapes."

The rest of the subjects did not offer comments.

Second Time Testing

In order to enquire into whether or not previous use of the system would affect the results in the system testing, two subjects, Subject 9 and 10, were invited to take part in system testing a second time. They did this ten days after taking part in the original test.

At the start of the second testing procedure the two subjects were informed that the procedure would be identical to that which they had originally encountered but that they would not receive any examples or explanation before starting the second test. They were also informed that the second test would be different from the first as the shapes and patterns they would hear might differ from those they heard in the first test.

In actual fact, the second test contained exactly the same shapes and patterns as the first in order to test if previous experience would affect the ability to recognise these shapes and patterns. The order in which the subjects heard the shapes and patterns was changed from the order used in the first test to avoid the potential for the users' memories of the first test to influence their responses. The subjects who took part in this second testing procedure were Subjects 9 and 10. These subjects were chosen simply because they were available to take part in a second set of tests.

The table below, Table 12, shows the results of section 1 of the system testing for Subject 9 for both the first and the second time the subject took part in testing. It can be seen that the subject did not correctly identify Shape 1 on either occasion and listened to the shape twice on both occasions. Shape 2 was also not correctly identified on either occasion but the subject listened to it four times during the first test but only twice during the second test. Shape 3 was correctly identified on both occasions but the subject listened to it twice the first time and thrice the second time. Shape 4 was correctly identified the first time, having been listened to four times, but was incorrectly identified the second time after being heard three times. Shape five was correctly identified the first time after being listened to twice but was incorrectly identified the second time after being listened to only once.

Subject 9 correctly identified three shapes during the first test, listened to each shape on average 2.8 times, and the modal number of times a shape was listened to was 2. The results for the second time of testing show that only one shape was correctly identified, the average number of times a shape was listened to was 2.2 and the modal number of times a shape was listened to is 2.5.

Table 12. Subject 9, Section 1, first and second test
Shapes 1 to 5, data on whether correctly identified and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5	
	correct	no. of times	correct	no. of times	correct	no. of times	correct	no. of times	correct	no. of times
Subject 9 first	NO	2	NO	4	YES	2	YES	4	YES	2
Subject 9 second	NO	2	NO	2	YES	3	NO	3	NO	1

Table 13, below shows the results for Subject 10 of Section 1 of the test on both occasions. Shape 1 was correctly identified on the first occasion after being listened to twice but was incorrectly identified on the second occasion after being heard only once. Shape 2 was correctly identified the first time after being listened to only once but was incorrectly identified the second time after being listened to twice. Shape three was not correctly identified the first time after being listened to twice but was correctly identified the second time after being heard only once. Shape 4 was incorrectly identified on both occasions but was listened to three times during the first test but only once during the second test. Shape 5 was correctly identified on both occasions and was listened to once during the first test and twice during the second test.

The results show that Subject 10 correctly identified three shapes during the first test but only two during the second. The average number of times each shape was listened to during the first test was 1.8 and the modal number is 1.5. The average number of times each shape was listened to during the second test was 1.4 and the modal number is 1.

Table 13. Subject 10, Section 1, first and second test
Shapes 1 to 5, data on whether correctly identified and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5	
	correct	no. of times	correct	no. of times	correct	no. of times	correct	no. of times	correct	no. of times
Subject 10 first	YES	2	YES	1	NO	2	NO	3	YES	1
Subject 10 second	NO	1	NO	2	YES	1	NO	1	YES	2

The table below, Table 14, which is split into two parts because of its size, shows the results for Subject 9 of Section 2 of the test on both the first and second occasions in which the subject took part in system testing.

Table 14 (part 1). Subject 9, Section 2, first and second test
Shapes 1 to 8, data on whether correctly identified, no. of times heard, and whiter correctly positioned.

	SHAPE 1			SHAPE 2			SHAPE 3			SHAPE 4		
	correct shape	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**
S9 first	YES	2	YES	YES	2	YES	YES	2	YES	YES	3	YES
S9 second	YES	1	YES	YES	2	NO	YES	3	YES	YES	2	YES

Table 14 (part 2). Subject 9, Section 2, first and second test

	SHAPE 5			SHAPE 6			SHAPE 7			SHAPE 8		
	correct shape	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**	**correct shape**	**no. of times**	**correct position**
S9 first	NO	5	YES	NO	2	YES	YES	1	YES	YES	3	YES
S9 second	NO	2	YES	YES	2	YES	NO	3	YES	YES	3	NO

Table 15 below summarises the results shown in Table 12, above. It can be seen from Table 13 that Subject 9 correctly identified the same number of shapes, six, on both occasions but that she

identified all eight of the positions correctly the first time but only six of them the second time. During the first test she correctly identified both the shape and its position simultaneously on six occasions, a success rate of 75%. During the second test, however, she correctly identified both the shape and its position simultaneously on only four occasions, a success rate of 50%. During the first test she listened to shapes a total of twenty times, giving an average of 2.50 listens per shape and a mode of 2. During the second test she listened to shapes a total of 18 times, giving an average of 2.25 and a mode of 2.

Table 15. Subject 9, Section 2, first and second test.
No. of correct shapes, no. of correct positions, no. of simultaneous correct shape and position. Totals, percentages, averages and modal values.

	no. of correct shapes (as a % of total)	no. of correct positions (as a % of total)	no. of both shapes and positions correct (as % of total)	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	6, (75%)	8, (100%)	6, (75%)	20	2.50	2
SECOND	6, (75%)	6, (75%)	4, (50%)	18	2.25	2

The table below, Table 16, which is split into two parts because of its size, shows the results for Subject 10 of Section 2 of the test on both the first and second occasions in which the subject took part in system testing.

Table 16 (part 1). Subject 10, Section 2, first and second test
Shapes 1 to 8, data on whether correctly identified, no. of times heard, and whiter correctly positioned.

	SHAPE 1			SHAPE 2			SHAPE 3			SHAPE 4		
	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position
S10 first	YES	3	YES	YES	1	YES	NO	1	YES	NO	2	YES
S10 second	YES	1	YES	NO	2	YES	YES	2	NO	NO	4	NO

Table 16 (part 2). Subject 10, Section 2, first and second test

	SHAPE 5			SHAPE 6			SHAPE 7			SHAPE 8		
	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position	correct shape	no. of times	correct position
S10 first	YES	2	YES	NO	2	YES	NO	1	YES	NO	3	YES
S10 second	YES	1	YES	YES	1	YES	YES	1	YES	NO	1	YES

Table 17 below summarises the results shown in Table 14, above. It can be seen from Table 15 that Subject 10 correctly identified three shapes during the first test, a success rate of 37.50%, but this had increased to five, a success rate of 62.50%, for the second test. During the first test, however, this subject correctly identified all eight of the positions but this figure fell to six (75%) in the second test. In the first test the subject correctly identified both the shape and its position simultaneously on three occasions, a success rate of 37.50%, and this increased in the second test to 4, a success rate of 50%.

During the first test the subject listened to sounds a total of fifteen times giving an average number of listens per shape of three and a mode of 1.5. During the second test the subject listened to sounds a total of thirteen times giving an average number of listens per shape of 2.6 and a mode of 1.

Table 17. Subject 10, Section 2, first and second test.
No. of correct shapes, no. of correct positions, no. of simultaneous correct shape and position. Totals, percentages, averages and modal values.

	no. of correct shapes (as a % of total)	no. of correct positions (as a % of total)	no. of both shapes and positions correct (as % of total)	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	3, (37.50%)	8, (100%)	3, (37.50%)	15	3.00	1.5
SECOND	5, (62.50%)	6, (75%)	4, (50%)	13	2.60	1

The table below, Table 18, which is split into two parts because of its size, shows the results for Subject 9 of Section 3 of the test on both the first and second occasions in which the subject took part in system testing.

Table 18 (part 1). Subject 9, Section 3, first and second test
Shapes 1 to 13, Grade awarded for identification and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5		SHAPE 6		SHAPE 7	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S9 first	2	1	3	1	2	2	3	1	2	4	0	3	1	4
S9 second	3	1	1	2	1	2	3	1	0	3	0	3	3	2

Table 18 (part 2). Subject 9, Section 3, first and second test

	SHAPE 8		SHAPE 9		SHAPE 10		SHAPE 11		SHAPE 12		SHAPE 13	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S9 first	1	4	3	2	0	1	0	5	3	3	3	1
S9 second	1	2	3	1	0	2	2	2	3	2	3	1

Table 19 below summarises the results shown in Table 16, above. The table shows the number of different grades (0, 1, 2, 3) awarded to the subject's responses. It also shows the total number of times the subject heard shapes, the average number of times a shape was heard and the modal number of times a shape was heard. The table gives the results for the first and second tests.

It can be seen that both times the subject's responses were awarded a 0 grade, indicating that the subject's drawing bore no resemblance to the shape the system was attempting to represent sonically. The subject was awarded the 1 grade twice during the first test and thrice during the second. During the first test the subject received the 2 grade twice and received this grade only

once during the second test. The 3 grading was awarded five times in the first test and six times in the second.

The subject listened to shapes a total of thirty two times during the first test (average number of times per shape of 2.46) but only twenty four times during the second test (average number of times per shape of 1.85). During the first test the modal number of times a shape was heard was one and this increased to two in the second test.

Table 19. Subject 9, Section 3, first and second test.
No. of each Grade awarded, no. of times heard, average and modal values.

	Grade 0	Grade 1	Grade 2	Grade 3	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	3	2	3	5	32	2.46	1
SECOND	3	3	1	6	24	1.85	2

The table below, Table 21, which is split into two parts because of its size, shows the results for Subject 10 of Section 3 of the test on both the first and second occasions in which the subject took part in system testing.

Table 21 (part 1). Subject 10, Section 3, first and second test
Shapes 1 to 13, Grade awarded for identification and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5		SHAPE 6		SHAPE 7	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S10 first	3	2	1	2	2	1	3	1	3	3	3	3	3	1
S10 second	3	1	3	1	3	1	1	1	0	1	2	2	2	1

Table 21 (part 2). Subject 10, Section 3, first and second test

	SHAPE 8		SHAPE 9		SHAPE 10		SHAPE 11		SHAPE 12		SHAPE 13	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S10 first	basic	3	0	2	0	1	1	2	1	2	3	1
S10 second	none	2	3	1	3	1	1	1	1	1	3	1

Table 21 below summarises the results shown in Table 16, above. The table shows the number of different grades (0, 1, 2, 3) awarded to the subject's responses. It also shows the total number of times the subject heard shapes, the average number of times a shape was heard and the modal number of times a shape was heard. The table gives the results for the first and second tests.

It can be seen that Subject 10 was awarded the 0 grade twice and the 3 grade six times during both the first and the second test. The 1 grade was awarded four times during the first test and

three times during the second test. The 2 grade was awarded once during the first test and twice during the second.

The subject listened to shapes a total of twenty four times during the first test (average number of times per shape of 1.85) but only fifteen times during the second test (average number of times per shape of 1.15). The modal number of times a shape was heard was one during both tests.

Table 21. Subject 10, Section 3, first and second test.
No. of each Grade awarded, no. of times heard, average and modal values.

	Grade 0	Grade 1	Grade 2	Grade 3	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	2	4	1	6	24	1.85	1
SECOND	2	3	2	6	15	1.15	1

The table below, Table 22, shows the results for Subject 9 of Section 4 of the test on both the first and second occasions in which the subject took part in system testing.

Table 22. Subject 9, Section 4, first and second test.
Shapes 1 to 7, Grade awarded for identification and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5		SHAPE 6		SHAPE 7	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S9 first	3	4	3	3	3	3	1	6	0	7	1	2	0	2
S9 second	3	1	3	2	3	2	1	2	1	1	0	2	3	1

Table 23 below summarises the results shown in Table 20, above. The table shows the number of different grades (0, 1, 2, 3) awarded to the subject's responses. It also shows the total number of times the subject heard shapes, the average number of times a shape was heard and the modal number of times a shape was heard. The table gives the results for the first and second tests.

Table 23. Subject 9, Section 4, first and second test.
No. of each Grade awarded, no. of times heard, average and modal values.

	Grade 1	Grade 2	Grade 3	Grade 4	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	2	2	0	3	27	3.86	2.5
SECOND	1	2	0	4	11	1.57	2

It can be seen that the subject was awarded the 1 grade twice and the 2 grade zero times in both tests. The 0 grade was awarded twice in the first test but only once in the second and the 3 grade was awarded thrice in the first test but four times in the second.

The subject listened to shapes a total of twenty seven times during the first test (average number of times per shape of 3.86) but only eleven times during the second test (average number of times per shape of 1.57). The modal number of times a shape was heard was two and three during the first test and two during the second.

The table below, Table 24, shows the results for Subject 10 of Section 4 of the test on both the first and second occasions in which the subject took part in system testing.

Table 24. Subject 10, Section 4, first and second test.
Shapes 1 to 7, Grade awarded for identification and no. of times heard.

	SHAPE 1		SHAPE 2		SHAPE 3		SHAPE 4		SHAPE 5		SHAPE 6		SHAPE 7	
	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times	grade	no. of times
S10 first	1	2	3	2	1	2	3	3	1	2	3	2	3	1
S10 second	1	1	3	2	0	2	0	4	1	5	2	3	3	2

Table 25 below summarises the results shown in Table 22, above. The table shows the number of different grades (0, 1, 2, 3) awarded to the subject's responses. It also shows the total number of times the subject heard shapes, the average number of times a shape was heard and the modal number of times a shape was heard. The table gives the results for the first and second tests.

Table 25. Subject 10, Section 4, first and second test.
No. of each Grade awarded, no. of times heard, average and modal values.

	Grade 1	Grade 2	Grade 3	Grade 4	number of times a shape heard	average number of times a shape heard	modal number of times a shape heard
FIRST	0	3	0	4	14	2	2
SECOND	2	2	1	2	19	2.71	2

It can be seen that the subject was awarded the 0 grade zero times in the first test but twice in the second. The 1 grade was awarded three times in the first test but only twice in the second. The 2 grade was not awarded in the first test but was awarded once in the second and the 3 grade was awarded four times in the first test but only twice in the second. The subject listened to shapes a total of fourteen times during the first test (average number of times per shape of 2) and nineteen times during the second test (average number of times per shape of 2.71). The modal number of times a shape was heard was two and three during the first test and two during the second. The modal number of times a shape was heard was two during both tests.

Summary and Conclusion

On repeating Section 1 both subjects performed less well than they did when they first took the test. Subject 9 performed Section 2 worse the second time round but Subject 10 performed it better. Both subjects performed Section 3 better the second time round. Subject 9 performed Section 4 better on the second occasion but the opposite was true of subject 10. In three of the

four sections both subjects had listened to each shape on average fewer times on the second time of taking the test than on the second.

The point of this second testing was to see if the fact of having completed the test once before would influence results when taking the test again. Once again, results are inconclusive but it may be stated that the fact of having taken the test before did not appear to significantly influence results on taking the test a second time.

Conclusion

This project set out to evaluate, through user testing, the efficacy of a simple two-dimensional screen reader system with regards to the quality and reliability of the information it could convey to a user in sonic form. The project also hoped to gain some insight into how the system might be implemented for practical use.

The test devised was considered successful as it tested for recognition of different shapes, different sizes of the same shape, positioning on screen of shapes and the ability of users to follow a shape's sonic representation as it moves around the screen. Future work could expand on the sections of the test dealing with the identification of small sized shapes as a practical implementation of a Graphical User Interface would be unlikely to be composed of shapes so large as the majority of the ones used in this project.

A questionnaire was delivered to subjects who took part in the testing. As hoped, this resulted in some interesting responses. Users of other screen-reader systems have reported that background noise can be very disturbing when making use of a system which represents graphical information in sonic form. It was expected that subjects who took part in this research project would find that they were greatly disturbed by the noise surrounding them in a busy electronics workshop whilst they were taking part in the testing. It was interesting, therefore, to find that only three of the ten subjects reported that they were disturbed by the background noise.

Seven subjects reported that they thought they would find the system difficult to use for extended periods of time. Future research might therefore address this issue specifically in an effort to determine at what point, if any, a subject's successful use of the system starts to decline as fatigue sets in.

Ten subjects were tested during this project, which was considered an acceptable, but minimal amount. Future work would perhaps benefit from testing a larger number of subjects. The subjects who took part in the testing were all students, many of them postgraduate students, at a leading university. Future tests might preferably use subjects representing a wider cross-section of society.

Two of the subjects were tested a second time in order to try to determine if the learning effect of having used the system before would significantly affect their results. In the event, there was no significant effect apparent and the overall results from the first and second tests were comparable to each other. Future research might address more fully the issue of learning effects. It must be stressed that those subjects who took part in the testing were only given a very brief introduction to the system and this must be taken into account when analysing the results. Future work might address the effect of teaching on how well a subject can use the system.

The overall results are hard to draw firm conclusions from. Some subjects simply performed better overall than others and it is perhaps constructive to suggest that some people have a greater natural ability than others to use the system.

An interesting point was that some subjects showed markedly different results across different sections of the test and it would be interesting for future research to examine why this is. There was no conclusive evidence to suggest that listening to a sound an increased number of times would lead to a greater chance of successfully identifying the corresponding shape or position of the sound.

As regards the positioning of sounds, it was found again that some subjects were simply more able than others to recognise the correct positioning and it was also found that some subjects were better able to recognise a shape than its position. Future research might hope to test more rigorously the correlation between successfully identifying a shape and subsequently identifying its position, and vice-versa.

There was no firm evidence to suggest that some shapes were harder to identify than others. It was expected that subjects would be better able to identify shapes which were familiar to them such as letters of the alphabet and various forms of triangles. The results of Sections 3 and 4 of the test found that this was not the case.

The successful recognition rates were, overall, poorer than expected. With this in mind it is difficult to suggest practical uses for the system in its current state. An additional barrier to implementing the system in its current state is the high level of variation in the results generated by the testing procedure. As noted already, there is not only substantial variation in the abilities of different individuals in using the system but there is also substantial variation in the results of some subjects for different sections and components of the test.

However, further development of the system, with an emphasis on developing its potential practical implementations, may prove very constructive indeed.

Appendix 1
Literature Review References and Bibliography

1 Gaver, W. , Auditory Icons: using sound in computer interfaces, *Human-Computer Interaction* 2, pp 167-177, 1986

2 Gaver, W. , *The SonicFinder: an interface that uses auditory icons,* Human-Computer Interaction 4, pp 67-94, 1989

3 Gibson, J.J. , *The ecological approach to visual perception,* Houghton Mifflin, New York, 1979

4 Gaver, W. , What in the word do we hear? An ecologicl approach to auditory event perception, *Ecological Psychology,* 5(1), 1993

5 Crispien, K and Petrie, H. Providing access to GUI's for blind people using a multimedia system based on spatial audio presentation, *95th Audio Engineering Society Convention,* New York: Audio Engineering Society, 1993

6 Blattner, M.M., Sumikaw, D.A. and Greenberg, R.M., Earcons and Icons: their structure and common design principles, *Human-Computer Interaction* 4, pp 11-44, 1989

7 Brewster, S.A., Wright, P.C. and Edwards, A.D.N., A detailed investigation into the effectiveness of earcons, in: *Proceedings of ICAD '92: International Conference on Auditory Displays,* Santa Fe, Nov. 92, Addison-Wesley, 1992

8 Burgess, D.A., Real-time audio spatialization with inexpensive hardware. (Report No. GIT-GVU-92-20). Graphics Visualization and Usability Center, Georgia Institute of Technology, 1992

9 Crispien, K and Petrie, H. Providing access to GUI's for blind people using a multimedia system based on spatial audio presentation, *95th Audio Engineering Society Convention,* New York: Audio Engineering Society, 1993

10 Visual Synthesis Incorporated, http://www.vsicorp.com/vsi4.html

Also consulted:

Begault, Durand R. "Challenges to the Successful Implementation of 3-D Sound", NASA-Ames Research Center, Moffett Field, CA, 1990.

Begault, Durand R. "An Introduction to 3-D Sound for Virtual Reality", NASA-Ames Research Center, Moffett Field, CA, 1992.

Burgess, David A. "Techniques for Low Cost Spatial Audio", UIST 1992.

Foster, Wenzel, and Taylor. "Real-Time Synthesis of Complex Acoustic Environments" Crystal River Engineering, Groveland, CA.

Stuart Smith. "Auditory Representation of Scientific Data", Focus on Scientific Visualization, H. Hagen, H. Muller, G.M. Nielson, eds. Springer-Verlag. 1993.

Stuart, Rory. "Virtual Auditory Worlds: An Overview", VR Becomes a Business, Proceedings of Virtual Reality 92, San Jose, CA, 1992.

Takala, Tapio and James Hahn. "Sound Rendering". Computer Graphics, 26, 2, July 1992.

Appendix 2

This document is that which is read out to subjects who take part in the system testing.

The system under investigation has been designed to use sound in an attempt to convey information to a computer user, and might be useful in helping a blind person use a computer.

It is the system which is being tested, not you. You will remain anonymous and the responses you give will simply be collated with those of other people in order to create data for statistical analysis.

The system test is divided into three separate sections. Each section will take only a few minutes to complete. Before we proceed, I shall play you some sounds and tell you which shape the sounds are designed to represent.

Section 1

You will be played a number of sounds, one at a time. After you are satisfied that you have heard the sound a sufficient number of times, I shall ask you to tell me what shape you believe the sound represented.

Each shape in this section will be of a standard nature:
e.g. square, circle, ellipse.....not a randomly generated shape.

When you give your response after hearing each sound, I will inform you immediately if the response you gave corresponds to that shape which was represented by the system. You will then move on to the next sound.

Section 2

In this section responses will no longer be as simple as 'square' or 'triangle'. I will ask you to draw square boxes on the paper you have already been given. For each sound you hear, I would like you to draw the shape you believe the sound to represent. In addition, I would like you to draw the shape in that area of the 'screen' which you believe the shape to be. I will demonstrate an example of this before you begin. In this test you will again be able to listen to the sounds as many times as you like before giving your response but you will not be given any feedback on your responses.

Section 3

In this section you will again be asked to draw in squares the pattern you think is being represented by the system. This time the patterns may not be distinct shapes. The patterns are

composed of lines which may or may not compose objects which you will recognise. In many cases the patterns are just randomly generated patterns.

In this test you will again be able to listen to the sounds as many times as you like before giving your response but you will not be given any feedback on your responses.

Section 4

In this section you will be played a number of sounds which correspond to definite, recognisable shapes. This section is designed to test if the system can produce sounds which will enable the user to distinguish between different forms of standard shapes, such as square and rectangle and equilateral and isosceles triangle.

Again you will be asked to draw what shape you believe corresponds to the sound produced by the system. You will again be able to listen to the sounds as many times as you like before giving your response but you will not be given any feedback on your responses.

This is the end of the whole test. Many thanks for your co-operation, which is greatly appreciated.

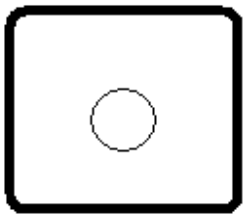
Appendix 3

Detailed Analysis of and Justification for the Chosen Test Structure

Section 1
The first section of the test contains only five different shapes, which are of a standard nature, and the subjects are informed of this. After the subject gives an answer, he or she is informed if they have correctly identified the shape or not before moving on to the next one.

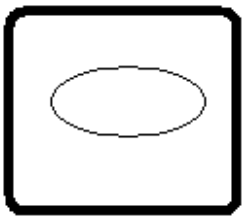
The first shape the subjects encounter is a relatively small circle, as shown below. It is purposely small as one of the example sounds played to the subjects before the testing begins is a large circle and it might be interesting to see if the subjects can then immediately recognise a smaller version of the shape they have recently heard.

Shape 1, Section 1



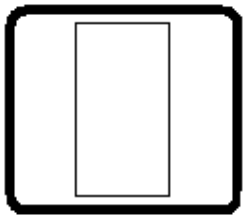
The second shape the subjects encounter is an ellipse, as shown below. This ellipse is of a different size than the one which the subjects hear in the introduction to the system. It is included to note if subjects are able to tell the difference between an ellipse and a circle at this early stage of system use. Although it must be noted, of course, that after giving their answer to the first shape subjects are told that the shape was a circle. Subjects may then be inclined to guess that the second shape is an ellipse, if they are debating between answering either 'circle' or 'ellipse' as they may assume that they would not be given the same shape twice in a row.

Shape 2, Section 1



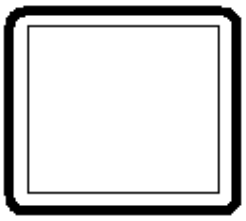
The third sound played to the subjects represents a rectangle and the rectangle is shown below. The subjects are not played a rectangle during the introduction to the system, but they are played a square, and so this shape is included to see if the subjects can recognise a new, standard shape so soon after starting the test.

Shape 3, Section 1



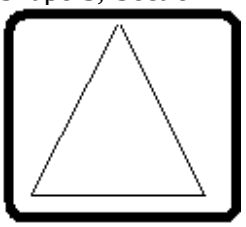
The next shape is a square, as shown below, and is a larger square than the one played during the introduction to the system. This shape is included to see if subjects can recognise it so soon after hearing a smaller square being played to them in the introduction and also to note how readily they perceive the differences between the square and the rectangle which came before it.

Shape 4, Section 1



The final shape in this the first section of the test is a triangle, as shown below. A triangle was not included in the introduction to the system. This shape tests whether or not the subjects can distinguish correctly a shape which has a point which is 'between two speakers'. In other words, the top point of the triangle is located in the middle of the screen and no single speaker is therefore dominant in the production of the sound to describe this point sonically.

Shape 5, Section 1



Section 2

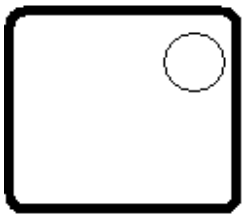
This section of the test requires that the subjects not only identify the standard shapes that the system is seeking to reproduce sonically, but that they also identify the location of the shape 'on screen'. They do this by drawing the shape they think they heard in a square box drawn on a piece of paper, one box for every sound. The square box is used to represent the computer screen and subjects are asked to draw the boxes themselves to allow them to better represent the shapes

they draw in relation to their perceived screen size. In this section, subjects are no longer informed if the answers they give correspond to the shapes the system is trying to represent and neither are they informed if they have correctly placed whatever shape they draw. This lack of any feedback obviously means that subjects do not learn as much as they would if feedback were given to them, as in the previous section. Before starting this section, however, subjects are given some examples to indicate to them how shapes can be positioned in different parts of the screen.

In order to position shapes in distinct areas of the screen, the shapes must necessarily be relatively small and are certainly smaller than the shapes which the subjects encountered in the previous section. The system represents a small shape by emitting a sound signal which is shorter in duration than that of a larger shape. This, preliminary testing showed, can make the shapes harder to distinguish. The software may, however, be reconfigured to lengthen the duration of the sound signal but this was not done in order to preserve the distinction between large and small shapes.

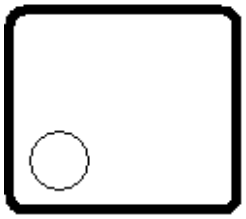
The first shape the subjects hear is a small circle which is positioned in the top right-hand corner of the screen, as shown below.

Shape 1, Section 2



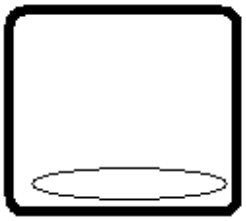
The second shape is a small circle which is drawn in the bottom left-hand corner of the screen, as shown below.

Shape 2, Section 2

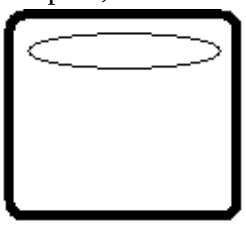


The third shape is an ellipse drawn along the bottom of the screen, as shown below and the fourth is an ellipse drawn along the top of the screen, as shown below. The ellipses were included to test if distinction could be made between them and the circles which preceded them.

Shape 3, Section 2

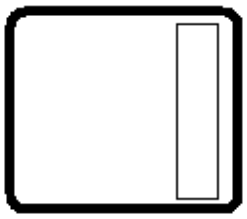


Shape 4, Section 2

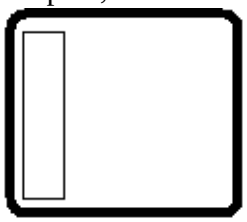


The fifth and sixth shapes are thin rectangles which are drawn down the sides of the screen, as shown below. Preliminary tests showed that thin rectangles were generally very difficult to correctly distinguish as the shorter sides were represented with a sound signal of a very short duration.

Shape 5, Section 2

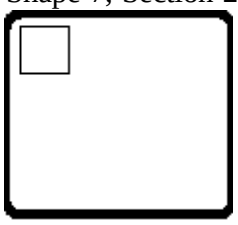


Shape 6, Section 2

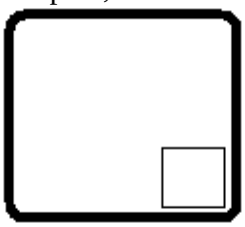


The seventh shape is a small square located in the top left corner of the screen, as shown below and the final shape in this section is a square located in the bottom right of the screen, as shown below.

Shape 7, Section 2



Shape 8, Section 7



The decision to use the same shape twice but located it in different areas of the screen was taken to examine whether or not the placement of a shape would significantly affect subjects' abilities to correctly identify it.

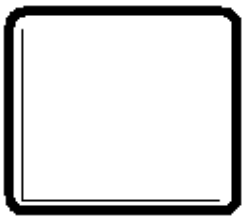
Section 3

In this section subjects are again requested to draw boxes on paper in which they will draw the shape they think each sound represents. This time, however, subjects are informed that the patterns they hear may not be distinct shapes.

The purpose of this section of the test is to note if subjects can follow a line as it begins in one part of the screen and makes its way to its eventual end point. Some of the patterns in this section are easily identified as letters of the alphabet whilst others are just randomly generated patterns. This choice was made to see if the visually recognisable patterns, the letters of the alphabet, would be correctly identified by the subjects more often than the randomly generated patterns. The subjects are observed at all times to note if they start their drawings in the part of the boxes on their paper which corresponds to that part of the screen in which the actual pattern begins.

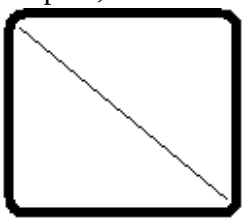
The first shape in this section is shown below and is in the form of the capital letter L. This pattern begins in the top left of the screen and moves to the bottom left before crossing the bottom of the screen and terminating in the bottom right corner.

Shape 1, Section 3



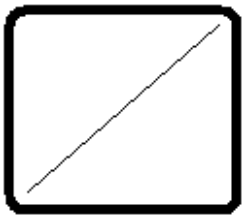
The second shape is a simple straight line drawn diagonally from the top left to the bottom right of the screen. This shape is shown below.

Shape 2, Section 3



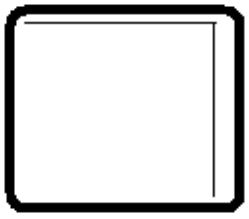
The third shape, as shown below, is similar to the previous one and is a simple, straight line drawn diagonally across the screen. This time it is drawn from the top right of the screen to the bottom left.

Shape 3, Section 3



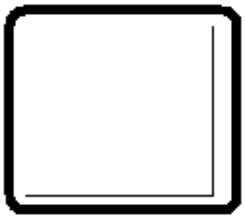
The fourth shape is similar to the first one, an 'L' shape, as shown below. This time, however, the pattern begins in the top left of the screen, moves along the top of the screen and then moves down the left of the screen to terminate in the bottom left corner.

Shape 4, Section 3



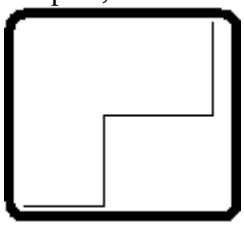
The fifth shape is similar to the first and the fourth and is shown below. This time the pattern begins in the bottom left corner, makes its way across the bottom of the screen and then goes up the right hand side of the screen before terminating in the top right corner. The similarity of shapes one, four and five, which are of the basic form of the capital letter 'L' was employed to test if subjects could recognise the same object under different representations on screen.

Shape 5, Section 3



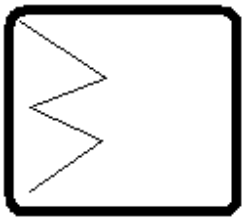
The sixth pattern begins in the bottom left of the screen and travels across to about half way across the bottom of the screen before going straight upwards to a height about half-way up the screen. It then travels in a straight line towards the right of the screen before changing direction to go straight upwards and then terminates in the top right of the screen. This pattern is included as it is slightly more advanced than those which preceded it whilst still being composed of straight lines. It also tests to see how well the subjects can identify how far across the screen the line travels before changing direction and heading upwards.

Shape 6, Section 3



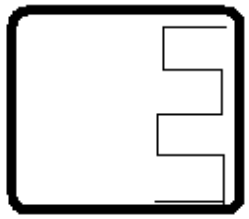
The seventh shape, shown below, is composed of a ziz-zag line down the left hand side of the screen with the points reaching almost into the middle of the screen. The pattern begins in the top left of the screen and then makes its way downwards to the bottom left.

Shape 7, Section 3



The eight shape is purposely complex and begins in the top right of the screen and makes its way down the right hand side of the screen. It is shown below. This pattern was constructed to test how well subjects could distinguish a line following such a complicated path down one side of the screen.

Shape 8, Section 3



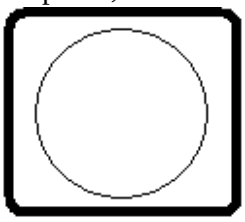
The following five shapes are letters of the alphabet and were chosen as some of them represent quite complex patterns, certainly more complex than some of the earlier patterns in this section of the test. They were included in the test to see if subjects could distinguish these shapes successfully, in spite of the inherent complexity of some of them compared to some of the earlier shapes, which might then suggest that ability to distinguish these letters could be based on the subjects' familiarity of the basic shape structures.

The ninth shape is simply the capital letter 'M', as shown below. This pattern begins in the bottom left of the screen and traces out the letter 'M' before terminating in the bottom right of the screen.

Shape 9, Section 3

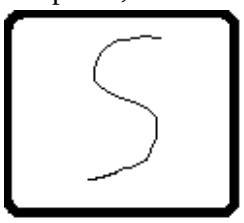
The tenth shape is the letter 'O', effectively a large circle, and is shown below.

Shape 10, Section 3



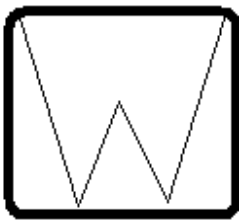
The eleventh shape is similar to the letter 'S', and is shown below. This shape is not a 'perfect' letter 'S' as it was drawn with a mouse and not simply selected from the system's shape menu. The system reproduces this shape extremely quickly in sonic form.

Shape 11, Section 3



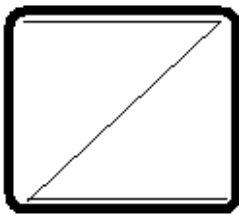
The twelfth shape is the letter 'W', as shown below, and the pattern begins in the top left corner of the screen and finally terminates in the top right of the screen after tracing through the letter.

Shape 12, Section 3



The thirteenth and final shape in this test is the letter 'Z', as shown below. This pattern begins in the top left of the screen and terminates in the bottom right of the screen.

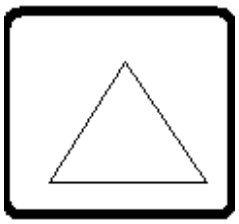
Shape 13, Section 3



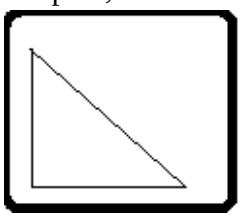
Section 4

The first shape in this section is a right angled triangle, as shown below. The second and third shapes are also triangles, of a different nature. Different forms of the triangle are used to test just how much of the differences between the three variants is discernible to the subjects. The second and third triangles are also shown below.

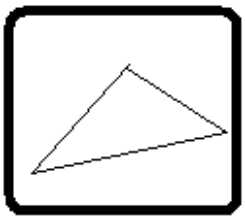
Shape 1, Section 4



Shape 2, Section 4

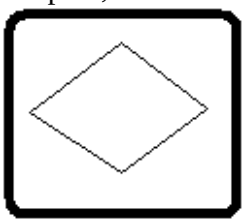


Shape 3, Section 4



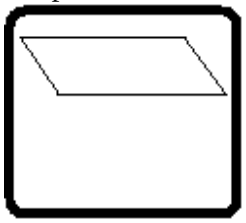
The fourth shape in this section is a rhombus, which might be thought of as two triangles joined together, and is shown below.

Shape 4, Section 4

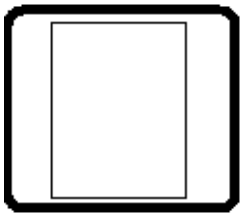


The fifth, sixth and seventh shapes were chosen because of their familiarity to each other. The fifth shape, a parallelogram as shown below, is similar to the rectangle which follows it. The rectangle is shape number six and is shown below. Finally, the seventh shape, a square, is shown below.

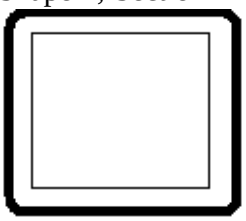
Shape 5, Section 4



Shape 6, Section 4



Shape 7, Section 4



Appendix 4

Questionnaire for those who took part in system testing

Having kindly taken part in the testing of the sound system I would now like to ask you to fill in this brief questionnaire. This is in order to record your views on your use of the system.
Thank you for your time.

Please circle as appropriate:

Question 1
Did you immediately find the system difficult to use (did you feel that you were unable to identify any of the shapes being represented in sound form)?

YES/NO

Question 2
Did you find that your ability to recognise shapes increased the further into the test you got?

YES/NO/NOT SURE

Question 3
Did you find that you had to concentrate hard in order to use the system?

YES/NO

Question 4
Did you find the test fatiguing?

YES/NO

Question 5
Do you think that you would find the system difficult to use for extended periods of time?

YES/NO

Question 6
Did background noise disturb you whilst you were using the system?

YES/NO

Question 7
Were you wary of others working around you being disturbed by the noise of the system as you were using it?

YES/NO

Question 8
Do you think that you would have found the system easier to use (you would have been more able to identify shapes correctly) if you had been given more examples/training before the testing began?

YES/NO/NOT SURE

Question 9
How well do you think you were able to identify the shapes represented sonically by the system?

quite well/very well/not well/not sure/not at all

Question 10
How well do you think you were able to recognise the positioning on the screen of the shapes represented by the sounds produced by the system?

` quite well/very well/not well/not sure/not at all

Question 11
Do you think that the system could be used to provide reliable/accurate information to a non-sighted computer user?

YES/NO/DON'T KNOW

If you have any comments on the system or on your use of it, please record them below: