DESIGNING AUDITORY GRAPH OVERVIEWS: AN EXAMINATION OF DISCRETE VS. CONTINUOUS SOUND AND THE INFLUENCE OF PRESENTATION SPEED

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ABSTRACT

A number of studies have reported that auditory graphs (AGs) can be used successfully by individuals to gain an overview of data series. Very little however is known about the effects that changing presentation parameters of AGs has on user's' ability to gain an overview or identify specific graph characteristics. This study investigates the effect of varying graph complexity, speed and mode of presentation of AGs. We examine the effects of these variations on graph comprehension as a whole and on specific graph analysis tasks such as point estimation.

Keywords: Discrete, Continuous, speed, audiograph, sonification

1. INTRODUCTION

The growth of mobile and ubiquitous computing has led to an increasing need to support novel forms of human computer interaction. The availability of highly portable devices such as mobile phones and PDAs enables people to perform interaction tasks in locations and circumstances, which previously would have been impossible. However, as expectations rise regarding what is feasible with mobile devices, the physical limitations of such devices become exposed. In particular, the dominance of visually mediated interaction becomes far less appropriate in the context of the small screens available on mobile devices, which are often used in situations where the visual attention of the user is required for other tasks during part or all of the interaction. One approach to reducing the reliance on visual interaction is to use other interaction modes. Data Analysis tasks are a good candidate for consideration for the use of alternative forms of interaction, as providing effective presentation and navigation of visual graphs on mobile devices is difficult and may often be inappropriate in many contexts of use when the users' vision is required for other tasks.

Auditory graphs have been of interest to the auditory display community for several years since the early work of Mansur [1] demonstrated their effective use by blind people. The motivation behind this study is to examine specifically the effects of varying graph complexity and presentation speed in both sighted and blind individuals using real data for typical data analysis tasks.

Some of the research that has been conducted in the field of auditory graphs includes the examination of how the use of different sound parameters affects the construction, perception and comprehension of auditory graphs [2] [3] [4]. Researchers presently try to use the knowledge gained from sonification in general such as the different effects sound parameters (e.g. frequency, amplitude, timbre, tempo, duration, volume/loudness, rhythm and location)[5] have on improving the presentation by varying parameters and assessing the efficiency these have on the mapping.

Research by Walker [6] suggests for example that pitch is better for representing temperature while tempo is better for representing size. When the mapping is selected, the polarity and scaling are chosen depending on the type of data being mapped. The polarity would indicate how the sound parameters would vary with the change of data. An example of this would be an increase in pitch i.e. having a positive polarity with the increase in data.

Although research on auditory graphs is steadily growing, there is however still a lack of basic research into the most effective ways of creating auditory graphs. Presenting overviews is a very under used concept when it comes to auditory displays and even more so when applied to auditory graphs.

The approach taken in this study is to evaluate the usability of auditory graphs presented to users employing different modes of presentation. Most applications that were investigated at the initial stages of this study [5, 6, 7] use discrete sound for the presentation of graphs. Although one attempt by NASA's MathTrax [7] renders line graphs as discrete sound, however, a number of intermediate notes were added between two data points to give a smooth line sound effect but nonetheless the application was not formally tested and the benefits of this alternative mode of presentation, if any, are still unknown. In this study we examine which of the two modes: discrete or continuous are most effective at presenting line graphs within the contexts of realistic data analysis tasks.

2. BACKGROUND

Frysinger [8] provides a number of examples of early work in the design and evaluation of Auditory Graphs. Particularly notable among these is the work of Bly [15], who investigated different approaches to mapping, scaling and correlation of multi-variate data displays. Bly tested these displays in sound only, graphics only and bimodaly. Bly's findings were that the auditory display outperformed the visual display, and that the combined (bimodal) display was better than either mode alone.

In 1984, Mansur devised a method for line graph sonification called Sound Graphs where the y-axis of the graph is mapped to continuous pitch and the x-axis to time. Movement along the x-axis in time causes the pitch to vary over a continuous scale depending on the current y value of the graph. Mansur found that after a small amount of training, test subjects were able to identify the overall qualities of the data, such as linearity, monotonicity, and symmetry, on 79 to 95% of the trials [1].

Mansur's experiments only map one type of data against another. What of data with two or more dimensions? Brewster and Browne [16, 17, 18] conducted a number of experiments sonifying graphs containing two data series and showed that sonification allowed users to visualise graphs containing two data series while listening to them and assigning different instruments to each range. Brewster and others [19] conducted experiments exploring 2D tables with speech and non-speech sound and discovered that users found pitch to be valuable in determining the shape of the data within the table.

The first international workshop on Auditory Graphs took place as part of the ICAD'05 conference. This workshop drew together a number of researchers who have made significant contributions in the area and the papers from the workshop provide a valuable snapshot of much of the auditory graph research at that time. A flower [9] provides a summary of a number of techniques that have been proved to work and of others that have failed. In particular, Flowers sites further evidence that mapping numeric values to pitch can be used to convey "function shape or data profile changes, even for relatively untrained observers". Walker [10] argues strongly for the inclusion of context in auditory graphs, highlighting the parallel that it would be very unusual to present a visual graph without providing any indicators of axes, scale or other signifiers of context. A number of the workshop papers provide useful agendas for auditory graph research, notably those of Walker [10], Bonebright [11] and Stockman [12]. The workshop paper by Neuhoff [13] sets out strong arguments however against the use of "low level acoustic dimensions" for representing data in auditory graphs, notably: that such dimensions have been shown to interact perceptually and that they fail to invoke an effective mental model that assists the listener internalize the shape of the data. Neuhoff sites the view of Gaver [14] that people listen to the sources and dynamic properties of sounds. Neuhoff [13] advocates an approach in which this attention to natural acoustic properties is exploited, by reflecting numeric changes in data through changes in typical acoustic properties of real world objects or systems, such as varying a sound from liquid to solid, or varying the speed of footsteps from slow to fast.

3. THE EXPERIMENT

3.1. Overview

The aim of the experiment was to evaluate the extent to which continuous as opposed to discrete sound presentation serve the purpose of presenting graph overviews. We were mainly interested in comparing the differences between the two presentation modes in supporting the different aspects of line graph overviewing in relation to the requirements outlined in section 3.4; we thus formulated the following three hypotheses:

H1. Graphs presented in the Continuous mode will be more accurately (graphically) reproduced.

H2. Graphs presented in the Discrete mode will be more accurately analysed by users for different peaks and troughs, and for point estimation on the x and y-axis.

H3. The Medium speed of audio graph presentation will form the most usable presentation speed.

3.2. Participants

A total of 16 sighted participants and 4 visually impaired volunteered to take part in the experiment. The sighted participants were undergraduate Computer Science students. Visually impaired participants were office-based professionals. Two of the participants had some level of formal musical training, and two others had informal training, while the rest had none. They were randomly assigned to two groups of eight in a within-subject experimental design.

3.3. Conditions

There were two main conditions in this experiment, in the first condition participants tested a "**Discrete**" sound presentation, which is a simple scaled note mapping of the data represented as pitch, this was programmed using CSound audio synthesis language [24]. A **"Continuous"** sound presentation was used in the second condition, in which a sine wave was used to represent the data points as represented by a line graph. JSyn sound synthesis API [25] was used to implement this condition.

3.4. Method

To quantitatively assess the efficiency of the two presentation modes in conveying appropriate graph overviews, we defined a set of requirements which we consider essential for the participants' performance to be described as a successful overview of line graphs. In the scope of this experiment, these requirements are:

Shape Accuracy: an overview should give a correct impression of the overall shape of the graph, including the number of peaks and troughs.

Feature Extraction: different points in the graph should be easily extracted from both the x and y-axis. Other features such as the relative scaling between peaks and troughs and point estimation should also be feasible.

Accuracy with varying data complexity: relative accuracy should be maintained with increasing data complexity both in size i.e. the number of data points, and the number of peaks/troughs.

These requirements were tested by asking the participants to a) graphically reproduce the auditory graph, and b) Extract features from the graph, such as maximum and minimum values and to estimate other points of interest.

In addition to these requirements, further tests were carried out to analyse the most suitable presentation speed at which each of the two modes are presented. Thus, the experiment was divided into two main phases. The first tested how each subjects performed under different presentation conditions when presented with graphs of varying complexity. The second phase tested the two presentation modes when played at 3 different speeds.

In the testing phase, each participant listened to twelve different graphs of varying *speed* or *data complexity* depending on which experiment they were carrying out, different graphs were used for every task. The graphs were pre-selected from real weather forecast data.

At the beginning of each task, the participants listened to the audio graph three times before attempting the first question; for each subsequent question within that task they were allowed to listen to the graph once more. The tasks included trying to graphically reproduce the graph (verbally for the visually impaired) and estimating variance of events on the x and y-axis. The reasons for allowing them to listen to it again were determined through a pilot study in which it was observed that participants focused or listens out for specific events blocking the rest of the information out. Hence, each time they were required to switch or change focus from one feature to another, they would be allowed to listen to the audio graph again.

At the end of each task, the participants were asked to answer a set of questions regarding the graph they had just explored. This questionnaire was employed to analyse the level of difficulty participants felt while answering the various questions about the graph. This is important as it gives a quantitative measure of the performance and confidence as perceived by each of the participants for each of the conditions, as sometimes it could be the case that although the results are more favorable for one condition, the overall effect on the user is detrimental to the performance due to increased workload or perceptual strain.

3.4.1. Phase One - Data Complexity

The aim of this phase was to observe the participants' performance in each condition when the data complexity varied. We defined the complexity as twofold: 1) increase in the overall size, through an increase in the number of data points. 2) Increase in the overall shape, through increase in the number of peaks/troughs. Thus, three complexity levels were used in this experiment. **"Low"** complexity – in this category, all the graphs had approximately 3-4 peaks and troughs and had 12 data points. **"Medium"** complexity – here all the graphs had approximately 3-4 peaks and troughs but the number of data points increased to 30. Finally, **"high"** complexity – here all the graphs had approximately 7-8 peaks and troughs and had 30 data points. The speed at which these were presented was kept at 7 seconds.

For each condition, each participant listened to one graph from each of the three categories listed above and were asked to draw the graph (this tests the first requirement of a successful graph overview) they were then asked to answer questions which tested how well they could estimate points where events occurred, such as the occurrence of a peak or a trough in both the x axis (time related) and y-axis (value related) (this tests the second requirement for a successful graph overview).

During the pilot study, it was noted that participants often looked back at their graphical reproduction in order to answer the following questions, although they were allowed to listen to the graph again for each question. This was not useful as this showed that they would rely on visual interpretation of the graph rather than on the auditory counterpart which is what is being tested. Furthermore, errors that arose when they drew the graph could lead to further errors being made when using it to answer the following questions. For this reason, users were not allowed to glance back at their original drawing in order to answer the follow up questions.

Each participant was given a short (ten-minute) training session in which both conditions were explained and presented. They were also presented with a simple graph, which they listened to while looking at the visual representation of it. This gave them a good feel as to what a rise, fall and steady sounded like in each condition. An explanation of what constitute a peak and a trough was also given. Finally, an example of the task sheet and a quick run through for the training graph was given.

For each task, the participants were allowed to listen to the graph three times; they were advised to listen to the graph once, then attempt to draw it the second time, then use the third listen to validate their drawings. A restriction on the number of times the participants were allowed to listen to the same graph was introduced as we were interested in analyzing the initial impression (overview) participants got from the audio graph rather than the detailed interaction with it. Once, they had carried out this task, they were then asked to move to the rest of the questions which focused on point estimation, where they were asked to estimate the time value at which the highest peak occurs as well as the value of the second highest peak when the value of the highest peak was given to them.

At the end of each task sheet, they were then asked to fill out a questionnaire on their ease and confidence in answering each of the sections within the task. This process was repeated for each category and in both conditions. Each participant therefore listened to six different graphs from each condition. The graphs within each category were similar in terms of the number of peaks/troughs but were not identical to avoid learning affects when testing each condition.

3.4.2. Phase two – Speed Comparison

The aim of this phase was to determine the speed at which each condition was performed best. The procedure, which was undertaken to test this, does not differ from the data complexity phase. In which each participant from the second group evaluated both conditions against three categories of speed. These are a referred to as: "s**low**" category in which the graph was presented in 14 seconds a "**Medium**" category in which the graph was presented in 7 seconds and a "**Fast**" category in which the entire graph was presented in 3 seconds [7].

To sum up the procedure, for each condition the participants listened to four graphs from each of the speed categories (two from each condition) and were asked to draw each graph after hearing it and then answer questions to perform point estimation tasks on the x and y-axis. They also had to fill in the same questionnaire asking them about their ease and confidence in carrying out the various tasks.

4. RESULTS

In general, the results of the experiment show that the Continuous presentation mode generated more accurate results when the participants were asked to draw the audio graph, with an average accuracy of 66% in both phases (data complexity and speed), in comparison to the Discrete mode of presentation, which had an average accuracy of 49% for the same tasks.

For point estimation tasks, however, the Discrete sound presentation generated a 64% accuracy while only a 53% was achieved when participants used the Continuous sound presentation to estimate the different events on both the axis.

For both phases, the comfort levels felt by the participants when reproducing the graphs was reflected in the accuracy of their drawings. In cases where they were asked to estimate points on the graph, results show that their confidence was overrated in comparison with their performance on those particular tasks. The next two sections report the detailed results obtained for the data complexity and speed phases of the experiment.

4.1. Data Complexity Phase

We discuss the results in terms of the extent to which the requirements that we defined in section 3.4 were satisfied. Here we consider the accuracy of the reproduced graph associated with each presentation mode of the two conditions when measured against the shape of the original sonified graph. Figure 1 shows three graphs, 1a represents the original graph that a participant heard and was asked to draw. Figure 1b shows the participant's attempt at drawing this graph using the continuous condition. Figure 1c. Shows the graph reproduced by the same participant when presented through the discrete mode. The accuracy of reproduction was clearly superior in the continuous mode as the figures show; the participant was given a percentage of 86% in the first instance and marked at 32% in the second.

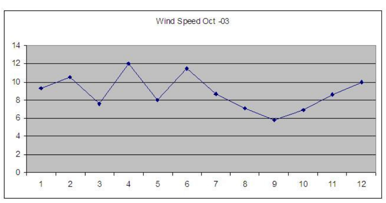

Figure 1. (a)

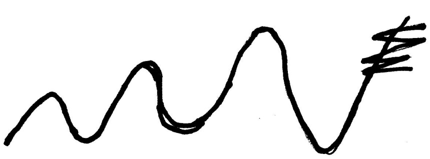

Figure 1. (b)

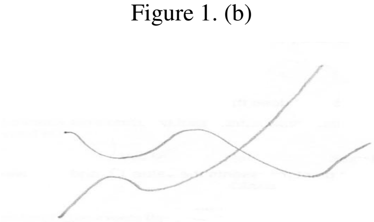

Figure 1. (c)

Figure 1. Graph with easy data complexity. 1(a) Represent the original graph. 1(b) Participant's attempt with continuous sound rendering. 1(c) Same participant's attempt with discrete sound rendering

Figure 2 shows the relative accuracy achieved across the two conditions for the first task; where the participants were asked to draw a given graph. We could observe that as graph complexity increased, accuracy in participant's drawing decreased. However, this was significantly less in the Continuous condition. Discrete sound representation starts off with an accuracy level of 57% at the "Easy" level but falls to 28% in the "Hard" level. A Wilcoxon test [27] was carried out to test whether the recorded differences were significant, the results of which showed that for the average data complexity levels used in this study there is a significant difference between the two presentation modes with a $p<0.025$ $W=4$ therefore satisfying the H1 hypothesis.

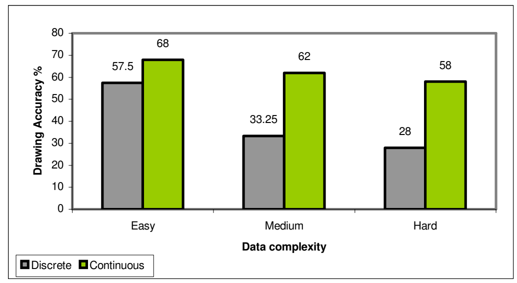

Figure 2. *The average accuracy of participant's drawing for the Data complexity phase.*

The second requirement that we tested was the accuracy in point estimation on both the x and y-axis. Examining the results, we observed that the Continuous condition generated worse results as opposed to the Discrete condition.

Table 1. shows that as complexity increased, the accuracy of point estimation fell. This was expected, as the participants' perceptual and processing demand in such a task would be at its utmost given the nature of the task where particular peaks had to be listened out for and identified from a larger set of peaks.

Comparing the two conditions, the Continuous mode of presentation generated lower accuracy percentage of 33% while accuracy in the Discrete mode was marked at 48.5%.

Interestingly, participants were better at scaling between the graph' peaks and troughs, that is, picking up the dynamism of the graph's shape, more than they were at point estimation i.e. Picking up absolute values on the axis.

	Discrete	**Continuous**
Easy	65	65
Medium	67.5	46.5
Hard	48.5	33

Table 1. *The average accuracy for point estimation for the data complexity phase*

These results examined the performance of the participants with each sound mode; another important aspect is to examine the ease and comfort felt by the participants while listening to the sonifications. Each participant was asked to scale from 1-5 the ease they felt when drawing the graphs. The results matched performance levels in that participants found it easier to draw the graph when it was rendered in a Continuous mode. On average the participants found it "relatively easy" to reproduce the graph with this condition and "extremely" hard with the Discrete condition.

For point estimation tasks there was relatively little difference in how participants rated the ease or comfort between the two conditions but the performance results showed that the Discrete presentation mode did generate better results.

The evaluation of the results from the visually impaired participants shows the same trend as those for the sighted participants. Here again, the Continuous mode of presentation was found to be more useful in the graph reproduction task while the Discrete mode was more suited for the point estimation task. Figure 3 shows the results of the drawing task; in this case participants verbally described the impression gain by the auditory rendering of the line graph. Better performance was observed for the visually impaired participants than that observed by the sighted participants.

We quote a visually impaired participant describing their reaction to the Discrete presentation mode:

"It's a nice sound but I found I had to listen all 3 times to this to get any kind of a feel for the shape. This sound is a bit hard to follow [..] But the shape isn't as easy to follow as the continuous graphs".

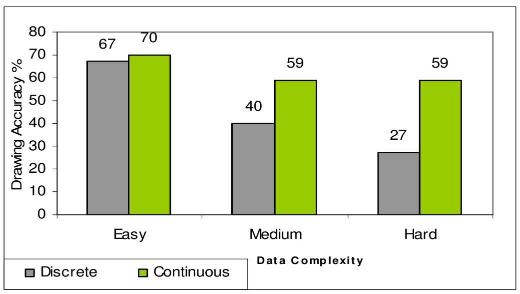

Figure 3. *The average accuracy of visually impaired participant's drawing for the Data complexity phase.*

4.2. Speed Phase

Figure 4. shows that participants could draw the visual equivalent of the auditory graph better when the graph was rendered in 7 seconds in both conditions. Continuous rendering generated more accurate drawings when compared with the discrete condition. The results also show that the slower presentation speed (14 seconds) was also better than the fast speed. It was also observed that during the experiment participants, particularly sighted users, were overwhelmed by the 3-seconds presentation speed, as they could not separate the different sound events at a fast enough pace to be able to draw the graphs. Having said this, it seems that graphs rendered at 14 second speed conveyed a false impression of the number of peaks and troughs that the graph had as it varied at too slow a pace.

Comparing results from the point estimation task in the two conditions at each speed we see that, again, the Discrete presentation mode generated better results than the Continuous mode. From table 2 we can also see that the most successful point estimation was achieved by the discrete condition with an average percentage correctness of 87% this was when presented in 7 seconds. It is interesting to note that as opposed to the drawing task in this phase of the experiment, where the discrete condition was best presented in the 14 seconds mode, in the point estimation task, it is not the case. We can see that in fact it resulted in the poorest results out of the three modes. This is because the delays between the notes were so significant that the sound reference of the previous note was lost.

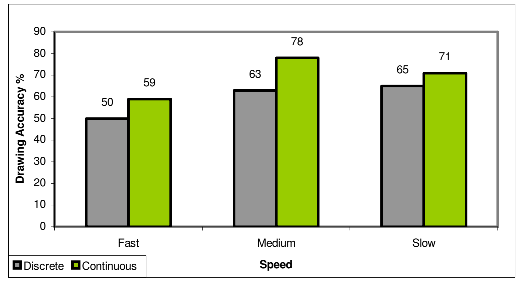

Figure 4. The average accuracy in the drawings of the participant's drawings for the speed phase

A Wilcoxon [27] test on these results showed a $p<0.05$ with a $W= 6$ confirming that the results are significant and satisfies the H1 hypothesis.

	Discrete	Continuous
Slow	56	50
Medium	87	69
Fast	61	58.5

Table 2. *The average accuracy for point estimation for the speed phase*

The participants were asked to rate the ease and comfort they felt while answering the various questions with each condition. In a similar way as with the data complexity phase,
on average the participant felt more comfortable answering the drawing task with the Continuous presentation mode rather than the discrete mode. In the speed phase on the other hand, most participants felt more comfortable answering questions related to point estimation with the Discrete presentation mode, which supports the performance results for these tasks.

The results for the visually impaired participants showed that presenting the graphs at a fast speed was very successful in producing drawings of the graphs, better than the 7 seconds presentation, which was successful with sighted participants.

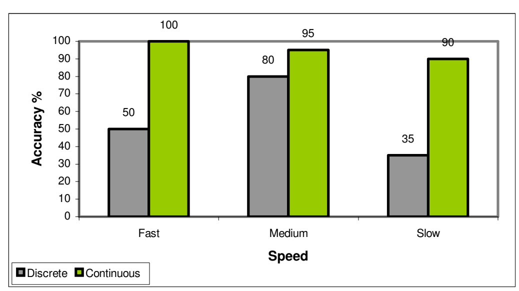

Figure 5. *The average accuracy in the drawings of the participant's drawings for the speed phase*

5. DISCUSSION

The results from the study are significant enough to satisfy our formulated hypotheses. It has been shown that a Continuous sound rendering for auditory line graph overviews produce more accurate graphical representations when compared against a Discrete sound rendering. As graph complexity increased (both in shape and size) performance accuracy dropped when the participants in our study attempted to reproduce the graphs. This drop, however, was less significant in the continuous presentation mode. This satisfies the first and third requirements for successful overviewing described earlier, which refers to the ability to reproduce an accurate graph shape and its features.

We also observed that the discrete sound mode was more usable than the continuous sound mode in tasks which required estimation of different features on the graph, such as the differences between two peaks or point estimation on the axis. This also confirms our H2 hypothesis, and satisfies the second requirement.

The speed phase of the experiment did not however produce the expected results. Although, the hypothesis that the medium speed presentation would support more accurate results was broadly satisfied; a bigger gap between the presentation speeds was expected. Generally sighted participants felt more comfortable with the “Medium” speed while the visually impaired participants preferred the “Fast” speed. The "Slow" mode on the other hand was the least useful for both visually impaired and sighted participants.

The discrete condition was the most demanding in terms of memory overload; to the extent that participants believed that the presentation time of the graph was longer than it actually was. Participants found it really difficult to follow the note-by-note presentation in the discrete mode, it was also observed that the first three or four points in the graph were listened to, and then placed relative to each other according to the participants’ estimation of their relative values. This however incurred time costs, which resulted in the participants losing focus and missing the remaining parts of the graph. This problem did not improve even when the duration of the audio presentation was made longer, in the speed phase, i.e. more silence was added in between notes to allow the participant to reflect on the previous note, the problem here is that auditory memory can only retain information for a short period of time [22] and it seems that the time elapsed between two consecutive notes had a negative impact on the participants ability to reference back to the previous note for an accurate estimation of their relative values.

In the continuous condition, a recurring problem with some participants' drawings was their inability to differentiate between a steady pitch and a slow increasing pitch. Most of those participants, especially those with no musical background, drew data points with the same value using a steadily increasing slope. Also, it was interesting to note that the produced drawings reflected the sound mode in which the graph was presented. Most participants drew the discretely presented graphs as either point-by-point or zigzagged drawings while the continuous graphs were drawn as a smooth curve. The dimensions of their drawing in the speed phase was also very reflective of the speed of presentation in the sense that very short graphs were drawn for the fast speed audiographs and very long graphs were drawn for the slow speed audiographs.

The participants’ performances were greatly influenced by their expectations of the graph either before the start of the sound graph presentation or during its early stages. This phenomenon is explained by McAdams in [20]. An example of this can be seen with participants who always expected the graph to start with an increasing slope. If this was not the case and the graph had a decreasing slope at the start instead, most participants would not rectify or even notice their mistake. This problem then created a breakdown in the interpretation of the remaining parts of the graph. For example, if they drew an increasing slope at the start while the sound presentation indicated that in fact it is a decreasing slope, the next sound extract they would hear would indicate that the slope is now increasing. At this point, they would not know what to do. They realise that the slope they are now listening to is increasing in pitch but since they have already drawn an increasing slope they can not draw another increasing slope! And hence some participants resorted to either extending the current slope or just "guessing" a direction. Very few participants went on to correct the graph. The importance of expectation was even articulated by the participants as many requested to know which condition was going to be played before the start of the task, this helped prepare them or maybe even switch the way they intend to proceed with the analysis of the sound source.

A related issue was the occurrence of what participants described as an unexplained sound extract between two points or a succession of points. If a participant heard a sound, which they failed to distinguish between an increasing and a decreasing pitch or because their interpretation of the sound did not fit their current representation, their ability to represent the rest of the graph from that point onward was compromised. In such a situation, the participants would listen to the graph again but fail to correct or carry on drawing the rest of the graph.

The evaluation highlighted another interesting point, which confirms Walker’s research on cues [21]. It was observed that many participants added cues when drawing their graph, this was done either by putting markers on their drawings, counting on fingers, drawing in the air or humming the tune. In his paper at the first Auditory Graphs symposium [26], Walker states that it is virtually impossible to interpret auditory graphs without context. Our position on this issue is that we very much support the idea in general of incorporating context in auditory graphs, but part of the aim of this experiment was to examine just to what extent are people in fact able to estimate graph shape and perform point estimation tasks in the absence of context.

In his initial work on adding cues such as tick marks [21]; Walker concludes by reporting that the results of his study supports the theoretical position that the addition of useful information through intentional cues enhances the perception of auditory graphs. We observed that participants did this unintentionally, which indicates that adding auditory context cues might improve their overall performance.

This finding is in line with theoretical findings by Dimitrios I. Rigas and James L. Alty. Who exploited the concept of mental model update through interaction with the display in the design of their AudioGraph [23]. McAdams [20] and others also describe a model of auditory processing which includes the building of a mental model. It seems likely that semantically well designed context cues are likely to help users in the formulation of accurate mental models of auditory graphs.

Finally, an interesting trend in the generation of the graph representation was the simultaneous or asynchronous rendering of the sound presentation. Some participants generated their graphs simultaneously with the sound and others waited until the end of presentation to try and recall the sound they had just heard. Both approaches have their advantages and disadvantages. In the case of drawing simultaneously with the sound the user’s attention is divided between the sound analysis and the rendering, however for users of this approach the retention of auditory information was not as demanding as for those users whose drawings were produced after the sound presentation was over.

6. FUTURE WORK

The ultimate goal of the research is to create a set of guidelines which best describe how to present auditory graphs in general and initially how to present graph overviews. A natural step forward from the findings of this study would be to try and combine the two sound modes presented here and explore under which conditions they would positively impact graph comprehension and how they might complement each other to support better graph overviews. The strategy for combining these presentation modes would need to be well thought through and empirical experiments conducted to extract the most successful combination. Exploring the expectation factor discussed in this paper would also give us a better understanding and allow us to include cues, which will augment the listener's overall understanding of the graph.

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