INDIVIDUAL DIFFERENCES IN INTERPRETING AUDITORY GRAPHS

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ABSTRACT

Very little research has been done on the role of individual differences in the interpretation of auditory graphs. Research with the visually impaired, musicians, and college students point to interesting differences in the way sound is interpreted. However, in order for auditory graphs to be successful, a more thorough understanding of individual differences is needed. This paper proposes a series of experiments that look at cognitive abilities, musical abilities, and other demographics in college students and the visually impaired. The author, however, stresses the importance of collaborating with other researchers to obtain data on other groups of people.

1. INTRODUCTION

1.1. Previous Studies

There has been little research in the area of individual differences with respect to sonifications and auditory graphs. Research with an auditory magnitude estimation task has demonstrated that important differences in the interpretation of auditory information arise within and between groups of listeners [1-3]. Walker [2] found individual differences in college students in the polarities of responses to data-to-sound mappings. The polarity of a mapping describes how changes in a display dimension signify changes in the data dimension. For example, in a positive polarity mapping, an increase in the data dimension (e.g., urgency) would be represented by an increase in the display dimension (e.g., tempo). If the tempo decreases with increasing urgency, then the respective mapping would be classified as a negative mapping. Walker [2] found that in some cases a majority of the listeners preferred a positive or negative polarity and in other cases the polarities were split within the data-to-display mappings. Siebenaler [1] and Walker and Lane [3] found differences between groups of visually impaired and sighted listeners. These two studies indicate that in some situations visually impaired and sighted listeners respond with similar polarities of data-to-display mappings, but in other cases different polarities result. Individual differences in the interpretation of auditory graphs were also found within the visually impaired population, demonstrating the importance of further inquiry into people with visual impairments. Neuhoff, Knight, and Wayand [4] found differences in listeners' perceptual and conceptual responses to pitch change. This study indicates that listeners with more musical experience scale frequency change differently from listeners with no musical experience. Neuhoff et al. [4] also found that greater musical expertise reduced the amount of errors in judging/labeling the direction of the pitch change.

These findings of a few select types of individual differences in interpreting auditory information have not been consistent or replicated. Walker and Mauney [5] look at a wider variety of individual differences and use a more systematic approach to their investigation. These researchers focused on cognitive abilities, musical abilities, and a variety of demographics (age, gender, handedness) in their study of individual differences in the auditory magnitude estimation task mentioned previously. Walker and Mauney [5] used exploratory statistics and found some support for cognitive abilities affecting the interpretation of auditory graphs. Listeners with better scores on certain cognitive abilities measures (working memory capacity and spatial reasoning) performed more consistently on the magnitude estimation task (R^2 values). However, the slope of the data-to-display mappings did not seem to be affected by cognitive abilities, musical abilities, and demographic variables. These results are sporadic and not entirely consistent, but are a starting point for a more thorough, systematic study of individual differences in auditory graph interpretation.

1.2. Task Analysis

Smith and Walker [6] performed a task analysis on determining the value of a specific data point on a basic auditory graph. According to Smith and Walker [6], this "point estimation" task consists of the following perceptual and cognitive subtasks:

> (1) listen to entire graph; (2) perform an interval division task to determine the part of the sound duration corresponding to the queried data point; (3) recall the pitches perceived both at the queried time and at the onset of the graph; (4) compare one pitch to the other and estimate the change in price represented by the difference…; and lastly, (5) recall the value of the initial data point, add or subtract the perceived change in price, and report the value. (p.8)

The first subtask discussed by Smith and Walker [6] is related to perceptual issues involved in hearing an auditory graph. The second subtask can be linked to spatial abilities in hearing and parsing the data set. The third subtask can be associated with both pitch discrimination and working memory capacity. The fourth subtask is also related to pitch discrimination. And lastly, the fifth subtask is connected to working memory capacity. By knowing what tasks are involved in interpreting an auditory graph, the Sonification Lab at Georgia Tech proposes a series of studies to approach various relationships between variables in a more systematic way. This investigation will be based on what is required to perform the task rather than "fishing" for correlations.

1.3. Proposed Studies

The aim of our (i.e., Sonification Lab) proposed plan of research is to gather a larger number of visually impaired and sighted participants and focus on the attributes of these different populations that may result in how they perceive the auditory graphs. We plan to attack this problem using these general approaches: (1) study the relationship between working memory capacity, spatial reasoning, tempo discrimination, and pitch discrimination; (2) study the predictive power of the above measures in the interpretation of auditory graphs; (3) study the predictive power of the above-mentioned measures of individual differences through the manipulation of different types of auditory graphs and cognitive abilities measures; (4) study the predictive power of musical abilities in the interpretation of auditory graphs; and (5) study how differences in mental models of individuals with congenital blindness versus those with late-onset blindness affect the interpretation of auditory graphs.

In Experiment 1, we hypothesize that (1) working memory and spatial reasoning will be correlated, and (2) a high working memory capacity and high spatial reasoning will predict performance for individuals with good pitch and tempo discrimination. Georgia Tech undergraduates will complete a computerized Operation Span task (O-span, a measure of working memory capacity), a computerized Raven's Progressive Matrices task (Raven's, a measure of spatial reasoning), a pitch discrimination task, a tempo discrimination task, Edinburgh Handedness test, and a series of musical abilities and demographics questions. Analyses will include correlations between the all of the variables and a multiple hierarchical regression analyses to see how the covariates (O-span, Raven's, handedness, musical abilities, demographics) predict performance on the dependent variables (tempo and pitch discrimination). Participants in Experiment 1 will then be called back to participate in Experiment 2, which involves the completion of an auditory point estimation task. For Experiment 2, we hypothesize that (1) good pitch and tempo discrimination will predict good performance on the auditory point estimation task, and (2) high working memory capacity and high spatial reasoning will predict good performance on the auditory point estimation task. The returning participants will complete an auditory point estimation task (see [6-8]) representing the changing stock market prices in a day of trading—participants will indicate the price of the stock at different times of the trading day. Performance in this task will be measured by Root Mean Squared (RMS) error (in dollars) and will be used as the dependent variable in a hierarchical regression analysis, where the covariates are the performance and demographic scores from Experiment 1 (O-span, Raven's, pitch and tempo discrimination, handedness, musical abilities, demographics).

If Experiment 1 and Experiment 2 show that O-span, Raven's, pitch discrimination, and tempo discrimination are highly correlated and are good measures of performance on an auditory point estimation task, then in Experiment 3 we will investigate how predictive these measures are on other auditory graphing tasks and new participants. In Experiment 3, we plan to investigate *auditory* measures of cognitive abilities tests as predictors of performance in sighted college students as well as blind/visually impaired listeners. Tasks that differ in the presentation of the data (i.e., discrete versus continuous data points) will also be explored, since we hypothesize that tempo discrimination will predict performance for auditory graphs that use discrete data points better than it will predict graphs that use continuous data points. Experiment 4 will investigate more comprehensive and thorough musical abilities tests to see if musical abilities do predict performance on auditory graphing tasks. Lastly, in Experiment 5, we hypothesize that, due to differences in mental models, (1) individuals who have late onset blindness will respond in a similar manner to sighted individuals in their performance on auditory graphing tasks, and (2) people with congenital blindness will respond in a different manner to sighted and late onset blindness individuals. Specifically, performance of blind/visually impaired participants will be compared to sighted participants, using at least one of the auditory graphing tasks that has been found to be a reliable and valid measure of auditory graph interpretation in the first four experiments. The differing levels of visual impairment and length of the impairment (i.e., congenital versus late-onset blindness) will be looked at specifically to determine if a more visual mental model has an impact on how a listener interprets an auditory graph.

Most, although not all, research to date has involved sighted undergraduates, which limits the generality of findings. The proposed plan of research would benefit from collecting data from additional populations--college students from different universities, members of the general community, people with visual impairments, and people from other countries and cultures. In order for research on individual differences in interpreting auditory graphs to be successful, collaboration amongst the auditory graphing community is essential.

2. CONCLUSIONS

Research, so far, in individual differences has shown the following: (1) differences between sighted and visually impaired listeners in auditory magnitude estimation tasks; (2) musicians and non-musicians differ in pitch change judgments; and (3) cognitive abilities seem to predict responses in auditory magnitude estimation tasks. However, more research in individual differences needs to be performed to confirm the above findings.

Smith and Walker [6] discuss a task analysis on what is required to make a judgment about an auditory graph. This task analysis shows the need to systematically study auditory perception, pitch discrimination, working memory capacity, and spatial reasoning. In accordance with the results of the task analysis, the author proposes a series of experiments that will study pitch and tempo discrimination, cognitive and musical abilities, and various demographics and their relationship with auditory graphs. The author proposes to use Georgia Tech undergraduates and people with visual impairments in this series of studies. However, collaboration with the auditory graphing community is urged, since a more diverse subject pool is critical for a thorough understanding of individual differences.

One practical implication of the proposed research is finding characteristics of listeners that predict how they interpret auditory information. We could gain knowledge of how to tailor or create auditory graphs specific for the user. Another practical implication of the proposed plan of research is gaining the ability to choose an operator more likely to interpret auditory graphs (e.g., multi-modal watch stations).

3. REFERENCES

[1] L. M. Siebenaler, "Magnitude Estimation of Sound Attributes Used in Auditory Displays: A Study of Blind and Visually Impaired Listeners." Atlanta, GA, Georgia Institute of Technology: Georgia Institute of Technology, 2002.

[2] B. N. Walker, "Magnitude estimation of conceptual data dimensions for use in sonification," *Journal of Experimental Psychology: Applied*, vol. 8, pp. 211-221, 2002.

[3] B. N. Walker and D. M. Lane, "Psychophysical scaling of sonification mappings: A comparison of visually impaired and sighted listeners," presented at Seventh International Conference on Auditory Display, Espoo, Finland, 2001.

[4] J. G. Neuhoff, R. Knight, and J. Wayand, "Pitch change, sonification, and musical expertise: Which way is up?" presented at Proceedings of the Eighth International Conference on Auditory Display, Kyoto, Japan, 2002.

[5] B. N. Walker and L. M. Mauney, "Individual Differences, Cognitive Abilities, and the Interpretation of Auditory Graphs," presented at Tenth International Conference on Auditory Display, Sydney, Australia, 2004.

[6] D. R. Smith and B. N. Walker, "Effects of Auditory Context Cues and Training on Performance of a Point Estimation Sonification Task," *Applied Cognitive Psychology,* in press.

[7] D. R. Smith and B. N. Walker, "Tick-marks, axes, and labels: The effects of adding context to auditory graphs," presented at Eighth International Conference on Auditory Display, Kyoto, Japan, 2002.

[8] D. R. Smith, "Effects of Training and Context on Human Performance in a Point Estimation Sonification Task," in *Psychology*, vol. Master of Science. Atlanta, GA: Georgia Institute of Technology, 2003, pp. 67.