Individual Differences and the Interpretation of Auditory Graphs: Cognitive Abilities and Demographics

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1 Abstract

Studied the relationship between cognitive abilities and interpretation of sonifications and auditory graphs. Listeners completed magnitude estimations relating sound dimensions to data dimensions. Multiple regression investigated utility of demographics, Raven's matrices, and n-back working memory task as predictors of auditory display interpretation. Raven's, gender, handedness, and musical ability were most effective predictors.

2 Introduction

Sonification and auditory graphs exploit the pattern recognition capabilities of human audition (Walker, 2002*a)*. However, there remain many unanswered questions in auditory display design, including the relationship between cognitive abilities, demographics, and the interpretation of sounds used to represent data. Previous research has found some differences between groups of individuals.

3 Research question

Does sex, handedness, age, musical experience, working memory, and spatial reasoning predict how listeners interpret what they hear.

4 Participants

- 160 undergraduates
- 93 males, 67 females
- Mean age 19.9 years, range 18-25

Demographics

Collected data on gender, age, handedness, and musical background.

5 Magnitude Estimation Task

Participants heard 10 sounds, one at a time, random order. Assigned a number for each sound that represented its size, number of dollars, temperature, velocity, pressure, danger, mass, urgency, proximity, or attractiveness. For example, "What 'Number of Dollars' does this sound seem to represent?" The three display (souund) dimensions were frequency, tempo, and spectral brightness. Details in Walker (2002a).

6 Cognitive Abilities Measures

Working Memory Task: n-back task (2-back).

Each block consisted of letters being presented rapidly one at a time on the computer screen. The participants were instructed to press the '1' key if the current letter was the same as the letter presented 2 letters before and '3' if the letter was not the same.

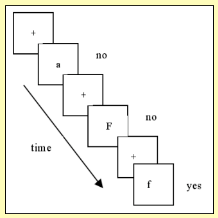

Figure 1. Example of 2-back task. The 'yes' or 'no' beside the different blocks indicates the correct response that should be made upon seeing the letter.

Spatial Reasoning Task: Raven's Progressive Matrices

A series of pictorial matrices were shown on the computer screen to participants. The participants had a choice of six or eight pieces that would fill in the missing part of the puzzle.

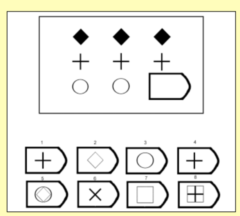

Figure 2. Sample Raven's Matrix. One of the bottom eight pieces is the correct pattern to complete the top matrix.

7 Results: Slope and R-squared Analyses

For each participant, in each block of trials (i.e., each combination of display and data variables) we calculated the slope and R-squared value for the magnitude estimation plot (see Figures 3 and 4). Slope indicates how much change in the data dimension (e.g., temperature) is indicated by a given change in the display dimension (e.g., pitch). Slopes were classified as being 'positive' or 'negative' ($r_{critical}$=|0.444|, p<0.05, 18 d.f.). See Figures 3 and 4, respectively. Slopes that were not statistically different from zero were classified as 'no' polarity. In general, the slopes and R-squared values for the different data and display dimensions fell in line with previous studies (Walker, 2002a, 2002b).

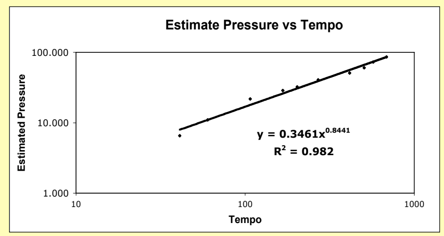

Figure 3. Sample magnitude estimation plot for tempo and estimated pressure. Note that the slope is positive and R-squared is relatively high.

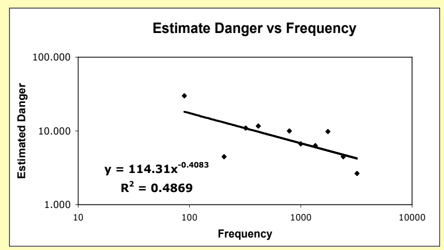

Figure 4. Sample magnitude estimation plot for frequency and estimated danger. Note that the slope is negative and R-squared is relatively low.

8 Results: Multiple Regression Analyses

Stepwise multiple regression was performed with cognitive abilities and demographics as predictors of slope and R-squared values from the magnitude estimation.

There was some support for several of the predictors; prediction was better for R-squared values than for slopes. Raven's and gender seem to be good predictors of auditory graph interpretation, though not universally effective. Handedness and musical ability had sporadic effectiveness. The 2-back was not a good predictor of auditory graph interpretation.

9 Conclusions

R-squared values, but not individual slopes, are good dependent variables to consider when designing auditory graphs. Raven's matrices, gender, handedness, and musical ability were most effective predictors of auditory graph interpretation. To be an effective predictor, working memory may need to be assessed via O-span or R-span, rather than n-back.

10 Future work

- Other cognitive abilities measures (e.g., Operation Span, Reading Span)
- Perceptual abilities measures (e.g., pitch discrimination, tempo discrimination)
- Different auditory graph interpretation tasks (e.g., point estimation)

References

Walker, B.N. (2002a). Magnitude estimation of conceptual data dimensions for use in sonification. *Journal of Experimental Psychology: Applied*, 8, 211-221.

Walker, B.N. (2002b). Magnitude estimation of sound attributes for sonification, a study involving sighted college students. Unpublished data, Georgia Tech, Atlanta, GA.