A System for Psychometric Testing of Auditory Representations of Scientific Data

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Abstract

This chapter describes a computing environment with which an investigator can interactively design and test an auditory data display. We describe the components of our system and how they are used, and we give some preliminary results from psychometric tests of a "granular" sound data representation. We also present some general observations on auditory data representation based on our experiences in developing and using the system.

1 Introduction

The principal aims of the work reported here were (1) to create an interactive computing environment that allows the development and evaluation of auditory representations of multidimensional data, (2) to develop several different auditory data representations and (3) to evaluate one of the auditory data representations using the interactive environment. With the computing environment described here, an investigator can interactively design an auditory display, choose the sound parameters to be tested and set their ranges, select the type of psychometric experiment to be performed, and set the number and order of trials the subjects are to complete. The administration of the experiments, monitoring of subjects' progress through the prescribed sequence of trials, and the storage of experimental data are all automated.

The system currently provides two different families of sounds for experimentation. The first is a relatively complex "granular" sound that provides ten data-controllable parameters, and the second is a generic drum sound that provides only three data-controllable parameters. These two sound families allow a wide variety of different auditory representations of the same data.

In this chapter we describe the components of our system and how they are used, and we discuss some psychometric experiments performed with the system. We also present some more general observations we have made in the course of developing and using the system.

Config Number	Signal (octaves)	Step (octaves)	Sounds/ Stimulus	Waveform ROC		Half Window ROC	
1	0.141	0.005	1	0	0	0	0
4	0.131	0.005	5	0	0	0	0
3	0.297	0.008	1	0	0	0.83	0
6	0.225	0.008	5	0	0	0.83	0
21	0.297	0.008	1	0	0	0	1
24	0.297	0.008	5	0	0	0	1
12	0.117	0.004	1	1	0	0	0
15	0.097	0.004	5	1	0	0	0
30	0.117	0.004	1	0	1	0	0
33	0.117	0.004	5	0	1	0	0

Table 1: Initial levels for signal and step size.

the distracting frequency-dependent amplitude modulation effects which result from equispaced grains.

The experiments employed a three-alternative, forced-choice, up/down method. In each trial, subjects were presented with three successive stimuli (either one cloud or five clouds per stimulus, depending on the experiment) and asked to indicate which stimulus was "higher" than the other two (what we meant by "higher" was demonstrated in a training session). Each time the subject gave two consecutive correct responses, the center frequency of the signal stimulus was reduced by a fixed step size, and each time the subject gave an incorrect response, the center frequency of the signal stimulus was raised by the same fixed step size. This procedure continued for a total of seven runs, where a run begins with an incorrect response and ends with the first occurrence of two correct responses. The estimate of the 70%-correct response level was then computed by taking for each run the geometric mean of the center frequency at the beginning and at the end of each run and then averaging these values.

In the experiments, both the initial level of the signal stimulus and the size of the increment/decrement step were specified in terms of octaves, and both had values chosen individually for each of the conditions enumerated above based on informal trials prior to the actual experiments. The center frequency of reference clouds had a mean of 800 Hz. and a standard deviation of 0.02 octaves. The center frequency of the signal clouds was initially set a fraction of an octave above that of the reference clouds and incremented or decremented by a fraction of an octave depending on the subject's responses. Table 1 summarizes the initial signal levels and step sizes. All clouds, both signal and reference, had a duration of 175 ms. The three stimuli presented during each trial were separated by an interval of 333 ms. The individual clouds in a five-cloud stimulus were separated by an interval of 15 ms.

Subjects listened to the stimuli over stereo headphones with the volume set to a comfortable level. The experiment-administration software allowed subjects to take a break after completing all seven runs of an experimental element or to stop for the day if they wished. The system kept a record of each subject's progress through the prescribed sequence of experiments and automatically began testing at the proper point the next time the subject logged in. The experiments were performed by nine student subjects, who were paid $30 for completing the full set of experiments, and the authors.

The following sections summarize the results of the experiments. The results are shown in Table 2 and Table 3, and are graphically rendered in Figure 2.

Config	Count	μ (octaves)	μ (hz)	σ (octaves)	Parameter tested
1	36	0.051289	828.95	0.014773	clean
4	36	0.028928	816.20	0.009665	clean
3	9	0.203889	921.44	0.031364	Half Window
6	9	0.111815	864.47	0.038563	Half Window
21	9	0.209741	925.18	0.036121	Half Window ROC
24	9	0.113963	865.76	0.038007	Half Window ROC
12	9	0.050111	828.28	0.010514	Waveform
15	9	0.028593	816.01	0.010154	Waveform
30	9	0.052778	829.81	0.011228	Waveform ROC
33	9	0.032555	818.26	0.014990	Waveform ROC

Table 2: Summary of results by configuration.

Subject	Configuration 1			Configuration 4		
number	μ (octaves)	μ (hz)	σ (octaves)	μ (octaves)	μ (hz)	σ (octaves)
67	0.045479	825.62	0.005799	0.021417	811.96	0.005129
70	0.059229	833.53	0.006363	0.042250	823.77	0.010030
74	0.069229	839.32	0.022784	0.031625	817.73	0.003756
75	0.046000	825.92	0.005796	0.022042	812.32	0.003492
78	0.040583	822.82	0.008106	0.027041	815.14	0.008071
79	0.038500	821.64	0.011129	0.019959	811.14	0.005158
80	0.061104	834.61	0.014091	0.038500	821.64	0.001215
82	0.047458	826.75	0.004295	0.028813	816.14	0.009512
83	0.054021	830.52	0.009351	0.028709	816.08	0.006281

Table 3: Summary of subject results for repeated configurations.

4.1 Clouds with Sinewave Grains and 0-Width Frequency Half-Window

Configurations 1 (one cloud per stimulus) and 4 (five clouds per stimulus) presented a "clean" granular sound consisting entirely of sinewave grains at a single frequency. These configurations were administered to each subject four times. As shown in Table 3, the average thresholds for the nine student subjects were approximately 0.05 octave for the one-cloud stimulus and approximately 0.03 octave for the five-cloud stimulus. Both of these are substantially less than a musical semitone (0.083 octave). Table 3 shows the performance of all nine subjects on Configurations 1 and 4. Of particular interest are the standard deviations, σ. These values are all in the range of a few thousandths of an octave.

4.2 Clouds with Band-Limited Pulse Grains

Configurations 12 (one cloud per stimulus) and 15 (five clouds per stimulus) presented clouds made of grains whose waveform was the band-limited pulse described above. As can be seen in Table 2 and Figure 2, the observed thresholds are essentially the same as for the sinewave cases, Configurations 1 and 4. Evidently using a more complex waveform neither hinders nor improves the subjects' ability to discriminate the relative heights of the stimuli.