The Effects of Reverberation Time and Amount on the Emotional Characteristics

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ABSTRACT

Though previous research has shown the effects of reverberation on clarity, spaciousness, and other perceptual aspects of music, it is still largely unknown to what extent reverberation influences the emotional characteristics of musical instrument sounds. This paper investigates the effect the effect of reverberation length and amount by conducting a listening test to compare the effect of reverberation on the emotional characteristics of eight instrument sounds over eight emotional categories. We found that reverberation length and amount had a strongly significant effect on Romantic and Mysterious, and a medium effect on Sad, Scary, and Heroic. Interestingly, for Comic, reverberation length and amount had the opposite effect, that is, anechoic tones were judged most Comic.

1. INTRODUCTION

Previous research has shown that musical instrument sounds have strong and distinctive emotional characteristics [1, 2, 3, 4, 5]. For example, that the trumpet is happier in character than the horn, even in isolated sounds apart from musical context. In light of this, one might wonder what effect reverberation has on the character of music emotion. This leads to a host of follow-up questions: Do all emotional characteristics become stronger with more reverberation? Or, are some emotional characteristics affected more and others less (e.g., positive emotional characteristics more, negative less)? In particular, what are the effects of reverberation time and amount? What are the effects of hall size and listener position? Which instruments sound emotionally stronger to listeners in the front or back of small and large halls? Are dry sounds without reverberation emotionally dry as well, or, do they have distinctive emotional characteristics?

2. BACKGROUND

2.1 Music Emotion and Timbre

Researchers have considered music emotion and timbre together in a number of studies, which are well-summarized in [5].

2.2 Reverberation

2.2.1 Artificial Reverberation Models

Various models have been suggested for reverberation using different methods to simulate the build-up and decay of reflections in a hall such as simple reverberation algorithms using several feedback delays [6], simulating the time and frequency response of a hall [7, 8, 9, 10], and convolving the impulse response of the space with the audio signal to be reverberated [11, 12]. They can be characterize by Reverberation time (RT_{60}) which measures the time reverberation takes to decay by 60dB SPL from an initial impulse [13].

2.2.2 Reverberation and Music Emotion

Västfjäll et al. [14] found that long reverberation times were perceived as most unpleasant. Tajadura-Jiménez et al. [15] suggested that smaller rooms were considered more pleasant, calmer, and safer than big rooms, although these differences seemed to disappear for threatening sound sources. However, it is still largely unknown to what extent reverberation influences the emotional characteristics of musical instrument sounds.

3. METHODOLOGY

3.1 Overview

To address the questions raised in Section 1, we conducted a listening test to investigate the effect of reverberation on the emotional characteristics of individual instrument sounds. We tested eight sustained musical instruments including bassoon (bs), clarinet (cl), flute (fl), horn (hn), oboe (ob), saxophone (sx), trumpet (tp), and violin (vn). The original anechoic sounds were obtained from the *University of Iowa Musical Instrument Samples* [16]. They had fundamental frequencies close to Eb4 (311.1 Hz), and were analyzed using a phase-vocoder algorithm [17]. We resynthesized the sounds by additive sinewave synthesis at exactly 311.1 Hz, and equalized the total duration to 1.0s. Loudness of the sounds were also equalized by manual adjustment.

We compared the anechoic sounds with reverberation lengths of 1s and 2s. The reverberation generator provided by *Cool Edit* [18] was used in our study. Its “Concert Hall Light” preset is a reasonably natural sounding reverberation. This preset uses 80% for the amount of reverberation corresponding to the back of the hall, and we approximated the front of the hall with 20%. Thus, in addition to the anechoic sounds, there were four reverberated sounds for each instrument.

34 subjects without hearing problems were hired to take the listening test. All subjects were fluent in English. They compared the stimuli in paired comparisons for eight emotional categories: Happy, Sad, Heroic, Scary, Comic, Shy, Romantic, and Mysterious. Some choices of emotional characteristics are fairly universal and occur in many previous studies roughly corresponding to the four quadrants of the Valence-Arousal plane [19]. In the listening test, every subject heard paired comparisons of all five types of reverberation for each instrument and emotional category. During each trial, subjects heard a pair of sounds from the same instrument with different types of reverberation and were prompted to choose which more strongly aroused a given emotional category. Each permutation of two different reverberation types were presented, and the listening test totaled $P_2^5 \times 8 \times 8 = 800$ trials. For each instrument, the overall trial presentation order was randomized (i.e., all the bassoon comparisons were first in a random order, then all the clarinet comparisons second, etc.). The listening test took about 2 hours, with breaks every 30 minutes.

4. LISTENING TEST RESULTS

We ranked the tones by the number of positive votes they received for each instrument and emotional category, and derived scale values using the Bradley-Terry-Luce (BTL) statistical model [21, 22]. The BTL value is the probability that listeners will choose that reverberation type when considering a certain instrument and emotional category. For each graph, the BTL scale values for the five tones sum up to 1. Therefore, if all five reverb types were judged equally happy, the BTL scale values would be 1/5 = 0.2.

Figures 1 to 5 show BTL scale values and the corresponding 95% confidence intervals for each emotional category and instrument. Based on Figures 1 - 5, Table 1 shows the number of times each reverb type was significantly greater than the other four reverb types (i.e., where the bottom of its 95% confidence interval was greater than the top of their 95% confidence interval) over the eight instruments. Table 1 shows the maximum value for each emotional category in bold in a shaded box (except for Shy since all its values are zero or near-zero).

Table 1 shows that for the emotional category Happy, Small Hall had most of the significant rankings. This result agrees with that found by Tajadura-Jiménez [15], who found that smaller rooms were most pleasant. The result also agrees with Västfjäll [14], who found that larger reverberation times were more unpleasant than shorter ones. However, for Heroic, our finding was in contrast to that found by Västfjäll and Tajadura-Jiménez. As Heroic is also high-Valence, they would have predicted that Heroic would have had a similar result as Happy. Though Large Hall Back was ranked significantly greater more often than all the other options combined.

Table 1 also shows that Anechoic was the most Comic, while Large Hall Back was the least Comic. This basically agrees with Västfjäll [14] and Tajadura-Jiménez [15].

Large Hall Back was the most Sad in Table 1 (though Small Hall Back and Large Hall Front were not far behind). Large Hall Back was more decisively on top for Scary. Since Sad and Scary are both low-Valence, these results agree with Västfjäll [14] and Tajadura-Jiménez [15] who found that larger reverberation times and larger rooms were more unpleasant. Reverb had very little effect on Shy in Table 1.

The Romantic rankings in Figure 5 were more widely spaced than the other categories, and Table 1 indicates that Large Hall Back was significantly more Romantic than most other reverb types. Like Heroic, this result is in contrast to the results of Västfjäll [14] and Tajadura-Jiménez [15] since Romantic is high-Valence. The bassoon for Romantic was the most strongly affected among all instruments and emotional categories. Similar to Romantic, the Mysterious rankings were also widely spaced.

In summary, our results show distinctive differences between the high-Valence emotional categories Happy, Heroic, Comic, and Romantic. In this respect, our results contrast with the results of Västfjäll [14] and Tajadura-Jiménez [15].

5. DISCUSSION

Based on Table 1, our main findings are the following:

1. Reverberation had a strongly significant effect on Mysterious and Romantic for Large Hall Back.
2. Reverberation had a medium effect on Sad, Scary, and Heroic for Large Hall Back.
3. Reverberation had a mild effect on Happy for Small Hall Front.
4. Reverberation had relatively little effect on Shy.
5. Reverberation had an opposite effect on Comic, with listeners judging anechoic sounds most Comic.

Table 1 shows very different results for the high-Valence emotional categories Happy, Heroic, Comic, and Romantic. The results of Västfjäll [14] and Tajadura-Jiménez [15] suggested that all these emotional characteristics would be stronger in smaller rooms. Only Happy and Comic were stronger for Small Hall or Anechoic, while Heroic and Romantic were stronger for Large Hall. The above results give audio engineers and musicians an interesting perspective on simple parametric artificial reverberation.

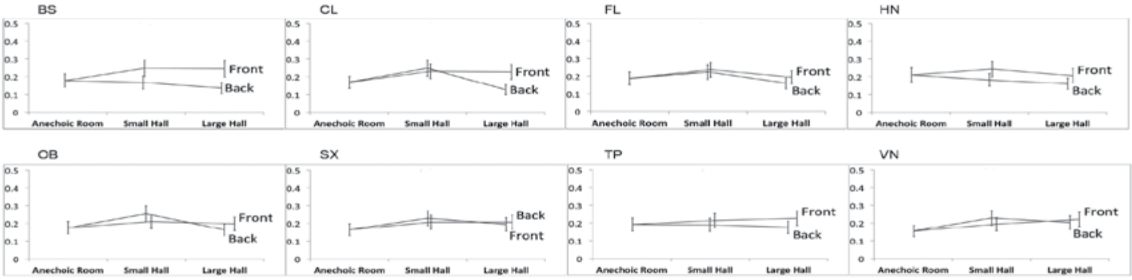

Figure 1. BTL scale values and the corresponding 95% confidence intervals for the emotional category Happy.

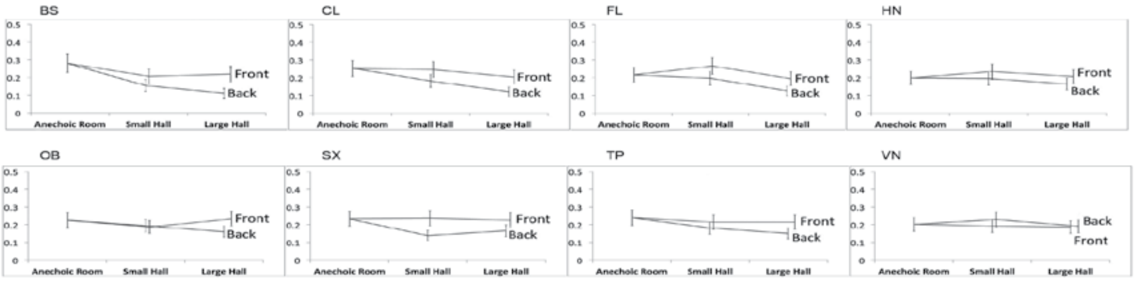

Figure 2. BTL scale values and the corresponding 95% confidence intervals for Comic.

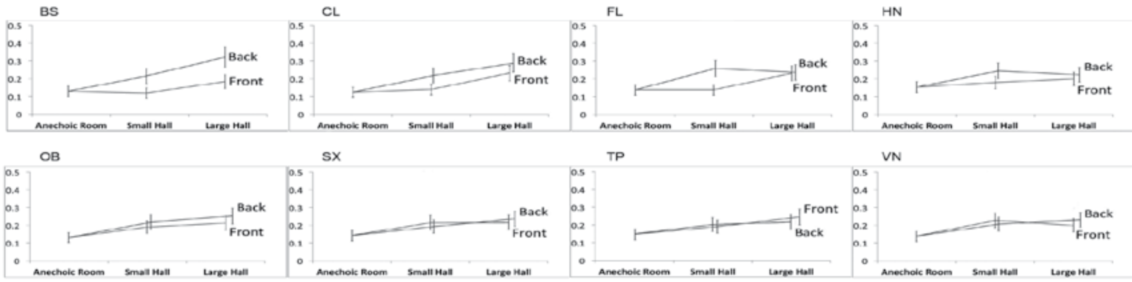

Figure 3. BTL scale values and the corresponding 95% confidence intervals for Sad.

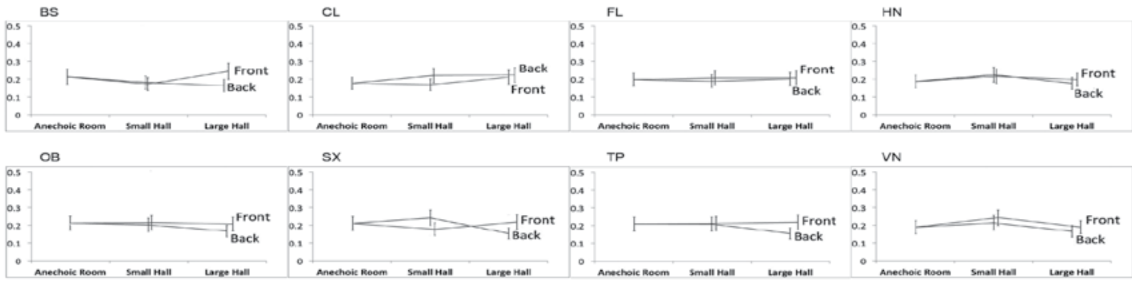

Figure 4. BTL scale values and the corresponding 95% confidence intervals for Shy.

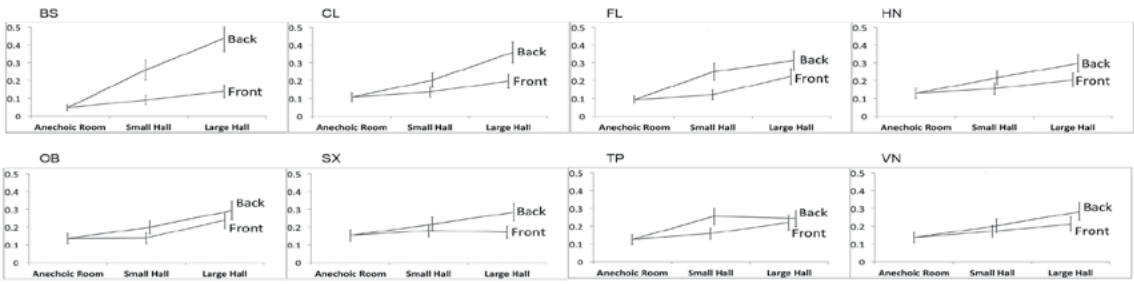

Figure 5. BTL scale values and the corresponding 95% confidence intervals for Romantic.

Emotion Category \ Reverb Type	Anechoic	Small Hall Front	Small Hall Back	Large Hall Front	Large Hall Back
Happy	0	**4**	3	2	0
Heroic	0	0	3	2	**7**
Comic	**6**	4	1	4	0
Sad	0	2	9	7	**11**
Scary	0	1	5	4	**11**
Shy	0	0	1	0	0
Romantic	0	1	9	9	**23**
Mysterious	0	1	12	7	**29**

Table 1. How often each reverb type was statistically significantly greater than the others over the eight instruments.

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