Audio Engineering Society

Convention Paper 8843

Presented at the 134th Convention
2013 May 4–7 Rome, Italy

Balance Preference Testing Utilizing a System of Variable Acoustic Condition

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ABSTRACT

In the modern world of audio production, there exists a significant disconnect between the music mixing control room of the audio professional and the listening space of the consumer, or end user. The goal of this research is to evaluate a selection of acoustic treatments commonly used in such listening environments. Expert listeners are asked to perform basic balancing tasks, under varying acoustic conditions. The listener can remain in position while motorized panels rotate behind a screen, exposing a different acoustic condition for each trial. Results show that listener fatigue as a variable is thereby eliminated, and the subjects aural memory is quickly cleared, so that the subject is unable to adapt to the newly presented condition for each trial.

1. INTRODUCTION

Over the past few years, interactive testing has been performed utilizing expert listeners, in an investigation into the optimal acoustic condition regarding small listening environments, specifically used for music production. Ultimately, the research investigates how trained mixing engineers perform when asked to carry out one of their normal tasks under varying acoustic treatments. Previous testing has been met with mixed results, as several varying conditions were compared. In previous studies, the subjects were asked to leave the room while the acoustic treatment on the side walls was modified between each block of trials, resulting in a delay of approximately three to five minutes between each trial block. It was well documented that the particular treatment presented during the third trial block was met with fatigue and in some cases apathy, as the subjects became tired or simply bored with the testing procedure. The recent introduction of the motorized panel system [1] allows for immediate comparison of up to three different wall surface treatments in one sitting.

Based on research the authors originally presented at the 129$^{\text{th}}$ Convention of the Audio Engineering Society [2], and in more detail in the *Journal of the Audio Engineering Society* [3], this paper investigates the effect of lateral reflections on the listener as they perform a simple task common to their daily work as mixing engineers. There is evidence in the literature showing that *in situ* [4] testing of this type will yield more meaningful results than more traditional methodology as seen in [5].

1.1. Motivation

To study the effects of rapidly changing amounts and characteristics of lateral reflections on the listener in a control room environment. As this is a preliminary test run of the motorized panel system, the choice of acoustic treatments is identical to previous investigations, and the musical excerpts were also the same. In this way, some comparisons could be made to baseline measurements obtained in the authors' earlier studies [2], [3]. The variance of the balancing task under these changing acoustic conditions could be quantified without the variable of the listener adapting to the environment. The notion of listener adaptation has proven to be underrated, as shown in [6], and therefore must be removed as a variable in order for this type of testing to show definitive results. As testing progresses, the study will incorporate more complex methodologies (involving variations in ceiling reflections, for example), with more subjects, and the inclusion of other musical genres of source audio. Very basic surface conditions with extreme variation in absorption coefficients and diffusion patterns were implemented in order eventuate the effect for the acoustic conditions.

1.2. Historical Context

In *Sound Reproduction*, F. E. Toole concludes that while a listener can normally adapt to reflections in a room, they can also clearly distinguish between acoustic comb filtering in a listening room, caused by differences of arrival between the direct and reflected sound, from the direct sound itself [6]. However, when the comb filtering is integrated with the direct signal (*i.e.* combined electronically), and produced together from the loudspeaker, the ability to discern the two components is greatly reduced. The motivation for this research stems from Toole's research in the changes on perceptual cues of sources when reflected energy is introduced [3]. Acoustic modifications to direct sounds (such as reflections) are often considered to have a positive impact on overall sonic presentation, especially in music reproduction. Moreover, anechoic listening has been described as "not particularly pleasant" and "unnatural" [7]. Reflections, and more specifically early reflections, can add power to direct sound and are important cues to shape timbre and spaciousness [8], [9]. A sense of spaciousness provided by the reflections is particularly dependent upon the frequency response of the reflected sound [10], again indicating the unique importance of spectral quality of early reflections. Similarly, early reflections have been shown to contribute to smoothing of comb filtering caused by inter-aural crosstalk in stereo loudspeaker playback situations [11].

Based on these findings, a general consensus exists that because of such robust listener adaptation to variations in acoustic environments, there is not a necessarily strong need to reduce reflections when designing control rooms for music mixing. Previous research by the authors focused on variances in mixing tasks by balance engineers over time [2]. Established as a baseline for future testing, the data set shows initial results of exceptionally low variance in consistency of mixing level over multiple trials, typically consistent with the subjects experience level. The average standard deviation for these mixing levels within one subject was 1.50 dB for classical music, 1.73 dB for jazz music, and 0.97 dB for rock music. The most consistent results belonged to the subjects with significant experience in their respective field (6+ years), performing as well as 0.45 dB. This data can now exist as a baseline to examine how acoustic treatments assist or hinder balance engineers, and their consistency in mixing level. For this study, wider variance would suggest the chosen acoustic modification is providing a more negative condition for the subject, hindering consistency across the multiple trials.

With the implementation of the motorized panels, the variable of adaptation is removed; the acoustic treatment has an immediate affect on the listener, as a new side wall surface is presented with each new trial throughout the performance of the balancing task described below.

2. TEST DESIGN

As this study continues previous investigations of the effects of lateral energy in critical listening environments, the focus lies directly on the practicing audio engineer within a typical working environment. This requires that testing occur in a high quality critical listening environment familiar to audio professionals, in order to maintain coherence with practical tasks. Likewise, the testing material employed will be musical in nature and of the highest quality.

Consistent with the standard professional audio production work environment, subjects were directed to create a balance between a stereo orchestral track and a soprano soloist. Both elements were premixed with using the appropriate processing and volume automation to allow for a static balance to be set without persistent adjustment of the soloist. Three 30-second excerpts were used for testing, all taken from a commercial classical release of songs by Richard Strauss. The original balance engineers mix level was used as a reference, henceforth referred to as "0 dB".

Subjects were directed to control the level of the soloist stem in relation to the preset level of the orchestral stem through the use of an unmarked, continuously variable rotary encoder. The solo track's starting level was set to -20 dB, randomized ± 1.5 dB. A resolution 0.5 dB was used, allowing for relatively precise refinement of a chosen balance. Each excerpt was automatically looped up to four times per trial (if necessary), allowing subjects the ability to confirm their choice of level at any point during their trial. A total of 24 trials were conducted per subject. A custom software system is used to control playback, acoustic condition, level adjustment, data capture as well as visual prompting.

Acoustic conditions were made variable via the use of rotating triangular frames with various acoustic treatment material on each of the three sides (Figure 1). Four panels, aligned to form sidewalls to the subject's immediate left and right, provided for immediate changes in lateral energy when rotated. These baffles were mounted on motors controlled by

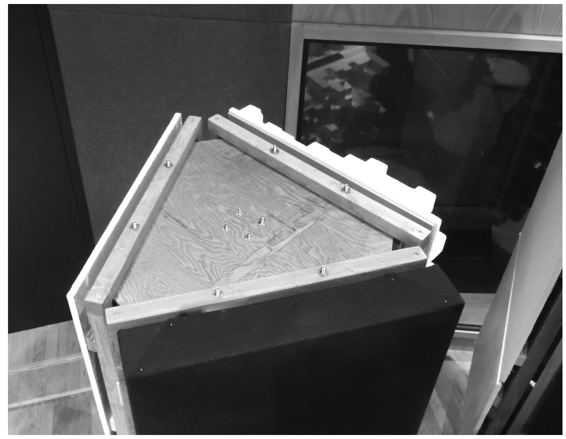

Fig. 1: One of the acoustic rotators with acoustic treatment mounted. The absorptive treatment is exposed to the subject, with diffusive treatment on the right side and reflective drywall on the left side.

the testing software, enabling variability in acoustic conditions between trials with less than ten seconds of idle time for changeover. During the trial set, acoustic conditions were varied randomly by the testing software. The sidewall variations were obscured from immediate view through the use of an acoustically transparent screen. The silent alteration of acoustic conditions, paired with careful lighting and visual shielding, ensured a truly "blind" test.

The testing was conducted in a small, well-isolated control room located at the Schulich School of Music designed for critical mixing and mastering applications, as well as technical ear training. The unaltered room displayed a relatively broadband RT60 of approximately 200 ms, and a flat frequency response (± 3 dB from 20 Hz to 18 kHz) when utilizing a professional full range loudspeaker reproduction system.

2.1. Acoustic Alterations

The rotating baffles described above provided a five foot by five foot (1.52 m^2) area for acoustical alteration immediately to either side of the subject. To maintain continuity with previous work, three treatments were chosen for this study. The first of the three treatments was a rock wool absorber module, six inches (15.25 cm) in thickness built into a wooden frame and covered with acoustic fabric, aimed to-

Fig. 2: Acoustical treatment position in relation to the subject and loudspeakers without the screen for obscuring current treatment. The picture shows the rotators in motion, changing between the diffusive and absorptive conditions.

wards absorption of low-mid frequencies. The second treatment option was a two-dimensional primitive root diffusor, with varying depths up to nine inches (22.9 cm), formed from polystyrene. The third treatment material was triple-painted half-inch (1.27 cm) drywall/gypsum board, aimed at providing increased reflectivity in the listening environment and offers contextual application to standard construction practices.

The acoustic alteration caused by the exposed treatment was primarily evident in the room's energy decay (Figure 3). As anticipated, the early energy present with the drywall exposed to the subject showed a higher initial energy level across the mid and high frequency range. The diffusive treatment showed a significantly lower energy level, with the absorptive treatment showing the lowest early energy return.

Lateral energy return for both the diffuse and drywall conditions was markedly higher than the testing environment without the additional treatment. The size of the acoustic rotators made optimization of lateral energy difficult, however. Unlike previous studies (*e.g.* [3]), the lateral fraction was not markedly increased in reflective and semi-reflective states. Nonetheless, almost all subjects reported an audible difference between room conditions.

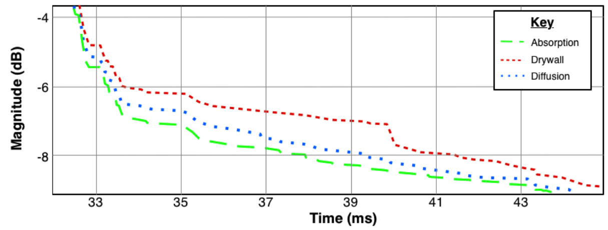

Fig. 3: Energy decay curve for the testing environment for each treatment type exposed to the subject. The reflective drywall treatment shows a significantly higher energy level for the first 10ms of decay time.

2.2. Subject Pool

Subjects for this test were members of McGill University's graduate program in Sound Recording. The individuals ranged in age from 22 to 45 years old, including both males and females. Each subject averaged over 10 years of formal musical training, and at least 5 years of music production experience, split evenly between the classical/jazz and pop/rock genres.

3. RESULTS

The results from this testing are not clearly definitive. While no factors were shown to be significant at a level of p=.05, two factors just missed this significance threshold. Although the mean level was not profoundly affected by acoustical condition (maximum mean difference of 0.8 dB), acoustical condition was shown to be significant factor for in the overall variance of level (p=.052) (Figure 4).

The other significant factor in evaluation of level data is the musical excerpt. Musical excerpt was significant at a level of p=.058. Likewise, there was a strong influence of excerpt on the overall variance of levels set. Excerpt two showed a markedly narrower variance across almost all subjects (Figure 5).

3.1. Elapsed Time Results

Examination of the time per trial data collected was less conclusive. There were no significant differences in mean or variance between either of the the primary factors acoustic treatment or musical excerpt.

4. ANALYSIS & DISCUSSION

The results gathered from this cursory study provide

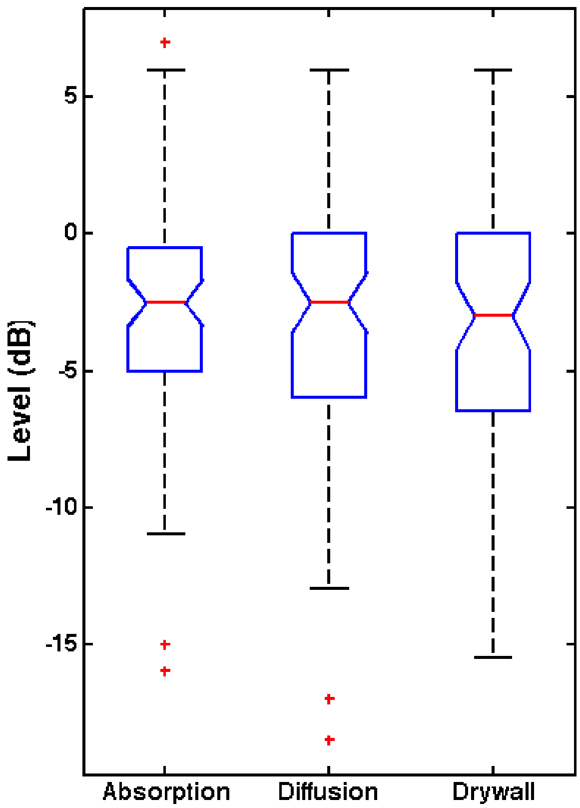

Fig. 4: Boxplot showing the effect of the acoustic condition on the level set by subjects, summed across all subjects.

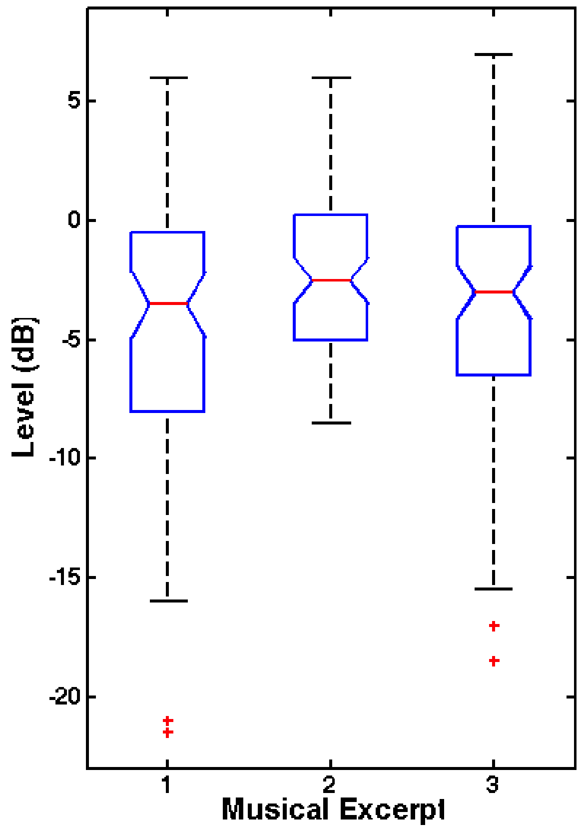

Fig. 5: Boxplot showing the effect of musical excerpt on levels set. While the levels themselves were not significant at p=.05, the range of variance between excerpt 2 and the other excerpts was significantly different.

some interesting insight into possible effects related to acoustic treatment and lateral reflections in critical listening spaces. The ability to rapidly present new acoustic conditions to listeners seems to bring out the true effect of the treatment while minimizing subject adaptation to the new acoustic environment. The variance of levels set under the absorptive acoustical condition indicated that there may be, infact, some benefit in consistency in regards to a particular type of acoustic treatment. While the results of this test cannot be directly compared to those of [3] (due to decreased lateral energy present in the current study), the minimization of adaptation has already led to increased significance in test results. The number of participants in the current study does not allow for the statistical power desired by the authors, but these preliminarily positive results are encouraging.

As this was a pilot study, the main objective of testing was to refine and enhance the testing procedure with the new rotator system in order to streamline and optimize future work. It is the authors' opinion that the single greatest issue with the current methodology is one of musical excerpts. The profound effect of musical excerpt on levels set must be eliminated to ensure that the primary dependent variables (level set and time per trial, as well as the variance thereof) are not altered by suppressor variables.

A second issue for consideration is the environment in which testing is conducted. The current testing room, while providing an ideal *in situ* environment, may be too small to accommodate the new rotator system. The rotational depth of the units necessitates placing the acoustic treatment unnaturally close to the listener, possibly negating the emulation of a normal critical listening space.

4.1. Future Work

There is no shortage of testing possibilities to be explored in the future. The first opportunity for further testing may be to somewhat abandon the true *in situ* conditions in this and previous studies to isolate only the acoustic effect of the treatments under test. Conducting similar testing in a primarily absorptive environment (approaching that of an anechoic chamber) may allow for specific examination of each treatment in isolation, rather than in combination with the room's natural acoustics.

Further testing will also employ a greater area of acoustic treatment. Ideally, a total of 48 ft^2 (14.6 m^2) of acoustic treatment would be used. Additionally, the placement of treatment will also be altered to include rear wall reflections. Lastly, additional treatments will be employed which have altered diffusion patterns and absorption coefficients.

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