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Listener Adaptation in the Control Room: The effect of varying acoustics on listener familiarization

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ABSTRACT

The area of auditory adaptation is of central importance to a recording engineer operating in new or less-than-ideal acoustic conditions. This study prompts expert listeners to perform a controlled level-balancing task while exposed to three different acoustic conditions. The length of exposure is varied to test the role of adaptation on such a task. Results show that there is a significant difference in the variance of participants' results when exposed to a condition for a longer period of time. In particular, subjects seem to most easily adapt to reflective acoustic conditions.

1. INTRODUCTION

Researchers have long acknowledged the ability of the human auditory system to adapt to new conditions. This work on perceptual plasticity has, in fact, become a central concept in modern psychoacoustics, particularly in the area of speech recognition, neuroscience and speech pathology [1, 2, 3, 4]. While the literature frequently deals with the topic of adaptation and auditory plasticity in abstract terms, there remains a tendency to overlook adaptation in music-centric research. In particular, short-term adaptation is often neglected when discussing the acoustic properties of critical listening environments.

1.1. Historical Context

Some music-centric researchers (Toole, Olive, etc.), however, present work that suggests the effects of adaptation can hardly be discounted [5, 6]. In fact, Toole states that a home theater's acoustic deficiencies can be easily overcome by even the novice listener [5]. How then, might trained listeners adapt to altered or non-ideal acoustics? While this question relates to today's shrinking production budgets and the popularity of the acoustically substandard project studio, little work has been done to examine the ability of trained listeners to adapt to new acoustic environments. A second question also arises - how does the mixing engineer keep a check list of the room's deficiencies in mind, if adaptation has occurred, and the artifacts of the untreated "mix room" have been subconsciously taken into account?

1.2. Motivation

The previous work of the authors has shown that trained recording engineers seem to be able to adapt and "listen through the room" when placed in new acoustic environments. This is certainly true where early reflections are concerned, specifically lateral reflections from the sidewalls of the room [7]. In these previous tests, expert subjects were asked to perform a basic mixing task, balancing a solo element or voice with a static backing track. The acoustic treatment in the room was manually altered between each trial block, alternating between reflective, diffusive and absorptive side wall panels. This allowed the subject a good deal time to adjust and adapt to the acoustical change for each trial block. When examined, the test results were similar for all acoustic treatments. Some more experienced subjects showed a variance of less than 1 dB across all acoustic conditions. This new study builds on previous work by presenting subjects with shorter periods of exposure to differing acoustic conditions, thereby allowing for further analysis of the time required for adaptation.

2. TEST METHODOLOGY

Testing was conducted with the same *in situ* manner as previous work [7, 8]. Subjects were instructed to level balance a soloist against a stereo backing track for three musical excerpts, taken from three different genres of music: pop, jazz, and classical. All elements were premixed by the same engineer, 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 commercial releases. The original balance engineer's mix level was used as a reference, henceforth referred to as "0 dB".

Subjects were instructed to adjust the level of the solo element in relation to the preset level of the backing element through the use of an unmarked, continuously variable rotary encoder. The starting level of the solo track was set to -20 dB, randomized ± 1.5 dB. A resolution of 0.5 dB was set, allowing for relatively precise refinement of a chosen balance if desired. Each excerpt was automatically repeated up to four times per trial (if no confirmation action was taken), 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 was used to control playback, acoustic condition, level adjustment, data capture as well as visual prompting.

Acoustic conditions were varied through the use of rotating triangular frames with various acoustic treatment materials on each of the three sides (Figure 1), as presented in [8]. Six panels, aligned to form sidewalls to the subjects immediate left and right, provided for immediate changes in lateral energy when rotated. These baffles were mounted on motors controlled by the testing software, enabling variability and randomization in acoustic conditions between trials with less than eight seconds of idle time for changeover. 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.

Rather than complete randomization of acoustic condition across each trial block, a testing sequence was created that allowed for control over the length of time and number of consecutive trials the subject tested under the same acoustic condition. This ability to regulate the subject's exposure to each treatment enabled not only evaluation of specific level preference settings per trial, but also the investigation of adaptation to acoustic environment on a temporal scale.

In a departure from previous studies, testing was conducted in a medium-sized hemi-anechoic laboratory located at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT) at the Schulich School of Music. In order to maximize the difference between conditions, it was felt

Fig. 1: Motorized acoustic treatment rotators, shown in the hemi-anechoic testing environment. The rotators are shown mid-rotation, with the acoustics screens removed.

that an optimally dry, clinical environment would be better suited to testing than the typical control room. While the room is not fully anechoic (the floor is a thick, absorptive carpet on a floating foundation), it exhibited an average EDT of less than 60 ms from 250 Hz to 4 kHz. The room has some extant modal action in the 150 Hz octave, but this energy was dissipated when the motorized baffle system was placed in the room.

2.1. Acoustic Conditions

The rotating baffles described above provided a ten-foot by six-foot (5.57 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 towards 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 a highly reflective lacquered wood panel. The panel was $\frac{3}{8}$ (9.5 mm) plywood, treated with stain and three coats of hard, high-gloss lacquer, making it extremely reflective.

The three acoustic treatments were measured *in situ* to determined their effect on the testing environment. As expected, the reflective wood treatment

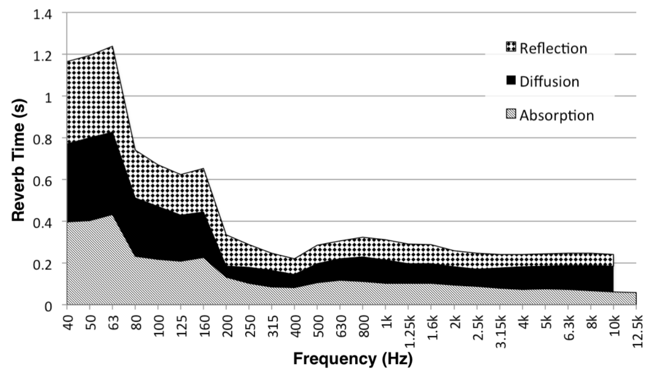

Fig. 2: Reverb time for three acoustic conditions under test.

was shown to cause an increase in reverberation compared to the other two treatments (Figure 2). Additionally, there was a significant difference in interaural cross correlation coefficient (IACC) between treatment types, with markedly higher correlation in the absorptive condition (Figure 3).

2.2. Test Subjects

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 & ANALYSIS

In order to look specifically at adaptation, data collected on preferred levels was analyzed based on the amount of time the subject was exposed to a particular acoustic condition (henceforth referred to as "exposure time"). This yields four sub-sets of data from each acoustic condition: exposure to a single trial, two trials, three trials and four trials. If adaptation occurs within the four-trial window of exposure, evidence should appear as a change in variance of level set.

The first step taken in data analysis was the examination of data distribution using Lilliefors' test for goodness-of-fit. The data distribution of levels set by subjects under each condition and number of trials was found to be non-normally distributed, so non-

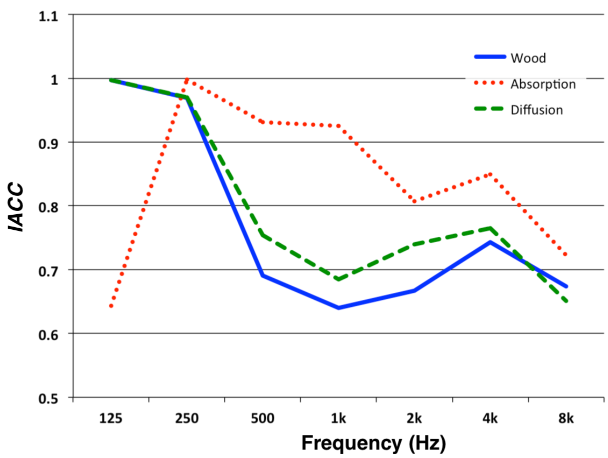

Fig. 3: Inter-aural Cross Correlation Coefficient (IACC) for three acoustic conditions, as measured in the listening environment.

parametric analyses were adopted for the duration. A Kruskal-Wallis nonparametric analysis of variance (ANOVA) reveals significant differences (p<0.05) of variance between all four exposure times across all three acoustic conditions (Figure 4). All three acoustic conditions exhibited similar significant differences in variance at a level of p<0.05 (Figure 5), but surprisingly the absorptive condition showed a greater variance at the longest exposure time of four trials (Figure 6).

3.1. Elapsed Time Results

An examination of elapsed time results showed this data to be normally distributed. An ANOVA within each acoustic condition found no significant difference between exposure times. While the absorptive and diffusive acoustic conditions showed almost perfectly equal variances across all exposure times, the reflective wood condition shows hints of non-normal or multimodal distribution in trials one, two and three (Figure 7).

4. CONCLUSION

The presence of profound adaptation within even a short period is confirmed by the findings of this study. The significant changes in level variance across increasing exposure times indicate that the professional recording engineer can decipher and, to some extent, nullify the effects of different acoustic conditions while performing critical listening tasks.

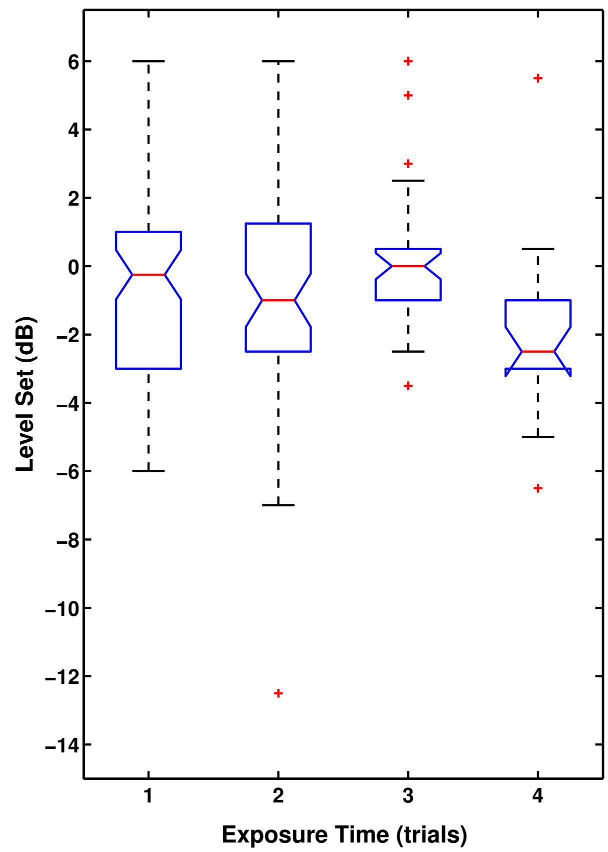

Fig. 4: Levels set for the reflective wood acoustic condition across the four exposure times. ariances are significantly different at the level of p<0.03

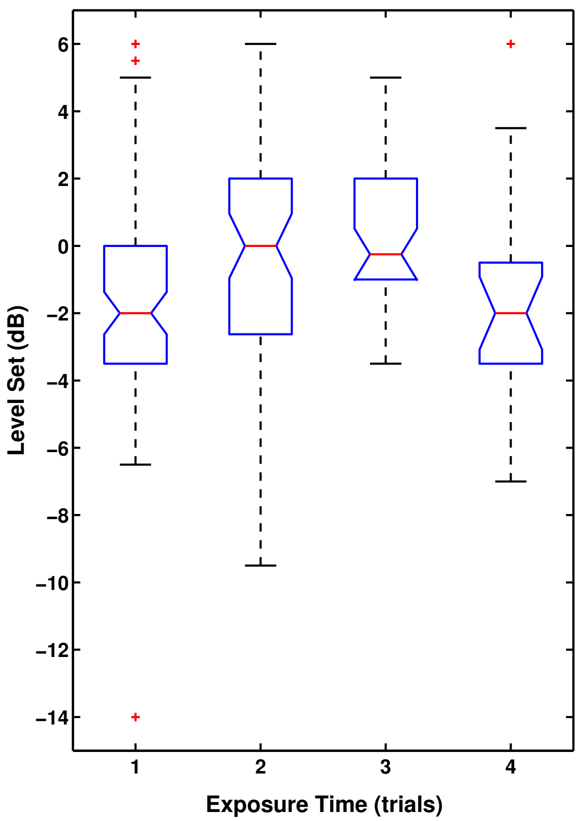

Fig. 5: Levels set for the diffusive acoustic condition across the four exposure times. Variances are significantly different at the level of p<0.0015

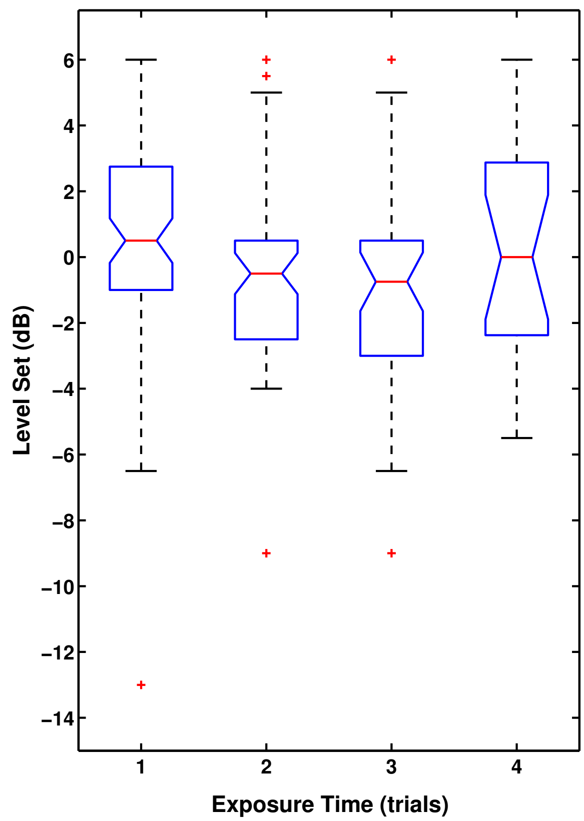

Fig. 6: Levels set for the absorptive acoustic condition across the four exposure times. ariances are significantly different at the level of p<0.025

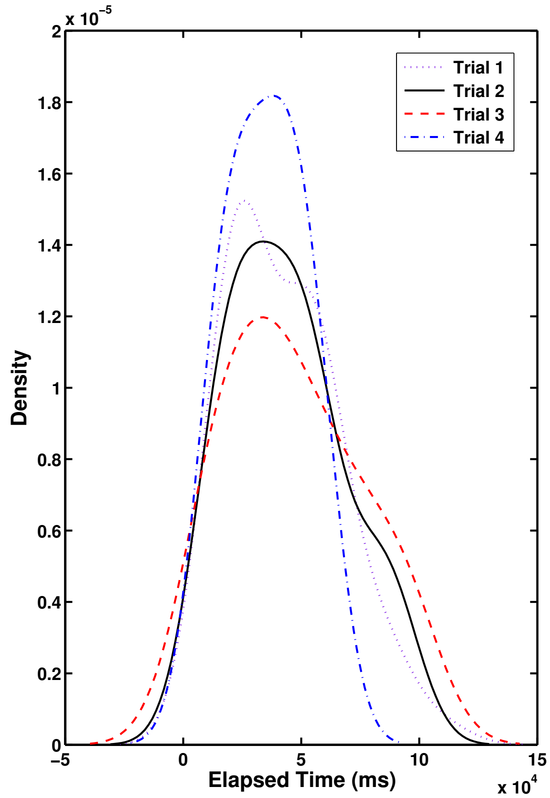

Fig. 7: Kernel density plot of elapsed time per trial for all exposure times in the reflective wood acoustic condition.

The results validate the expectation of adaptation, but the reflective wood acoustic condition gives pause. While the other two conditions show a tightening of variance that seems to imply a positive or productive adaptation to the change in acoustic condition, the wood treatment yielded an increase in variance. This could indicate that such highly reflective treatments require a greater period of time to be completely understood and adapted to, even by such trained listeners.

4.1. Future Work

This is by no means an exhaustive study and the results from this testing certainly warrant further investigation of the topic. The issue of listener fatigue could play a significant role in this test and others of its kind. Finding ways to increase exposure time while ensuring listeners are fresh and focused suggests other testing options should be examined, including testing with less acoustic variables (e.g. two alternating acoustic conditions), or perhaps longer sessions with breaks or even repeated test sessions on consecutive days.

5. ACKNOWLEDGEMENTS

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