# Noticeable rate of continuous change of intensity for naturalistic music listening in attentive and inattentive audiences

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### ABSTRACT

An investigation was done into the threshold of noticeability for a continuous rate of change in intensity and how listener attention affects this threshold rate. Results suggest listener attention has a strong effect on the threshold. Much previous work has been done to try and find the intensity discrimination threshold of human hearing involving comparison of consecutive stimuli differing in intensity, but not with a constant change over a long time for a continuous stimulus. Exposure to high intensity sounds over time can damage hearing, so the driving goal behind this investigation is to inform development of a mechanism that will lower the intensity of sound listeners are subjected to when consuming music while having minimal effect on perceived loudness.

## 1 Introduction

This study is motivated by the need to better protect music listeners from possible hearing damage. Exposure to high sound pressure levels for long periods of time can cause such damage, and the specific need for answering this threat in music playback from personal devices was thoroughly described by SCENIHR [1]. In attempting one possible solution it becomes desirable to design a level attenuation mechanism for sound playback that transparently reduces sound intensity, meaning reducing sound pressure exposure while maintaining perceived loudness for the listener. To do this, a rate of attenuation is desired which will not be perceived by listeners. While other considerations arise in designing such a system, this study focuses on achieving near constant loudness during intensity reduction.

The mechanism initially hypothesized to help achieve the constant loudness desired was that of the stapedius muscle. The stapedius muscle is described by Jan Schnupp and King [2] as capable of a relatively slow contraction or relaxation in response to heard and anticipated sound intensity, thus changing the dynamic range of hearing at any given moment to the relevant subset within the larger possible range of human hearing.

The phenomena of loudness adaptations of different kinds may certainly affect and complicate the results in this experiment. The literature shows that a decrease in loudness is sometimes reported even in the case where no change occurred. Canévet et al. [3] show the existence of loudness adaptation, and certain conditions that may induce it. Tang et al. [4] overview and test the effects of loudness adaptation for different frequencies, intensities, and with different participant hearing conditions, and suggest a neurological feedback mechanism to be involved in the attenuation. These studies and others of similar approach seemed to rely on stimuli made up of sine tones and noise, while this current study is more interested in naturalistic music playback. The way in which these mechanisms interact is difficult to piece apart, especially with musical stimuli, so a black box approach was used to test for the existence of imperceptible rates of change instead.

A preliminary study with 25 participants supported the existence of an imperceptible rate of intensity attenuation for music playback. Follow up work between that study and this one attempted to piece apart some of the important factors relevant in achieving a transparent attenuation. Listener attention was noted as an exceptionally salient factor, informing the design of this experiment.

One other important factor to come out of the preliminary study was an observed effect of gain reduction on perceived overall timbre. Looking at equal loudness curves, such as those presented by ISO [5], it is easy to see that an equal reduction in intensity may result in different changes in loudness across different areas in the frequency spectrum. This may limit the imperceptibility of the manipulation when using a flat gain multiplication across the frequency spectrum. The measurements obtained in the experiment presented in this paper, which employs a flat gain reduction, are meant to stand as a baseline for comparison in further work on achieving a potentially more transparent intensity reduction.

The experiment presented here is ongoing at the time of this writing. It is expected that when the results are presented in October of 2018 the desired larger data set will have been collected in full. For inquiries regarding the current state of work please contact the author.

## 2 Methods

While more participants are planned for this study, at the time this paper was submitted 20 participants had taken part in the experiment. Participants were college aged students with a range of musical training backgrounds. A more thorough breakdown of the participant population will be conducted when the desired amount of participants is reached.

Stimuli presented were comprised of two sections. The first was a 1 minute long segment of pink (1/f) noise generated in Audacity DAW. This was for allowing all participants to adapt to the same playback level of the experiment setup and reduce the effect of exposure to varying sound levels immediately before the experiment. The second section was a 5 minute playlist of 5 consecutive 1 minute song segments, randomly chosen. The 5 songs were selected from 15 possible choices of 1 minute segments of popular music by various artists. The choice of genre allowed for segments that were of flat overall dynamic envelope and relative saturation of loudness throughout. All songs were produced by the same producer, allowing to attempt control for production values as well.

All 1 minute segments, including the pink noise, were normalized to equal loudness relative to each other according to ITU-R [6] BS1770, as implemented in Adobe Creative Cloud Audition software. For the various intensity attenuation conditions, the 5 minute section of song segments was multiplied by a decreasing envelope of constant and continuous change in dB, sample by sample, to achieve a gradual change in intensity. Rates of reduction ranged from 0dB per minute (no change) to -4dB per minute (-20dB overall by the end of the playlist.)

All participants were first asked to complete a short demographics questionnaire giving age, years of musical training, and years of sound engineering experience. They were then asked to sit in a noise controlled room with less than 30dB SPL of measured background noise, and given headphones (MDR-ZX100, Sony, USA) through which they would hear the 6 minute stimulus, played back in stereo through MATLAB, on a MacBook Air 13 inch mid-2013 laptop computer with OS X Sierra, version 10.12.6. To avoid reference sounds in the room all instructions were given in advance and the participant was left in the room alone for the duration of the playback.

Sound playback from the headphones at peak level (without attenuation) was measured at 90dB SPL, and level reduction was verified at the output as well, with the most severe rate of reduction reaching 70dB SPL as expected.

Participants were instructed to flip over a clipboard containing a written task once the 1 minute noise section was over and the music began to play. The clipboard had different instructions for the attentive and inattentive groups. The attentive group was prompted with the following: "You will now hear 5 minutes of short music clips shuffled in a playlist. Listen to the music played, and keep track of whether there are any overall gradual changes to qualities such as brightness, presence of bass, and/or loudness throughout the playlist." The inattentive group was given a competing distracting task - a 25 question visual task requesting the participant to identify the missing square in a 3x3 matrix of patterns, with eight possible squares as answers for each question. The task was adapted from a Raven et al. [7] test meant for fluid intelligence estimation, with all mention of this function redacted. The performance was not graded or collected as data, it served only as a distraction from the sonic stimuli.

When the music playback concluded both groups were then presented the same three questions, asking if they noticed a change in brightness, presence of bass, and loudness during the playback overall, with the options of a noticed increase, decrease, and no change offered in random order. This concluded the experiment.

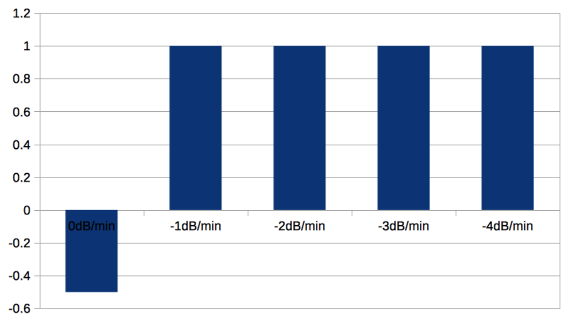


**Fig. 1:** Attentive group mean score per condition

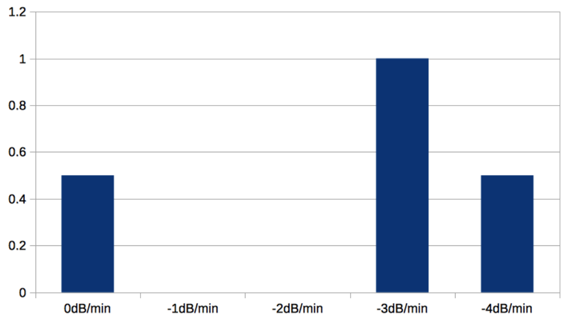


**Fig. 2:** Inattentive group mean score per condition

## 3 Results

The graphs presented in Figure 1 and Figure 2 show the results collected so far. Points were given for each participant as follows: 1 for a reduction perceived, 0 for no change perceived, and -1 for an increase in loudness perceived. The mean point score per condition is shown.

## 4 Discussion

The hypothesized form that the data might show upon further collection is of the average score rising from close to 0 (allowing for false detections at the baseline case of no attenuation) to 1 (correct detection at steep rates of attenuation), with the threshold of detectability being around the transition band. The data collected so far does not contradict this trend, but is not yet strong evidence in any direction.

The current data might suggest a threshold rate around -1dB/min for the attentive group, and at -3dB/min or above for the inattentive group. A more robust statistical analysis of the results is avoided at this time, due to the low number of data points per experiment condition.

Overall it is noted that the distracted group had participants who did not notice a change in loudness for different rates of attenuation, even for the condition that resulted in a -20dB attenuation overall. On the other hand, the attentive group asked to track these changes were apparently able to correctly detect a reduction of -1dB/min.

Due to the large range of rates needed to show the thresholds of the two different overall condition groups, there seems to be a lack of precision for the attentive group's threshold location, where a 1dB/min difference between rates in the slower rates of attenuation might be too coarse. A finer set of conditions to test between 0dB/min and -2dB/min is desirable. It might also be desirable to extend the range to include steeper rates of reduction to reach a 100% detection rate among the inattentive listeners. These two suggestions only further demonstrate the impact of a distracting task on the detectability of gradual sound attenuation.

The musical stimuli set used in this experiment is limited in scope, and further work could be done to generalize the results shown here to more dynamically varied musics. Other listening conditions could also be useful expansions of this work, especially those approaching ecological validity, using more natural conditions listeners encounter outside of the lab.

## 5 Summary

Likely regions for imperceptible rates of attenuation of sound intensity for music playback were noted for the attentive and inattentive groups. A strong effect of listener attention on the detectability of gradual intensity attenuation was possibly observed. Further data collection, which is ongoing, is needed for statistically valid results.

The results obtained could inform the design of a system that controls sound playback levels to reduce sound pressure exposure, possibly without affecting listener experience, and thus potentially promoting listener health through damage prevention.

Future directions of this work are planned to focus on other aspects possibly affecting the perceptibility of the attenuation of intensity of music playback. Specifically of interest is the perceived timbrel change resultant of intensity reduction done through gain multiplication, and an attempt at compensating for this to achieve a more transparent manipulation overall.

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