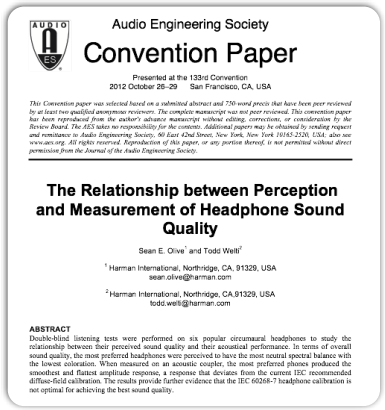
# DEVELOPMENT OF HARMAN HEADPHONE TARGET CURVE

**14 APRIL 2016**

DR. SEAN E. OLIVE, ACOUSTIC RESEARCH FELLOW

# WE'VE BEEN BUSY THE PAST 2 YEARS RESEARCHING THE PERCEPTION AND MEASUREMENT OF HEADPHONES…



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## The Relationship between Perception and Measurement of Headphone Sound Quality

Sean E. Olive[1] and Todd Welti[2]

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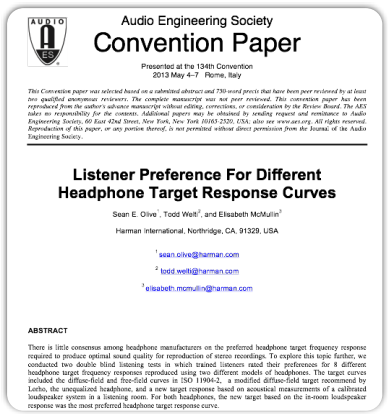
**ABSTRACT**

Double-blind listening tests were performed on six popular circumaural headphones to study the relationship between their perceived sound quality and their acoustical performance. In terms of overall sound quality, the most preferred headphones were perceived to have the most neutral spectral balance with the lowest coloration. When measured on an acoustic coupler, the most preferred phones produced the smoothest and flattest amplitude response, a response that deviates from the current IEC recommended diffuse-field calibration. The results provide further evidence that the IEC 60268-7 headphone calibration is not optimal for achieving the best sound quality.



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## Listener Preference For Different Headphone Target Response Curves

Sean E. Olive[1], Todd Welti[2], and Elisabeth McMullin[3]

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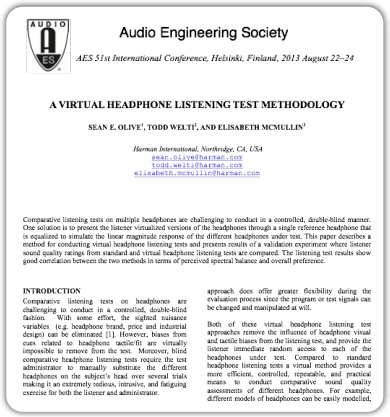
**ABSTRACT**

There is little consensus among headphone manufacturers on the preferred headphone target frequency response required to produce optimal sound quality for reproduction of stereo recordings. To explore this topic further, we conducted two double blind listening tests in which trained listeners rated their preferences for 8 different headphone target frequency responses reproduced using two different models of headphones. The target curves included the diffuse-field and free-field curves in ISO 11904-2, a modified diffuse-field target recommend by Lorho, the unequalized headphone, and a new target response based on acoustical measurements of a calibrated loudspeaker system in a listening room. For both headphones, the new target based on the in-room loudspeaker response was the most preferred headphone target response curve.



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*AES 51st International Conference, Helsinki, Finland, 2013 August 22–24*

## A VIRTUAL HEADPHONE LISTENING TEST METHODOLOGY

SEAN E. OLIVE[1], TODD WELTI[2], AND ELISABETH MCMULLIN[3]

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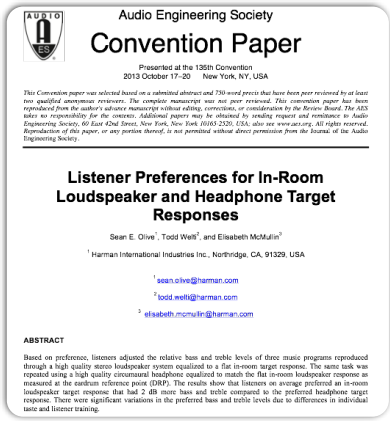
Comparative listening tests on multiple headphones are challenging to conduct in a controlled, double-blind manner. One solution is to present the listener virtualized versions of the headphones through a single reference headphone that is equalized to simulate the linear magnitude response of the different headphones under test. This paper describes a method for conducting virtual headphone listening tests and presents results of a validation experiment where listener sound quality ratings from standard and virtual headphone listening tests are compared. The listening test results show good correlation between the two methods in terms of perceived spectral balance and overall preference.

**INTRODUCTION**

Comparative listening tests on headphones are challenging to conduct in a controlled, double-blind fashion. With some effort, the sighted nuisance variables (e.g. headphone brand, price and industrial design) can be eliminated [1]. However, biases from cues related to headphone tactile/fit are virtually impossible to remove from the test. Moreover, blind comparative headphone listening tests require the test administrator to manually substitute the different headphones on the subject's head over several trials making it an extremely tedious, intrusive, and fatiguing exercise for both the listener and administrator.

approach does offer greater flexibility during the evaluation process since the program or test signals can be changed and manipulated at will.

Both of these virtual headphone listening test approaches remove the influence of headphone visual and tactile biases from the listening test, and provide the listener immediate random access to each of the headphones under test. Compared to standard headphone listening tests a virtual method provides a more efficient, controlled, repeatable, and practical means to conduct comparative sound quality assessments of different headphones. For example, different models of headphones can be easily modelled,



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## Listener Preferences for In-Room Loudspeaker and Headphone Target Responses

Sean E. Olive[1], Todd Welti[2], and Elisabeth McMullin[3]

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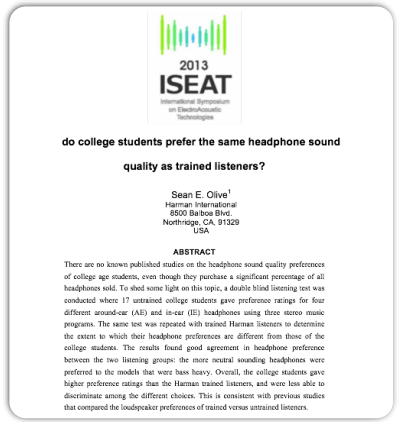
**ABSTRACT**

Based on preference, listeners adjusted the relative bass and treble levels of three music programs reproduced through a high quality stereo loudspeaker system equalized to a flat in-room target response. The same task was repeated using a high quality circumaural headphone equalized to match the flat in-room loudspeaker response as measured at the eardrum reference point (DRP). The results show that listeners on average preferred an in-room loudspeaker target response that had 2 dB more bass and treble compared to the preferred headphone target response. There were significant variations in the preferred bass and treble levels due to differences in individual taste and listener training.



2013
ISEAT
International Symposium on Electro-Acoustic Technologies

**do college students prefer the same headphone sound quality as trained listeners?**

Sean E. Olive[1]
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Northridge, CA, 91329
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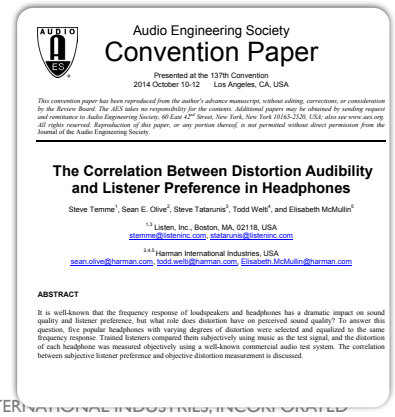
**ABSTRACT**

There are no known published studies on the headphone sound quality preferences of college age students, even though they purchase a significant percentage of all headphones sold. To shed some light on this topic, a double blind listening test was conducted where 17 untrained college students gave preference ratings for four different around-ear (AE) and in-ear (IE) headphones using three stereo music programs. The same test was repeated with trained Harman listeners to determine the extent to which their headphone preferences are different from those of the college students. The results found good agreement in headphone preference between the two listening groups: the more neutral sounding headphones were preferred to the models that were bass heavy. Overall, the college students gave higher preference ratings than the Harman trained listeners, and were less able to discriminate among the different choices. This is consistent with previous studies that compared the loudspeaker preferences of trained versus untrained listeners.



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## The Correlation Between Distortion Audibility and Listener Preference in Headphones

Steve Temme[1], Sean E. Olive[2], Steve Tatarunis[3], Todd Welti[4], and Elisabeth McMullin[5]

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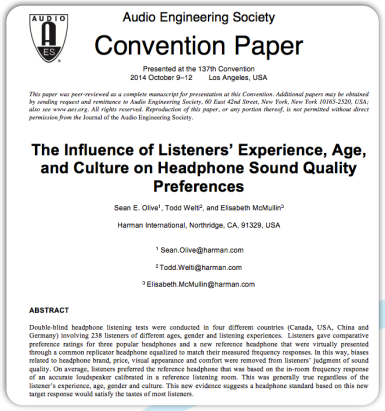
**ABSTRACT**

It is well-known that the frequency response of loudspeakers and headphones has a dramatic impact on sound quality and listener preference, but what role does distortion have on perceived sound quality? To answer this question, five popular headphones with varying degrees of distortion were selected and equalized to the same frequency response. Trained listeners compared them subjectively using music as the test signal, and the distortion of each headphone was measured objectively using a well-known commercial audio test system. The correlation between subjective listener preference and objective distortion measurement is discussed.



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## The Influence of Listeners' Experience, Age, and Culture on Headphone Sound Quality Preferences

Sean E. Olive[1], Todd Welti[2], and Elisabeth McMullin[3]

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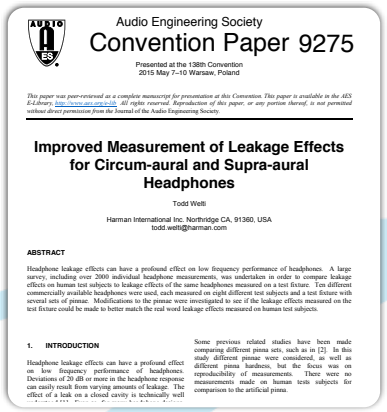
[3] Elisabeth.McMullin@harman.com

**ABSTRACT**

Double-blind headphone listening tests were conducted in four different countries (Canada, USA, China and Germany) involving 238 listeners of different ages, gender and listening experiences. Listeners gave comparative preference ratings for three popular headphones and a new reference headphone that were virtually presented through a common replicator headphone equalized to match their measured frequency responses. In this way, biases related to headphone brand, price, visual appearance and comfort were removed from listeners' judgment of sound quality. On average, listeners preferred the reference headphone that was based on the in-room frequency response of an accurate loudspeaker calibrated in a reference listening room. This was generally true regardless of the listener's experience, age, gender and culture. This new evidence suggests a headphone standard based on this new target response would satisfy the tastes of most listeners.



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## Improved Measurement of Leakage Effects for Circum-aural and Supra-aural Headphones

Todd Welti

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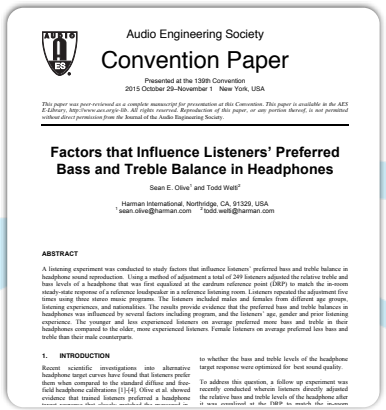
**ABSTRACT**

Headphone leakage effects can have a profound effect on low frequency performance of headphones. A large survey, including over 2000 individual headphone measurements, was undertaken in order to compare leakage effects on human test subjects to leakage effects of the same headphones measured on a test fixture. Ten different commercially available headphones were used, each measured on eight different test subjects and a test fixture with several sets of pinnae. Modifications to the pinnae were investigated to see if the leakage effects measured on the test fixture could be made to better match the real word leakage effects measured on human test subjects.

**1. INTRODUCTION**

Headphone leakage effects can have a profound effect on low frequency performance of headphones. Deviations of 20 dB or more in the headphone response can easily result from varying amounts of leakage. The effect of a leak on a closed cavity is technically well

Some previous related studies have been made comparing different pinna sets, such as in [2]. In this study different pinnae were considered, as well as different pinna hardness, but the focus was on reproducibility of measurements. There were no measurements made on human tests subjects for comparison to the artificial pinna.



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## Factors that Influence Listeners' Preferred Bass and Treble Balance in Headphones

Sean E. Olive[1] and Todd Welti[2]

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sean.olive@harman.com [2] todd.welti@harman.com

**ABSTRACT**

A listening experiment was conducted to study factors that influence listeners' preferred bass and treble balance in headphone sound reproduction. Using a method of adjustment a total of 249 listeners adjusted the relative treble and bass levels of a headphone that was first equalized at the eardrum reference point (DRP) to match the in-room steady-state response of a reference loudspeaker in a reference listening room. Listeners repeated the adjustment five times using three stereo music programs. The listeners included males and females from different age groups, listening experiences, and nationalities. The results provide evidence that the preferred bass and treble balances in headphones was influenced by several factors including program, and the listeners' age, gender and prior listening experience. The younger and less experienced listeners on average preferred more bass and treble in their headphones compared to the older, more experienced listeners. Female listeners on average preferred less bass and treble than their male counterparts.

**1. INTRODUCTION**

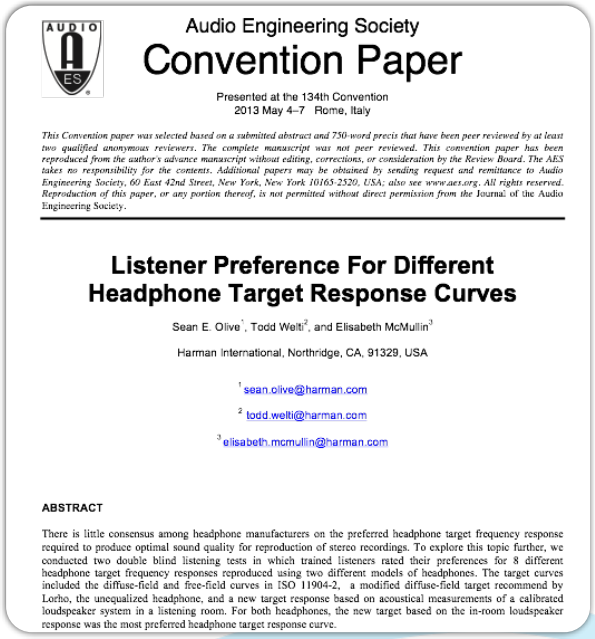
Recent scientific investigations into alternative headphone target curves have found that listeners prefer them when compared to the standard diffuse and free-field headphone calibrations [1]-[4]. Olive et al. showed evidence that trained listeners preferred a headphone

to whether the bass and treble levels of the headphone target response were optimized for best sound quality.

To address this question, a follow up experiment was recently conducted wherein listeners directly adjusted the relative bass and treble levels of the headphone after

# HARMAN TARGET CURVE (2013)

**In this paper we reported experiments where trained listeners evaluated two different headphones (Sennheiser HD 518 and Audeze LCD-2) unequalized and equalized to different target curves (diffuse, modified diffuse, free-field) and two Harman target curves based on the equalized in-room response of a loudspeaker**



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**Listener Preference For Different Headphone Target Response Curves**

Sean E. Olive[1], Todd Welti[2], and Elisabeth McMullin[3]

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**ABSTRACT**

There is little consensus among headphone manufacturers on the preferred headphone target frequency response required to produce optimal sound quality for reproduction of stereo recordings. To explore this topic further, we conducted two double blind listening tests in which trained listeners rated their preferences for 8 different headphone target frequency responses reproduced using two different models of headphones. The target curves included the diffuse-field and free-field curves in ISO 11904-2, a modified diffuse-field target recommend by Lorho, the unequalized headphone, and a new target response based on acoustical measurements of a calibrated loudspeaker system in a listening room. For both headphones, the new target based on the in-room loudspeaker response was the most preferred headphone target response curve.

# HARMAN TARGET CURVE (2013)

**One of the Harman headphone target curves was based on a preferred in-room loudspeaker target curve (RR1) that came from a study (see next slide) on room correction products**

**Listeners preferred this room correction over other room corrections and target curves**

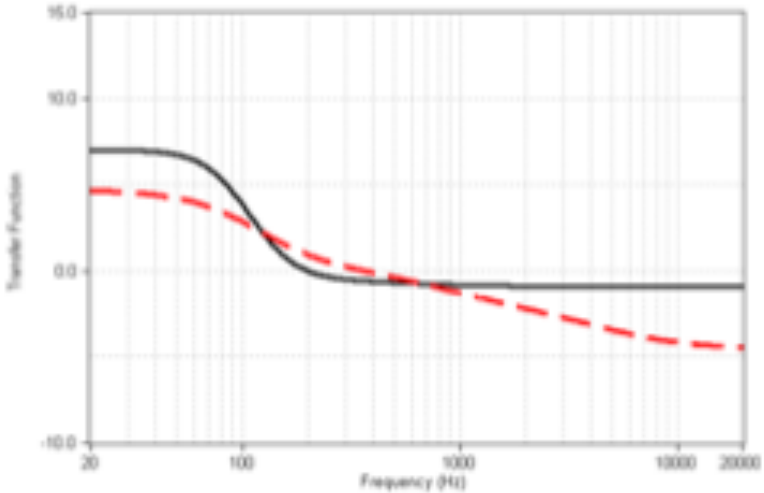
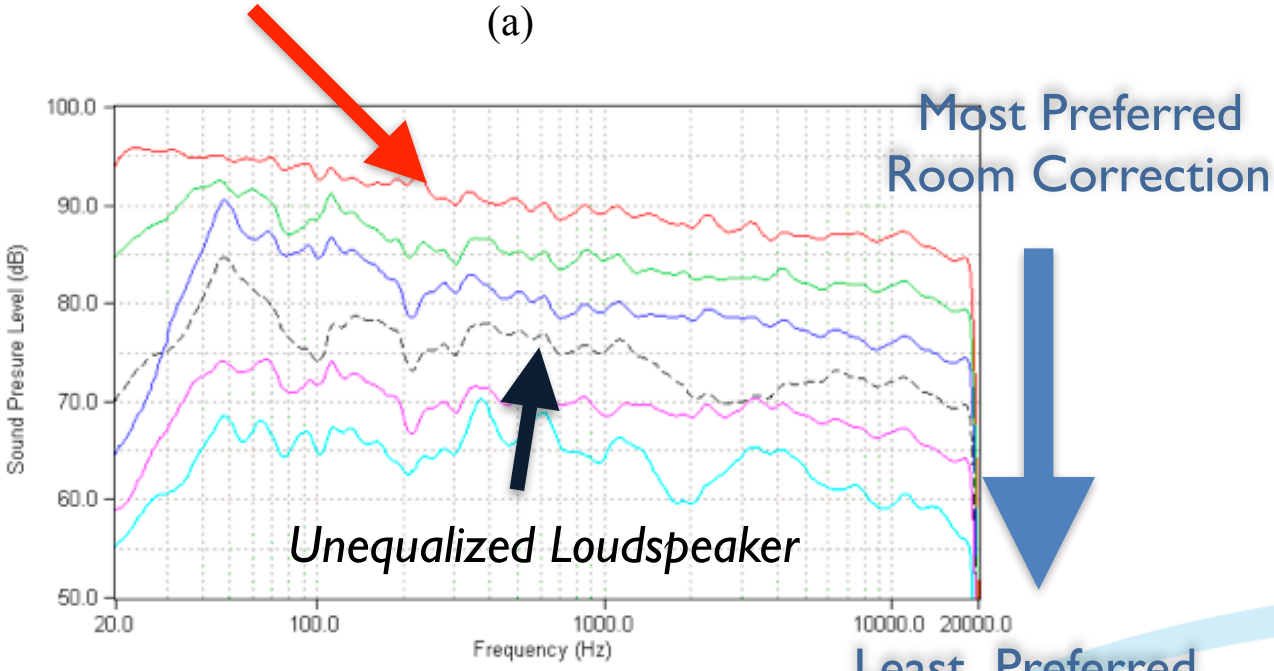



**Figure 1** The standard RR (solid line) and modified RR1 (dotted line) in-room target response of the loudspeaker system in the Harman Reference Listening Room [9].

# IN-ROOM MEASUREMENTS OF SPEAKER AFTER DIFFERENT ROOM CORRECTIONS ARE APPLIED

Room Correction based on Harman Target Curve

(a)




(b)

Audio Engineering Society

## Convention Paper 7960

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2009 October 9–12 New York, NY, USA



### The Subjective and Objective Evaluation of Room Correction Products

Sean E. Olive[1], John Jackson[2], Allan Devantier[3], David Hunt[4] and Sean M. Hess[5]

Harman International, Northridge, CA, 91329, USA

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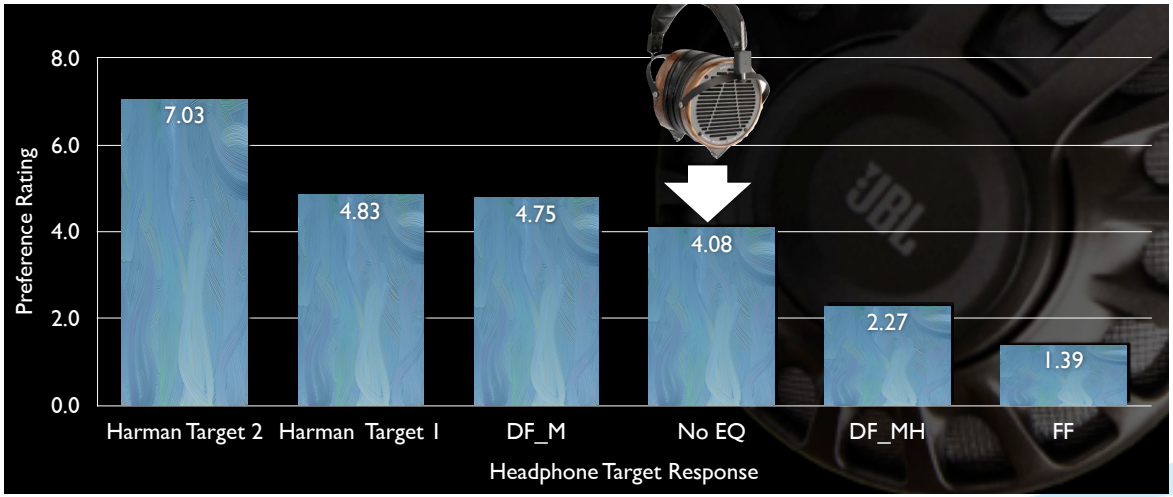
[3] Allan.Devantier@harman.com
[4] David.Hunt@harman.com
[5] Sean.Hess@harman.com

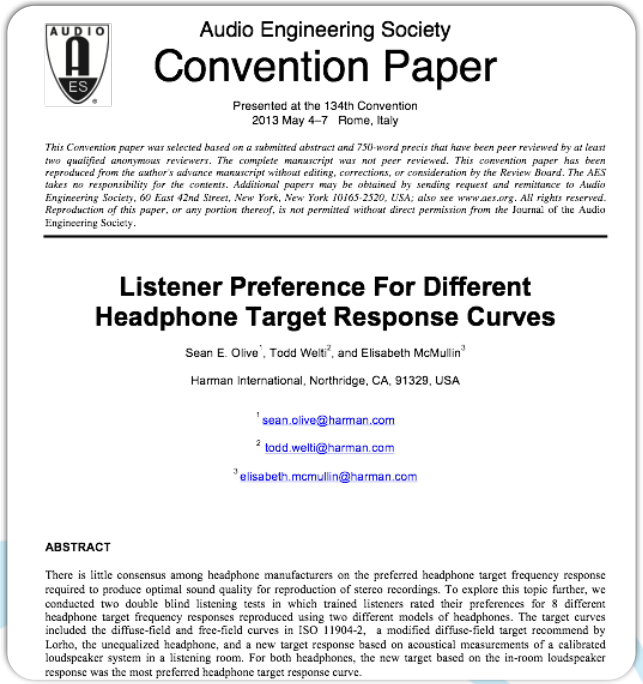
ABSTRACT

A panel of eight trained listeners gave comparative ratings for five different room correction products based on overall preference and spectral balance. The room corrections were applied to a single loudspeaker/subwoofer in a typical semi-reflective listening room, and evaluated using three different music programs. The same loudspeaker/subwoofer without correction was included as a hidden anchor. The results found significant differences in sound quality among the room correction products based on listeners' preferences and spectral balance ratings. These differences can be largely explained by examining the steady state, spatially averaged frequency response measurements of the room corrections measured at the listening location.

# LISTENING RESULTS

**Listeners preferred the Audeze LCD-2 equalized to match Harman Target Curve 2 (RR1) compared to the unequalized Audeze or any of the different DF and FF target curves**



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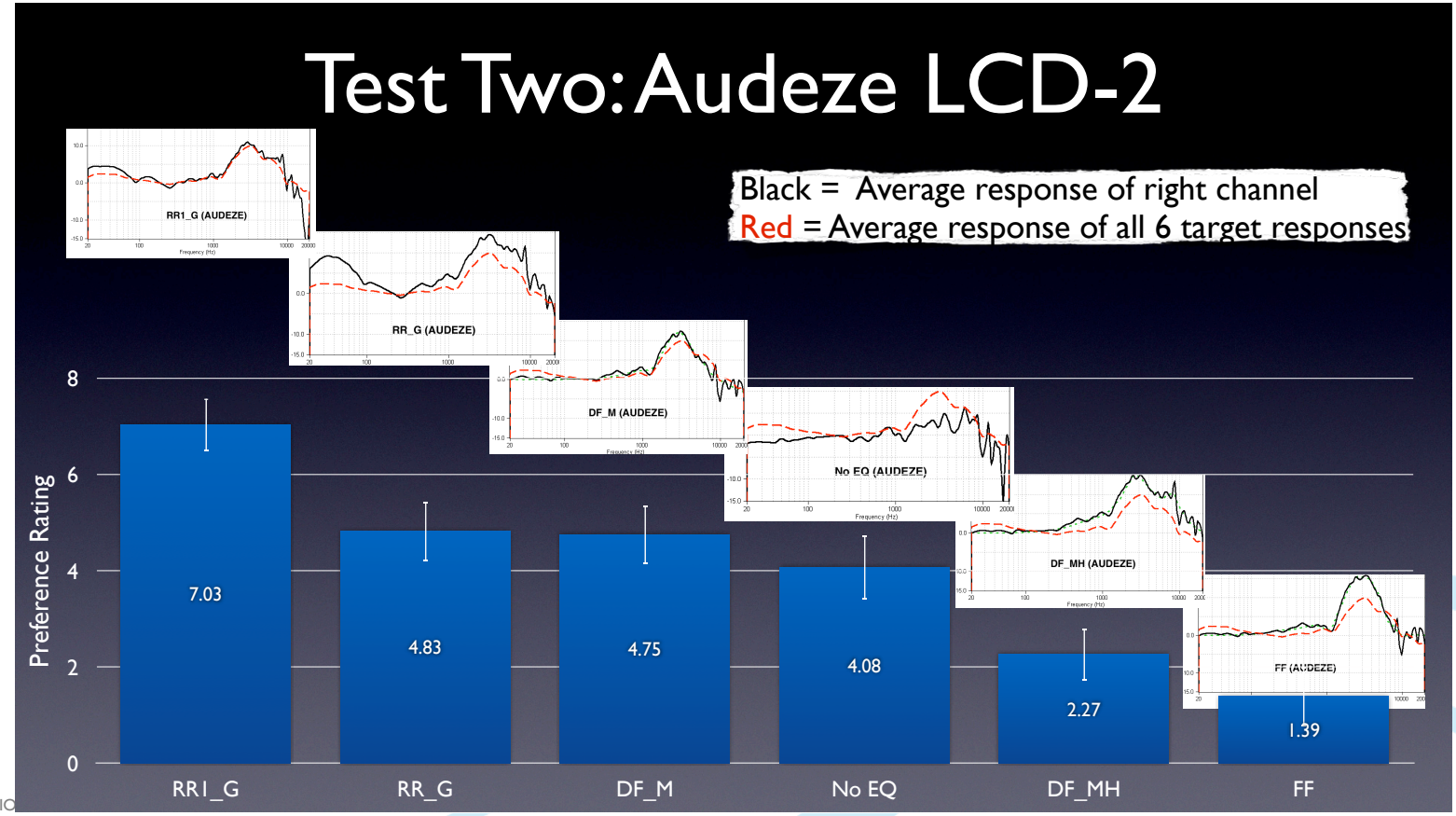
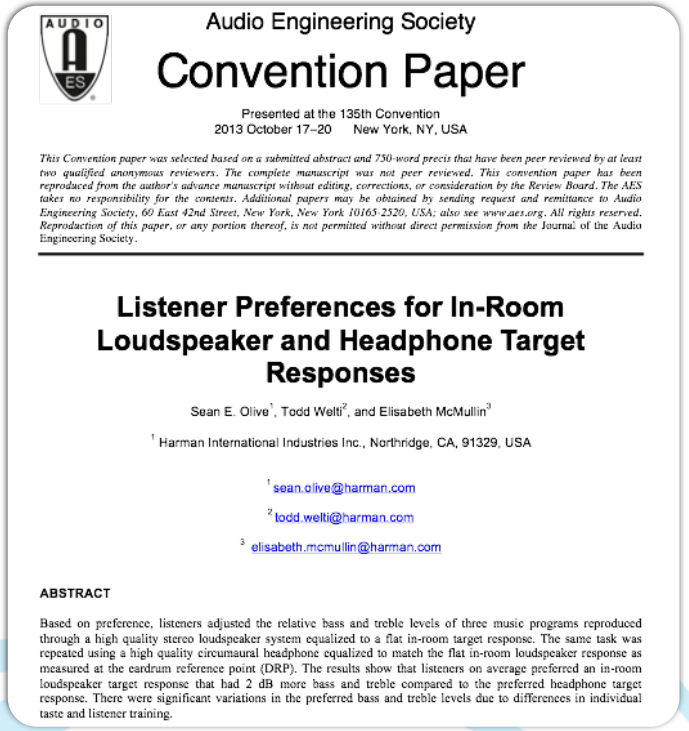
# HEADPHONE TARGET CURVE MEASUREMENTS



# ADJUSTING HEADPHONE AND IN_ROOM LOUDSPEAKER TARGET CURVES

**In this paper we had 6 trained and 3 untrained listeners adjust the bass and treble levels of a headphone (Senn. HD 800) equalized at the DRP to match a "flattened" (not ideal) in-room response of an accurate loudspeaker in the Harman Reference Room;**

**Listeners repeated the same test in the Harman Reference Room using an accurate stereo loudspeaker (Revel F208)**



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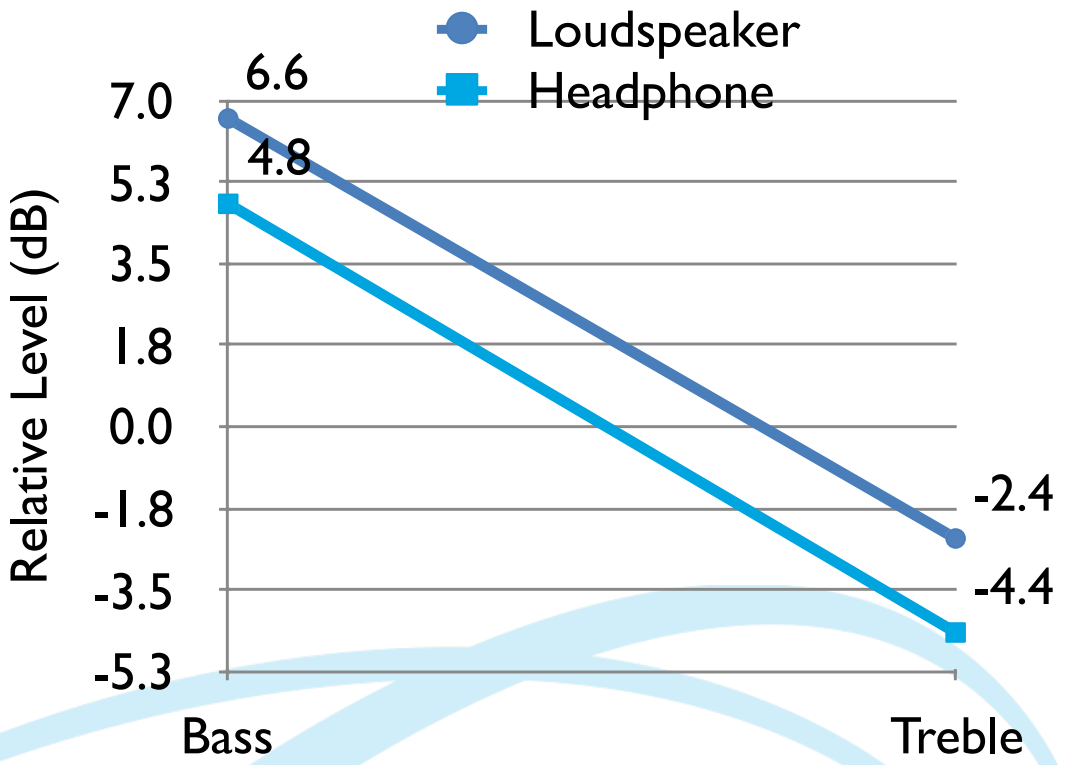
**ABSTRACT**

Based on preference, listeners adjusted the relative bass and treble levels of three music programs reproduced through a high quality stereo loudspeaker system equalized to a flat in-room target response. The same task was repeated using a high quality circumaural headphone equalized to match the flat in-room loudspeaker response as measured at the eardrum reference point (DRP). The results show that listeners on average preferred an in-room loudspeaker target response that had 2 dB more bass and treble compared to the preferred headphone target response. There were significant variations in the preferred bass and treble levels due to differences in individual taste and listener training.

# MEAN PREFERRED BASS AND TREBLE LEVELS

- On average, listeners preferred the headphone target response after adjusted to 4.8 dB bass gain (2nd order LF shelf at 105 Hz) and -4.4 dB treble cut (2nd order HF shelf at 2.5 kHz)
- For the loudspeaker playback condition they preferred about 2 dB more bass and treble than the headphone condition



# RESULTS

**This measurement shows the headphone adjusted to the target response based on listeners bass and level preferences**

**The green dotted curve is response of the loudspeaker equalized to a flat in-room curve. Listeners did not like this baseline curve and adjusted the bass 6.6 dB higher and the treble -2.4 dB lower. More evidence that the in-room loudspeaker target should have a 9-10 dB downward slope from 20-20 kHz**

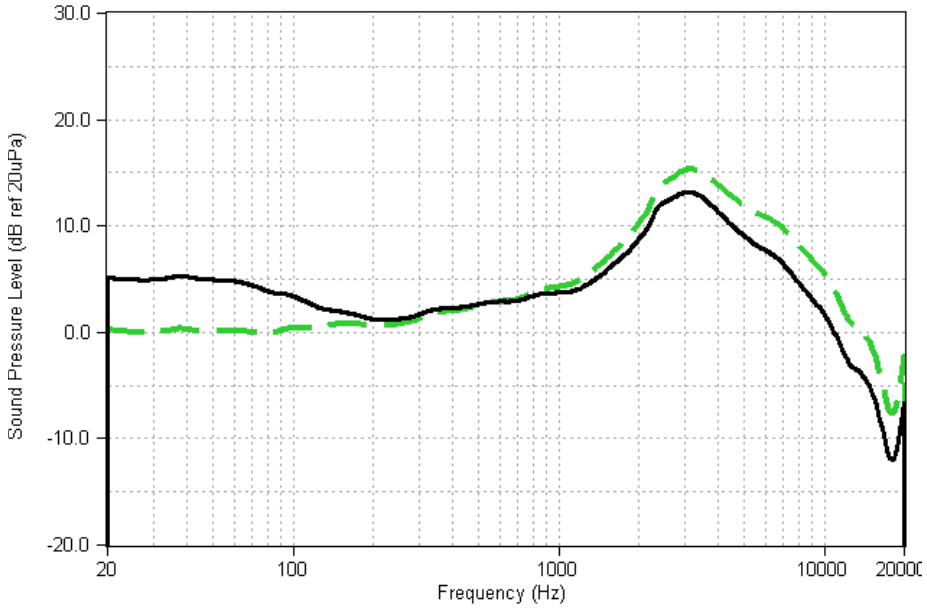



Figure 17 The preferred headphone target response measured at DRP (black) based on this study. Also shown is the measured response of the loudspeaker equalized to a flat in-room target response.

# PREFERRED IN-ROOM TARGET FOR LOUDSPEAKER

A flat in-room target curve (green curve) is <u>not</u> preferred; to achieve the preferred target (the black curve). The preferred in-room target has a response with a ~10 dB downward slope from 20 Hz- 20 kHz.

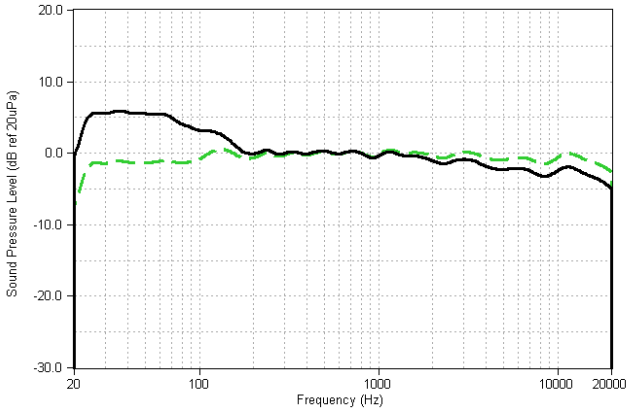



Figure 18 The measured in-room response of the Revel F208 (solid line) equalized to the preferred target response curve. Also shown is the measured response of the loudspeaker equalized to a flat target response (dotted).

Based on listening results, the Revel requires some bass boost in this room but no treble adjustment to its flat on-axis response/ Also the original RR1 target curve (red curve ) is close to what listeners preferred in this study (black curve)

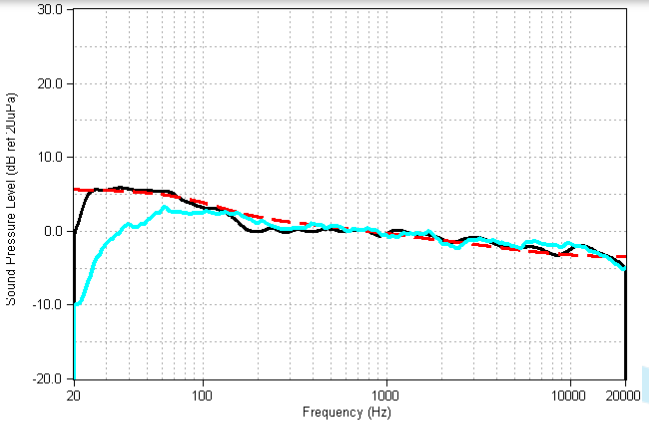
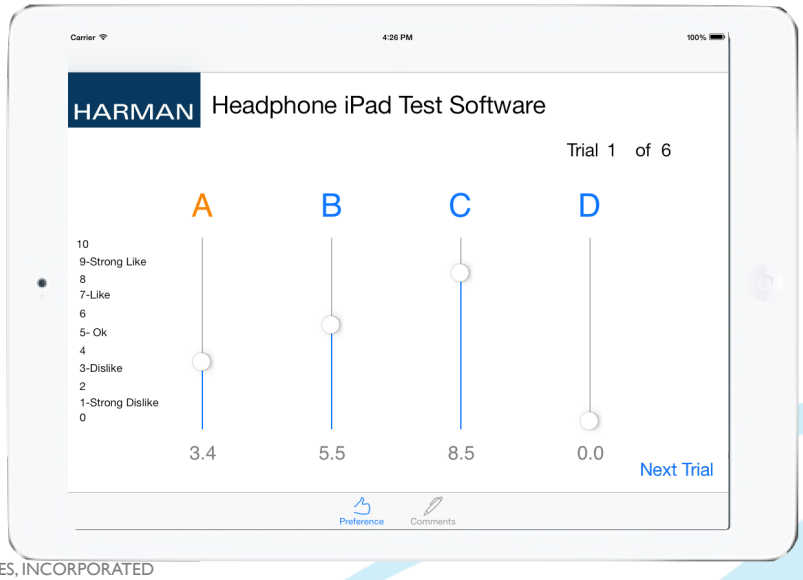
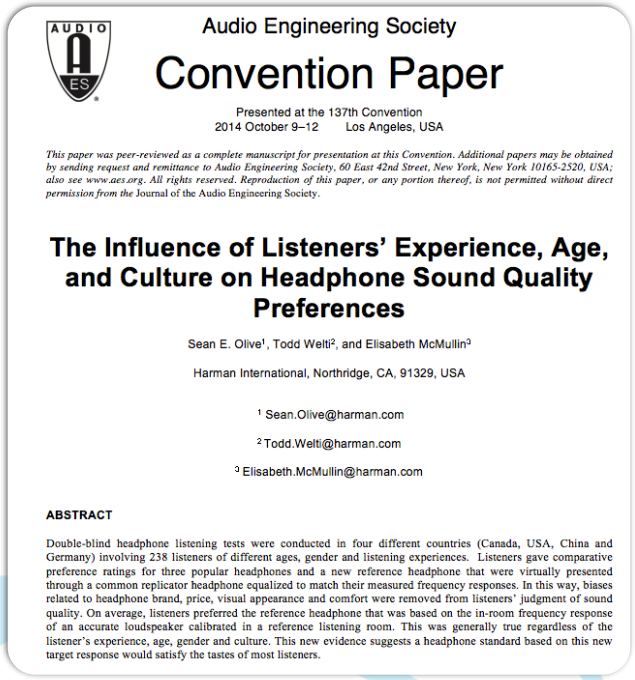



Figure 19 The measured in-room response of the Revel F208 loudspeaker equalized to the preferred in-room target curve (black), the predicted in-room response of the loudspeaker (cyan) based on anechoic measurements (see Fig. 1), and the modified in-room loudspeaker target curve, RR1 (red dotted) from [6].

# 2014 PAPER

**In this paper we had 238 listeners from four countries give preference ratings for 4 virtualized headphones including one equalized to the Harman Target Curve (top left graph). The other three were Sennheiser HD800, Audeze LCD-2 and Beats Studio.**

Audio Engineering Society

Convention Paper

Presented at the 137th Convention
2014 October 9–12 Los Angeles, USA



**The Influence of Listeners' Experience, Age, and Culture on Headphone Sound Quality Preferences**

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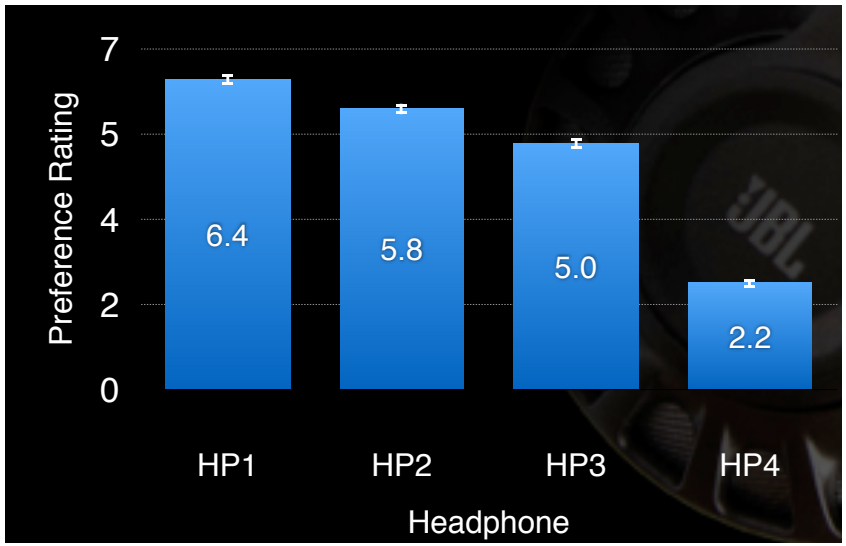
**ABSTRACT**

Double-blind headphone listening tests were conducted in four different countries (Canada, USA, China and Germany) involving 238 listeners of different ages, gender and listening experiences. Listeners gave comparative preference ratings for three popular headphones and a new reference headphone that were virtually presented through a common replicator headphone equalized to match their measured frequency responses. In this way, biases related to headphone brand, price, visual appearance and comfort were removed from listeners' judgment of sound quality. On average, listeners preferred the reference headphone that was based on the in-room frequency response of an accurate loudspeaker calibrated in a reference listening room. This was generally true regardless of the listener's experience, age, gender and culture. This new evidence suggests a headphone standard based on this new target response would satisfy the tastes of most listeners.

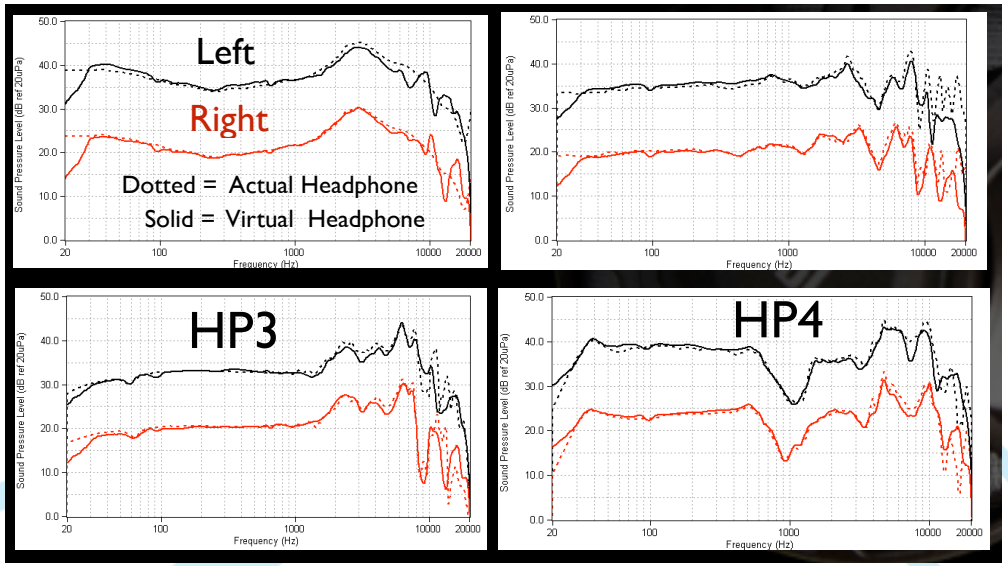
# RESULTS

## Subjective Results

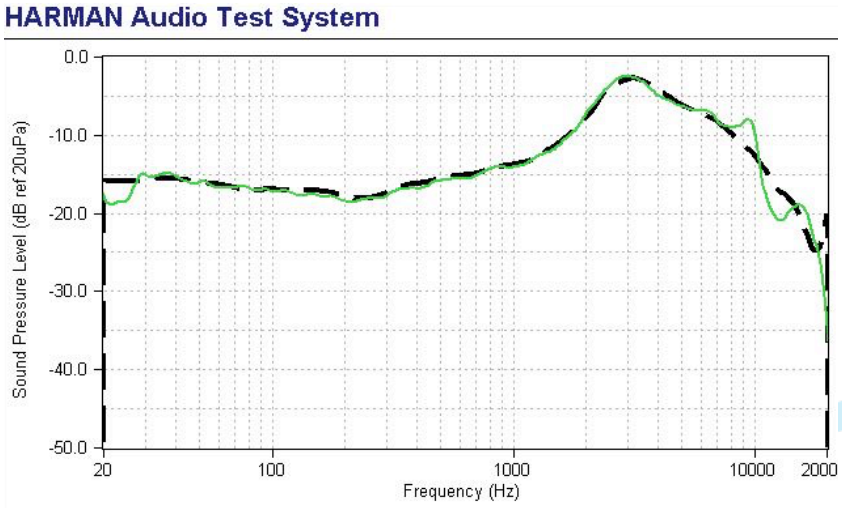


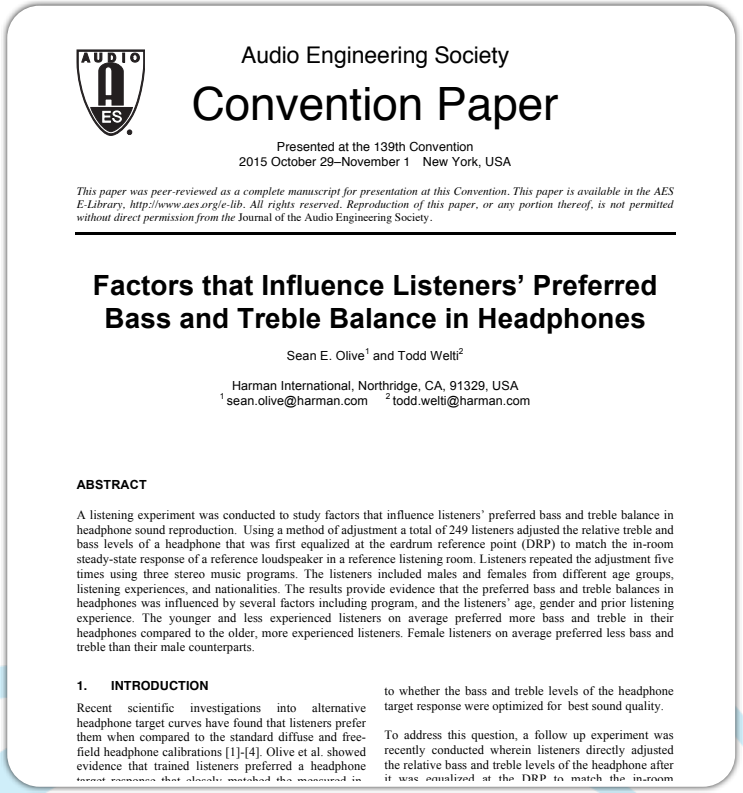

## Objective Results

Harman Target Curve (2013)



# In this paper, we had 249 listeners from 4 countries adjust the bass and treble level of a headphone according to preference after it was equalized to match the flat in-response of the loudspeaker



Audio Engineering Society

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Presented at the 139th Convention
2015 October 29–November 1 New York, USA

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**Factors that Influence Listeners' Preferred Bass and Treble Balance in Headphones**

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**ABSTRACT**

A listening experiment was conducted to study factors that influence listeners' preferred bass and treble balance in headphone sound reproduction. Using a method of adjustment a total of 249 listeners adjusted the relative treble and bass levels of a headphone that was first equalized at the eardrum reference point (DRP) to match the in-room steady-state response of a reference loudspeaker in a reference listening room. Listeners repeated the adjustment five times using three stereo music programs. The listeners included males and females from different age groups, listening experiences, and nationalities. The results provide evidence that the preferred bass and treble balances in headphones was influenced by several factors including program, and the listeners' age, gender and prior listening experience. The younger and less experienced listeners on average preferred more bass and treble in their headphones compared to the older, more experienced listeners. Female listeners on average preferred less bass and treble than their male counterparts.

**1. INTRODUCTION**

Recent scientific investigations into alternative headphone target curves have found that listeners prefer them when compared to the standard diffuse and free-field headphone calibrations [1]-[4]. Olive et al. showed evidence that trained listeners preferred a headphone

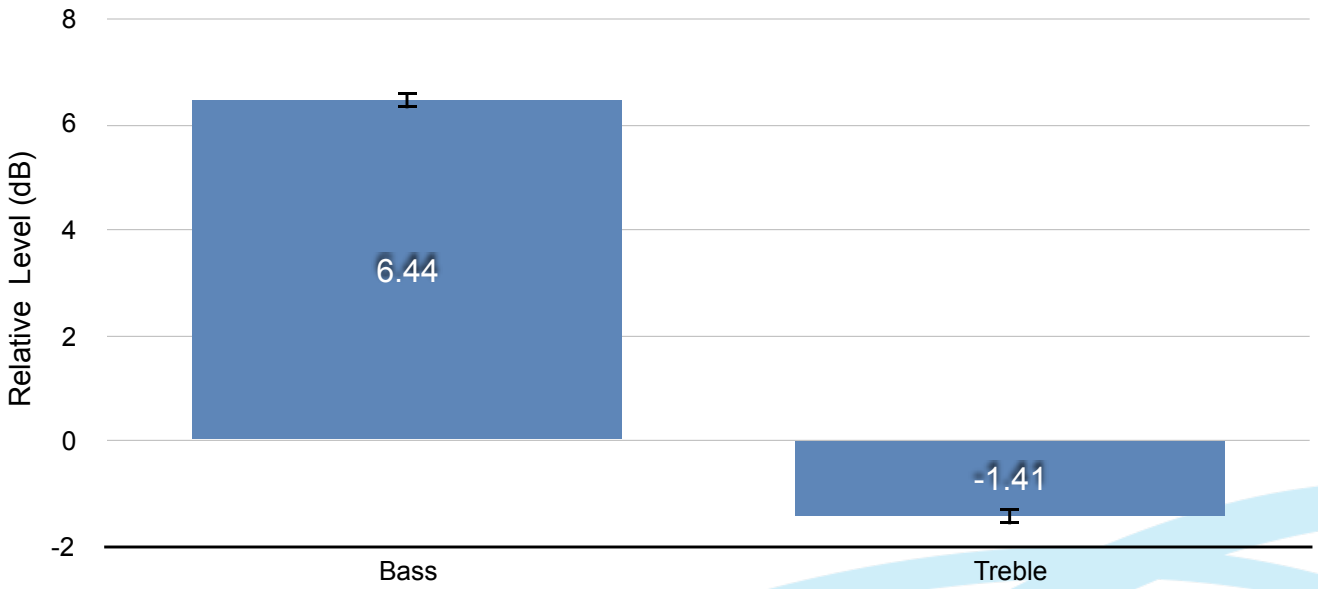
to whether the bass and treble levels of the headphone target response were optimized for best sound quality.

To address this question, a follow up experiment was recently conducted wherein listeners directly adjusted the relative bass and treble levels of the headphone after

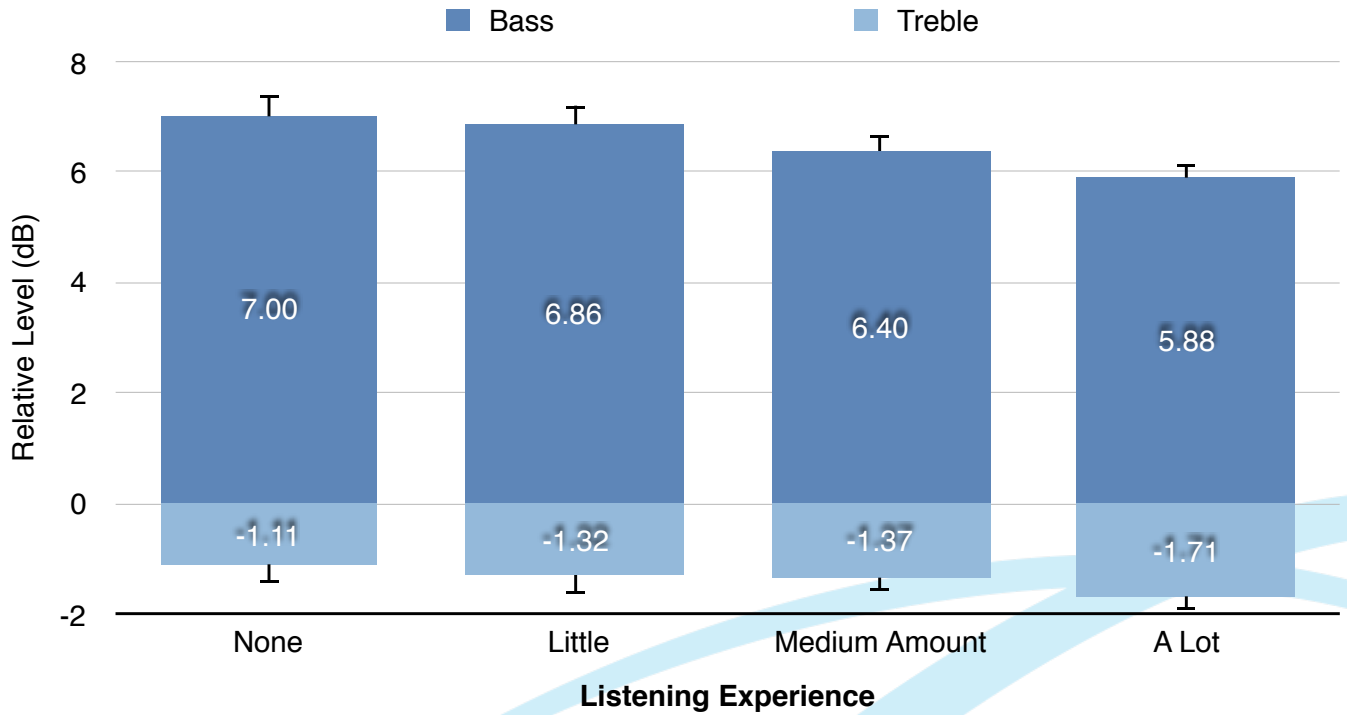
# RESULTS

## PREFERRED BASS AND TREBLE LEVELS

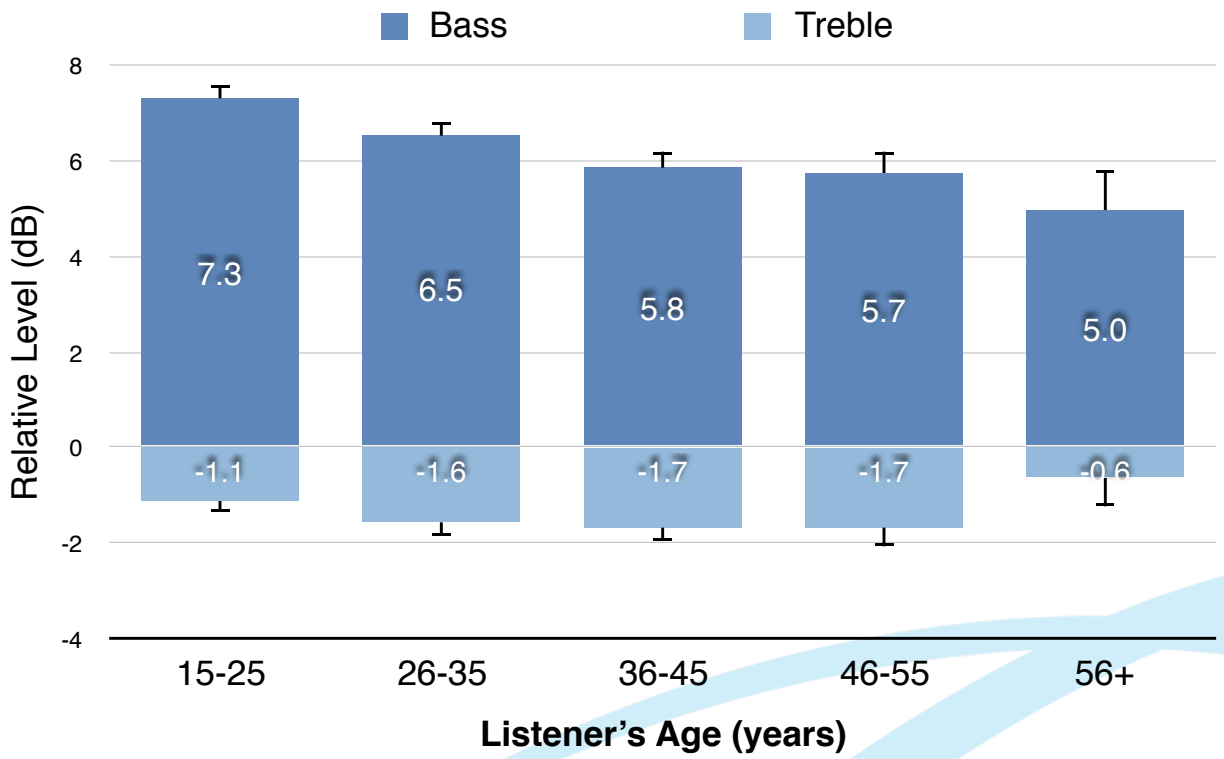
Averaged across all programs and all listeners (n=249)



# EFFECT OF LISTENING EXPERIENCE ON PREFERRED BASS AND TREBLE LEVELS

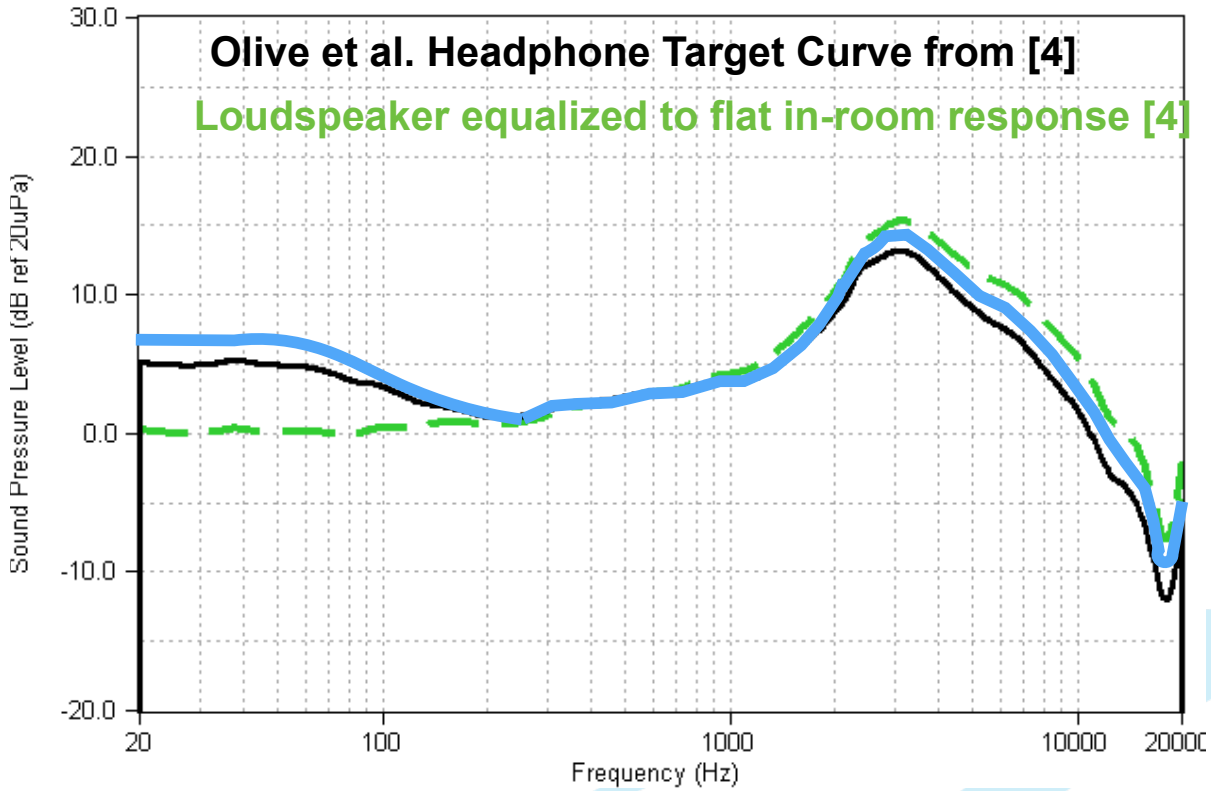


# EFFECT OF AGE OF LISTENER



# RESULTS

## Olive & Welti Headphone Target Curve (this study)





[4] S.E. Olive, T. Welti and E. McMullin, “Listener Preferences for In-Room Loudspeaker and Headphone Target Responses,” presented at the 135Convention, Audio Eng., Soc., preprint 8994, (2013 October).

# CONCLUSIONS

**The preferred Harma nheadphone target response closely matches the preferred in-room response of an accurate loudspeaker in a reference listening room having about a 10 dB downward slope from 20 Hz-20 kHz**

**The preferred headphone target shape may vary depending on several factors:**

- **the spectrum and balance of the recording (circle of confusion issues)**
- **listeners' age, listening experience: younger, less experienced listeners tend to prefer more bass and treble; older listeners may prefer more treble to compensate for hearing loss**
- **individual taste**
- **bass loss due to leakage/fit (closed headphones and IE types)**
- **masking of bass/mids from background noise**

# THE END