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WILL THE HEADPHONE INDUSTRY EVER AGREE ON A DESIGN TARGET CURVE?

SEAN OLIVE,
SENIOR FELLOW, INTELLIGENT AUDIO
HARMAN X

November 9 2022

TALK OVERVIEW

- Is there a universal headphone target curve that most people prefer?
- What factors influence listener preferences?
- Some challenges/considerations in designing and testing headphones that satisfy listeners' sound quality preferences

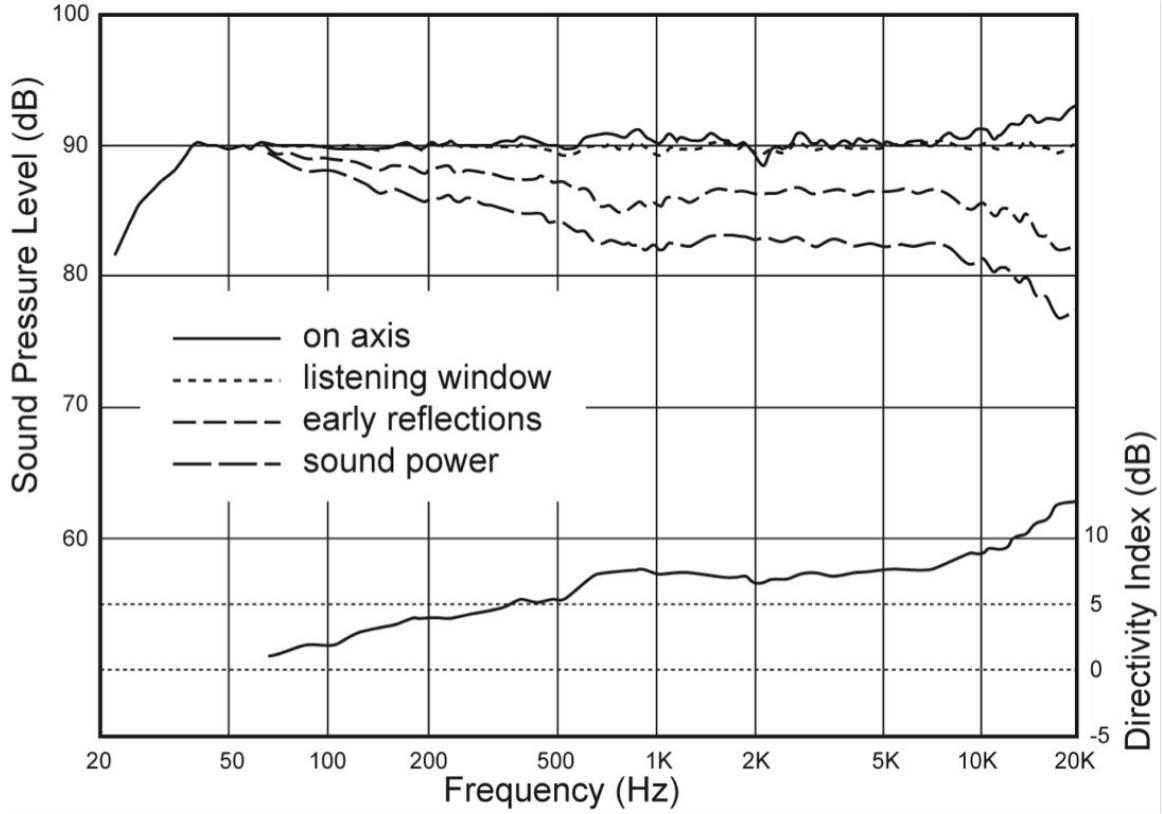
DO PEOPLE AGREE ON WHAT MAKES A LOUDSPEAKER SOUND GOOD?

Since Floyd Toole's landmark AES papers on listener loudspeaker preferences (1985-86) the industry seems to have converged on what makes a loudspeaker sound good and how to measure it…

National Research Council (NRC) of Canada's IEC Listening Room

JBL M2 PRO REFERENCE LOUDSPEAKER

Since 1980's controlled listening test results confirm listeners prefer loudspeakers that are anechoically flat on axis with smooth well-behaved off-axis responses to produce neutral direct sound, early reflections and sound power



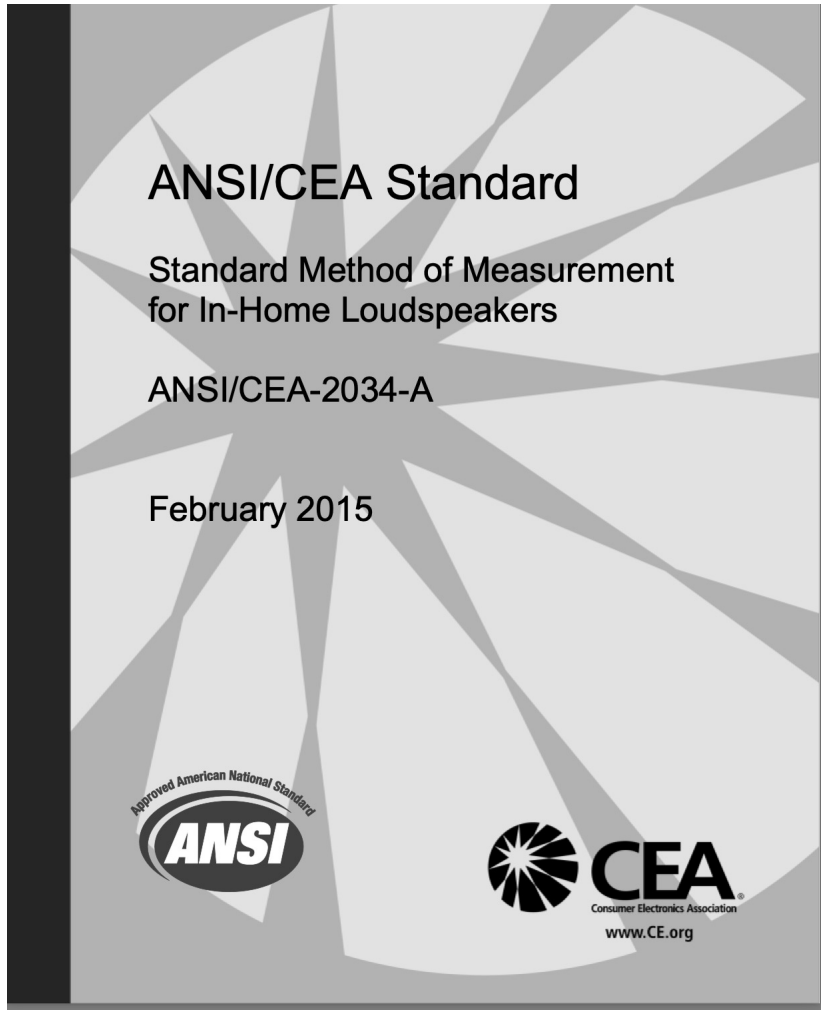
CORRELATION BETWEEN SUBJECTIVE AND OBJECTIVE MEASUREMENTS

r = 0.86

Using anechoic measurements for 70+ different loudspeaker models, a model was developed to predict listeners' preference ratings with a correlation of 0.86 between predicted vs measured results.

ARE THE LOUDSPEAKER TARGET CURVES AN INDUSTRY STANDARD?

- The research has been published and widely widely disseminated in scientific audio literature
- Measurements are an ANSCI-CEA 2034A standard
- Harman brands and others apply it
- Used by consumer testing sites (www.asr.com, www.erincorner.com, www.audioholics.com)
- But the targets themselves are not part of any international standard; at best they have become a De Facto standard



WHAT ABOUT HEADPHONE STANDARDS?

- The current IEC 60268-7 & ITU-R BS 708 headphone standards recommend diffuse-field calibration but no one seems to be following it.
- New evidence shows there are alternative headphones targets based on loudspeakers captured in semi-reflective sound fields that are more preferred
- Without a meaningful standard for guidance there seems to be little consensus on how to make a headphone sound good or how to measure it

Acoustics Today

AT Collections | On – Line Features | News | FAQ

FEATURED ARTICLE

The Perception and Measurement of Headphone Sound Quality: What Do Listeners Prefer?

Sean E. Olive

Headphones are the primary means through which we listen to music, movies, and other forms of infotainment. They have become an indispensable accessory for our mobile phones, providing a 24/7 connection to our entertainment, colleagues, and loved ones. This trend is reflected in the exponential growth in sales. The global market for wireless headphones alone was estimated at $15.9B in 2020 and is projected to rise to $45.7B by 2026, a compound annual growth rate of 19.1% (PRNewsWire, 2021). With this growth has come a renewed interest in improving the sound quality of headphones.

Unfortunately, headphone sound quality has not kept pace with consumers' demands and expectations. Two recent studies have measured the variance in frequency response of more than 400 headphones and found no correlation between their retail price and frequency response (Breebaart, 2017; Olive et. al., 2018a). They included the three most common types: headphones that fit around the ear

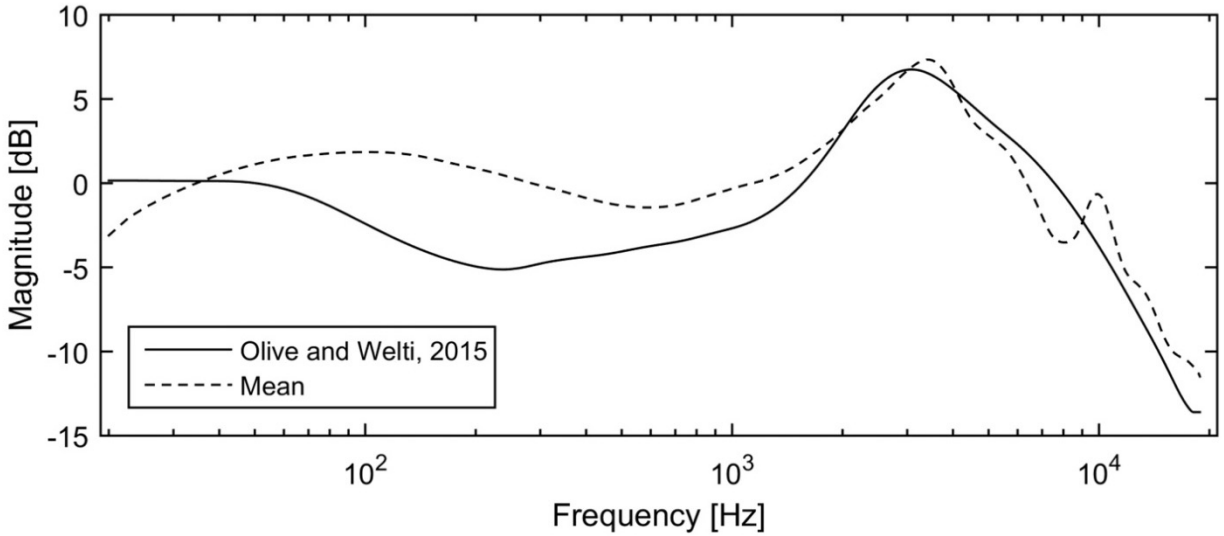
recommends that professional headphones be designed to the DF target curve to achieve best sound, but most headphone designers have rejected this suggestion and probably for good reasons. Recent psychoacoustic investigations provide evidence that listeners prefer alternative headphone targets to DF and FF target standards (Olive et al., 2013a).

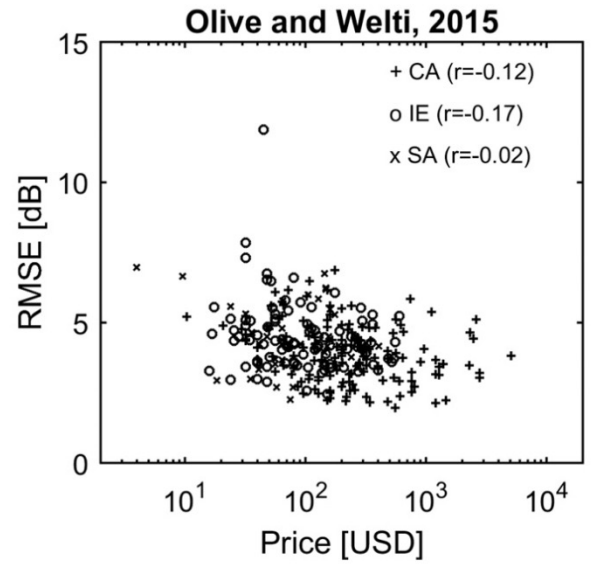
The chaos that exists within the headphone industry today is reminiscent of the loudspeaker industry 30 years ago when there was insufficient knowledge on listeners' loudspeaker preferences and which loudspeaker measurements best predict them. The situation improved after Floyd Toole, an acoustician at the National Research Council of Canada, published seminal scientific papers that provided guidelines in how to measure and design loudspeakers that most listeners prefer (Toole, 1985, 1986). Later, a mathematical model was developed that could predict listeners' preference ratings of the loud-

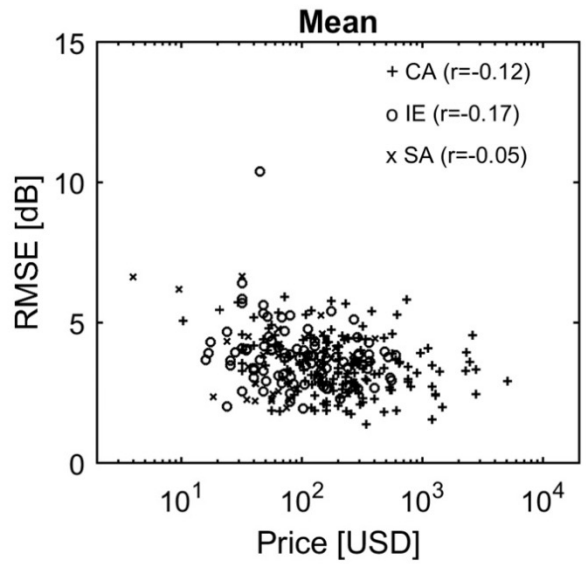
Spring 2022, vol 18, No 1

NO CORRELATION BETWEEN HEADPHONE FREQUENCY RESPONSE AND PRICE (BREEBART 2017)

- The average frequency response of 283 headphones compared to preferred Harman target response for AE headphones
- The Root Mean Square Error varies from 2.5 to 13 dB
- No correlation between price and frequency response







SONARWORKS 2022

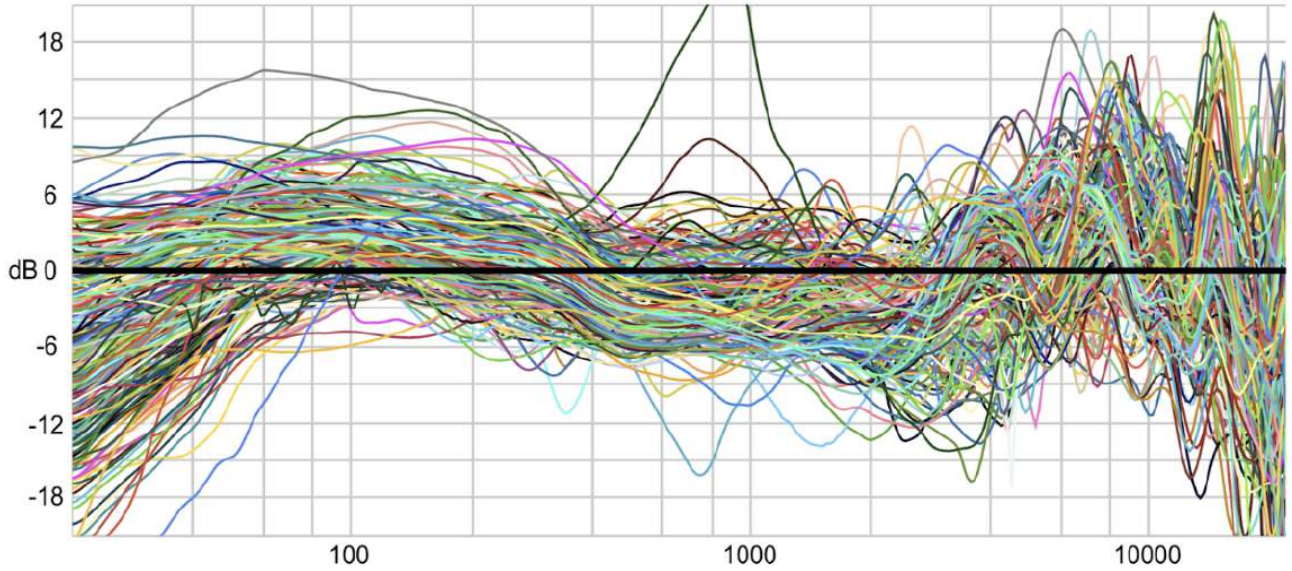
https://www.sonarworks.com/blog/research/white-paper

Abstract

Currently, each headphone manufacturer develops frequency response sound targets using proprietary methods. There is no dominant standard on how to measure headphone frequency response. The measurement equipment that is available on the market, yields diverging results, and none matches human perception to a sufficient degree. Also, the headphones on the market exhibit very little consistency of frequency response, even within a single manufacturer's catalog. Furthermore, our research shows that user preferences are also varied and do not converge on one sound target, and in 78% of the cases, consumer experience can be enhanced through frequency response target personalization.

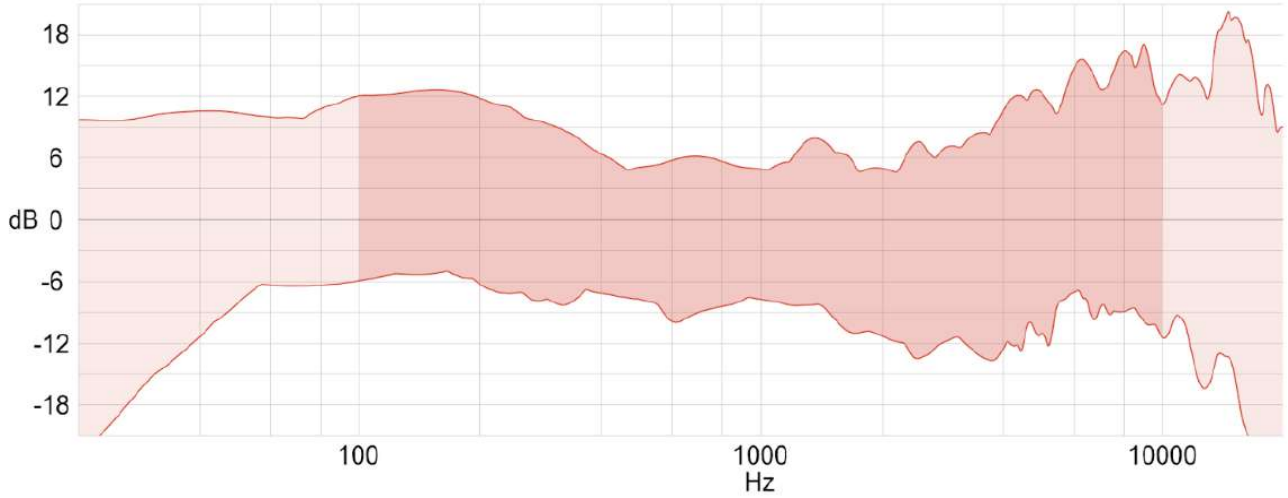
"….There is no universal headphone sound target: Consumer preferences do not converge…"

SONARWORKS (2022)



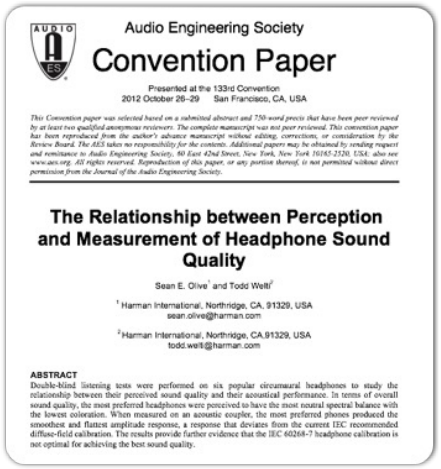
Frequency response of 400 headphones in the market measured by Sonarworks

”..there is no common ground on how headphones sound..”



95% confidence intervals of the above 400 headphones

HARMAN HEADPHONE RESEARCH SINCE 2012



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Convention Paper

Presented at the 133rd Convention
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The Relationship between Perception and Measurement of Headphone Sound Quality

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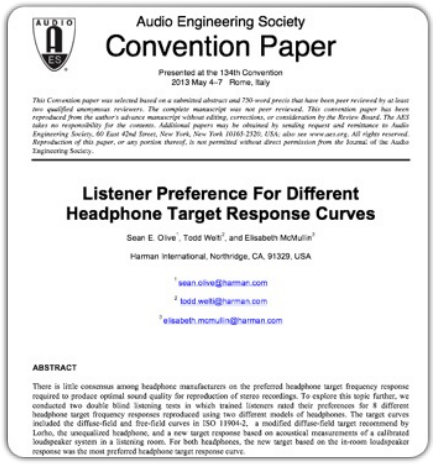
ABSTRACT

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

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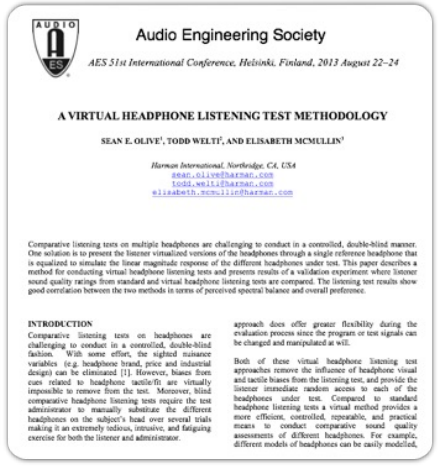
ABSTRACT

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.



Audio Engineering Society

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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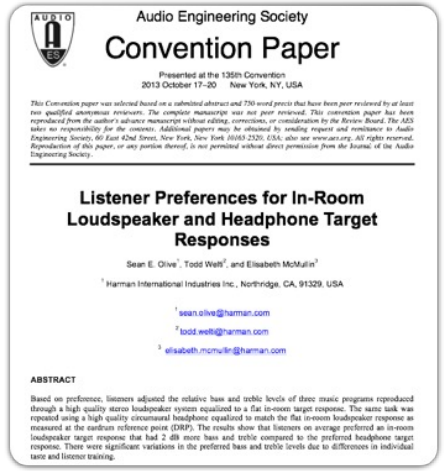
Comparative listening tests on multiple headphones are challenging to conduct in a controlled, double-blind manner. One solution is to present the listener virtualized versions of the headphones through a single reference headphone that is equalized to simulate the linear magnitude response of the different 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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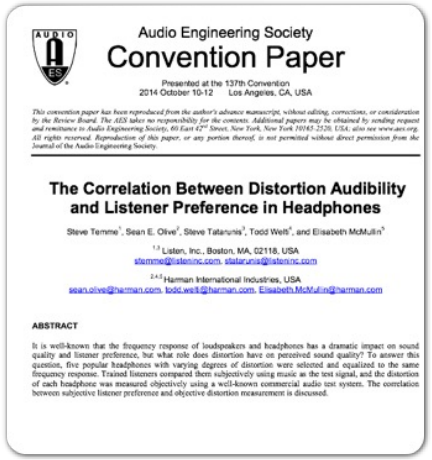
ABSTRACT

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.



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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.

Audio Engineering Society

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

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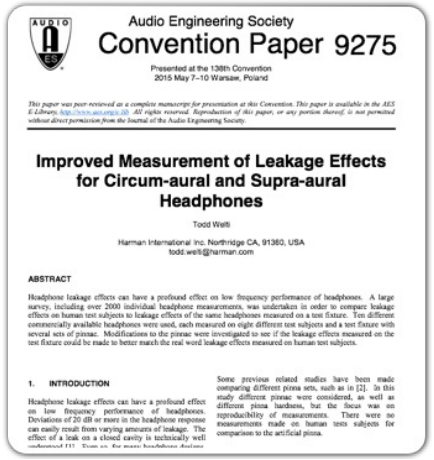
ABSTRACT

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.



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

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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.

Audio Engineering Society

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

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ABSTRACT

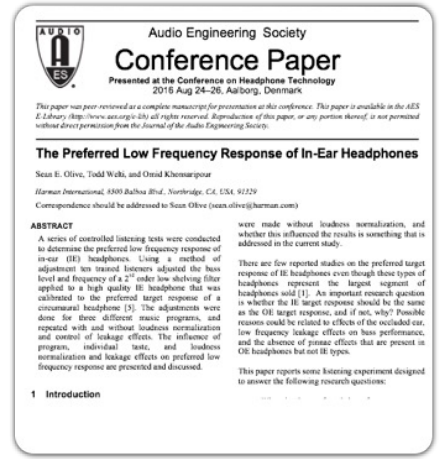
A listening experiment was conducted to study factors that influence listeners' preferred bass and treble balance in headphone sound reproduction. Using a method of adjustment a total of 249 listeners adjusted the relative treble and bass levels of a headphone that was first equalized at the eardrum 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



Audio Engineering Society

Conference Paper

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The Preferred Low Frequency Response of In-Ear Headphones

Sean E. Olive, Todd Welti, and Omid Khonsaripour

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Correspondence should be addressed to Sean Olive (sean.olive@harman.com)

ABSTRACT

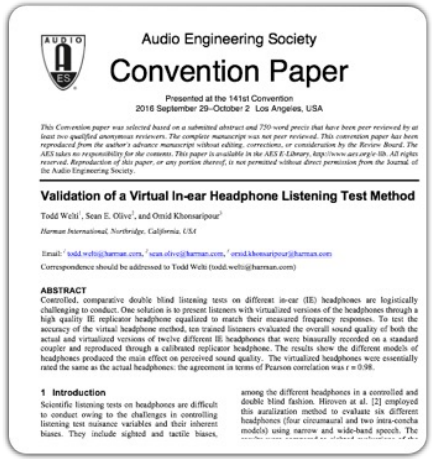
A series of controlled listening tests were conducted to determine the preferred low frequency response of in-ear (IE) headphones. Using a method of adjustment ten trained listeners adjusted the bass level and frequency of a 2nd order low shelving filter applied to a high quality IE headphone that was calibrated to the preferred target response of a circumaural headphone [3]. The adjustments were done for three different music programs, and repeated with and without loudness normalization and control of leakage effects. The influence of program, individual taste, and loudness normalization and leakage effects on preferred low frequency response are presented and discussed.

1 Introduction

were made without loudness normalization, and whether this influenced the results is something that is addressed in the current study.

There are few reported studies on the preferred target response of IE headphones even though these types of headphones represent the largest segment of headphones sold [1]. An important research question is whether the IE target response should be the same as the OE target response, and if not, why? Possible reasons could be related to effects of the occluded-ear, low frequency leakage effects on bass performance, and the absence of pinnae effects that are present in OE headphones but not IE types.

This paper reports some listening experiment designed to answer the following research questions:



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Validation of a Virtual In-ear Headphone Listening Test Method

Todd Welti[1], Sean E. Olive[2], and Omid Khonsaripour[3]

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Correspondence should be addressed to Todd Welti (todd.welti@harman.com)

ABSTRACT

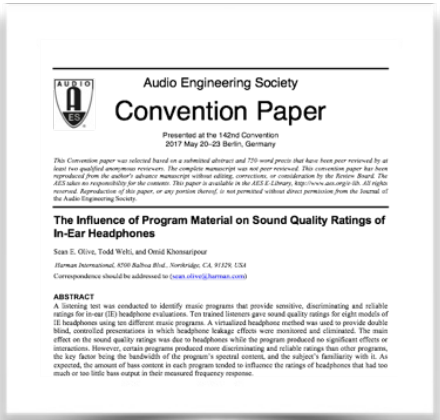
Controlled, comparative double blind listening tests on different in-ear (IE) headphones are logistically challenging to conduct. One solution is to present listeners with virtualized versions of the headphones through a high quality IE replicator headphone equalized to match their measured frequency responses. To test the accuracy of the virtual headphone method, ten trained listeners evaluated the overall sound quality of both the actual and virtualized versions of twelve different IE headphones that were binaurally recorded on a standard coupler and reproduced through a calibrated replicator headphone. The results show the different models of headphones produced the main effect on perceived sound quality. The virtualized headphones were essentially rated the same as the actual headphones: the agreement in terms of Pearson correlation was r = 0.98.

1 Introduction

Scientific listening tests on headphones are difficult to conduct owing to the challenges in controlling listening test nuisance variables and their inherent biases. They include sighted and tactile biases,

among the different headphones in a controlled and double blind fashion. Hiroven at al. [2] employed this auralization method to evaluate six different headphones (four circumaural and two intra-concha models) using narrow and wide-band speech. The

HARMAN HEADPHONE RESEARCH SINCE 2012


Audio Engineering Society
Convention Paper
Presented at the 142nd Convention
2017 May 20–23 Berlin, Germany

The Influence of Program Material on Sound Quality Ratings of In-Ear Headphones

Sean E. Olive, Todd Welti, and Omid Khonsaripour


2017
ISEAT

A statistical model that predicts listener's sound quality preferences for in-ear headphones

Sean E. Olive


Audio Engineering Society
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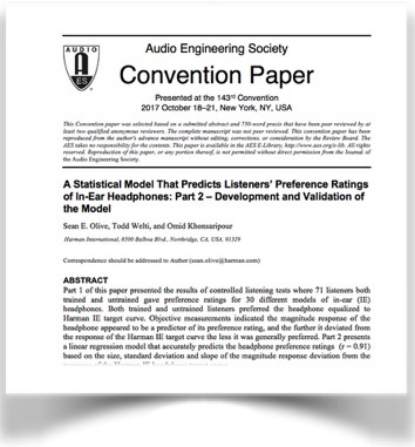
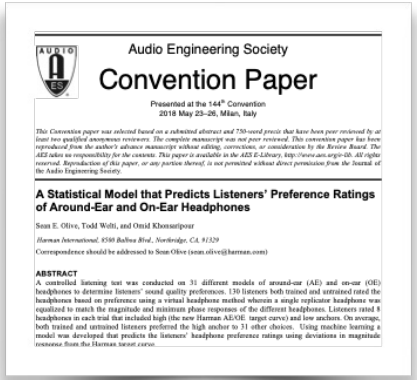
Presented at the 143rd Convention
2017 October 18–21, New York, NY, USA


Audio Engineering Society
Convention Paper
Presented at the 143rd Convention
2017 October 18–21, New York, NY, USA

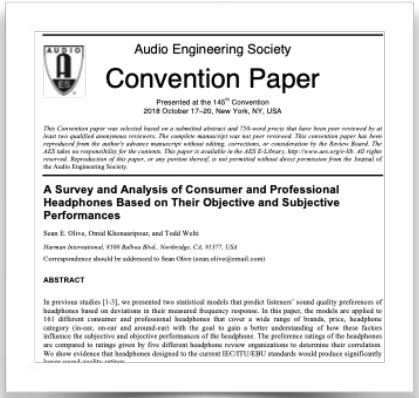
A Statistical Model That Predicts Listeners' Preference Ratings of In-Ear Headphones: Part 2 – Development and Validation of the Model

Sean E. Olive, Todd Welti, and Omid Khonsaripour


Audio Engineering Society
Convention Paper
Presented at the 144th Convention
2018 May 23–26, Milan, Italy

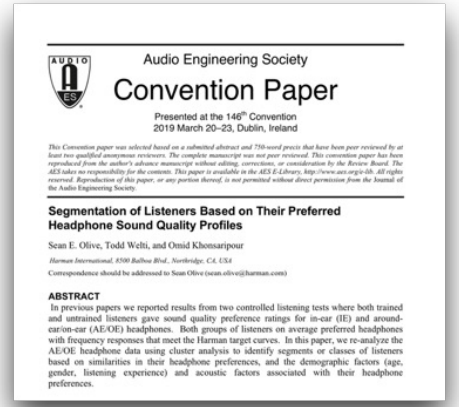
A Statistical Model that Predicts Listeners' Preference Ratings of Around-Ear and On-Ear Headphones

Sean E. Olive, Todd Welti, and Omid Khonsaripour


Audio Engineering Society
Convention Paper
Presented at the 145th Convention
2018 October 17–20, New York, NY, USA

A Survey and Analysis of Consumer and Professional Headphones Based on Their Objective and Subjective Performances

Sean E. Olive, Omid Khonsaripour, and Todd Welti


Audio Engineering Society
Convention Paper
Presented at the 146th Convention
2019 March 20–23, Dublin, Ireland

Segmentation of Listeners Based on Their Preferred Headphone Sound Quality Profiles

Sean E. Olive, Todd Welti, and Omid Khonsaripour

19 paper publications
Two book chapters
3 patents, several pending
1-click headphone measurement that predicts sound quality rating

PREVIOUS DANISH SOUND CLUSTER PRESENTATION

HARMAN
A SAMSUNG COMPANY

Danish Sound Cluster

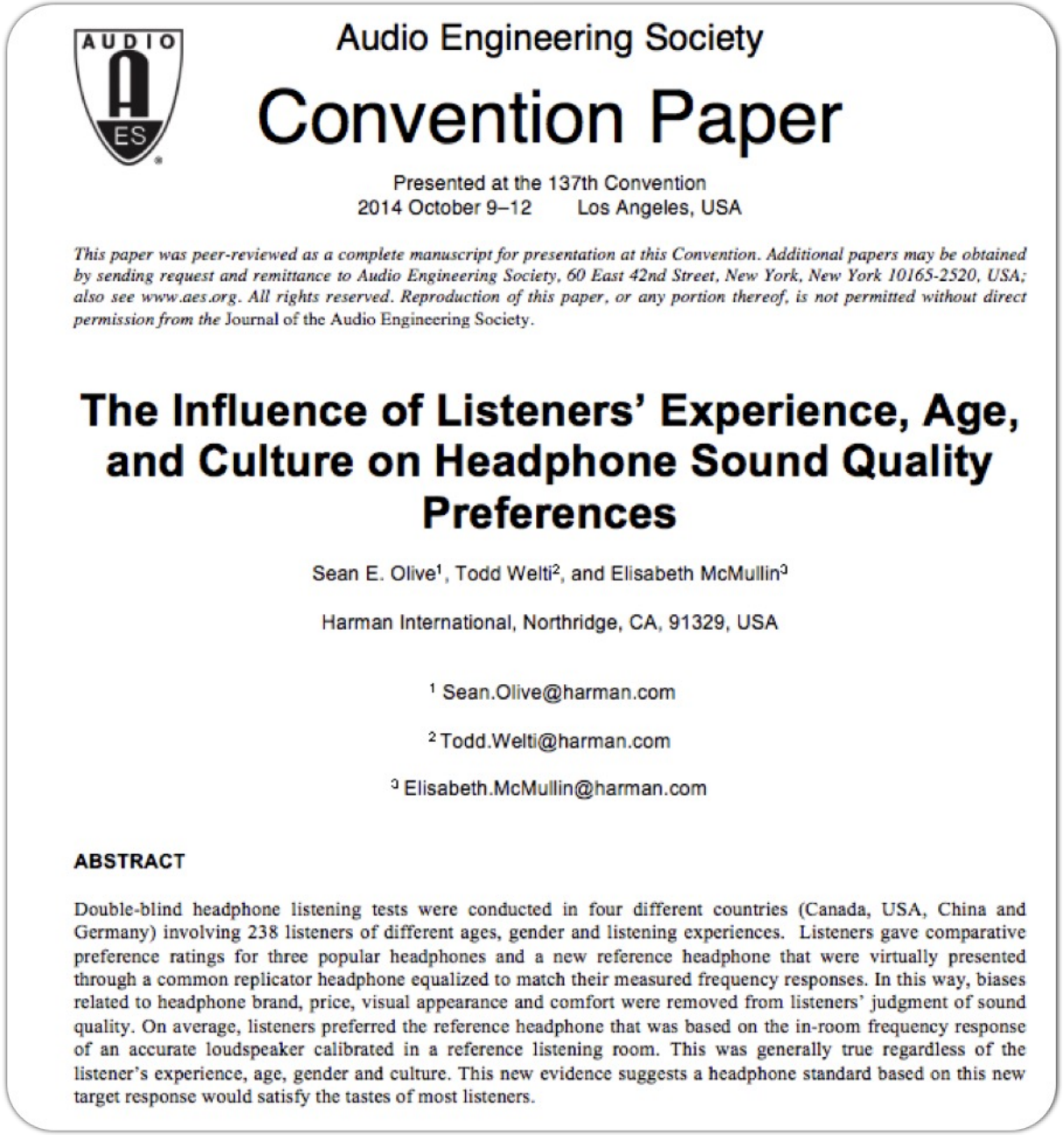
Designing Headphones to Satisfy Listeners' Sound Quality Preferences

November 2, 2021 @ 15.00 – 16.30

Sean Olive is certainly a voice of authority when it comes to listener preferences. He has written over 50 published papers on the perception and measurement of audio and has won numerous awards for his lifetime of work with headphones and loudspeakers. Do not miss this special opportunity to speak with Sean directly and learn more about how to satisfy your customers.

CLICK HERE TO REGISTER

https://danishsoundcluster.dk/en/headphone-listening-preferences/



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

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

Harman International, Northridge, CA, 91329, USA

[1] Sean.Olive@harman.com

[2] Todd.Welti@harman.com

[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.

HARMAN A SAMSUNG COMPANY

2014

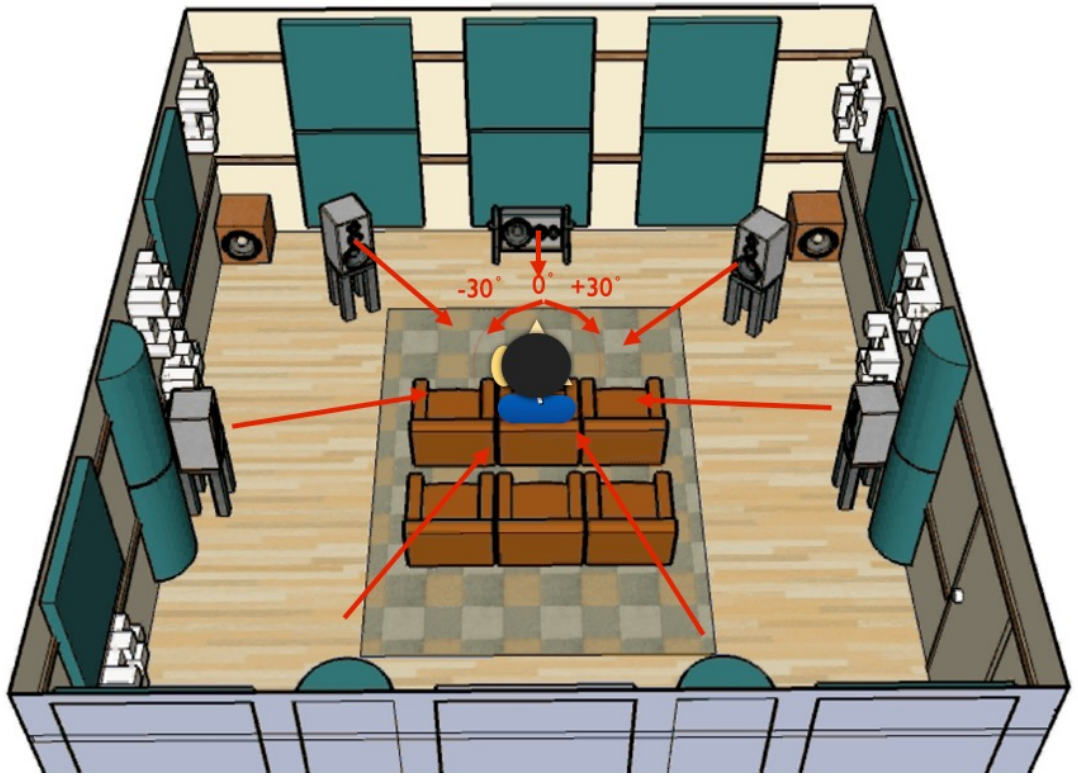
Do listeners have different headphone preferences related to their age, listening experience, culture or gender?

HARMAN TARGET CURVE: BASED ON A NEUTRAL LOUDSPEAKER IN A SEMI-REFLECTIVE ROOM

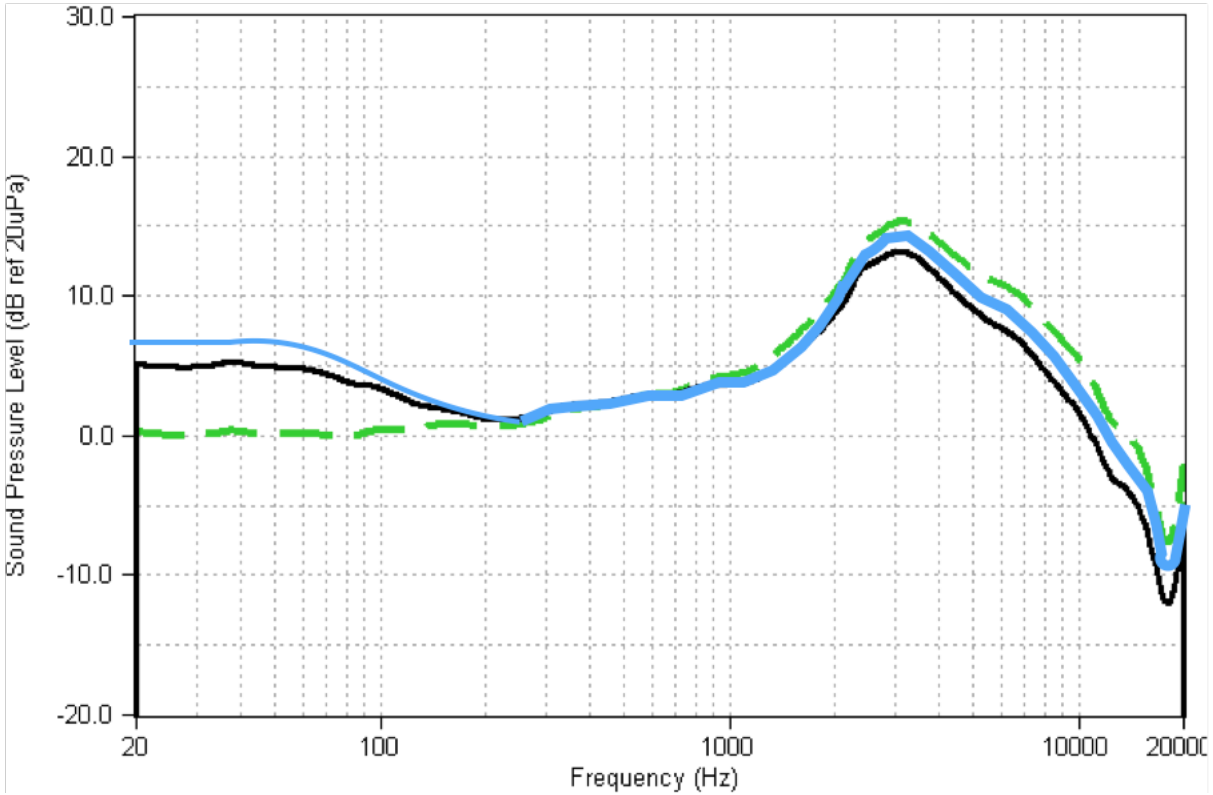
- Since stereo recordings are optimized to sound good over neutral loudspeakers in a semi-reflective room headphones should be based on what listeners hear in such conditions

- This became the baseline of the Harman Target Curve

- Further adjustments were made to the bass of the target curve based on psychoacoustic experiments and listening tests



HARMAN AE/OE HEADPHONE TARGET CURVE BASED ON GRAS 45CA MEASUREMENT



Flat in-room loudspeaker

Target Curve (Olive et al. 2013)

Target Curve (Olive & Welti 2015)

Note: To make an anechoically flat loudspeaker "flat" in a room requires EQ to cut the bass and boost the treble- a base line for method of adjustment studies. The adjustment experiment results tell us listeners do not prefer this for their loudspeakers or headphones.

TEST CONDUCTED IN FOUR COUNTRIES (238 LISTENERS)

Canada
(untrained)

United States
(trained vs untrained)

China
(trained vs untrained)

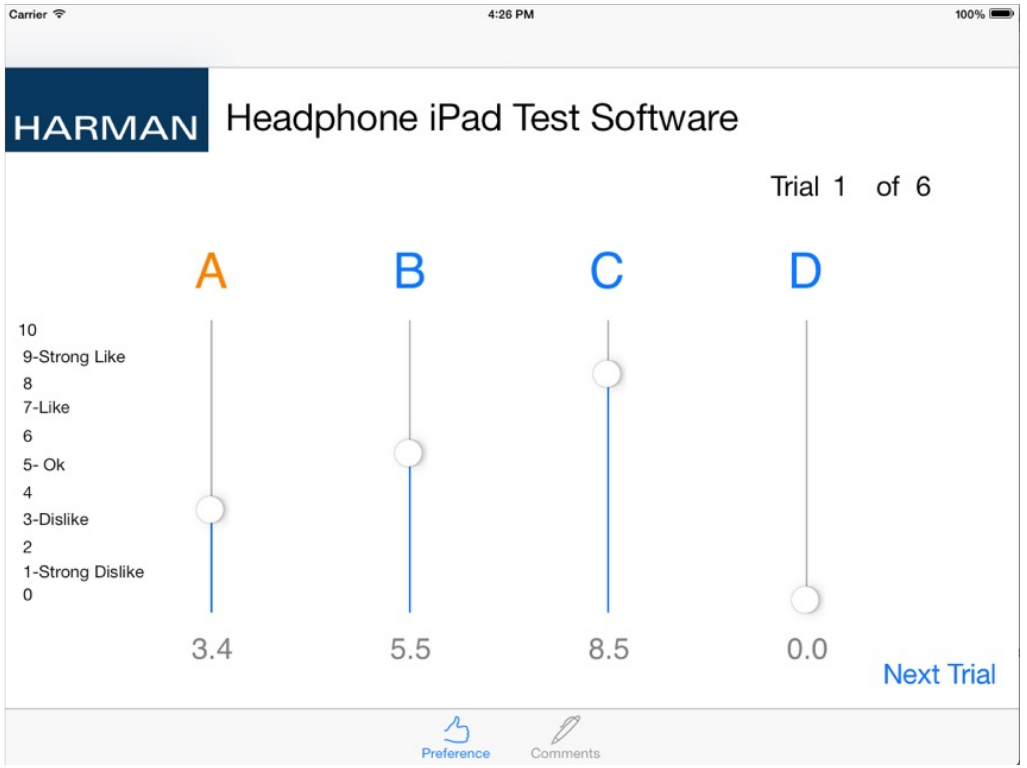
Germany
(trained vs untrained)

HEADPHONES TESTED

Brand / Model		Price
Harman Target Curve	Based on latest AES paper October 2013	----
Sennheiser HD800		$1500
Audeze LCD2 (rev 2)		$995
Beats by Dre Studio Limited Edition		$270

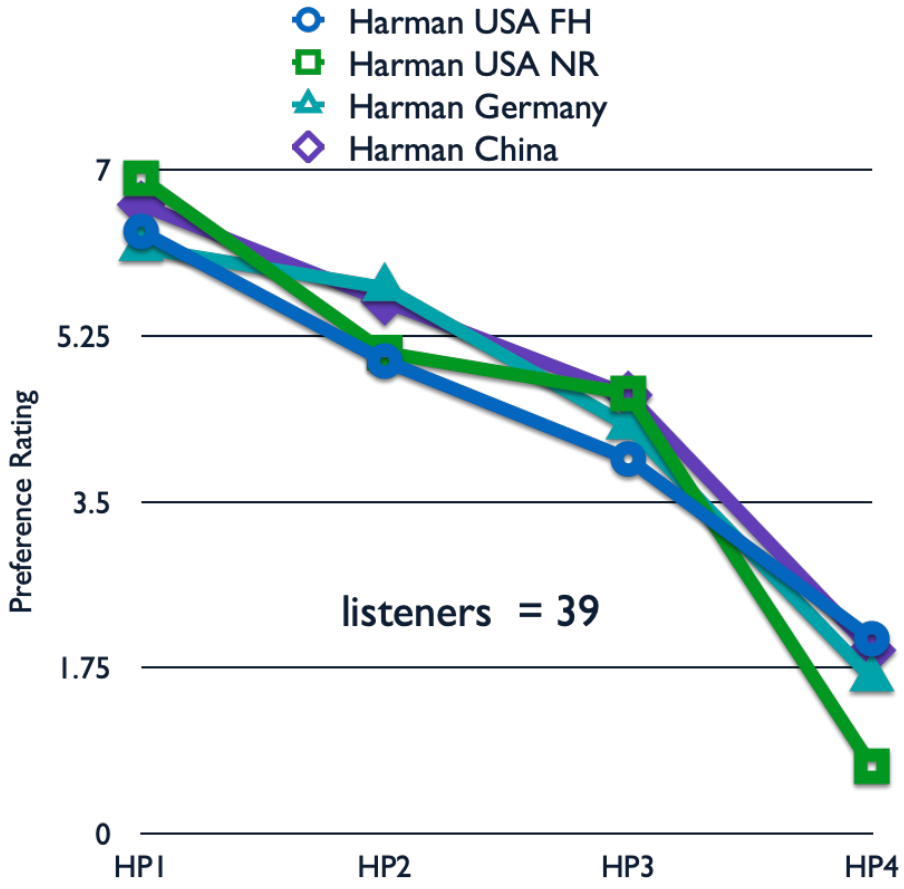
X

VIRTUAL HEADPHONE METHOD

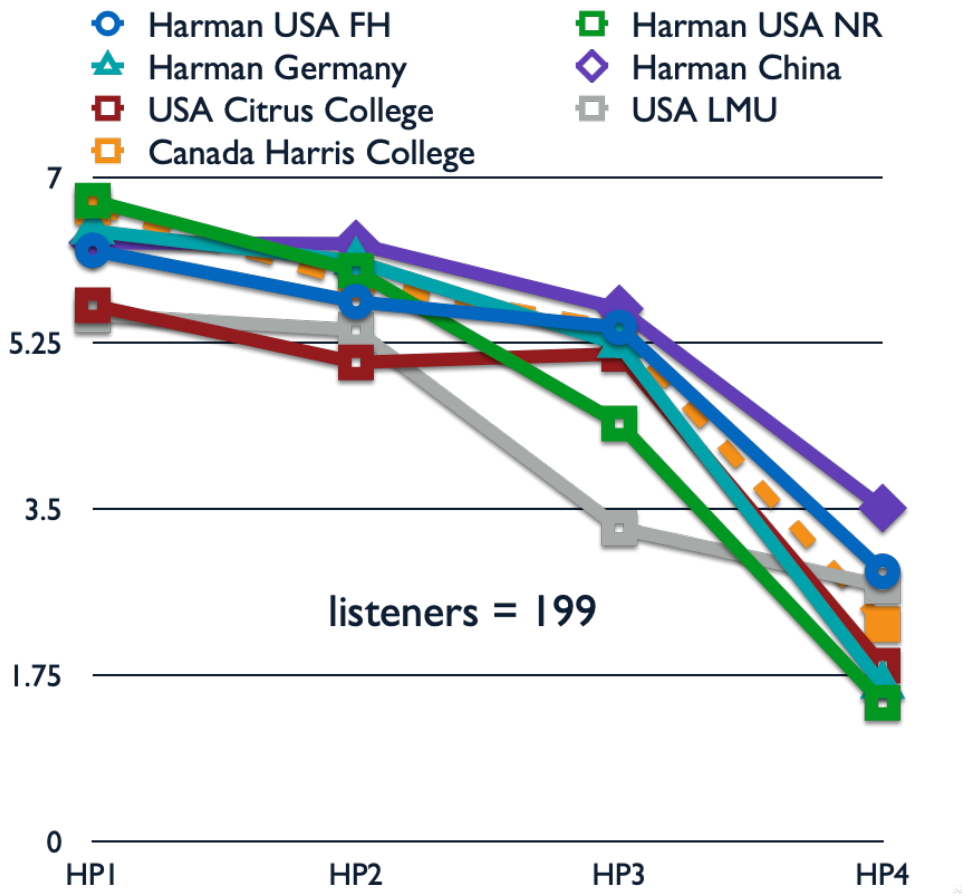


RESULTS

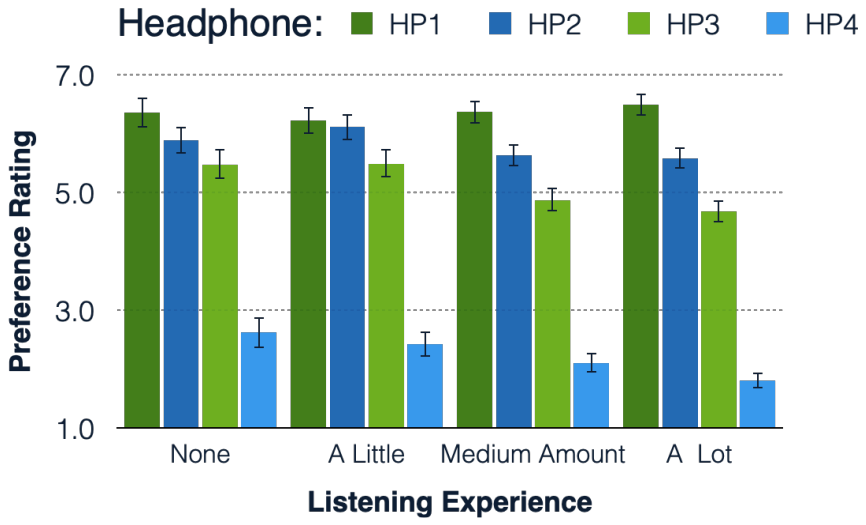
Trained Listeners

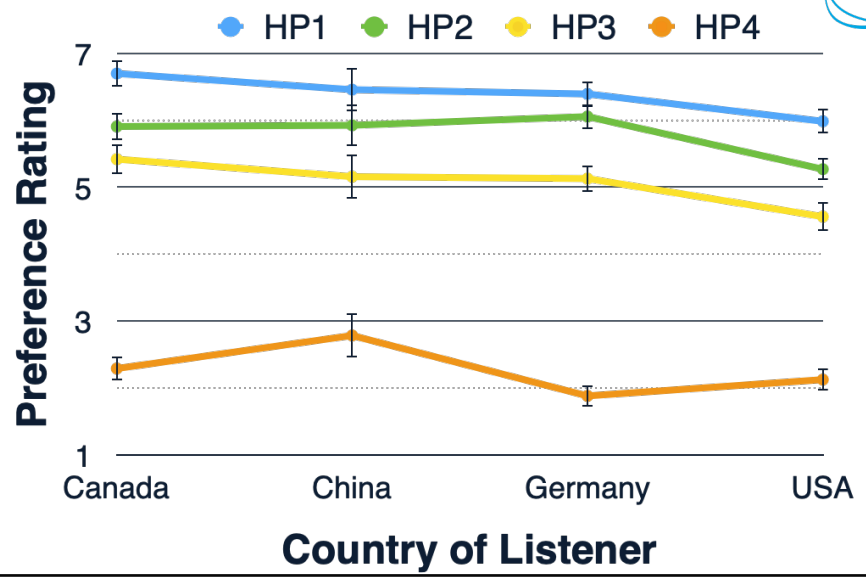


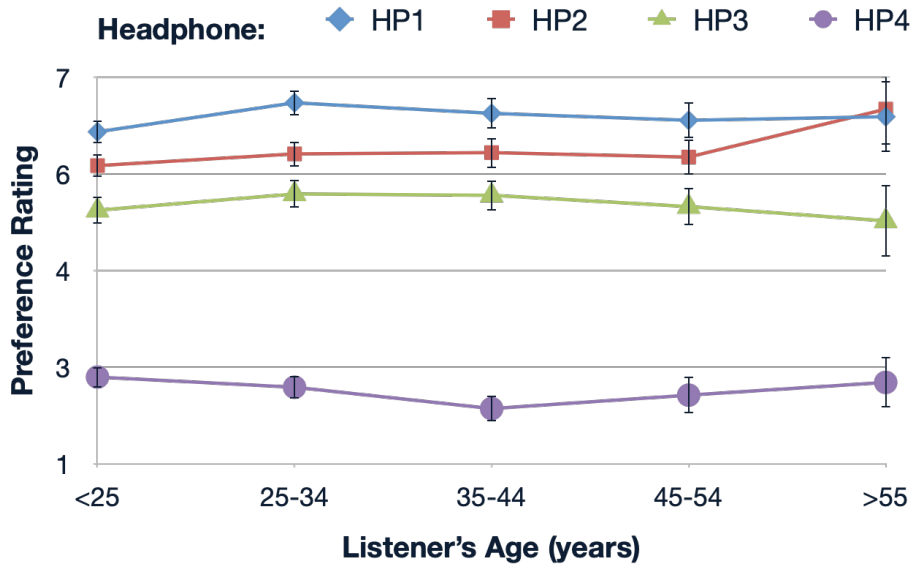
Untrained Listeners



EXPERIENCE, COUNTRY AND AGE EFFECTS



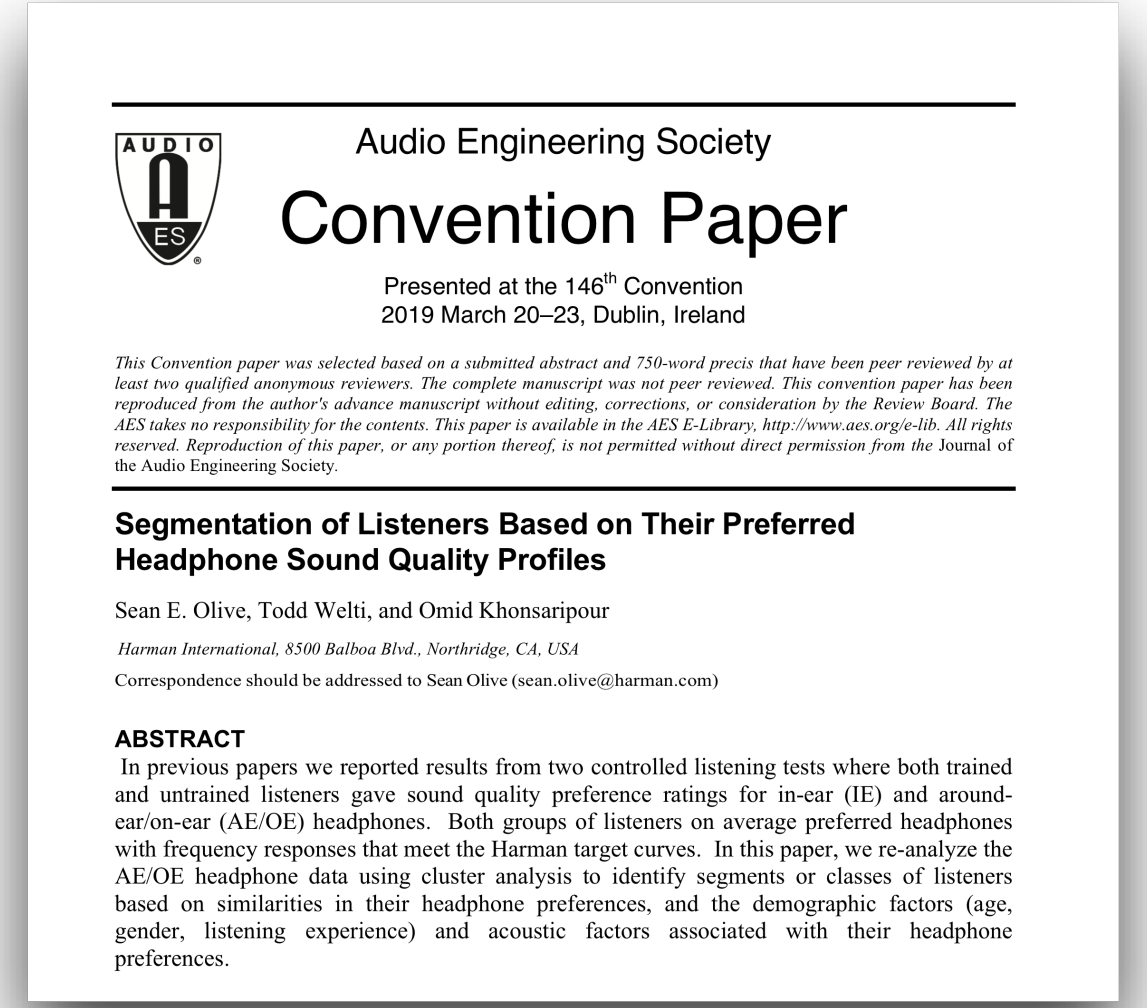




- No significant effect in headphone preference related to listening experience or country
- Preference was consistent across age categories except for older listeners who equally preferred Harman Target and a brighter headphone with less bass

SEGMENTATION OF LISTENERS BASED ON PREFERRED HEADPHONE SOUND PROFILE

2019



Audio Engineering Society

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Segmentation of Listeners Based on Their Preferred Headphone Sound Quality Profiles

Sean E. Olive, Todd Welti, and Omid Khonsaripour

Harman International, 8500 Balboa Blvd., Northridge, CA, USA

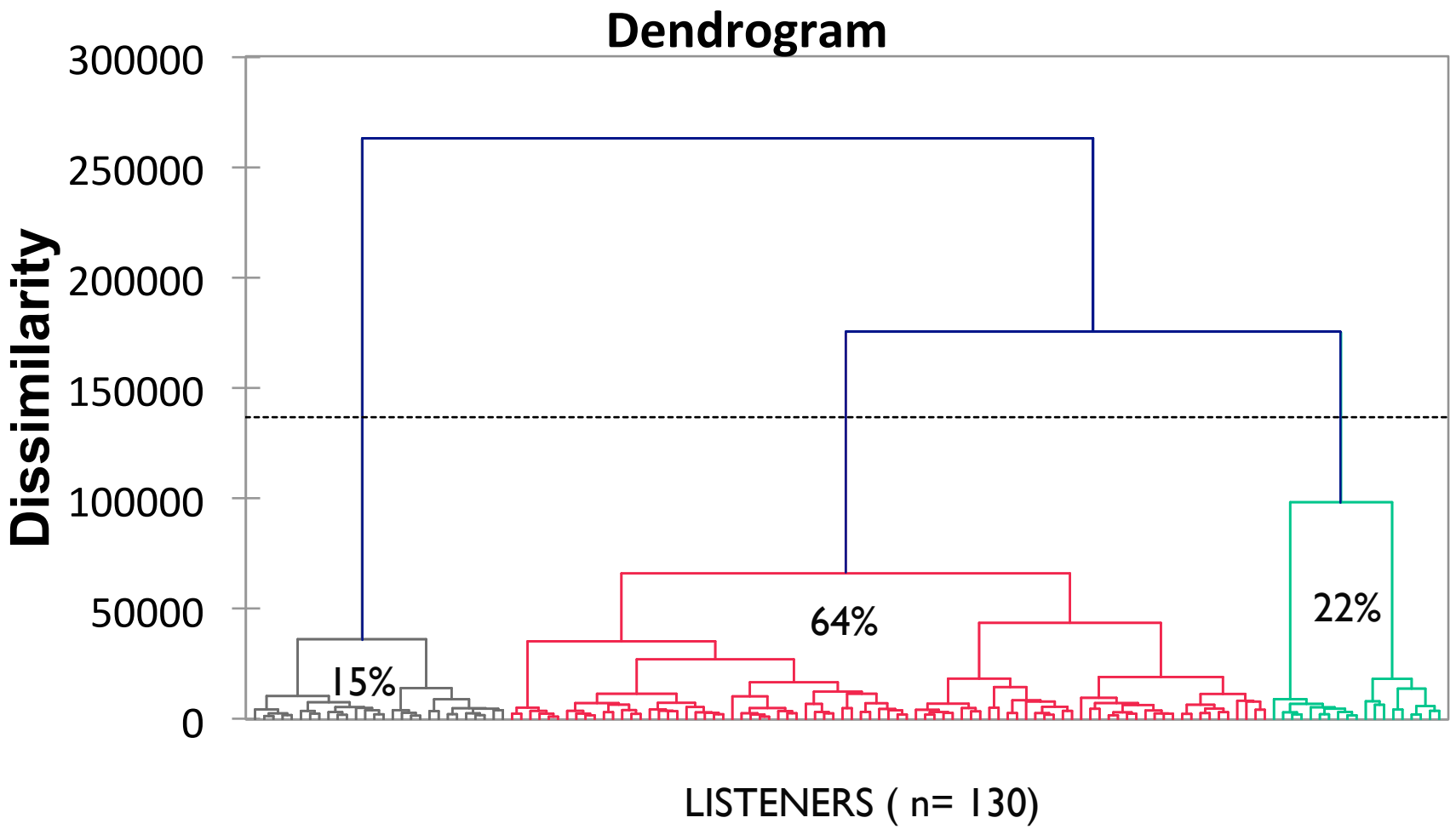
Correspondence should be addressed to Sean Olive (sean.olive@harman.com)

ABSTRACT

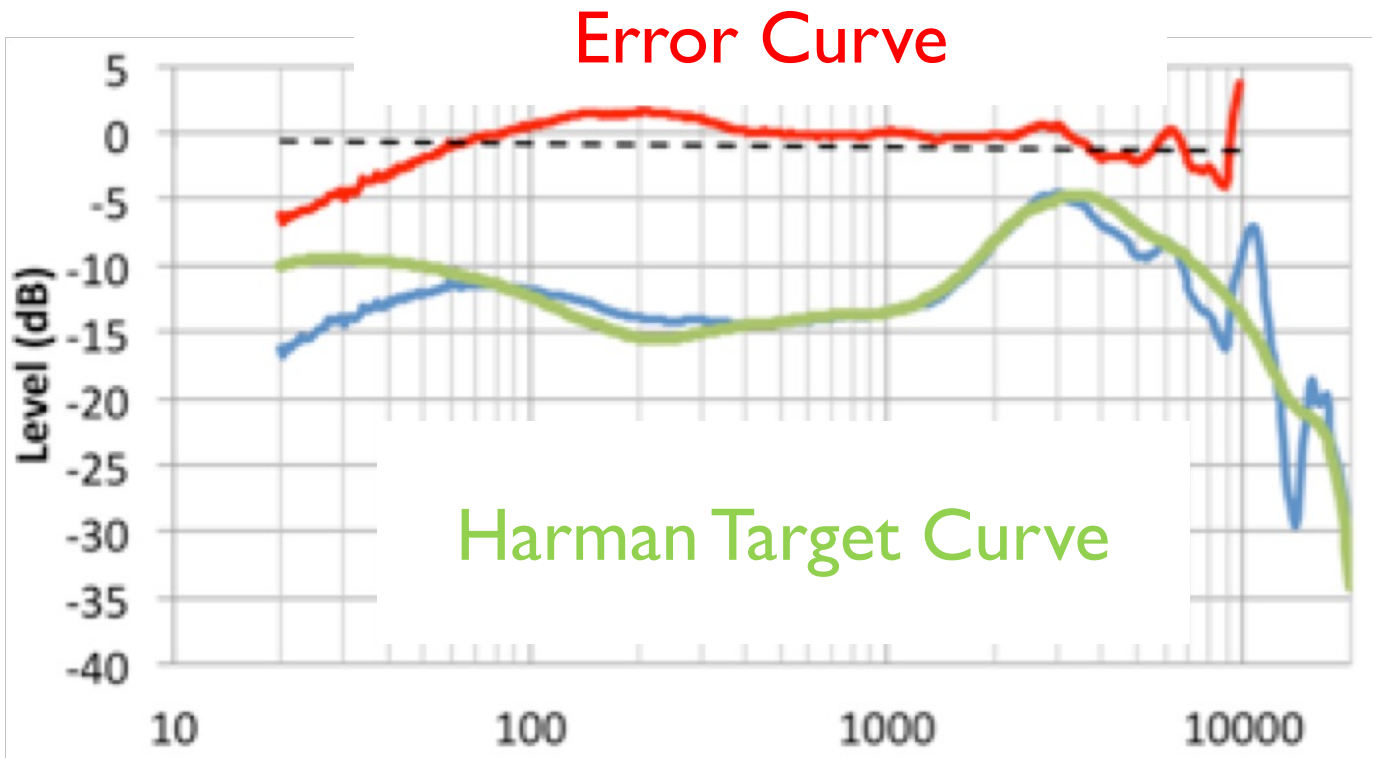
In previous papers we reported results from two controlled listening tests where both trained and untrained listeners gave sound quality preference ratings for in-ear (IE) and around-ear/on-ear (AE/OE) headphones. Both groups of listeners on average preferred headphones with frequency responses that meet the Harman target curves. In this paper, we re-analyze the AE/OE headphone data using cluster analysis to identify segments or classes of listeners based on similarities in their headphone preferences, and the demographic factors (age, gender, listening experience) and acoustic factors associated with their headphone preferences.

- 130 listeners rated 31 different headphones based on preference using a MUSHRA-like method
- Cluster analysis performed to determine number of segments of based on headphone preference
- What are the acoustic features of the headphones for each class and demographic factors associated with class?

AHC ANALYSIS OF LISTENER HEADPHONE PREFERENCES



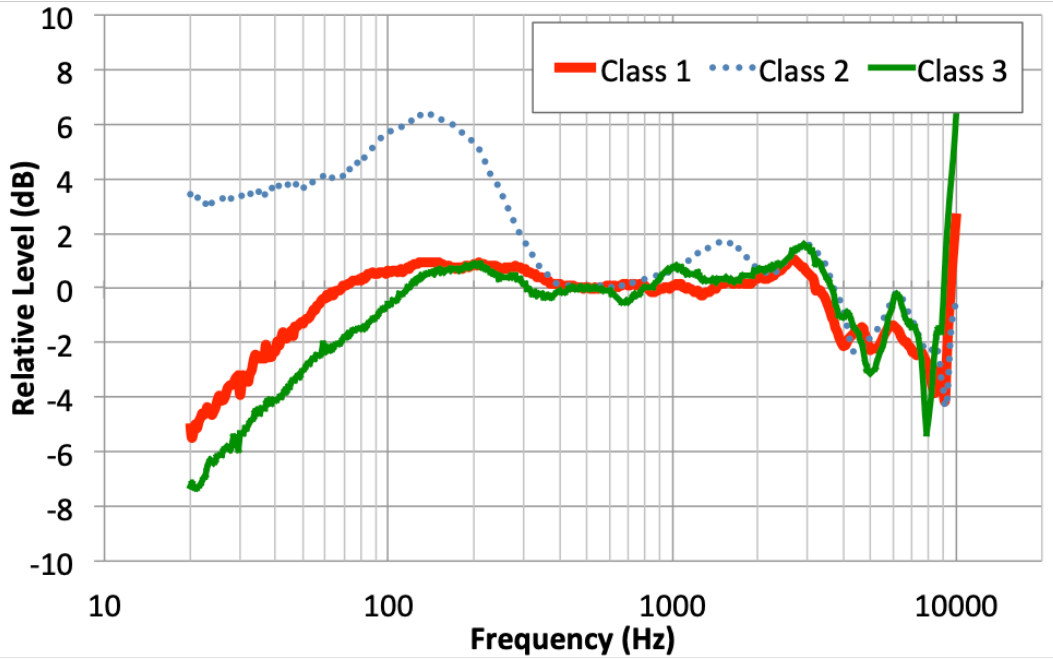
ACOUSTIC FEATURES OF PREFERRED HP IN EACH CLASS



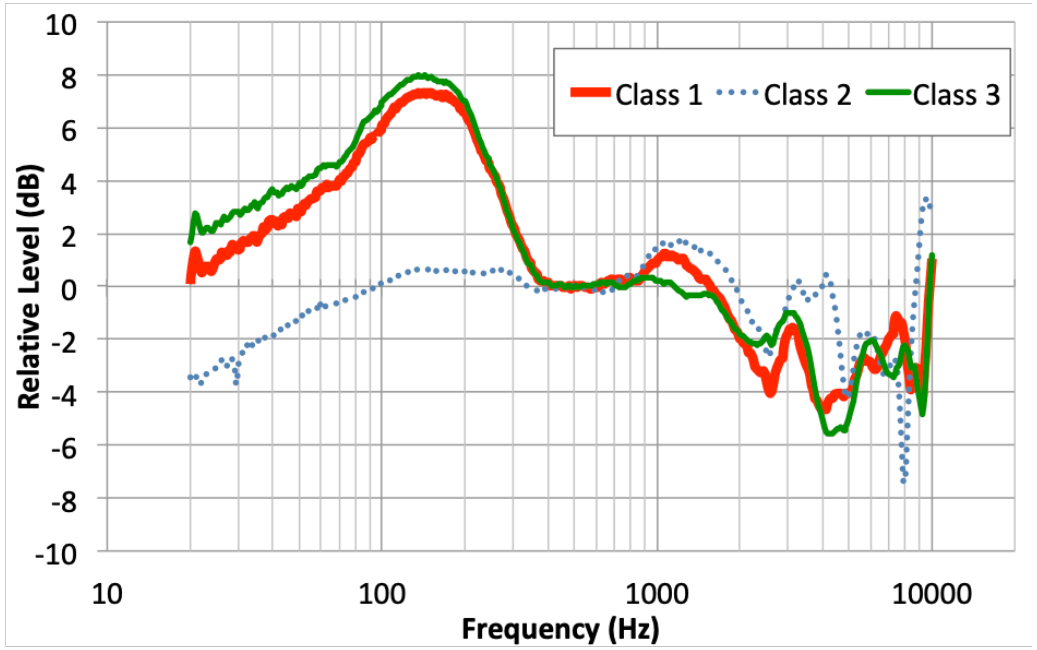
We calculated the average error response curve for the 5 most and least preferred headphones for each class to see how they differ.

ACOUSTIC FEATURES OF PREFERRED HEADPHONES IN EACH CLASS

Most Preferred



Least Preferred

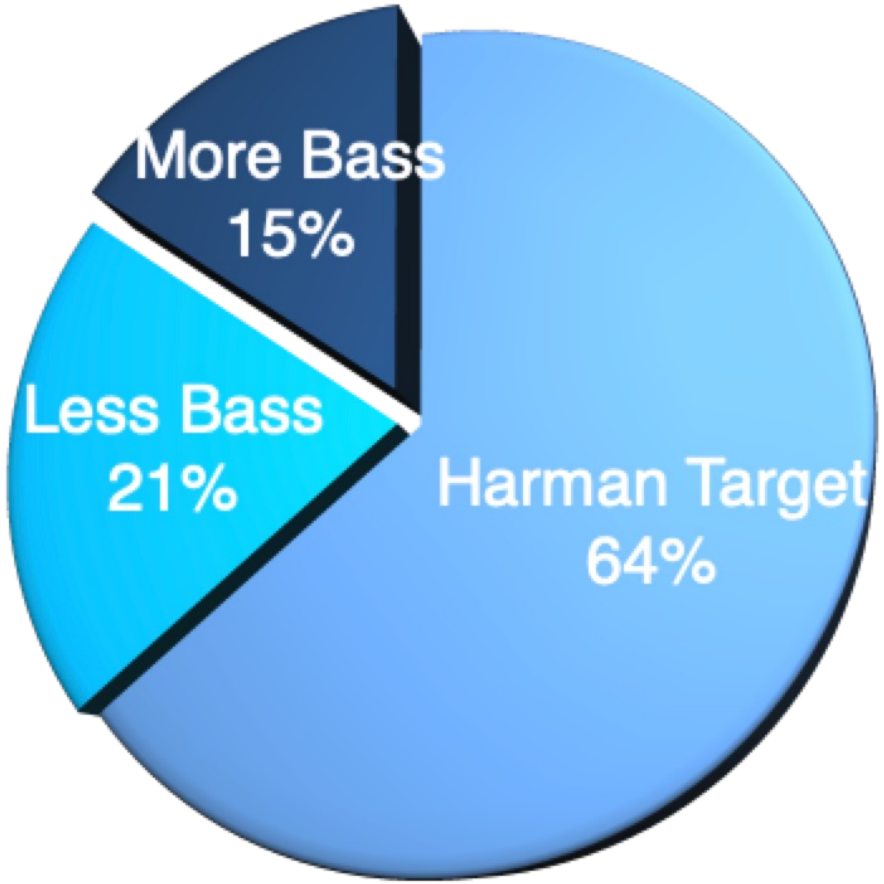


SUMMARY

Class 1: 64% of listeners
Demographic Profile: includes all categories (gender, trained/untrained, ages (fewer over 50 years old)
Sound Profile: Prefer headphones tuned close to (or close to) Harman target curve

Class 2: 15% of listeners
Demographic Profile: Male, younger listeners (<50 years)
Sound Profile: Prefer headphones with 3-6 dB more bass than Harman target below 300 Hz, and +1 dB above 1 kHz.

Class 3: 21% of listeners
Demographic Profile: Untrained, disproportionate percentage of females, and people 50+ years old
Sound Profile: Prefer 2-3 dB less bass than Harman target and +1 dB more treble above 1 kHz



HEADPHONE RESPONSES ON HUMANS CAN. VARY DRAMATICALLY

MY RECENT STUDY ON HEADPHONE MEASUREMENTS

HARMAN
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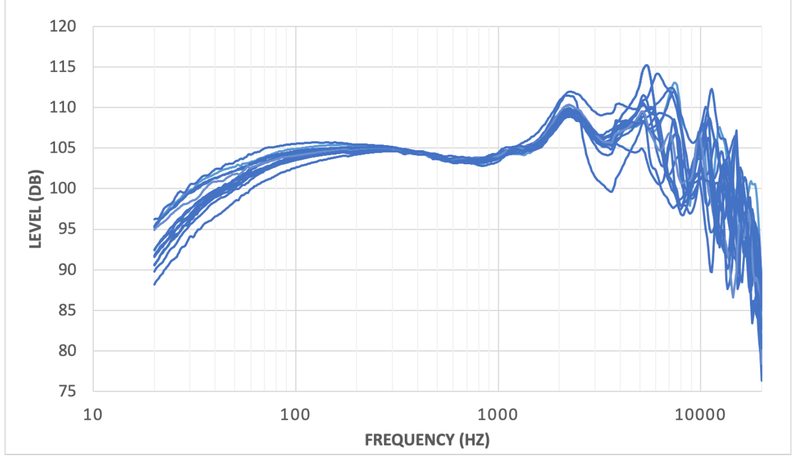
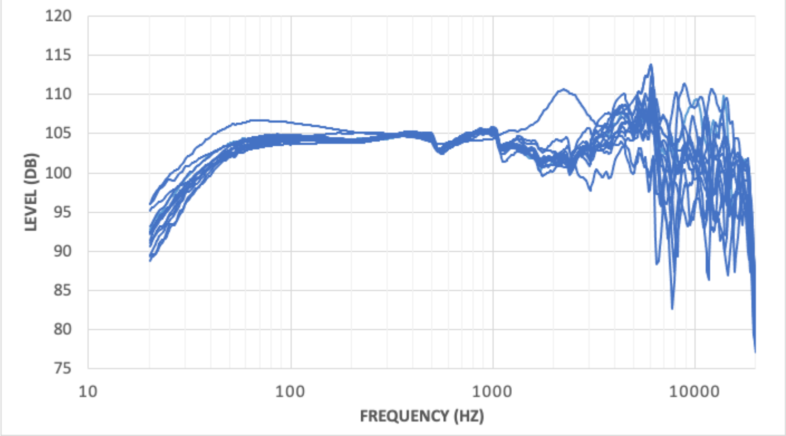
- 9 different models of headphones measured on 15 human subjects using blocked canal microphones
- Same headphones measured on 9 test fixtures using the same blocked canal microphone
- Each measurement repeated with 5 reseats
- Test signal is a log-sweep with 48-points per octave resolution
- Headphone measurements on humans normalized at average level calculated between 200 Hz – 1kHz
- Same normalization between compared test fixture and human measurements

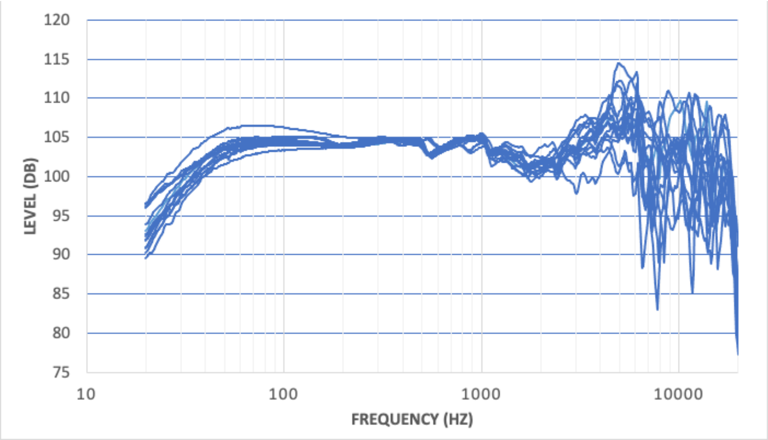
A CURRENT STUDY AT HARMAN

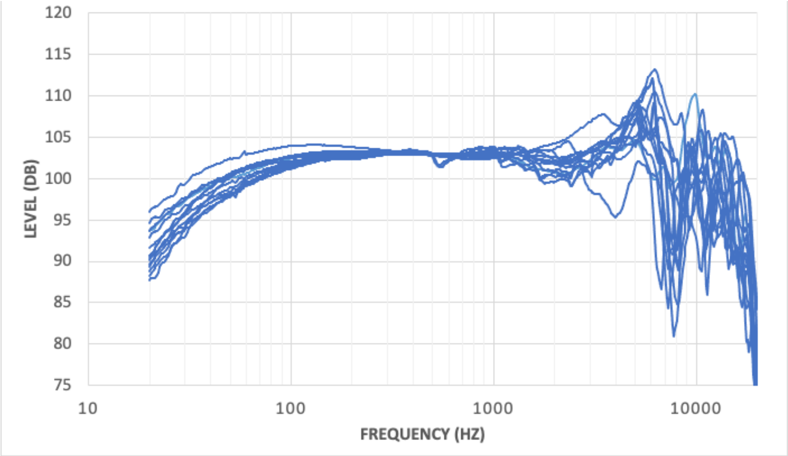
- Which headphone measures most consistently across humans?
- Which test fixture best represents human measurements?

OPEN BACK DESIGNS

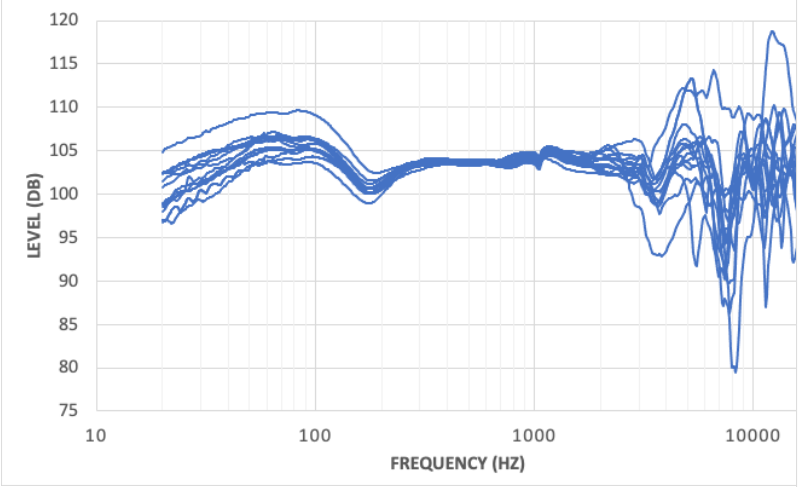


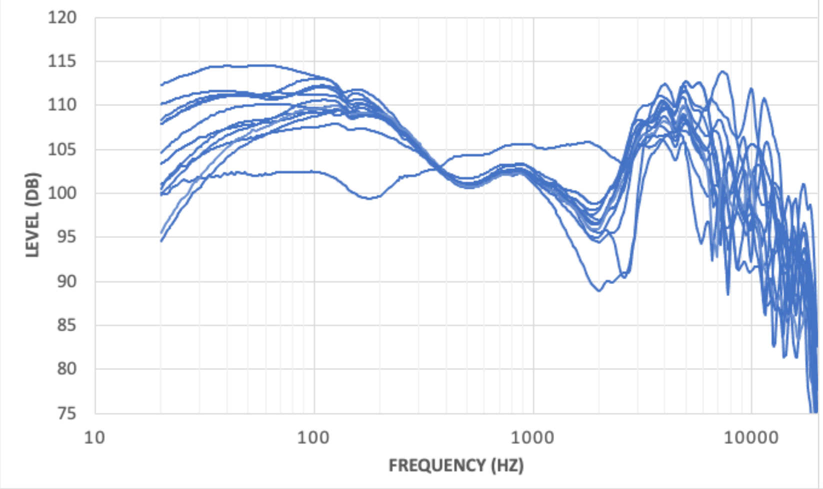


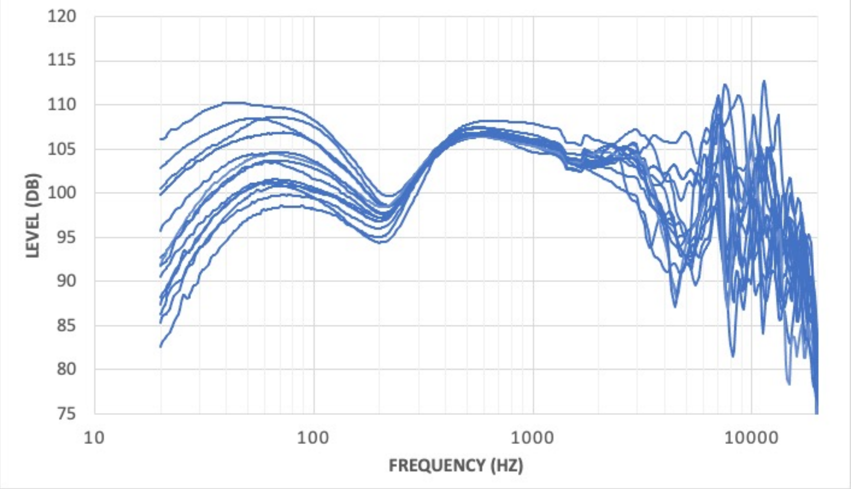


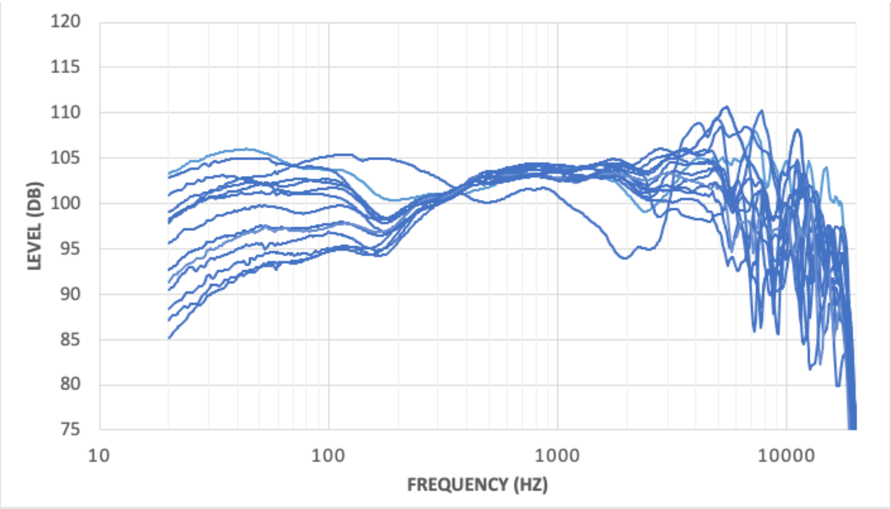


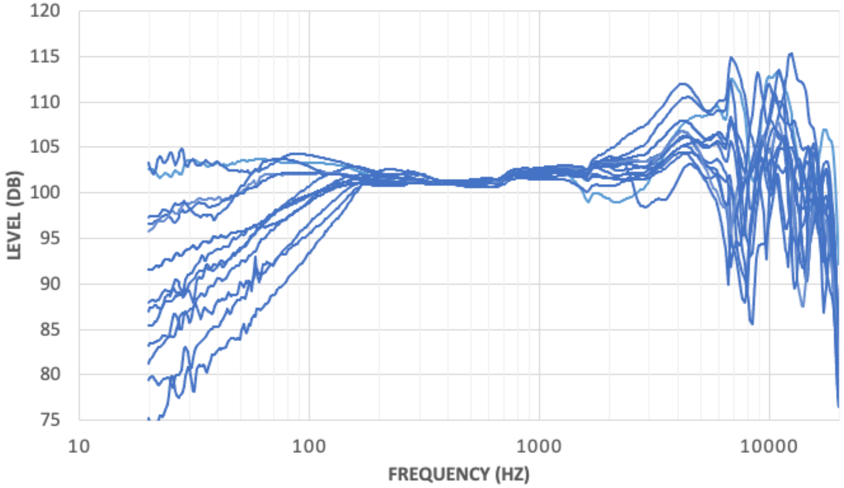
CLOSED BACK DESIGNS



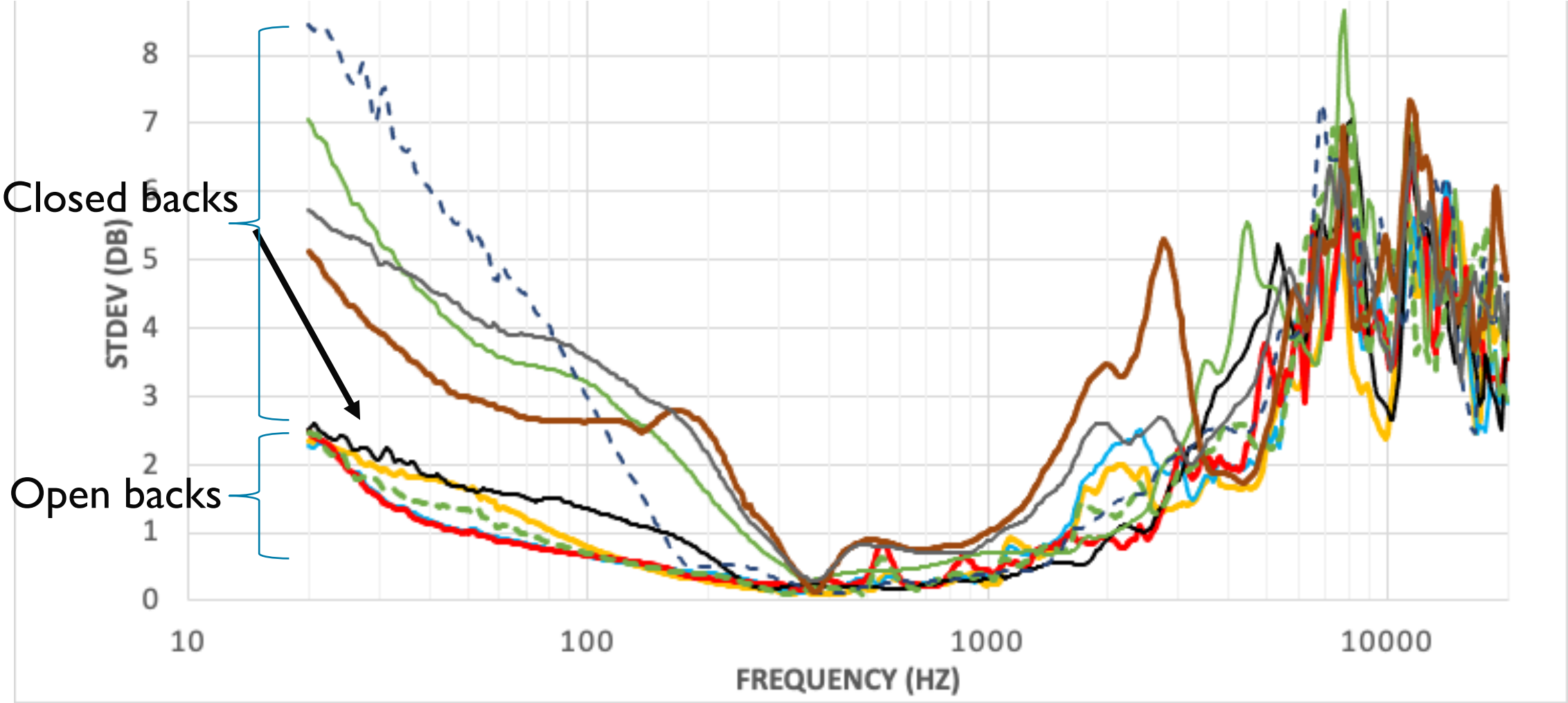




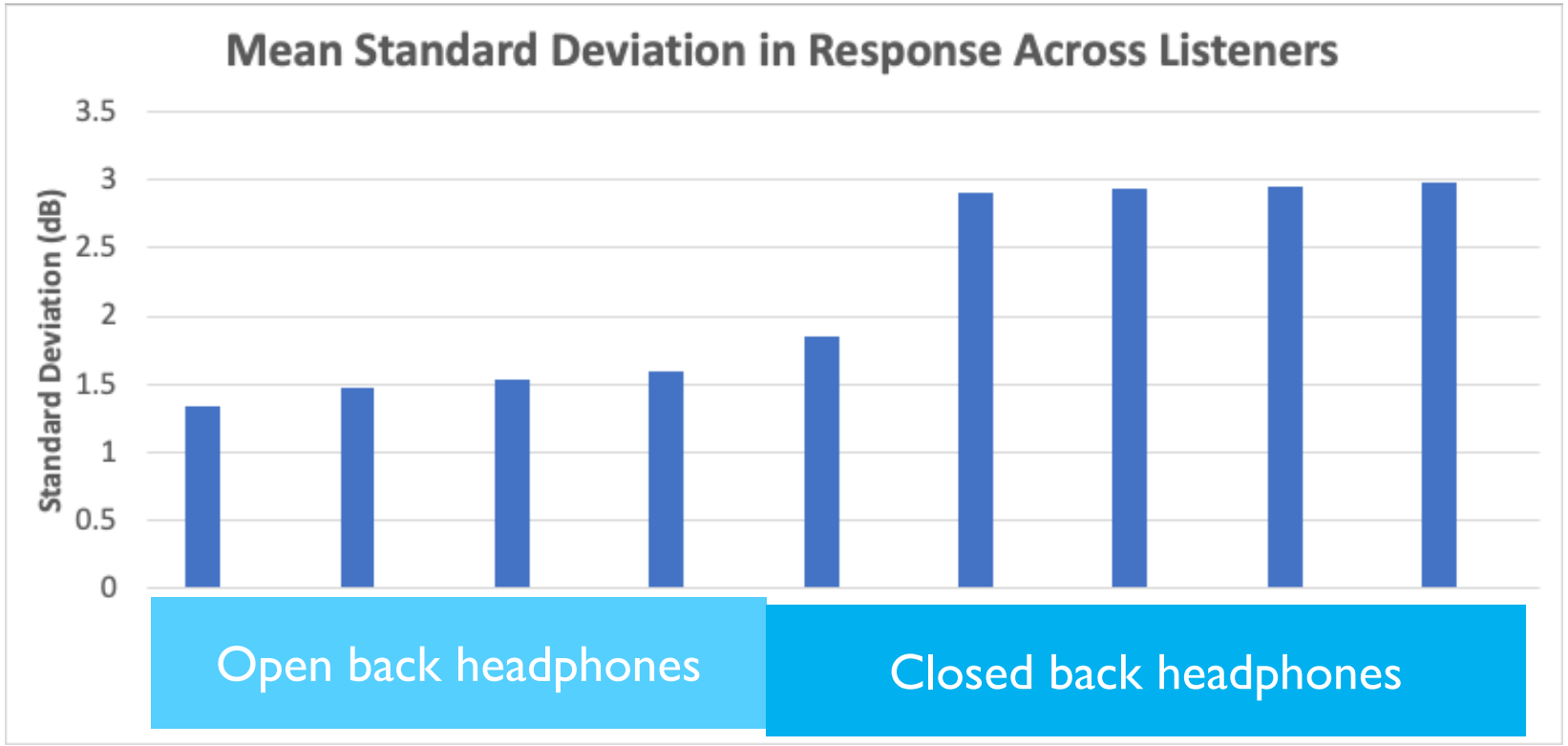




VARIANCE IN FREQUENCY RESPONSE MEASURED AMONG 15 LISTENERS



STANDARD DEVIATION IN RESPONSE ACROSS 15 HUMANS



- Open back headphones have less variation in measured response across humans than closed backs

TEST FIXTURES DON'T ACCURATELY CAPTURE THESE DIFFERENCES

NINE HEADPHONE TEST FIXTURES

KEMAR B&K 5128

GRAS 45CA MOD

GRAS 45CA KB5000
Anthropomorphic

Burt v1

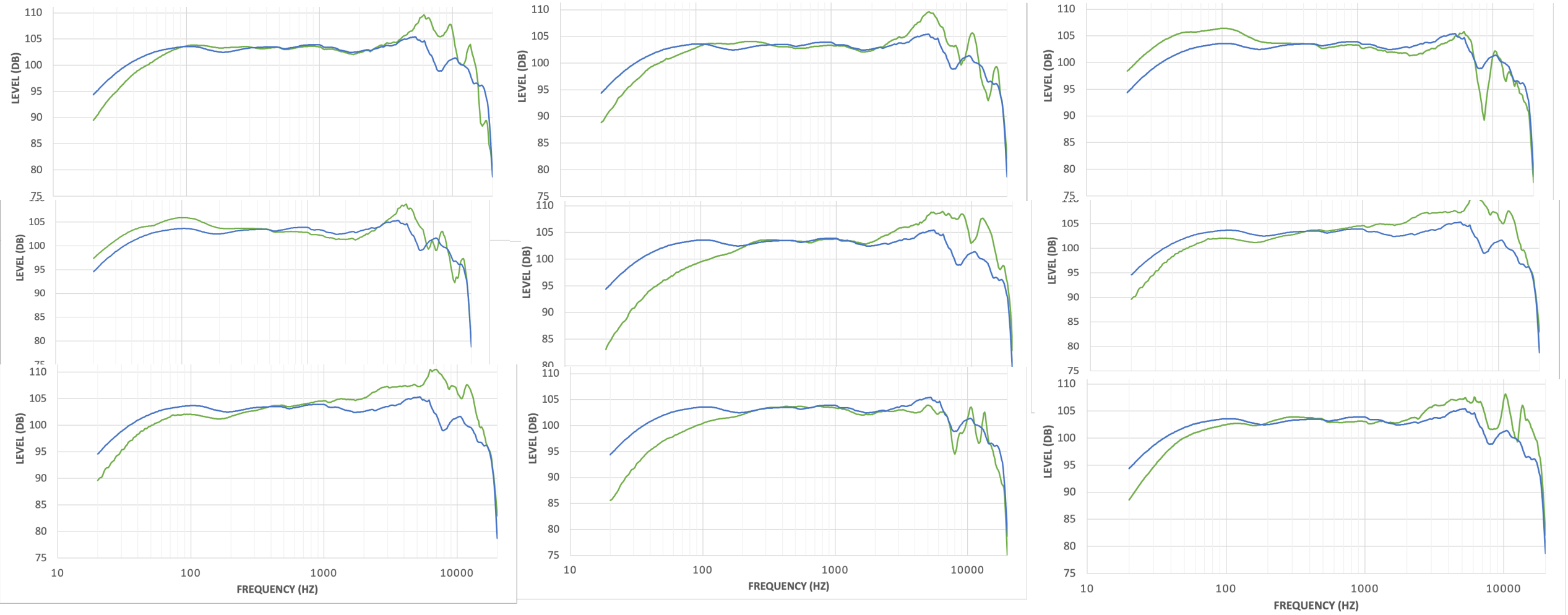
Burt v2

Thomas V1

Thomas V2

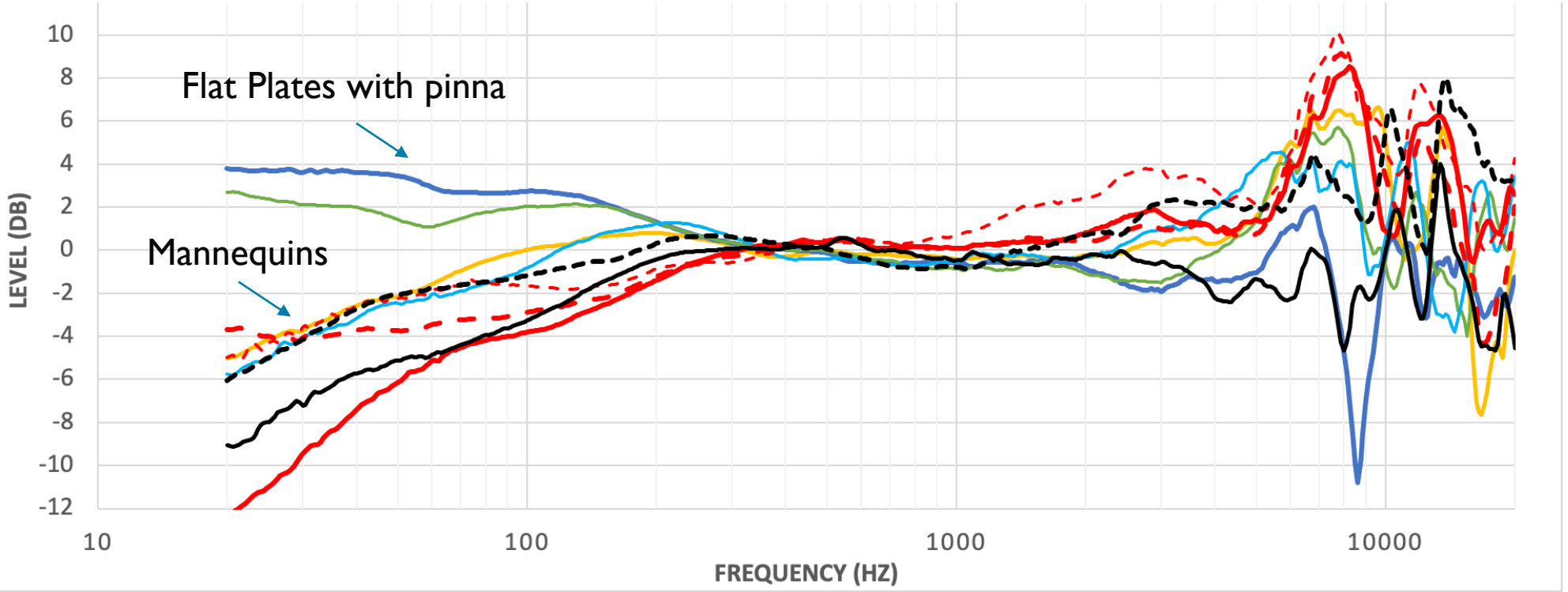
Burt v2 with mics

MEASUREMENTS OF HEADPHONES ON TEST FIXTURES (GREEN) VS HUMANS (BLUE)



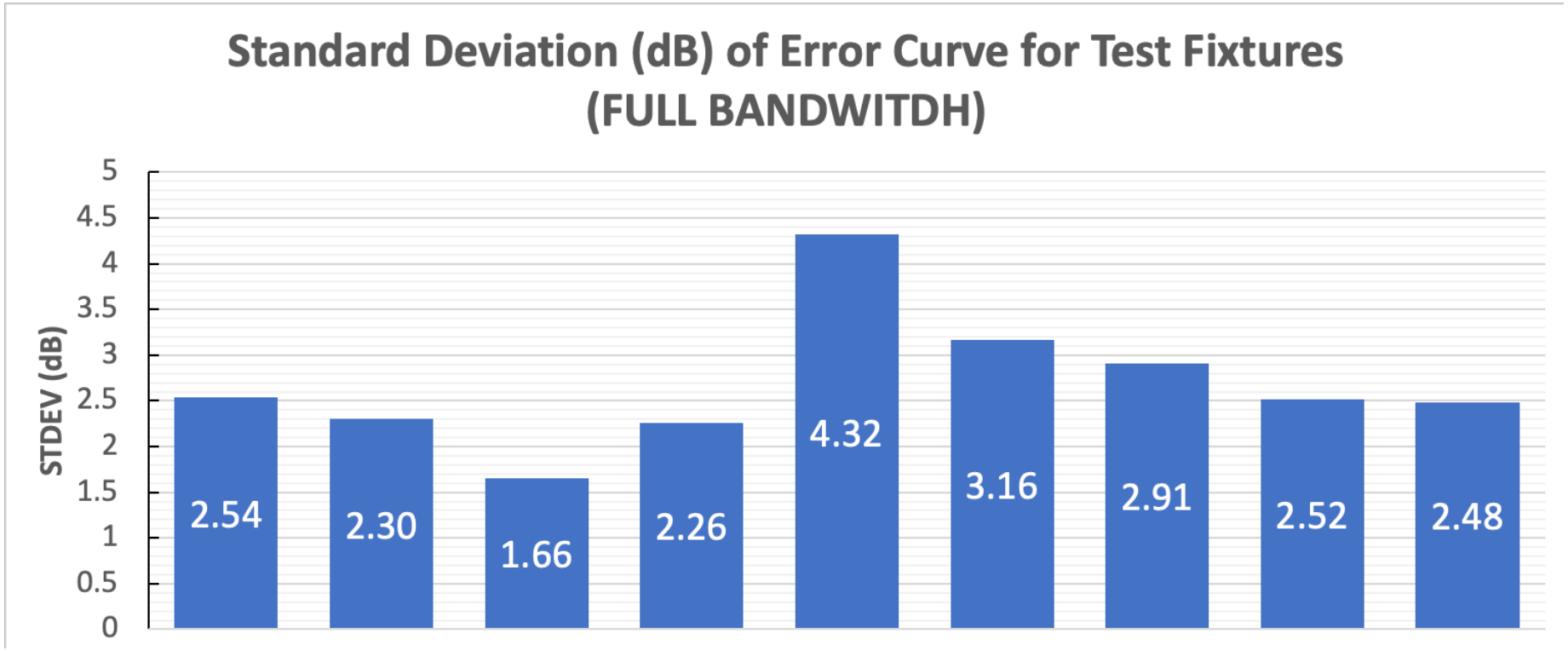
The average frequency response of 9 headphones measured on 15 humans (Blue) vs the same headphones measured on different test fixtures (Green)

ERRORS OF TEST FIXTURE VS HUMAN MEASUREMENTS



- Mannequin test fixtures tend to overestimate low frequency leakage on humans.
- Flat plates tend to underestimate leakage on humans.
- Test fixture headphone measurement above 2 kHz diverge with human measurements and tend to overestimate frequency energy.

AGREEMENT BETWEEN TEST FIXTURES AND HUMANS (20 TO 20 KHZ)



Test Fixtures

HEADPHONE PERSONALIZATION

CHALLENGES WITH HEADPHONE PERSONALIZATION

- There is evidence that the preferred frequency response may depend on several factors:
  - Age (hearing loss),
  - Gender?
  - Listening Experience,
  - Individual anthropometric differences in human ear canal/pinna and acoustics
- How do we best measure and account for these differences?
- How important are these on perceived sound quality and spatial quality?
- To what extent do we adapt/accommodate to these differences?

AGE RELATED HEARING LOSS

Miller and Downey "A Wideband Target Response Curve for Insert Earphones"153rd AES Convention, October 2022

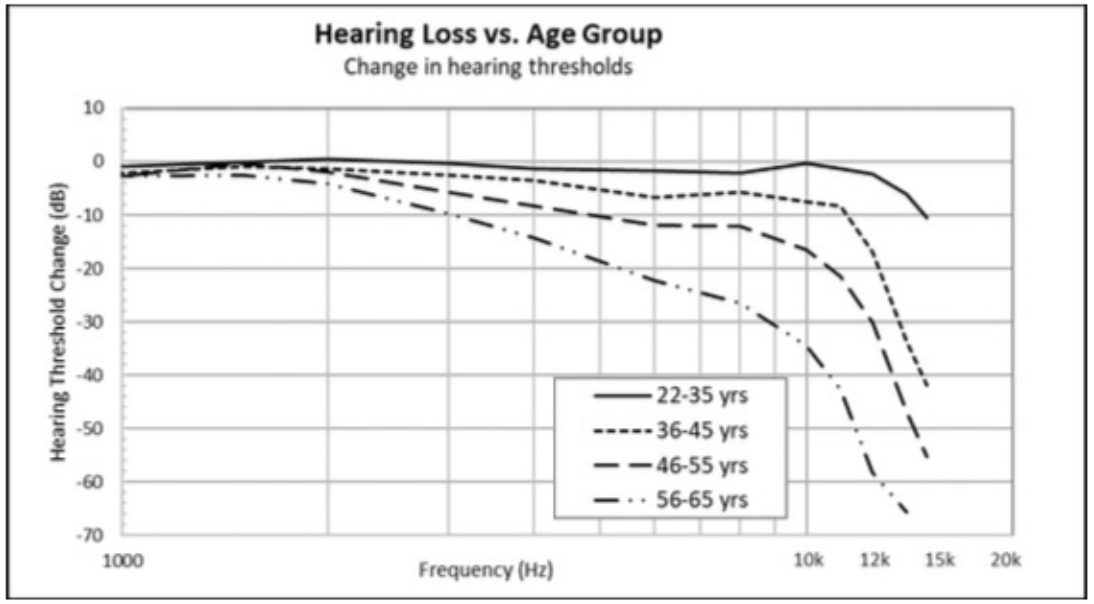


Fig. 9: Change in hearing thresholds with age, relative to 10-21 year old group.

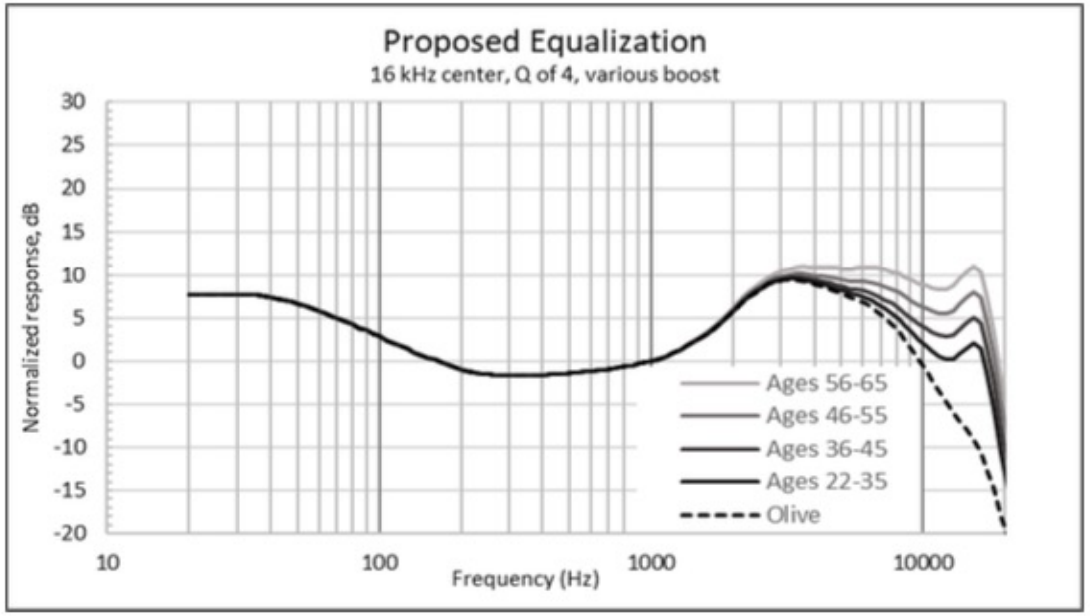
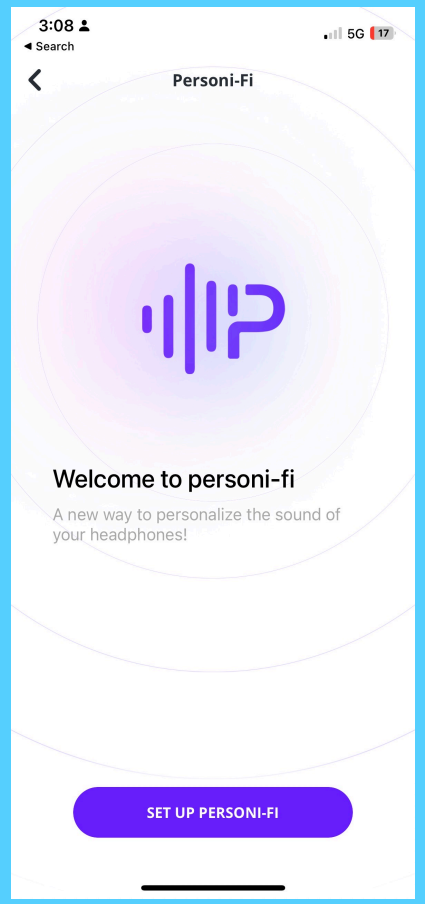
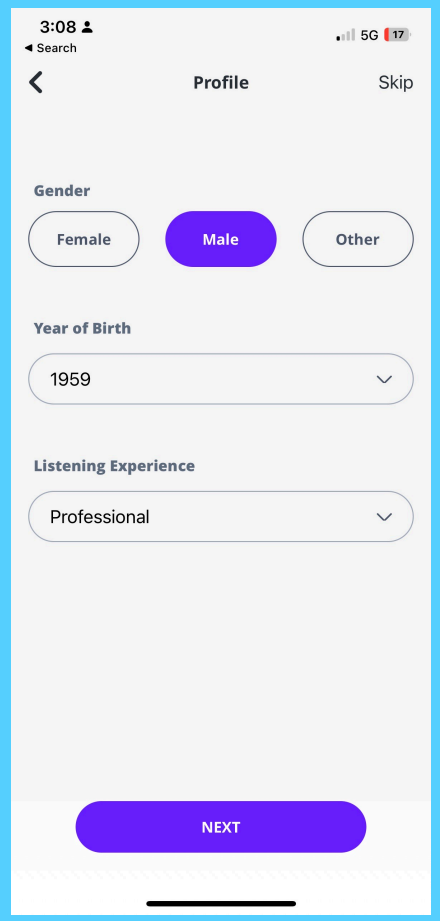
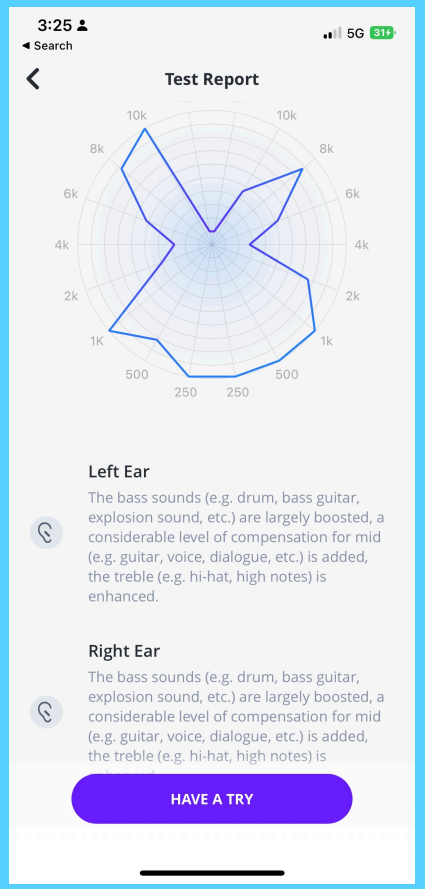


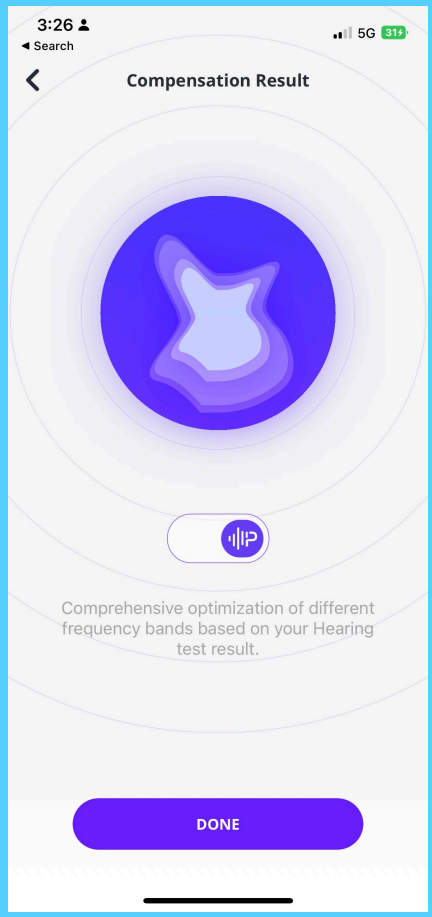
Fig. 12: Most preferred response curves for 4 age groups vs. Olive

HARMAN PERSONI-FI





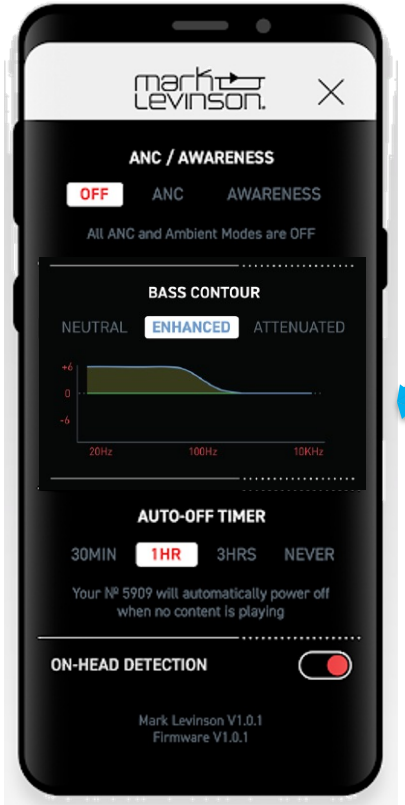


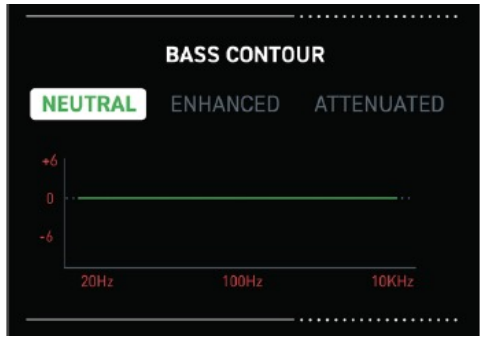


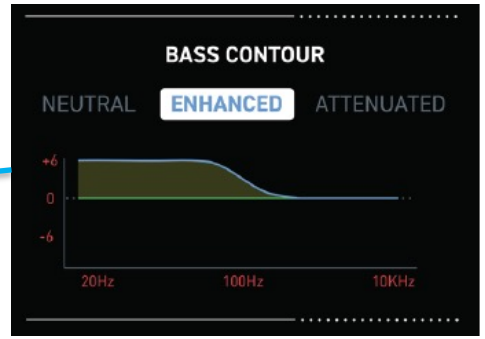
An app to personalize headphone sound based on gender, age, listening experience, and hearing loss

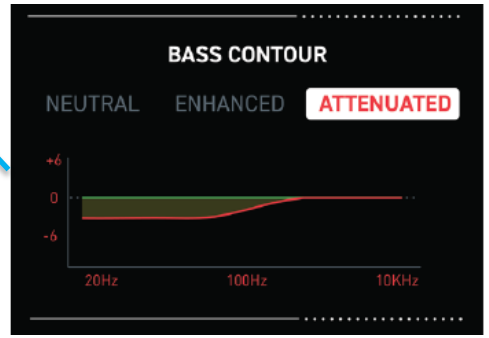
MARK LEVINSON № 5909 HEADPHONES

iOS & Android Mobile Apps



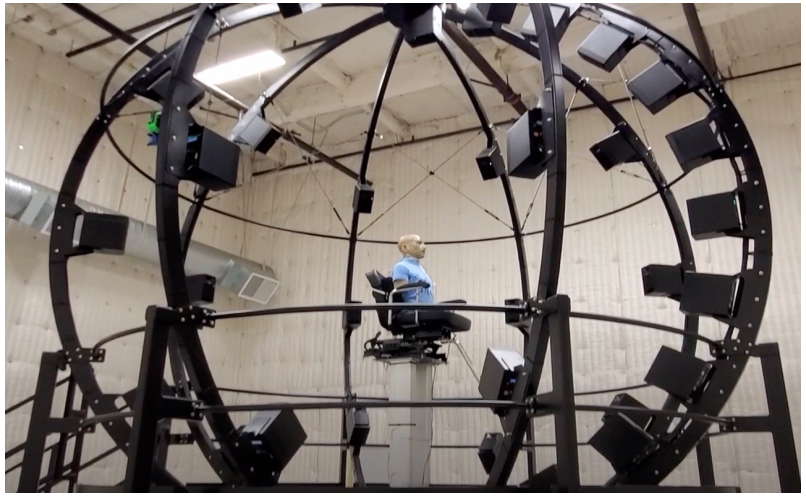


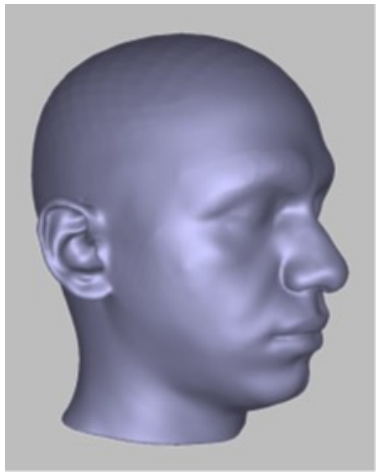


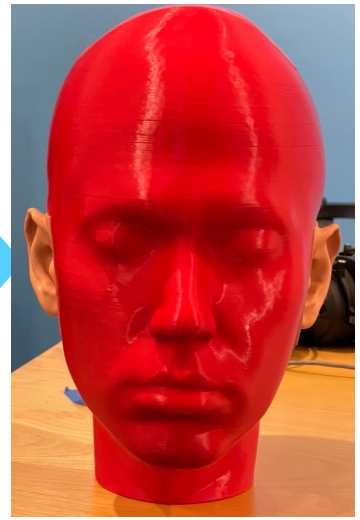


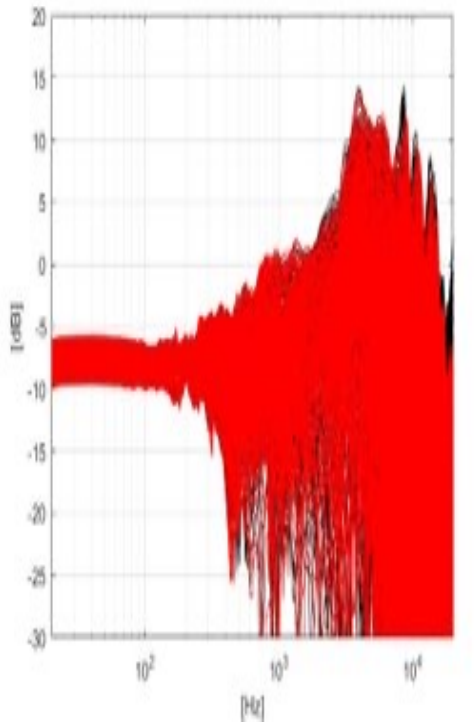
Three bass adjustments based on research showing 3 different segments of taste

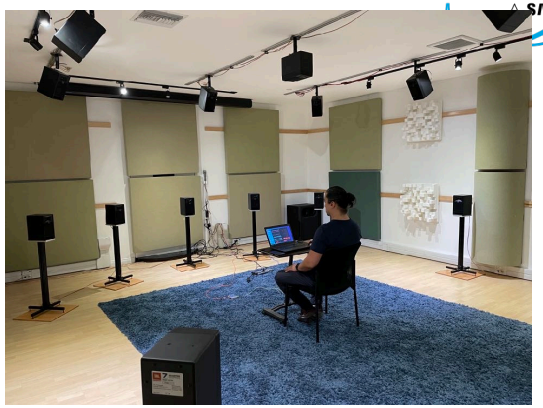
HARMAN RESEARCH: PERSONALIZED SPATIAL AUDIO











Capture / 3D Scan / Model diverse spatial HRTF

Large diverse population to generate…

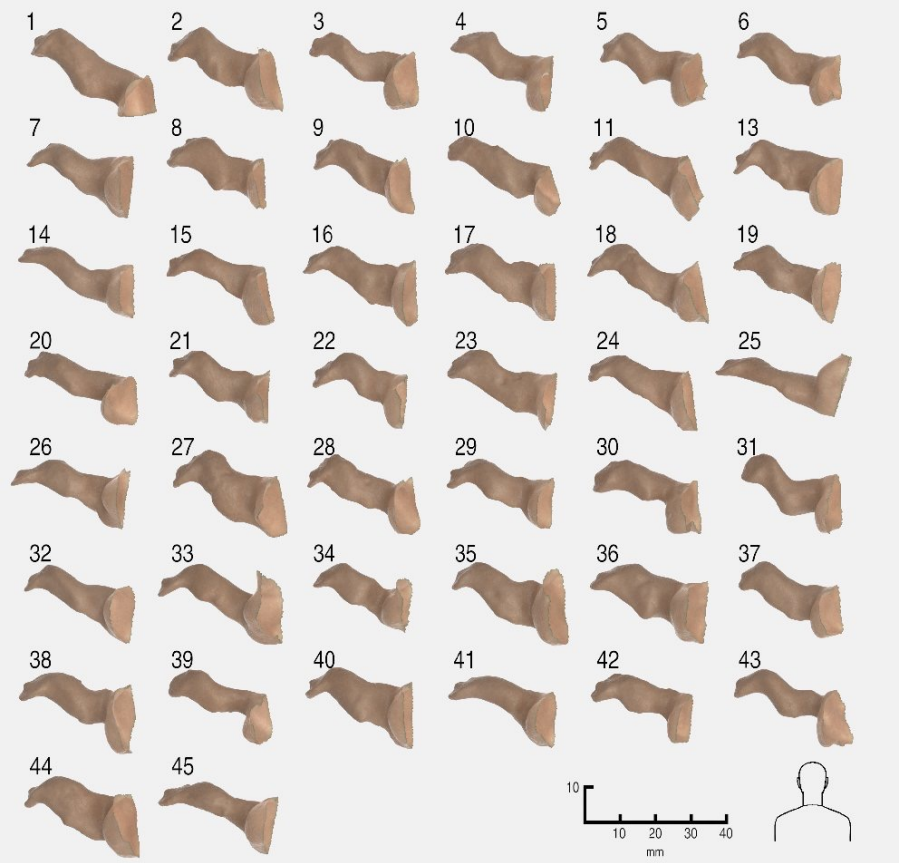
Immersive audio filter set

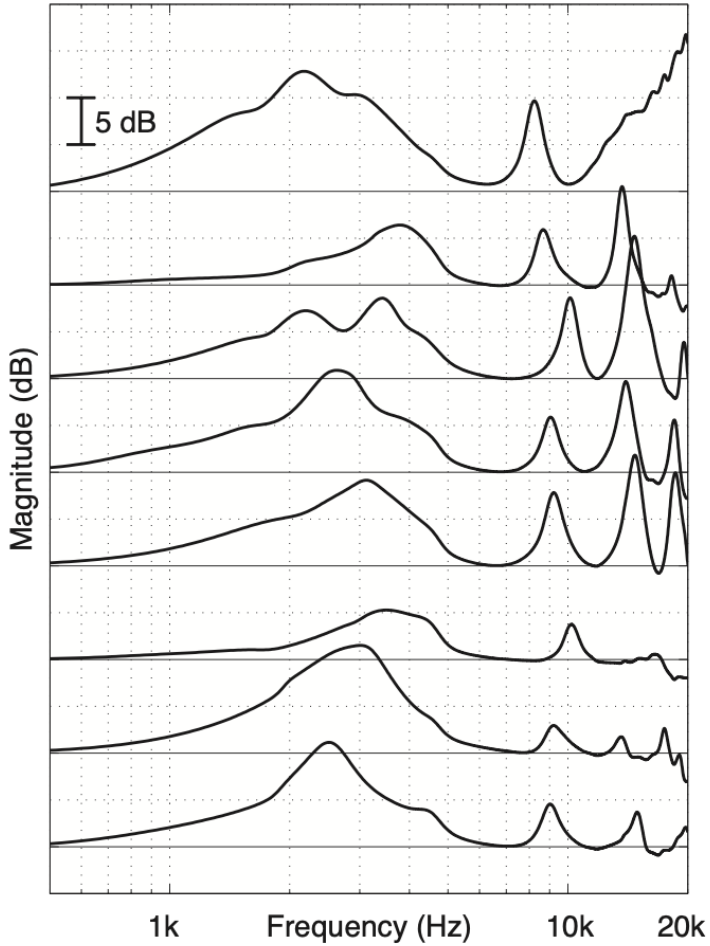
Used to …

Convolve with signals for playback through speakers at home, car and headphones

EAR CANAL ACOUSTIC EFFECTS

- Ear canal shapes and sizes vary significantly among individuals
- With insert earphones the sound pressure at the ear drum can vary 10 dB above 1 kHz
- Middle-ear pathologies can produce up to 35 dB effects
- Leakage effects can reduce bass below 300 Hz
- Do we need to compensate/personalize for this?





Darkner et al, "**An Average of the Human Ear Canal: Recovering Acoustical Properties via Shape Analysis**, 2018

Oksanen et al. "**Estimating individual sound pressure levels at the eardrum in music playback over insert headphones** "AES 47TH INTERNATIONAL CONFERENCE, Chicago, USA, 2012 June 20–22

CONCLUSIONS

- Most listeners (64%) prefer a headphone target based on an accurate loudspeaker calibrated in a semi-reflective listening room w. 2 smaller segments preferring slight adjustments to the bass and treble

- Personalization can improve headphone sound & spatial quality to accommodate differences in taste, hearing, listening experience and ear shape/size acoustics

- Closed headphones produce inconsistent bass across listeners vs. open back designs

- Different headphone test fixtures produce measurements that diverge below 200 Hz and above 2 kHz and here they don't accurately represent average measurements made on humans.

- While there is a strong argument for a better industry standard headphone target, loudspeaker history tells us it is unlikely to occur.

THANK YOU!

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