Comparative Evaluation of Headphone Target Curves Using Virtual Listening Tests

Saurav Chala[1], A.W.[1]

[1] PEQdB Inc., Stanford, CA, 94305, USA

support@peqdb.com

ABSTRACT

An online listening test evaluating the perceived sound quality of 6 in-ear and 6 over-ear headphone magnitude frequency response target curves was conducted across 403 listeners, identified with browser cookies, over the course of 40 days. Listeners identified a preference for A, B, or no preference in 24 trials where A was randomly selected from the 6 available target curves and B was randomly selected from the 5 remaining curves. Testing was performed across four neutral song segments with appropriate loudness normalization applied. On average, listeners preferred the PEQdB and HiFiEndgame headphone target curves to the four other target curves tested per headphone class.

1 Introduction

The PEQdB in-ear and over-ear headphone target curves are the result of 455 and 293 respective online listening tests, where users rated the sound quality of equalized song files on a 10-point scale over 40 trials. The conception of the PEQdB in-ear and over-ear magnitude frequency response target curves was previously discussed in a white paper titled *Large-Scale Optimization of Perceptual Headphone Sound Quality Target Curves* [1]. Some of the most commonly referenced headphone target curves are the Harman in-ear 2019 [2] and Harman over-ear 2018 [3] target curves. However, these target curves possess significant differences relative to the PEQdB headphone target curves. There are hundreds of examples of headphone target curves created by various individuals. We selected six for each type of headphone (in-ears and over-ears) with predicted high and low anchors based on the magnitude response deviation versus the PEQdB target curves. Unbiased direct comparisons between such target curves have been limited, so they should lend credence to optimized headphone tuning when properly executed. This paper is organized into five primary sections. In Section 2, we discuss the methodology used to compare the headphone target curves tested. Section 3 presents the results of the listening tests, and Section 4 discusses them, including their strengths and limitations. Finally, conclusions are given in Section 5.

2 Method

2.1 In-Ear Headphone Target Curve Selection

The six target curves compared in the in-ear tests were the Moondrop VDSF [4], JM-1 5128 to IEC 60318-4 delta with a -10 dB tilt [5], HiFiEndgame [6], PEQdB in-ear [1], Harman in-ear 2019 [2], and IEF Preference 2025 [7].

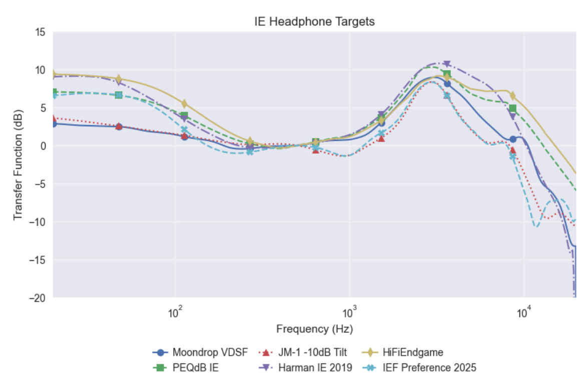

Figure 1. In-ear headphone target curves tested.

The Moondrop VDSF target is the result of measuring Genelec loudspeakers in what Moondrop claims is an ideal listening room at the drum reference point (DRP) of a Brüel & Kjær 4128-C head and torso simulator (HATS) [8].

The JM-1 head-related transfer function was created as an attempt to address the brighter than the population average diffuse-field head-related transfer function (HRTF) of the B&K 5128 HATS by creating a weighted average diffuse-field HRTF that predicts the relative contribution of the pinnae and ear canal [9]. The HRTF shifts the weight towards the eardrum (DRP) diffuse-field HRTF of 47 individuals outlined in Determination of Noise Immission From Sound Sources Close to the Ears [10], adhering to ISO 11904-1:2002 [11], at frequencies where the HRTF is influenced more by the outer-ear, while shifting the weight toward the ear canal transfer function of the B&K 5128 at frequencies where the ear canal's influence is more significant. Since we used IEC 60318-4 measurements for our listening tests, we employed a translated JM-1 HRTF, which was derived by calculating the delta between several IEMs measured using both the B&K 5128 and an IEC 60318-4 coupler. A -10 dB tilt was selected as the adjustment to the HRTF since companies such as Headphones.com referred to it as the "new meta" in in-ear headphone tuning [12].

The HiFiEndgame target was conceived by an individual who cross-referenced the magnitude frequency response performance of popular audio equipment with his preferences for bass, ear gain, and treble adjustments [13], relative to the average diffuse-field HRTF of 47 individuals [10].

The PEQdB in-ear target is the result of 455 40-trial online listening tests, where listeners rated the perceived sound quality of samples on a 10-point scale. The filter parameter selection was optimized using the Gaussian process and Probability of Improvement Acquisition function as the test progressed [1]. The baseline HRTF used was the average diffuse-field HRTF of 47 individuals [10], adhering to ISO 11904-1:2002 [11]. Nine variable parameters were distributed across a low-shelf filter, an ear-gain peaking filter, and a high-shelf filter. Each filter had variable frequency, gain, and Q-factor within a predefined range.

The Harman in-ear 2019 target curve was created through a collaboration between Harman and Listen Inc., where the high frequencies of the Harman in-ear 2017 target were smoothed out [2]. While the Harman in-ear 2017 target curve was directly validated in a published study [14], the Harman in-ear 2019 target was not, aside from in a paper titled "A comparison of in-ear headphone target curves for the Brüel & Kjær Head & Torso Simulator Type 5128," where the IEC 60318-4 Harman in-ear 2019 target curve was converted to be compatible with the B&K 5128 and compared to other B&K 5128 target curves [15].

The In-Ear Fidelity (IEF) Preference 2025 target curve was created by an internet personality known as Crinacle, who claims that the B&K 5128-derived target curve reflects his personal preference [16]. He converted his 5128 target curve to an IEC 60318-4 compatible target curve by measuring an in-ear monitor (IEM) complying with his 5128 target curve on both his B&K 5128 and IEC 60318-4 clone coupler, and having the IEC 60318-4 measurement essentially be the IEC 60318-4 target curve.

2.2 Over-Ear Headphone Target Curve Selection

The six target curves compared in the over-ear tests were the Harman over-ear 2013 [17], Harman over-ear 2018 [3], Harman over-ear 2018 with linear bass below 500 Hz [18], Kemar KB50xx measured diffuse-field HRTF with a -10 dB tilt [19], HiFiEndgame [6], and PEQdB over-ear [1].

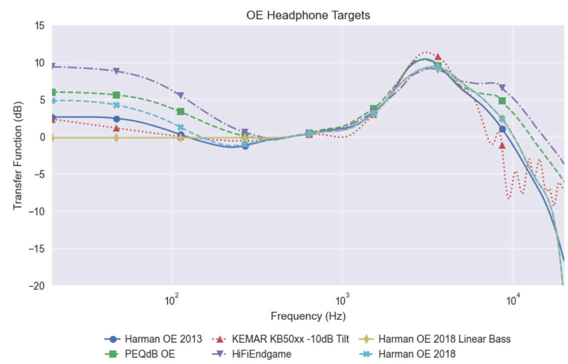

Figure 2. Over-ear headphone target curves tested.

The Harman over-ear 2013 target curve was created by first equalizing the individual channels of a pair of loudspeakers to a flat steady-state measurement from ~23 Hz to 20 kHz when measured with an array of flat omnidirectional microphones at the prime listening position in a typically reflective listening room [17]. The loudspeakers were then measured over a custom head fitted with two GRAS 43AGs, one for each ear. The resulting flat baseline HRTF was modified by eleven listeners in a methodical adjustment procedure, where the gains of a 105 Hz low-shelf filter with a Q-factor of ~0.65 and a 2500 Hz high-shelf filter with a Q-factor of ~0.49 could be adjusted.

The Harman over-ear 2018 target was a modification to the Harman over-ear 2015 target curve, which applied the same method of adjustment procedure as the Harman over-ear 2013 target, but over 249 listeners and a pair of Sennheiser HD518 headphones. The Harman over-ear 2018 target curve primarily reduced the energy around 3 kHz of the Harman over-ear 2015 target curve and was validated in [3].

The Harman over-ear 2018 linear bass target curve is the Harman over-ear 2018 target curve, but with a flat bass response below 500 Hz. It was commonly used as a reference for open-back headphones, which were unable to achieve the desired bass shelf of the Harman over-ear 2018 target curve [18].

Oratory1990 developed the KEMAR KB50xx diffuse-field HRTF by measuring the diffuse-field HRTF of a KEMAR with attached KB50xx pinnae [20]. We chose to apply a -10 dB tilt to the HRTF since it is one of the most commonly applied modifications to the HRTF [19].

The HiFiEndgame target is the same for over-ear and in-ear headphones [13].

The PEQdB over-ear target was created with the same methodology as the in-ear target, but with 293 listeners [1].

2.3 Selection of Headphone Measurements

The measurements used in this study were collected from various public online measurement repositories. The accuracy of the measurement fixtures and measurements determined the priority order for the different measurement sources. The two highest-priority over-ear magnitude response databases utilize GRAS 43AG [21] or 45BC [22] test fixtures with RA040x [23] couplers and KB5000 [24] and KB5001 [25] pinnae. The third-highest priority over-ear measurement database utilizes a GRAS 43AG [21] test fixture with an RA0045 [26] coupler and a KB5000 [24] pinna. All in-ear measurements use clone IEC 60318-4 [27] couplers with minimal standard deviations between each other and versus official manufacturer measurements.

	In-Ear Headphones	Over-Ear Headphones
1.	squig.link [28]	Hangout-Audio GRAS [35]
2.	timmyv.squig.link [29]	Oratory1990 [36]
3.	therollo9.squig.link [30]	sai.squig.link [37]
4.	precog.squig.link [31]	gadgetrytech. squig.link [38]
5.	vsg.squig.link [32]	kuulokenurkka. squig.link [39]
6.	audioamigo.squig.link [33]	squig.link/ headphones [40]
7.	pw.squig.link [34]	ish.squig.link [41]

Table 1. Priority list for the first seven in-ear and over-ear headphone measurement databases.

The following figures demonstrate the measurement accuracy of the two highest-priority clone IEC 60318-4 couplers by first comparing squig.link's [28] Softears VolumeS measurement to the official manufacturer measurement [42] and the second comparing timmyv.squig.link's [29] Truthear Nova measurement to squig.link's. IEC 60318-4 tolerance [23] error bars are overlaid for the specified measurement accuracy from 100 Hz to 10 kHz. Both comparisons fall well within the tolerance bounds. Above 10 kHz, there is a discrepancy between the manufacturer's Softears VolumeS measurement and squig.link's. The differences between timmyv.squig.link's and squig.link's measurements above 10 kHz are minuscule. Whether any differences are due to variations in the in-ear headphones or the couplers is unknown. Nevertheless, the minimal deviation signifies high accuracy and consistency, especially for measurements of separate units on inexpensive test equipment.

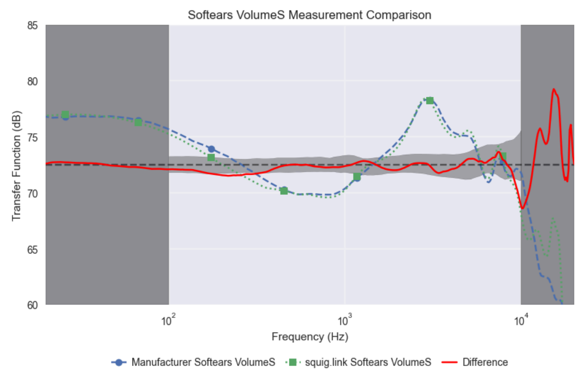

Figure 3. Softears VolumeS manufacturer measurement [42] versus squig.link [28] measurement.

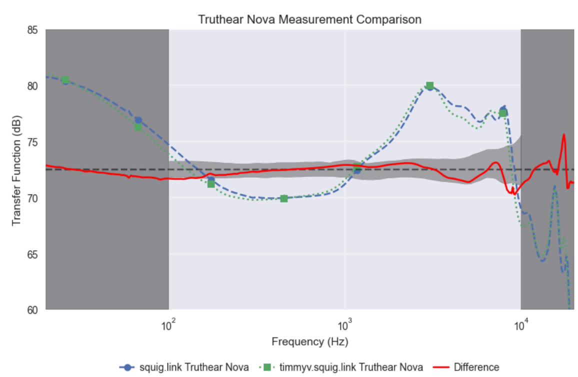

Figure 4. Truthear Nova squig.link [28] and timmyv.squig.link [29] measurement comparison.

A total of 151 different models of in-ear headphones and 104 models of over-ear headphones were selected by users in the listening tests. The following figures display the equalized magnitude responses of the diffuse-field HRTF [10] for the top five most selected in-ear and over-ear headphones.

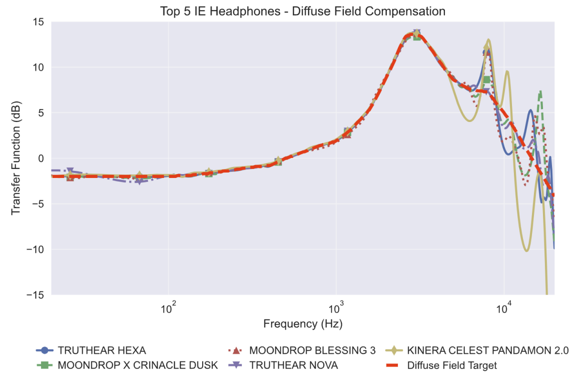

Figure 5. Diffuse-field HRTF equalized magnitude responses of the top five most selected in-ear headphones.

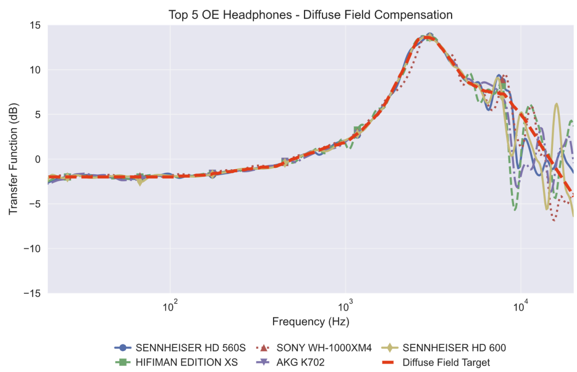

Figure 6. Diffuse-field HRTF equalized magnitude responses of the top five most selected over-ear headphones.

2.4 Program Selection

We used four ~20-second segments from four unique songs for the listening tests, two from the Polygondwanaland album by King Gizzard and The Lizard Wizard [43] and two from the Out of It album by Brad Sucks [44]. The song samples were chosen due to their relatively neutral spectra, as referenced in the figure below.

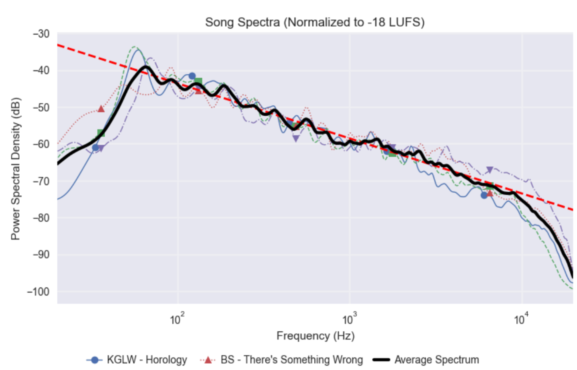

Figure 7. Spectrums of song selection.

2.5 Test Procedure

Once listeners selected their headphones from our collective measurement database, they pressed a "Start" button, where they could then listen to the A and B sound samples for each of the 24 trials and identify a preference for A, B, or neither. The song samples were randomly assigned per trial. Target curve A was randomly selected from the pool of 6 target curves, and target curve B was randomly chosen from the remaining five targets.

The magnitude frequency response of the user's selected headphone was first equalized to the diffuse field HRTF using a configured AutoEQ algorithm [45].

	Count	Frequency	Q-factor
Low-shelf filter	1	105 Hz	0.71
Peaking filter	13	Up to 7500 Hz	0.1 to 4.0
High-shelf filter	1	10000 Hz	0.71

Table 2. Categorization of the 15 filters used to compensate for the headphone magnitude response relative to the diffuse-field HRTF.

Each of the song clips was convolved with a minimum-phase impulse response filter that compensated for the diffuse field HRTF to match each of the target magnitude frequency responses.

2.6 Loudness Normalization

Loudness normalization was performed using the standard ITU-R BS.1770-4 [46] algorithm. As we received comments from listeners indicating that the samples appeared to have different loudness levels, we replaced the K-weighting filter with the Fenton/Lee filter 1 [47], which was verified by informal listener feedback to be more suitable.

3 Results

The test participants completed 324 in-ear and 200 over-ear listening tests. Tables 3 and 4 below display the win/loss matrices of the in-ear and over-ear tests, with the scores being derived such that a win = +1 to the winning target curve and a draw = +0.5 to both target curves. The results are weighted based on the number of results the user has submitted, such that the overall score contribution a user can provide is 24 (one point for each trial). We also calculated the Bradley-Terry [48] scores (tables 5 and 6), the estimated probability of the pairwise comparisons of the Bradley-Terry model fit under normal approximation (tables 7 and 8), and the Bradley-Terry rankings for each of the songs (tables 9 and 10).

% W L (Score)	PEQdB IE	HiFi Endgame	VDSF	Harman IE 2019	JM-1	IEF 2025
PEQdB IE		53.4 (158.8)	30.1 (99.6)	26.8 (83.8)	19.9 (74.3)	21.5 (70.2)
HiFi Endgame	46.6 (138.5)		24.5 (76.8)	21.4 (67.7)	20.8 (66.6)	18.3 (55.1)
VDSF	69.9 (231.4)	75.5 (236.6)		44.4 (151.4)	28.2 (91.4)	20.5 (64.9)
Harman IE 2019	73.2 (228.5)	78.6 (248.7)	55.6 (189.2)		32.9 (99.2)	22.3 (76.2)
JM-1	80.1 (300.0)	79.2 (253.6)	71.8 (232.4)	67.1 (202.5)		41.1 (135.2)
IEF 2025	78.5 (256.4)	81.7 (246.6)	79.5 (252.4)	77.7 (265.8)	58.9 (193.5)	

Table 3. In-ear target curve win-loss matrix.

% W L (Score)	PEQdB OE	HiFi Endgame	Harman OE 2018	Harman OE 2013	Harman OE 2018 Linear	KEMAR
PEQdB OE		50.6 (108.2)	28.4 (53.0)	23.4 (55.5)	24.8 (56.7)	11.6 (26.4)
HiFi Endgame	49.4 (105.7)		30.0 (62.0)	31.3 (66.0)	29.0 (65.6)	15.5 (33.3)
Harman OE 2018	71.6 (133.4)	70.0 (144.7)		39.3 (82.2)	42.0 (95.9)	12.5 (27.3)
Harman OE 2013	76.6 (181.5)	68.7 (144.6)	60.7 (127.0)		48.1 (100.2)	14.1 (25.8)
Harman OE 2018 Linear	75.2 (200.2)	71.0 (160.9)	58.0 (132.4)	51.9 (107.9)		13.7 (29.6)
KEMAR KB50xx -10 dB Tilt	88.4 (200.2)	84.5 (180.9)	87.5 (190.9)	85.9 (157.0)	86.3 (186.1)	

Table 4. Over-ear target curve win-loss matrix.

2.54	**HiFiEndgame**
2.13	**PEQdB IE**
1.09	**Moondrop VDSF**
0.94	**Harman IE 2019**
0.51	**JM-1 -10 dB Tilt**
0.37	**IEF Preference 2025**

Table 5. Bradley-Terry scores for in-ear tests.

2.47	**PEQdB OE**
2.16	**HiFiEndgame**
1.16	**Harman OE 2018**
0.89	**Harman OE 2013**
0.89	**Harman OE 2018 Linear Bass**
0.20	**KEMAR KB50xx -10 dB Tilt**

Table 6. Bradley-Terry scores for over-ear tests.

% W L	PEQdB IE	HiFi Endgame	VDSF	Harman IE 2019	JM-1	IEF 2025
PEQdB IE		99.10	0.00	0.00	0.00	0.00
HiFi Endgame	0.90		0.00	0.00	0.00	0.00
VDSF	100.00	100.00		0.44	0.00	0.00
Harman IE 2019	100.00	100.00	99.56		0.00	0.00
JM-1	100.00	100.00	100.00	100.00		0.00
IEF 2025	100.00	100.00	100.00	100.00	100.00	

Table 7. Estimated probability of the in-ear pairwise comparisons of the Bradley-Terry model fit under normal approximation.

% W L	PEQdB OE	HiFi Endgame	Harman OE 2018	Harman OE 2013	Harman OE 2018 Linear	KEMAR
PEQdB OE		6.17	0.00	0.00	0.00	0.00
HiFi Endgame	93.83		0.00	0.00	0.00	0.00
Harman OE 2018	100.0	100.0		0.10	0.07	0.00
Harman OE 2013	100.0	100.0	99.90		47.44	0.00
Harman OE 2018 Linear	100.0	100.0	99.93	52.56		0.00
KEMAR	100.0	100.0	100.00	100.00	100.00	

Table 8. Estimated probability of the over-ear pairwise comparisons of the Bradley-Terry model fit under normal approximation.

	KGLW - Horology	KGLW - Inner Cell	BS - There's Something Wrong	BS - Dropping Out of School
1	HiFiEndgame	HiFiEndgame	HiFiEndgame	PEQdB IE
2	PEQdB IE	PEQdB IE	PEQdB IE	Moondrop VDSF
3	Harman IE 2019	Harman IE 2019	Moondrop VDSF	HiFiEndgame
4	Moondrop VDSF	Moondrop VDSF	Harman IE 2019	JM-1 -10 dB Tilt
5	JM-1 -10 dB Tilt	JM-1 -10 dB Tilt	JM-1 -10 dB Tilt	Harman IE 2019
6	IEF Preference 2025	IEF Preference 2025	IEF Preference 2025	IEF Preference 2025

Table 9. In-ear tests individual Bradley-Terry score rankings per song.

	KGLW - Horology	KGLW - Inner Cell	BS - There's Something Wrong	BS - Dropping Out of School
1	HiFiEndgame	PEQdB OE	HiFiEndgame	PEQdB OE
2	PEQdB OE	HiFiEndgame	PEQdB OE	Harman OE 2018
3	Harman OE 2018	Harman OE 2018	Harman OE 2018	Harman OE 2013
4	Harman OE 2018 Linear Bass	Harman OE 2018 Linear Bass	Harman OE 2018 Linear Bass	HiFiEndgame
5	Harman OE 2013	Harman OE 2013	Harman OE 2013	Harman OE 2018 Linear Bass
6	KEMAR	KEMAR	KEMAR	KEMAR

Table 10. Over-ear headphones individual Bradley-Terry score rankings per song.

4 Discussion

4.1 Preferred Target Responses

In both the in-ear and over-ear listening tests, the HiFiEndgame and PEQdB target curves were the most preferred by listeners. The HiFiEndgame target achieved a statistically significant preference bias ($p < .05$) in the Bradley-Terry probability model for the in-ear tests, and the PEQdB over-ear target achieved a statistically insignificant preference bias ($p > .05$) in the over-ear tests. The remaining target curves were far less preferred by the listeners, with the Harman targets achieving average results in both tests. The IEF Preference 2025 target performed the worst in the in-ear test, and the KEMAR KB50xx with a -10 dB tilt scored the worst in the over-ear test.

Kendall's coefficients of concordance for target curve rankings across the different songs were 0.857 ($p = 0.0042$) for in-ear tests and 0.836 ($p = 0.005$) for over-ear tests, indicating a firm agreement between target curve and song selection.

4.2 Limitations

Since participants self-selected their headphone models from our database before testing, we could not verify that their selected entry matched the device used or account for unit variation between the user's and the measured unit.

Since the study was conducted online across 403 unique listeners using their playback chains, we could not control the absolute sound pressure level (SPL) at the ear. The results should be interpreted as reflecting preferences at each listener's chosen listening level rather than a calibrated SPL. Additionally, the background noise level was uncontrolled.

Because the in-ear and over-ear target tests compared different sets of target curves, preferences between classes are not directly comparable.

5 Conclusion

The results of this study demonstrate that current industry standard headphone target curves, such as the Harman targets, are significantly less preferred than alternatives such as the PEQdB and HiFiEndgame target curves.

Intriguingly, the HiFiEndgame target curve performs at the top of the rankings despite being created by a single individual based on his intuition. Considering the HiFiEndgame target curve sits on the edge of the parameter bounds of the PEQdB listening tests, reworking the PEQdB listening tests with an improved set of parameters centering around the HiFiEndgame target curve may result in a better-sounding target curve.

Future work would include in-person listening tests with controlled listening conditions, using the same target curves for both the in-ear and over-ear tests.

6 References

[1] Chala, S., et al. (2025, June 3). *Large-scale optimization of perceptual headphone sound quality target curves (PEQdB White Paper)*. PEQdB Inc. https://peqdb.com/wiki/PEQdB-White-Paper.pdf

[2] Listen, Inc. (2019, August 12). *Prediction of listener preference of in-ear headphones using the Harman model*. https://www.listeninc.com/products/test-sequences/fr

ee/prediction-of-listener-preference-of-in-ear-headphones-using-the-harman-model/

[3] Olive, S. E., Welti, T., & Khonsaripour, O. (2018, May). A statistical model that predicts listeners' preference ratings of around-ear and on-ear headphones (Convention Paper 9919). *Audio Engineering Society Convention Paper*. Presented at the 144th Convention of the Audio Engineering Society, Milan, Italy.

[4] MOONDROP. (n.d.). *Graph tools | MOONDROP official website*. https://moondroplab.com/en/graph

[5] Super* Review. (n.d.). Δ *JM-1 -10dB tilt target – Frequency responses – Squiglink by Super Review**. Squiglink. https://squig.link/?share=%E2%88%86_JM-1_-_10dB_Tilt_Target

[6] HiFiEndgame. (n.d.). *Custom tilt – Frequency responses – Squiglink by HiFiEndgame*. https://earphones.hifiendgame.com/?share=Custom_Tilt&bass=12&tilt=0&treble=1&ear=-5

[7] Crinacle. (n.d.). *Crinacle's 711 graph tool – IEF Preference 2025 target*. Hangout.Audio. https://graph.hangout.audio/iem/711/?share=IEF_Preference_2025_Target

[8] MOONDROP. (2023, May 28). *The story of KATO, revealing the technologies and challenges* [Video]. YouTube. https://youtu.be/1kazXvo1zKs?t=150

[9] Silver, G. (2024, June 21). *Understanding the Headphones.com IEM measurements* [Online forum post]. The Headphone Community. https://forum.headphones.com/t/understanding-the-headphones-com-iem-measurements/23607

[10] Hammershøi, D., & Møller, H. (2008). Determination of noise immission from sound sources close to the ears. *Acta Acustica united with Acustica, 94*(1), 114–129. https://doi.org/10.3813/AAA.918014

[11] International Organization for Standardization. (2002). *ISO 11904-1:2002 Acoustics — Determination of sound immission from sound sources placed close to the ear — Part 1: Technique using a microphone in a real ear (MIRE technique)*. https://www.iso.org/standard/33944.html

[12] Loo, C. (2024, October 3). *Redefining neutral? A buyer's guide to IEMs from the "New Meta."* Headphones.com. https://headphones.com/blogs/buying-guides/redefining-neutral-comparing-iems-from-the-new-meta

[13] HiFiASMR. (2024, July 8). *Endgame Target – Renamed to V-Shaped Target* [Online forum post]. HiFiEndgame. https://hifiendgame.com/index.php?threads/endgame-target-renamed-to-v-shaped-target.10/

[14] Olive, S. E., Welti, T., & Khonsaripour, O. (2017, May). The influence of program material on sound quality ratings of in-ear headphones (Convention Paper 9778). *Audio Engineering Society Convention Paper*. Presented at the 142nd Convention of the Audio Engineering Society, Berlin, Germany. https://secure.aes.org/forum/pubs/conventions/?elib=18654

[15] Olive, S. E. (2024, October 8). A comparison of in-ear headphone target curves for the Brüel & Kjær Head & Torso Simulator Type 5128 [AES convention presentation]. *Audio Engineering Society Convention Paper*. Audio Engineering Society 157th Convention, New York, NY. https://aes2.org/publications/elibrary-page/?id=22696

[16] Crinacle. (2025, February 5). *The new 2025 IEF target*. https://crinacle.com/2025/02/05/the-new-2025-ief-target/

[17] Olive, S. E., Welti, T., & McMullin, E. (2013, October). Listener preferences for in-room loudspeaker and headphone target responses (Convention Paper 8994). *Audio Engineering Society Convention Paper*. Presented at the 135th Convention of the Audio Engineering Society, New York, NY, USA.

[18] Sai. (n.d.). *Harman OE 2018 linear target – Frequency responses – Squiglink by Sai*. https://sai.squig.link/?share=Harman_OE_2018_Linear_Target

[19] SupOrSalad. (n.d.). *KEMAR DF (KB50xx) 10dB tilt target – Frequency responses – Squiglink by SupOrSalad*. https://suporsalad.squig.link/headphones/?share=KEMAR_DF_(KB50xx)_10dB_Tilt_Target

[20] Mad_Economist. (2023, September 26). *DFHRTFs used at Headphones.com* [Online forum post]. The Headphone Community. https://forum.headphones.com/t/dfhrtfs-used-at-headphones-com/22038

[21] GRAS Sound & Vibration. (n.d.). *GRAS 43AG Ear & Cheek Simulator*. https://www.grasacoustics.com/products/ear-simulator-kit/constant-current-power-ccp-1/product/737-43ag

[22] GRAS Sound & Vibration. (n.d.). *GRAS 45BC*

KEMAR head & torso with mouth simulator, non-configured. https://www.grasacoustics.com/products/head-torso-simulators-kemar/kemar-non-configured/product/749-45bc

[23] GRAS Sound & Vibration. (2019). *Improved ear simulators for headphone testing: IEC 60318-4 compliant/compatible ear simulators for testing of headphones, earphones and headsets up to 20/50 kHz (Brochure No. LI0215_2019)*. GRAS Sound & Vibration. https://www.gras.dk

[24] GRAS Sound & Vibration. (n.d.). *GRAS KB5000 Right Anthropometric Pinna 35 Shore OO*. https://www.grasacoustics.com/products/accessories/for-artificial-ears-and-mouths/product/729-kb5000

[25] GRAS Sound & Vibration. (n.d.). *GRAS KB5001 Left Anthropometric Pinna 35 Shore OO*. https://www.grasacoustics.com/products/accessories/for-artificial-ears-and-mouths/product/730-kb5001

[26] GRAS Sound & Vibration. (n.d.). *GRAS RA0045 Externally Polarized Ear Simulator according to IEC 60318-4 (60711)*. https://www.grasacoustics.com/products/ear-simulator/externally-polarized-cartridges-200-v-1/product/248-ra0045

[27] AliExpress. (n.d.). *Precision Artificial Ear IEC711 Frequency Response Curve Tester Artificial Ear 318-4 Headphone Tester*. https://www.aliexpress.us/item/3256805222108700.html

[28] Super* Review. (n.d.). *Squiglink: IEM and headphone frequency response database*. https://squig.link/

[29] TimmyV. (n.d.). *Timmy's squig.link*. https://timmyv.squig.link/?share=Custom_Tilt&bass=6&tilt=-0.6&treble=0&ear=0

[30] Rollo. (n.d.). *Rollo's Squiglink: IEM frequency response database*. https://therollo9.squig.link/

[31] Precogvision. (n.d.). *Squiglink: IEM frequency response database by Precogvision*. https://precog.squig.link/

[32] VSG. (n.d.). *Squiglink: IEM frequency response database by VSG*. https://vsg.squig.link/

[33] AudioAmigo. (n.d.). *Squiglink: IEM frequency response database by AudioAmigo*. https://audioamigo.squig.link/

[34] Paul Wasabii. (n.d.). *Squiglink: IEM frequency response database by Paul Wasabii*. https://pw.squig.link/

[35] Hangout.Audio. (n.d.). *Crinacle's Headphone Graph Tool*. https://graph.hangout.audio/headphones/

[36] u/oratory1990. (n.d.). *r/oratory1990 Wiki: Headphone EQ Presets*. Reddit. Retrieved May 19, 2025, from https://www.reddit.com/r/oratory1990/wiki/index/list_of_presets/

[37] Sai. (n.d.). *Squiglink: IEM frequency response database*. https://sai.squig.link/

[38] GadgetryTech. (n.d.). *Squiglink: IEM frequency response database by GadgetryTech*. https://gadgetrytech.squig.link/

[39] Kuulokenurkka. (n.d.). *Squiglink: Headphone frequency response database by Kuulokenurkka*. https://kuulokenurkka.squig.link/

[40] Super* Review. (n.d.). *Squiglink: Headphone frequency response database*. https://squig.link/headphones/

[41] Kyle @ Den-Fi. (n.d.). *ish.squig.link: Headphone and IEM frequency response database*. https://ish.squig.link/

[42] Softears. (n.d.). *Softears VolumeS dual modes switchable in-ear hi-fi earphones*. https://softears.store/products/softears-volume-s-hifi-in-ear-hd-audiophile-headphones-two-levels-tuning-3-5-4-4

[43] King Gizzard & The Lizard Wizard. (n.d.). *Polygondwanaland*. https://kinggizzardandthelizardwizard.com/polygondwanaland

[44] Brad Sucks. (n.d.). *Out of it*. https://www.bradsucks.net/releases/out-of-it

[45] Pasanen, J. (n.d.). *AutoEq: Automatic headphone equalization from frequency responses*. GitHub. https://github.com/jaakkopasanen/AutoEq

[46] International Telecommunication Union Radiocommunication Sector. (2015). Recommendation ITU-R BS.1770-4: Algorithms to measure audio programme loudness and true-peak audio level. https://assets.corusent.com/wp-content/uploads/2021/10/ITUR_BS_1770_4_Audio_Program_Loudness_En.pdf

[47] Fenton, S., & Lee, H. (2017, October 18–21). Alternative weighting filters for multitrack programme loudness measurement (Convention Paper 9818). *Audio Engineering Society Convention Paper*. Audio Engineering Society 143rd Convention, New York, NY.

https://www.aes.org/e-lib/browse.cfm?elib=19215

[48] Stanford University. (2016). *STATS 200: Lecture 24 — The Bradley-Terry model* [PDF file]. Retrieved from https://web.stanford.edu/class/archive/stats/stats200/stats200.1172/Lecture24.pdf

[49] Charles. (2024, July 24). *Kendall's Concordance (W)*. Real Statistics Using Excel. https://real-statistics.com/reliability/interrater-reliability/kendalls-w/