Proceedings of the 3rd International Conference on Music & Emotion (ICME3), Jyväskylä, Finland, 11th - 15th June 2013. Geoff Luck & Olivier Brabant (Eds.)

# HOW MUCH DOES EARPHONE QUALITY MATTER WHILE LISTENING TO MUSIC ON BUSES AND TRAINS?

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**Abstract**

We report results from an investigation into the relationships between acoustic performance, price, and perceived quality of earphones. In Singapore today, the most common situation where people listen to music is while commuting, however such environments have generally high ambient noise levels. A survey (N=94) of listener habits on buses and trains was conducted. Results showed that people use a wide range of earphones, both in terms of price and measurable acoustic performance. Five typical earphone models were identified and employed in a perceptual experiment (N=15). Volunteers rated various aspects of earphone quality while listening to music under two conditions: studio silence and a reproduced commuter environment. Results showed that participants displayed a strong preference towards in-ear earphones and this can be attributed to these having better *acoustic isolation* than on-ear earphones. People tend to describe the music listening experiences in terms of sonic clarity and noise isolation. We believe that these results can inform development of an ecologically valid model of how noisy environments affect people's perception of audio quality, and through that, of music experience. Such a model could inform consumers as well as manufacturers.

**Keywords:** earphones, sound quality, perception

## 1. Introduction

There is an extensive variety of earphones available now in the market, partly due to the fact that we are living in a time where entertainment can be portable. A surround sound system to engulf us into a music or sound euphoria can now be placed into our pockets using digital signal processing (McCormick, 2005). In most developed societies like Singapore, more and more commuters are using earphones (Flamm, 2005). Commuters listen to music while on the train or bus for various reasons, such as to relax or as a form of entertainment. One other possible reason why listening to music is the most popular activity is because it allows the user to free up his or her hands to do something else or help maintain balance. Also, in a crowded train or bus, it can be very difficult to do anything that requires both hands, for example play a game.

A commuter's choice of earphone is influenced by price, information about acoustic performance, visual aesthetic, and other factors, varying greatly. For example, there is no standard of how to report acoustic performance for consumers on packaging. There are tests (Audio Check, 2013) and information to help consumers make better-informed purchases, however these materials do not necessarily have sufficient scientific backing to support the claims. Inevitably, their perception of sound and listening experience are affected. Plus, to a certain extent, damage their hearing.

Our research aims to analyze typical technical specifications of earphones and understand earphone consumer behavior through a multi-methodology. The present study is a pilot investigation involving a questionnaire survey, a series of technical measurements and a perceptual experiment.

## 2. Survey

There was no available data for earphone usage of commuters in Singapore. Therefore we performed a questionnaire study. Responses were collected on buses and trains at different locations and hours. Commuters who were actively using their earphones were approached. 100 people completed the questionnaire, out of which 94 could be used in the analysis. Respondents filled up a questionnaire sheet that included questions about:

- what they were listening to;
- what they were listening to;
- the level of *satisfaction* and *physical comfort* they felt with their set of earphones;
- the *brand*, model and price of their current set of earphones;
- which aspect of earphones they considered most important.

87% of respondents indicated that they were listening to music when they were approached to complete the survey. 50% of respondents were using earphones that were free of charge or costing less than $4USD. 75% of the respondents stated that sound quality was the most important aspect of earphones. A correlation analysis of the main survey results is shown in Table 1.

**Table 1.** Main correlations from survey (Pearson's *r*).

| | *Age* | *Priciness* | *Satisfaction* |
|---|---|---|---|
| *Priciness* | -0.091 | | |
| *Satisfaction* | -0.019 | 0.18 . | |
| *Comfort* | 0.119 | 0.224 * | 0.42 *** |

*Priciness* is an estimate of earphone cost. From the results, there is no significant relationship between *Satisfaction* and *Priciness* (t(88) = 1.71, r = 0.18, p-value = 0.09), and that none of the factors are dependent on *Age*. However, there was significant correlation between *Comfort* and *Priciness* (t(88) = 2.16, r=0.22, p-value = 0.03). Another correlation result to take note of would be *Satisfaction* and *Comfort* (t(92) = 4.4417, r=0.42, p-value = 2.481e-05). The strong correlation between them allows us to know that how satisfied the respondents feel about their set of earphones is related to how physically comfortable they feel with them. Listening to music through earphones was found to be the most popular activity during commuting compared to watching film or being engaged in other activities. This helped us determine the type of music played for the perceptual experiment.

From the survey, fourteen commonly used earphones were chosen for technical measurements.

## 3. Technical measurements

Measurements were made using a manikin head (Neumannn KC100) in an acoustically isolated recording room. A frequency sweep file, 12 Hz to 30 kHz over 30 seconds was played through the earphones and recorded with the built-in microphones. Technical aspects tested were frequency response, impedance, total harmonic *distortion* (THD) and isolation. *Acoustic isolation* are given in Table 2, and other results are reported in (Lim, 2013).

From Table 2, we can see that in-ear earbuds are able to provide more noise isolation (>2.0 dB) than non in-ear types. Flanged earbuds are able to provide the most amount of *noise isolation* (-14. 9 dB).

A Principal Component Analysis of frequency responses guided the selection of 5 physical earphones (referred to as C, G, H, I, and J4) to be used in the perceptual experiment, for being substantially different in terms of acoustic performance. Details are reported in (Lindborg & Lim, 2013)

## 4. Perceptual experiment

Although technology can analyze sound, it is ultimately up to the human ear to tell the designer that the right sound is heard (Brüel & Kjær, 2013). Thus, our aim was to compare different aspects of earphones, in terms of visual appearance, physical comfort and perceived audio quality.

15 people volunteered to take part in this experiment (10 females, median age 23 years). They were all survey respondents who had expressed interest in participation. The experiment session lasted for about an hour and each participant was given a movie voucher as a token of appreciation.

The procedure was as follows. Firstly, all earphones were ranked by visual aesthetic appeal, presented in individually sealed, transparent plastic bags.

Secondly, 3 different types of earbuds (flanged, foam, and silicon) were rated for physical comfort, using an Index by Casali et al. (1987) with minor adaptations. The index varies between 14 (most comfortable) and 70 (least comfortable) (Byrne, Davis, Shaw, Specht, & Holland, 2011).

Thirdly, sound quality was rated under two conditions: studio silence and reproduced commuter ambient noise. Music from a shuffled playlist of 14 songs was played through the earphones. Aspects of sound quality were rated on 6 separate scales, each represented by a 100mm horizontal line on a questionnaire sheet, anchored by adjectives at each end.

- *Clarity* (0= 'muddled', 100='clear')
- *Distortion* (0='annoying', 100='relaxing')
- *Sharpness* (0='boomy', 100='sharp')
- *Envelopment* (0='constricted', 100= 'expansive')
- *Tonality* (0='monotonous', 100='rich')

## 5. Results

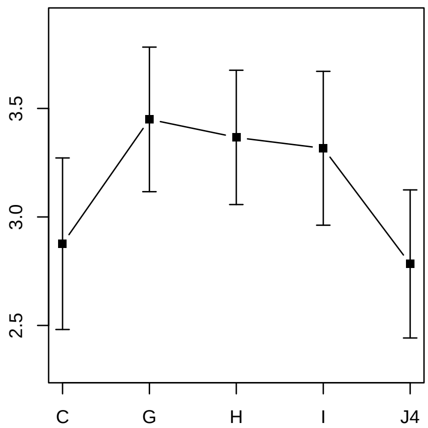


**Figure 1.** Rated Overall audio experience (95% conf. int.)

Overall, earphones C and J both have consistently low scores across the 4 qualities, while earphones G and H generally have higher scores. This means that G and H are perceived to deliver better sound quality.

The main results of independent (*price, acoustic isolation*) and dependent measures (perceptual ratings) are shown in Table 2.

Under the category of Price, rank 1 means the cheapest to rank 5 which is the most expensive. From the visual aesthetics ranking, 1 would be the set of earphones which most participants felt was the most visually pleasing to them while 5 meant the least visually pleasing. G was rated as the most visually attractive. It is a completely black, in-ear earphone with silicon earbuds. It has a small, simple earpiece and flat cables. J4 was rated least visually attractive and it is a white in-ear earphone with flanged earbuds. It has an angularly-shaped earpiece and has grey round cables. Tabulated scores based on the Comfort Index showed that foam was perceived to be most comfortable followed by flanged and silicon. However, their average scores were only marginally different: foam (35.9), flanged (36.9), silicon (37.7). Values reflected in perceptual ratings are the means calculated for each set of earphones across condition.

**Table 2.** Main results from perceptual ratings and objective measures of five earphones

| | | | | | Perceptual Rating | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ear-phone* | *Brand* | *Price* (rank) | *Visual* (rank) | *Com-fort* | *Over-all* | *Clarity* | *Dis-tortion* | *Sharp ness* | *Envel-opment* | *To-nality* | *Noise isola-tion* | *Isola-tion* (dB) |
| *C* | Apple | 1 | 3 | - | 2.9 | 55 | 50 | 52 | 47 | 48 | 2.1 | -0.5 |
| *G* | A-Jays | 2 | 1 | 37.7 | 3.4 | 70 | 58 | 59 | 54 | 62 | 2.8 | -2.5 |
| *H* | Senn-heiser | 4 | 2 | 37.7 | 3.7 | 61 | 49 | 65 | 51 | 63 | 2.9 | -2.5 |
| *I* | TDK | 3 | 5 | 35.9 | 3.3 | 66 | 54 | 66 | 56 | 58 | 2.5 | -6.3 |
| *J4* | Shure | 5 | 4 | 36.9 | 2.8 | 56 | 50 | 61 | 50 | 52 | 2.2 | -14.9 |

**Table 3**. Correlations between independent and rated measures (Spearman's rho)

| | *Overall Experience* | *Isolation Perceived* | *Clarity* | *Distortion* | *Sharpness* | *Envelopment* | *Tonality* |
|---|---|---|---|---|---|---|---|
| *Price (SGD)* | -0.06 | -0.04 | -0.05 | -0.06 | 0.14 | 0.01 | 0.03 |
| *Visual Rank* | -0.16 | -0.26 | -0.09 | -0.02 | 0.02 | -0.02 | -0.18 |
| *Physical Comfort* | -0.21 | -0.09 | -0.25 | -0.26 | -0.19 | -0.17 | -0.24 |
| *Acoustic Isolation* | 0.06 | 0.10 | -0.01 | 0.01 | -0.13 | -0.06 | 0.01 |

A repeated-measures MANOVA was performed with the perceptual ratings as dependent variables, and *Acoustic Isolation*, *Price (SGD)*, *Visual Rank*, and *Physical Comfort* as independent variables, plus their interaction with *Condition* (silence, noise), as shown in Table 3.

Within-participants, significant main effects were found for *Acoustic Isolation* with *Overall Experience* (F=4.03, p=0.047) and with *Perceived Isolation* (F=4.87, p=0.029). There were also significant correlations for *Perceived Isolation* with *Price* (F=7.12, p=0.008) and with *Visual Rank* (F=5.13, p=0.02). This is similar to the correlation between *Tonality* with *Price* (F=4.33, p=0.04) and with *Visual Rank* (F=8.41, p=0.004).

As for interaction effects with Condition, there was a significant correlation for Price with *Distortion* (F=8.70, p=0.004) and with *Clarity* (F=4.39, p= 0.04). There were also significant correlations for *Envelopment* with *Acoustic Isolation* (F=5.26, p=0.023).

There was no significant relationship between the *physical comfort* of the 3 earbuds nor does it affect the overall perceived sound quality (F(2, 28) = 0.35, p = 0.7). Flanged earbuds fared very differently in the acoustic measurement and perceptual experiment. Technical measurements showed that flange is the most efficient in isolating noise (-14.9 dB) but silicon earbuds were perceived to be the most isolating.

The correlation between *tonality* and *visual rank* suggests that the price of earphones and the way it looks does affect a person's perception of how rich music sounds. The correlation between *isolation perceived* and *visual rank* shows that people do base their perception of noise isolation on how the set of earphones look and if they are perceived to be more noise isolating, they somehow can cause the user to feel that the earphones are more expensive. Correlation of *overall experience* with *acoustic isolation* reinforced the earlier finding that noise isolation affects a person's perception of music and sound.

Qualities that were affected by noise conditions were price with *Distortion* and with *Clarity*, and *Envelopment* with *Acoustic Isolation*. This tells us that the level of noise in the environment can affect our perception of how distorted and clear music is. The playlist did not have songs that were clipped, hence noise in the environment could have confused the participant, leading them to perceive distorted and muddled sounds. The correlation of noise on *Envelopment* with *Acoustic Isolation* shows that in a noisy environment, the level of isolation measured can determine how enveloped one feels by his music.

## 6. Conclusion

The human perception of music when using earphones are not only affected by sound quality, but also the physical aspects of earphones. Initially driving this research, we hypothesized a correlation between perceived quality and price of earphones. The survey showed no such relationship suggesting an alternative hypothesis that the price tag of earphones is not a good indicator of sound quality, neither perceived nor when measured acoustically. However, comfort ratings were correlated with the amount of *satisfaction* a person expresses with regards to his or her usage of earphones.

*Physical comfort* was then analyzed to find out which aspects of it was responsible for delivering comfort to the commuter. This led us to test 3 commonly found types of earbuds and we found that the level of comfort which a commuter would feel only affected how satisfied they are with their earphones but not their perception of music or sound quality. Earbuds could affect a person's perception of music through the level of noise isolation it can deliver. People seem to value noise isolation because from the analysis done, a more noise isolating set of earphones seem to allow the user to feel that they are having a better audio experience. Also, the more noise isolating the earphones are perceived to be, the more expensive it appears to the user.

From this study, we have observed how people tend to tie noise isolation with sound quality, suggesting to us the importance of it. This could be because when people use earphones, they expect it to shut off the noise from the outside, giving them the sense of tranquility.

This study faced the limitation of not being able to answer why people turn up their volumes and the emotions related to sound quality. The sample size of participants in the perceptual experiment could also be larger, including a wider range of ages. Another limitation would be the inability to run audiometric tests on experiment participants. Without knowing the full extent of each participant's sense of hearing, we had to assume that their perceived level of noise isolation was an accurate measure of their ability to discern music from background noise.

Further research involving *physical comfort* of would require a more discerning Comfort Index and its relevance to the earbuds on earphones. Further work based on this paper could be a research on the relationship of listening pleasure and volume levels, as well as the feelings associated with overall audio experience.

## 7. Acknowledgement

The 1st author is currently completing an undergraduate Final Year Project with the 2nd author as supervisor. The work focused upon in the present text represents a part of the FYP.

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