Users Perceptions of Headphones and Earbuds in Norway and Brazil: An Empirical Study based on a Kahoot Quiz

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Abstract. Headphones and earbuds are seemingly more popular than ever with the wide availability of smartphones and music streaming services. Such personal audio systems are also essential for many blind and visually impaired computer users that relies on text-to-speech. Few published studies address the users' perceptions of such personal audio output devices. However, past research shows that negative perceptions may lead to device abandonment. General-purpose equipment may therefore be more successful than special purpose assistive technologies for marginalized groups. We therefore set out to gain insight into how users generally perceive headphones and earbuds, and we wanted to base our study in two different cultural contexts. A questionnaire built on a Kahoot quiz was developed involving 12 questions related to headphones and earbuds. A total of 100 participants were recruited in Norway and Brazil. The results show that intuitiveness is the most valued feature of these devices and cost was not. Brazilians expressed skepticism regarding the use of headphones while walking and when travelling on public transport, while Norwegians expressed that headphones were safe to use in such situations. Our experiences showed that Kahoot is a promising platform for conducting such experiments, as it may appear more engaging than regular questionnaires. Moreover, they are relatively easy to set up and allow response times to be measured.

Keywords: accessibility, assistive technology, headphones, earbuds, perceptions, design, Kahoot quiz

1 Introduction

Smartphone technology has drastically changed how people listen to music. The general smartphone has replaced audio specific devices such as stereo systems and portable mp3-players. Internet connectivity allows users to subscribe to and access huge music libraries and audio books via streaming. Such personal audio systems are also an essential tool for blind and visually impaired users who use screen readers with text-to-speech [1] as users without vision must rely on audio or haptics instead [2]. Music and other audio contents are highly personal, and most people listen to their audio content via headphones (see Fig. 1) or earbuds (see Fig. 2). Both are seemingly popular. Headphones may be viewed as preferred by music enthusiasts and air-travelers, while earbuds seem to be preferred by joggers and other individuals active in physical sports and exercises. There are also earplugs that are inserted deeper into the ear canal, while earbuds hang on the side of the outside of the ear canal. Occasionally the term earphone is used to refer to such personal audio output devices. Bone conducting headphones and Apple's transparency mode for the AirPods Pro and AirPods Max have also recently emerged as alternatives for users who want to also be aware of their surroundings while listening to an audio source.

Fig. 1. Headphones.

Fig. 2. Earbuds

The headphone and earbud technologies are mostly driven by manufacturers as there is not much academic work on these audio devices. Yet, there is much research that suggests that the physical appearance of devices affect our attitude towards these technologies. Color is one example of a visual attribute that attracts much attention among designers and users [3, 4, 5, 6]. This is especially an important factor for assistive technologies as users' perception of these devices are related to the degree in which these devices are used or abandoned [7, 8]. Studies have shown that also visually impaired users are concerned with how the visual aesthetics of the devices they use are perceived by onlookers [9].

In this study we wanted to gain a better understanding about how users perceive these devices according to several dimensions. As the work reported here in is part of a bilateral interdisciplinary Brazil-Norway collaboration project [10, 11, 12], we wanted to explore whether these perceptions also are related to culture. We therefore designed a questionnaire that probed participants about 12 characteristics related to both headphones and earbuds. Instead of using a traditional questionnaire we employed a Kahoot quiz (an online game-based learning platform) to make participation more engaging and fun, thereby making it easier to recruit participants. In total we managed to easily recruit 100 participants from Norway and Brazil. Figs. 1 and 2 are the authors' own photographs and not the same as the one used in the quiz due to copyright issues.

The rest of this paper is structured as follows. Related work is briefly outlined in the next section, followed by a description of the methodology in Section 3. The results are presented in Section 4, followed by a discussion of these results in Section 5. Concluding remarks are provided in Section 6.

2 Related work

Some of the research efforts into personal audio technology such as headphones and earbuds have explored the dangers that listening to music at high volumes over prolonged times pose to the loss of hearing [13]. The effects of hearing loss due to prolonged headphone use on academic performance has also been studied [14]. However, on a more positive note, low-cost general-purpose earbuds have also been identified as an emerging competitor to special purpose more expensive hearing aids [15]. Bone conducting headphones is a technology that do not obstruct the ear canal and thus allows the wearer to hear all the sounds from the environment [16, 17].

The last decade has demonstrated the emergence of the noise cancellation headphones and earplugs [18] that are highly popular among air travelers. Such noise cancellation technology has also been studied with specific applications in mind. For instance, Kari, Makkonen and Frank [19] studied the effects of using noise cancellation earplugs in open plan offices among software engineers. They did not find that the noise cancellation technology had any effects on stress, strain, or stress recovery. In fact, they found a negative effect on the perceptions on well-being and work performance. Their explanation for these results was that earplugs that are inserted into the ear canal are uncomfortable to wear. Gallacher et al. [20] found more positive results with active noise cancellation headphones in hospitals with noise pollution. The noise reduction helped participants rest and sleep. Bickford, Stanyek, and Gopinath [21] studied how "sharing" of earbuds was an essential part of social interaction and practices among schoolchildren, their role in relationships with friends, networking, and hierarchies. Woods et al. [22] proposed an interesting procedure to test if participants are wearing headphones in remote experiments to ensure a close to constant setup. It works by playing a tone that is phase shifted 180 degrees to the left and the right channel. If played through loudspeakers the sound is difficult to hear as it cancels itself out, while it is easy to hear using headphones as the signal is not canceled due to the phase shifting.

There are also a handful of academic papers related to the design of personal audio output systems [23]. Rogfelt and Lundstrom [24] designed a set of earbuds that aimed at the needs and wants of mobile gamers specifically. Manabe and Fukumoto [25] used earphones as tapping input devices by reversing them as microphones. Xu et al. [26] employed similar ideas but using the built-in microphone currently found on most smartphone earbuds. Young [27] discusses how to design sound for earbuds, as opposed to design sound for loudspeakers.

Reinfelt, Hardish and Ernst [28] studied how the design of headphones affect its use. They conducted a questionnaire study involving 125 participants. They concluded that headphones to some degree are a "hedonic technology" as their use is affected by perceived enjoyment. They recommend that manufacturers consider this during design of headphones. Lin et al [29] employed a Kansei engineering methodology to find how users perceive headphone designs to identify the optimal characteristics. They conducted an experiment where the participants evaluated 14 different headphone designs and evaluated these using 7-point semantic differentials including the dimensions old-fashioned/fashionable, complicated/simple, ugly/nice-looking, cheap/expensive, bulky/lightweight, uncomfortable/comfortable, difficult-to-use/easy-to-use, and business/casual. Semantic differentials are commonly used to measure perceptions of designs such as assistive technologies [8]. Based on the results the authors conclude on several detailed and specific design choices that are more beneficial than others in terms of users' perceptions of the headphones [29].

3 Method

3.1 Experimental design

A questionnaire was devised with type of audio-device as within-groups independent variable and cultural affiliation as between-groups independent variable. The audio-device had two levels, namely headphones and earbuds, while the culture had two levels, namely Norway and Brazil. The dependent variables included perceived features described in detail in the following sections.

3.2 Participants

A total of 100 participants accepted to complete the survey. Of these, 44 were recruited in Norway and 56 were recruited in Brazil. The participants were mostly recruited from the authors' respective universities and comprised mostly young adults in their 20s. The participants comprised a balanced mix of both males and females.

3.3 Materials

A questionnaire with 12 questions related to both headphones and earbuds were designed, totaling 24 questions, in addition to a couple of general questions. The questionnaire probed the participants' perception of the respective audio device with regards to price, trendiness, aesthetics modifications, aesthetically pleasing, safe to use on public transport or while walking, robustness, aesthetics, comfort, easy to use and intuitive (see Table 1). Each question was assigned a 4-item Likert scale from 1 to 4. Hence, the participants were forced to indicate a positive or negative direction as there was no neutral option.

Table 1. Questionnaire Likert statements.

Question ID	Likert statements (earbuds/headphones)
Q1, Q13	This product is comfortable.
Q2, Q14	The product looks like it is built robustly and will not easily break.
Q3, Q15	It is intuitive to use.
Q4, Q16	The product aesthetics are pleasing.
Q5, Q17	The product aesthetics need some changes.
Q6, Q18	I would buy this product because it is easy to use.
Q7, Q19	I would buy this product because it looks trendy.
Q8, Q20	I would buy this product because it is the cheapest option.
Q9, Q21	I would buy this product as I like the design.
Q10, Q22	I feel safe to walk outside using the product.
Q11, Q23	I feel safe to take the public transportation using the product.
Q12, Q24	This product would make me look trendy.
Q25	I prefer to use earbuds.
Q26	I prefer to use headphones.
Q27	In my opinion, I think it is relevant to use Kahoot! in scientific research.
Q28	I am more motivated to participate in research using kahoot than regular questionnaires.

The questionnaire was implemented in Kahoot, which is a popular online quiz engine which often is used by teachers to engage students in the classroom [30, 31] and has also been used as a platform for controlled experiments [32]. We used a quiz in personal mode. Kahoot has also been used for research projects. Kahoot was chosen over an ordinary questionnaire as it was deemed more fun and engaging and hence thereby increasing the change of acquiring respondents. Another advantage of Kahoot is that it also records the time it takes for each participant to provide the response, which allows the responses also to be analyzed in terms of potential hesitations. The questions were presented in a fixed order, first asking about the earbud characteristics, followed by the headphone characteristics. The Portuguese language version of the questionnaire was translated after the English language version was completed.

3.4 Procedure

The Kahoot quiz was both conducted in several group settings and individually in person or remotely over the internet. The data collection was conducted over a period of two months during the spring of 2020 in both Oslo, Norway and Bauru, Brazil. The Norwegian participants responded to the English-language Kahoot, while the Brazilian participants responded to the Portuguese-language Kahoot.

3.5 Analysis

The responses and timing data were extracted from Kahoot and analyzed using the JASP version 0.12.2.0 statistical software package [33]. The responses to the questionnaire were analyzed using non-parametric tests as the responses were ordinal. Shapiro Wilks test showed that the timing observations did not satisfy the assumption of normality and these were therefore also analyzed using non-parametric tests.

4 Results

4.1 Perception of audio device characteristics

Fig. 3 and 4 shows shorted diverging stacked bar graphs [34] of the participants perceived characteristics for headphones and earbuds, respectively. Inspecting the graphs reveal that the participants generally were more positive regarding headphones compared to earbuds as headphones only had 3 characteristics tending towards the negative side while earbuds had 4 of its characteristics tending towards the negative side. Both audio types received the lowest scores related to price and the highest scores related to intuitive.

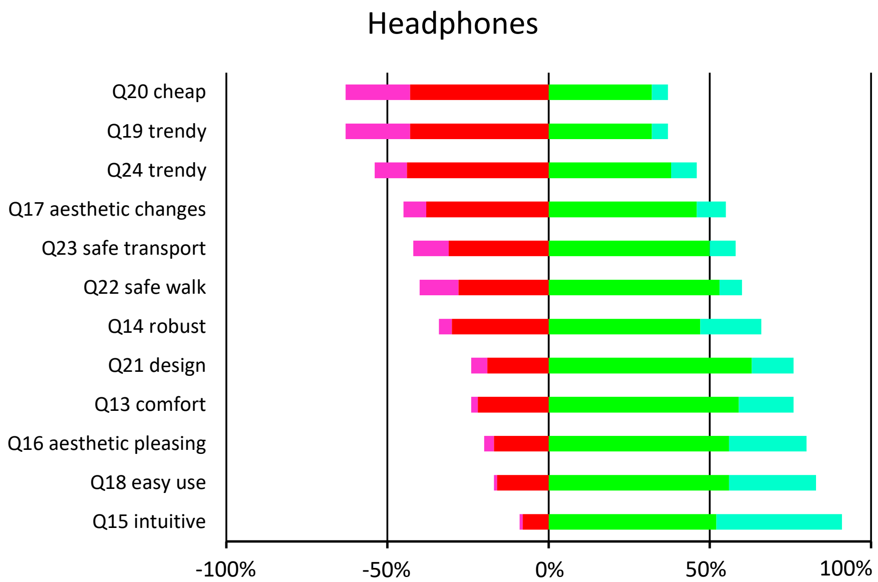

Fig. 3. Diverging stacked bar graph showing perceived headphone characteristics. Likert scale responses are represented by 1 = magenta, 2 = red, 3 = green and 4 = cyan. The gridlines show 50% divisions.

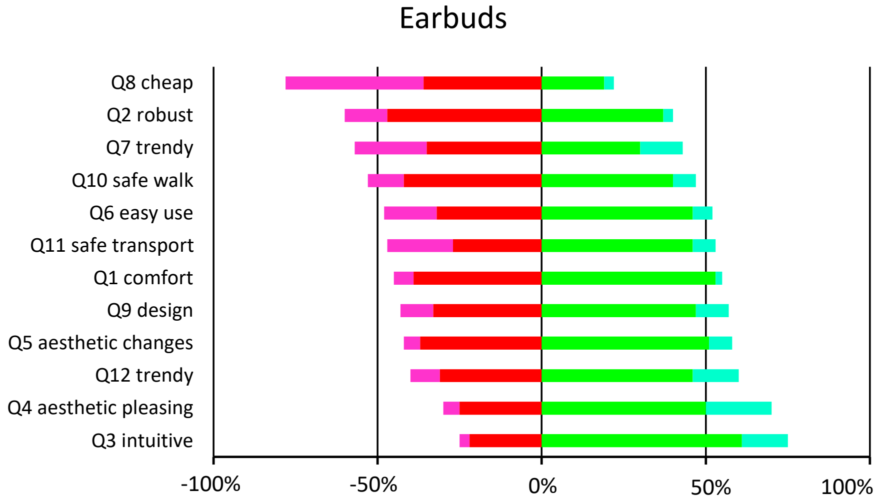

Fig. 4. Diverging stacked bar graph showing perceived earbuds characteristics. Likert scale responses are represented by 1 = magenta, 2 = red, 3 = green and 4 = cyan. The gridlines show 50% divisions.

Wilcoxon signed rank tests reveal that the main differences observed were as follows: Headphones were perceived as more comfortable than earbuds ($W = 208.0$, $p < .001$), with 55 positive and 45 negative responses for earbuds, and 76 positive and 24 negative responses for headphones. Headphones were perceived as more robust than earbuds ($W = 1435.0$, $p < .001$), with earbuds: 40 positive, 60 negative, and headphones: 66 positive, 34 negative. Although both were perceived as positive, headphones (91/) were perceived as more intuitive than earbuds (75/25) to use ($W = 165.5$, $p < .001$). Headphones (83/17) were perceived as easier to use than earbuds ($W = 1604.0$, $p < .001$) being the 2nd highest ranking headphone feature, with overall neutrally balanced response for earbuds (52/48). Although both headphones (37/63) and earbuds (22/78) received the lowest score on price the earbuds were perceived as more expensive than headphones ($W = 902.5$, $p < .001$). The headphones (76/24) also received a higher score than the earbuds (57/43) in terms of design ($W = 501.0$, $p = .018$).

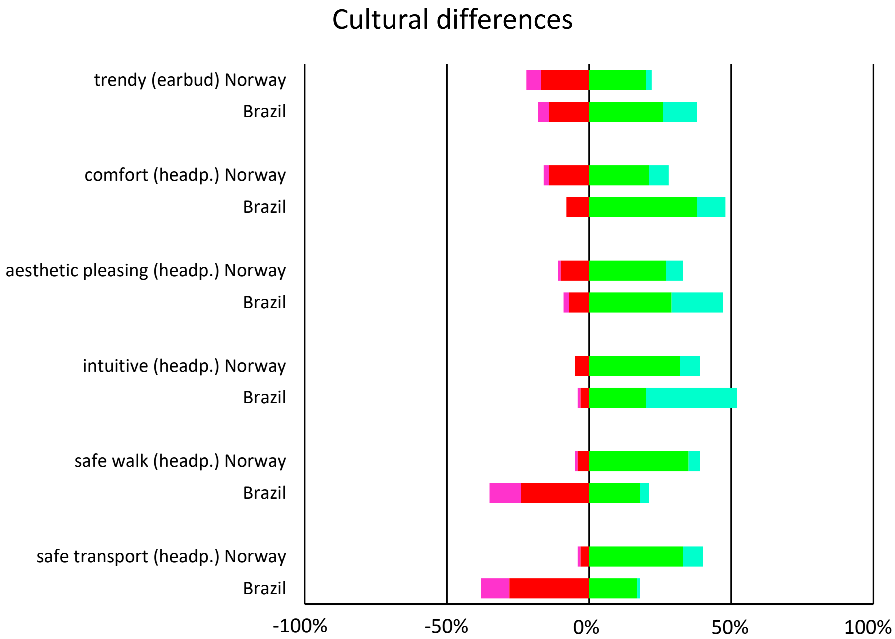

Fig. 5. Diverging stacked bar graph of features flagging significant differences across cultures (Norway vs Brazil). Likert scale responses are represented by 1 = magenta, 2 = red, 3 = green and 4 = cyan. The gridlines show 50% divisions.

4.2 Cultural differences

Mann-Whitney U tests were used to indicate any significant differences across cultures and the six characteristics that were significantly different are shown in Fig. 5. The largest differences were observed for the perceived safety of use on public transport ($W = 464.0$, $p < .001$) and safety of use while walking ($W = 608.5$, $p < .001$). For both dimensions the Norwegian responses were positive (transport 40/4, walking 39/5) and Brazilian responses were negative (transport 18/38, walking 21/35).

The differences were smaller for the remaining four features and in all cases the Brazilian responses were more positive than the Norwegian responses. Brazilians (52/4) rated the headphones as more intuitive than the Norwegians (39/5) and this difference was significant ($W = 1723.5$, $p < .001$). The Brazilian respondents (47/9) ranked the headphone more aesthetically pleasing than the Norwegian respondents (33/11), also to a level of significance ($W = 1491.5$, $p = .045$). Headphone comfort also triggered a significant difference ($W = 1484.0$, $p = .048$), with more positive responses among the Brazilians (48/8) compared to the Norwegians (28/16). Perceived trendiness was the only earbud characteristic that triggered a culturally related difference ($W = 1547.0$, $p = .019$), also with more positive responses among the Brazilian respondents (38/18) compared to the Norwegian respondents (22/22).

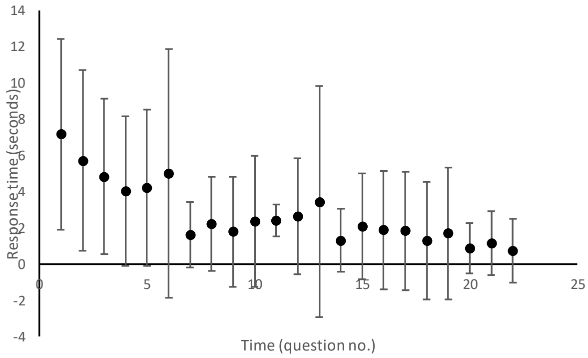

Fig. 6. Mean response times for the sequence of questions. Error bars show standard deviation.

4.3 Response time

The observations show that the mean response time reduced gradually with the number of questions starting with a mean of 7.1 seconds for the first question and ending with a mean of 0.7 for the last question (see Fig. 6). It therefore did not make sense to compare the timing for the within factor (audio-device type). However, Fig. 6 reveals that a few questions stand out with higher mean and larger spread than the others, question 6: how easy it is to use the earbuds, and question 13: headphone robustness.

However, we observed the culturally related response time differences (between-group factor) and a series of Mann-Whitney U tests flagged 6 questions. Measured in seconds the Brazilians (M = 4.9, SD = 4.4) responded in nearly half the time as the Norwegians (M = 8.4, SD = 5.8) on the question related to earbud robustness (W = 257.500, p = .004). The Brazilians (M = 1.3, SD = 2.8) responded a bit slower than the Norwegians (M = 1.2, SD = 1.0) on the question related to earbud trendiness (W = 320.0, p = .035). In terms of headphone comfort (W = 661.5, p = .015), the Brazilians (M = 3.0, SD = 3.5) were nearly three times as slow to respond as the Norwegians (M = 1.4, SD = 1.2). Although significant the cultural differences related to headphone design (W = 250.0, p = .002), safety of using headphones on public transport (W = 212.0, $p <$ .001), headphone trendiness (W = 252.0, p = .002) were too small to be of any practical significance.

5 Discussions

5.1 Perception of audio device characteristics

The results point in the direction that, from the respondent's perspective, headphones have more beneficial characteristics overall, including better design, better comfort, more robust, more intuitive to use and easier to use. However, these characteristics may also depend on context. Headphones clearly are very suitable when the listener is sitting still, while earbuds are designed for sports and physical activity. It seems that the advertising of earbuds is targeting individuals doing sports and exercise. Especially large headphones may have reduced sound quality while running for instance caused by thumps as the feet hit the ground. Moreover, over the ear headphones may be warm and not allow sweat to dissipate while with earbuds this is not a problem. However, we did not include this element in our study. The perception of comfort and discomfort related to the use of audio-devices is multi-factorial as the interaction encompasses not only physical aspects, but also temperature and sound.

It is also interesting that earbuds were perceived as more expensive than headphones. In fact, it seems that the price range for headphones is much wider than for earbuds. It would have been interesting to probe more deeply into why the respondents provided these answers. We can only speculate that headphones have been around for a long time and there is an established inexpensive high quality headphone, while earbuds is comparatively a younger type of product with some element of fashion and hence the starting price is comparatively higher.

On a different note, headphones are more visible than earbuds, as earbuds sometimes are almost invisible if hidden behind hair and clothing. The visual aesthetics of headphones would therefore seem to be more influential and important than earbud aesthetics when viewed from a social perspective.

Note that this study did not explicitly consider, or compensate, for possible effects of participants' preconceptions, abstract understanding, and experiences related to on-ear versus over-ear headphones and on-ear versus in-ear earbuds. Such effects could have affected the results. The participants were instructed to answer the questions according to their own understanding of headphones and earbuds; the images were just provided as examples.

Moreover, this study did not include cohorts of disabled users. Users with reduced vision (and uncorrected hearing) may be the most relevant cohort to include in this regard. One may speculate that safety in public spaces and ability to be aware of the surroundings would be perceived as important. Technologies such as bone conducting headphones and transparency modes may hold potential. The study of their applicability for disabled users may be fruitful directions for further inquiry.

5.2 Cultural differences

The most noticeable difference attributed to culture was regarding the safety of use of the headphones on public transport and while walking. One explanation of this result could perhaps be a symptom of differences in the traffic situation in the two countries rather than the audio devices themselves. Norwegian traffic may be comparatively more strongly regulated than the Brazilian traffic situation, and the Norwegian cities are more tailored to pedestrians. Also, one may argue that the Norwegian government has invested more in the public transport in Oslo, than what has been invested in the public transport in Bauru. Therefore, if the walking and public transport situation is viewed as somewhat unsafe in the first place, one may rate the use of headphones lower than when the walking and public transport situation is viewed as safe, in which case the headphone use is also considered safe. If the traffic situation is dangerous the pedestrians need to be careful and able to hear the traffic sounds and probably should not wear headphones to protect their own safety.

It is quite interesting that the Brazilians were generally more positive than the Norwegian respondents in terms of the intuitiveness of the headphones, the aesthetics of the headphones and comfort. This positive perspective can be influenced by the context of use of those products. In Brazil headphones are more frequently used and earbuds are considerably a new product compared to headphones.

5.3 Response time

Fig. 6 shows that the mean response time becomes smaller with each question. This is an indication of a learning curve where the participants learn how to operate within the Kahoot quiz. Once the participants have gained their skills, they are generally able to respond to questions within one second.

However, Fig. 6 also reveals two outliers with larger mean response time and a larger spread than their immediate neighbors. This indicates that the respondents hesitated with these questions, namely how easy it was to use the earbuds, and how robust the headphones were. We can only speculate what the cause for these hesitations were. One explanation could be that the questions were unclear such that the participants needed more time to decipher the intended meaning, or unclear language in the questionnaire or lacking language ability among the participants. For instance, the Norwegian respondents were presented with the quiz in English, yet we did not screen the participants' English abilities. Another explanation may be that the participants had not thought about these aspects before and needed more time to reflect upon the answer. From one perspective the timing of responses can give a clue to the quality of the questionnaire.

The observed differences in response time attributed to culture could probably be explained by language barriers. For instance, the fact that Norwegians needed a mean of 8 seconds to determine the robustness of earbuds, while the Brazilian participants only needed 4 seconds. One possible explanation for some of these observations could be that the respondents were asked to answer based on pictures on the screen, and did not have the chance to see, handle and try the products. However, this study aimed to address people's perceptions on the design features of such devices. From the perspective of the practical functions of the products, this research approach can contribute to the comprehension on how the appearance of a product communicates its functions and usage. In the context of global increase of online stores, the use of pictures that best demonstrate the products' features and qualities – thus providing proper estimation of usage - may result in an approximation of the subject's expectation to the experience of use and, ultimately, benefit users' satisfaction with the product.

6 Conclusions

This study measured participants' perceptions of headphones versus earbuds according to 12 dimensions including design, aesthetics, safety, cost, intuitiveness, ease of use, robustness, etc. Participants were recruited in both Norway and Brazil. We therefore explored differences related to culture. Overall, the participants exhibited more positive perceptions of headphones compared to earbuds. Cost was the most negative aspect for both audio devices while intuitiveness was the most positive aspect. In terms of cultural differences, the Brazilians were negative towards using headphones while walking or on public transport while the Norwegians were comparatively positive. We also explored the quality of the questionnaire by analyzing the response times and participant hesitations. Our experiences were that Kahoot is a suitable platform for conducting such types of studies as they are easy to configure, allows responses and response times to be recorded automatically, and may come across as more engaging than a regular questionnaire. It may thus be more easy to recruit participants for an interactive "quiz" than a regular questionnaire.

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