Acceptable Operating Force for Buttons on In-Ear Type Headphones

Vincent Buil, Gerard Hollemans
Media Interaction group – Nat.Lab.
Philips Research Laboratories
Eindhoven, The Netherlands
{vincent.buil, gerard.hollemans}@philips.com

Abstract

The Touch Headphones are a solution for providing playback and volume controls on in-ear type headphones. One of the issues with placing controls on earpieces is that applied pressure is transferred to the inner ear, which potentially creates discomfort. The experiment described in this short paper shows that conventional button switches are not well accepted. Users preferred to operate a button on an earpiece with a force of around 85 grams.

1. Introduction

Headphones are becoming more interactive as we start using them for various activities on the move. Hands-free headsets for the mobile phone [1], as well as the emerging stereo Bluetooth headphones have controls for phone communication and music playback [2]. The more discrete, in-ear type headphones could have such controls on the earpieces as well. The limited space for placing controls is one issue to overcome. This could be done by using different control patterns on one switch per earpiece (click, double click, hold). This would already result in six addressable functions – or more if combinations of left and right are used – as we have implemented in our Touch Headphones prototype (see table 1): in-ear headphones with integrated music playback control.

Table 1: Mapping of controls in Touch Headphone prototype

Pattern	Left earpiece	Right earpiece
Single click	Pause	Play
Double click	Previous track	Next track
Hold	Volume down	Volume up

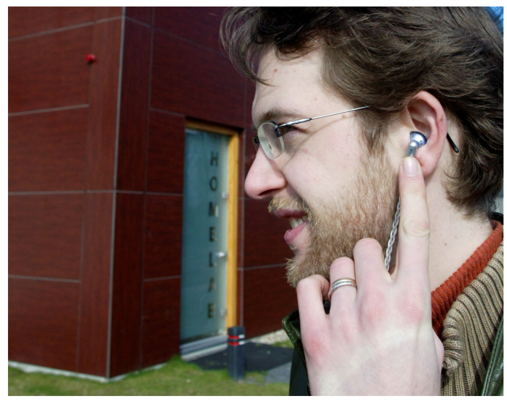

Figure 1: Touch Headphones prototype

Besides the issue of limited space, there is another issue with placing controls on in-ear type headphones: the inner ear is sensitive to pressure applied through manipulation of the earpieces. When push buttons are used, their operating force is directly transferred to the inner-ear (dependent on their exact placement).

In this short paper we will describe an experiment to assess the users accepted operating force of a push button on the earpieces of in-ear type headphones.

2. Acceptable operating force

Conventional button switches (e.g. dome switches [3] and tactile switches [4]) typically have an operating force of around 200 grams. For example, the button on the i.Tech Dynamic Bluetooth Clip Headset [5] (see Figure 2) has an operating force of 200 grams. Dependent on the placement of the button, the force applied by the user is directly transferred to the inner ear. If the force needed to make the button switch (operating force) is high, this could create discomfort for the user.

Figure 2: i.Tech dynamic bluetooth clip headset (l) and measurement prototype (r)

We have conducted an experiment to assess the minimum and maximum acceptable operating force, and the most convenient operating force (as perceived by users) for a button on an earpiece of in-ear type headphones. The experiment aimed to get answers to the following questions:

- What is the fraction of participants for whom 185 grams is above their maximum acceptable operating force? (The typical operating force of buttons used today on in-ear type headphones is 200 grams, however, our measurement instrument can maximally measure 185 grams reliably.)
- What is the most convenient operating force for the majority of the participants?
- What is the fraction of participants for who this most convenient operating is acceptable, thus within their range of acceptable operating forces?

2.1. Equipment

We have developed a special prototype of an in-ear earpiece to measure the user-accepted operating force of a push button placed near the speaker (see Figure 2). This in-ear earpiece was equipped with a button operating a strain gauge with a travel distance of 1 mm to measure pressure in a range of 0 to approximately 185 grams. We used an HBM Scout 55 measurement amplifier to read the voltage differences produced when pressing the strain gauge, which was calibrated to grams.

We provided the participant with a minimum amount of feedback in our setup to avoid possible influence on the measurements. The button on the earpiece and the measurement amplifier did not provide any tactile ‘click’ or auditory feedback. The only feedback available was the force felt in the inner ear, the tactile feedback on the fingertip, and the maximal 1 mm movement of the button.

2.2. Participants

Sixteen people volunteered to participate in this experiment (8 male and 8 female). The participants were students and colleagues working at our research laboratory, ranging from 24 to 61 years old. The participants were not paid.

2.3. Setup

The dependent variable in this experiment was the actual force that the participants applied to the specially prepared earpiece, converted to grams. In general, people operate buttons in different ways. For example, they show their own preferences for the angle and duration of presses. This influences the sensation of pressure perceived by the participant. Therefore, we asked the participants to apply the force themselves rather than using a mechanical setup to apply the force. In this way, the tactile feedback on the fingertip could be taken into account. The tactile feedback likely influences the minimum and maximum accepted operating force levels, as well as the level of operating force perceived as most convenient. For this reason, we did not instruct the participants how to hold their hand while operating the button on the earpiece; we let the participants freely choose their preferred hand position.

The independent variables were *tapping pattern*, *earpiece position*, and *requested force*. The experiment was set up using a within-subjects design, so that all participants experienced all conditions.

The independent variable *tapping pattern* had three levels, namely *single tap*, *double tap*, and *hold* (continuous pressure for a short period). The *earpiece position* was either in the *left ear* or the *right ear* of the participant. The variable *requested force* had three levels, which were created by asking the participants to apply a force that was considered by the participant as either *most convenient*, *as light as acceptable*, and *as strong as acceptable*. Each condition consisted of five trials, resulting in a total of 90 measurements per participant (5 trials, times 3 tapping patterns, times 2 positions, times 3 requested force levels).

A carry-over effect was expected between the levels of the independent variable *requested force*. For example, after having experienced how lightly a button can be operated while generating an acceptable pressure on the ear, the participant might become more critical with respect to what he considers *most convenient*. Conversely, following the condition where the participant applies a force that is as strong as acceptable, the participant might become more lenient with respect to what he considers *most convenient*. In practice, we expect that the participant would not first try the conditions *as light as acceptable* and *as strong as acceptable* before starting to use the buttons as *most convenient* to him. Therefore, the condition *most convenient* was always placed first in our experiment. The order of the two subsequent conditions was counterbalanced, thus dividing the participants in two groups, as shown in Table 2.

Between the different levels of *requested force* (convenient, light, and strong) the participants performed a small task with the mouse on a PC (3D Pinball from Maxis/Microsoft) to reset their tactile thresholds [6]. Before starting the next condition the participants were offered a few trials on the headset. This allowed them to determine the requested force while evaluating the pressure experienced in the inner ear and tactile feedback on the fingertip. After the session was completed, participants were asked their most preferred level of force that they applied (convenient, light, or strong).

Table 2: Experimental Design

Group (Order)	*Male*	*Female*
1. Convenient > Light > Strong	*4*	*4*
2. Convenient > Strong > Light	*4*	*4*

The experiment was conducted at an office desk, with the experiment leader at one side of the desk and the participant at the other side. The Scout 55 was placed between them, facing the experiment leader, such that the display was only readable to him.

During a short introduction the participant was informed about the purpose of the test, namely to determine the acceptable operating force range of mechanical pushbuttons on earpieces.

3. Results

The results for the three *requested force* conditions produced the operating force statistics shown in Table 3 (in grams). Overall, 7 out of 16 participants finally preferred the operating force they applied in the light condition instead of the convenient condition, confirming the expected carry-over effect as discussed in section 2.3.

Table 3: Requested force levels, in grams (M = mean, SD = standard deviation)

Requested force level	*M*	*SD*
Most convenient	109	54
Lightest acceptable	59	52
Strongest acceptable	163	36

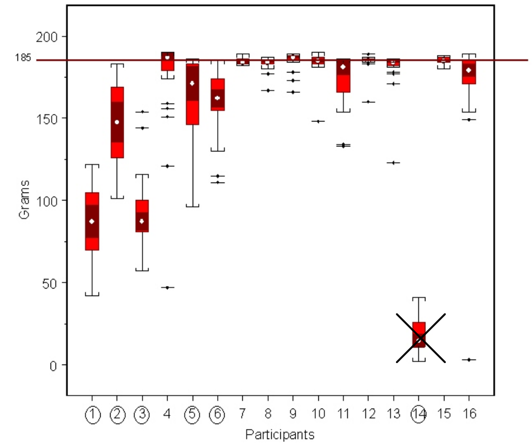

Figure 3: Box plots of strongest acceptable operating force per participant

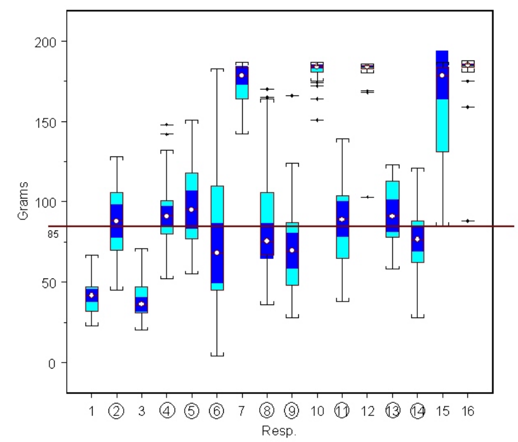

Figure 4: Box plots of most convenient operating force per participant

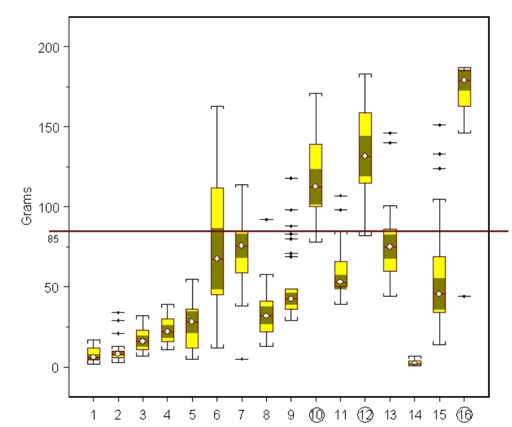

Figure 5: Box plots of lightest acceptable operating force per participant

Table 4 shows the average forces applied in the different levels, per group (order). The average forces in group 2 (Convenient>Strong>Light) are all higher than the average forces in group 1. This difference was not significant (F(1,14)=3.48, p>.05).

Table 4: Difference in means (in grams) between groups, per requested force level

Requested force level	*Group (Order)*	
	1. C>L>S	*2. C>S>L*
Most convenient	88	129
Lightest acceptable	33	84
Strongest acceptable	148	160

For our research questions we found the following:

- An operating force of 185 grams was unacceptably high for 5 out of 15 participants (see Figure 3: for the 5 circled participants the upper and lower quartiles of the box plots were below 185 grams; participant 14 misunderstood the request for this condition, this data is disregarded in the analysis).
- An operating force of 85 grams satisfied most participants, 9 out of 16 (53%, see Figure 4: for the 9 circled participants 85 grams was within the upper and lower quartiles of the box plots).
- For 13 out of 16 participants the operating force of 85 grams was inside their range of acceptable operating forces. The other 3 participants consider 85 grams too light (see Figure 5: for the 3 circled participants the upper and lower quartiles of the box plots were above 85 grams).

We did not measure a significant difference in operating forces applied by men versus women (F(1,14)=0.17, p>.05). Also, the force levels on the left versus the right ear did not differ significantly (paired t = 1.72, df = 15, p > .05). Finally, there were no significant differences in the forces applied with single taps, double taps and hold (F(1,46)= 0.07, p = 0.80).

4. Discussion

Our study showed that 5 out of 15 participants found an operating force of 185 grams unacceptably high. Furthermore, the majority of participants (53%) found an operating force of around 85 grams most convenient. As such we concluded that conventional switches with an operating force of around 200 grams are not well suited for use on in-ear type headphones. This result holds for conventional in-ear type headphones with the button close to the speaker. Other design or ergonomics (such as the Jabra EarGels [7]) could have a different comfort zone.

According to these results, for 3 of 16 participants (19%) an operating force of 85 grams would be below their indicated level of 'as light as acceptable'. The question is however, whether these people would really not accept an 85 operating force switch, as they can operate it with a higher force just as well. It remains unclear whether the participants interpreted the question as 'as light as I would ever tap'. Robustness against accidental activation by head motion or hair could be a more truthful lower bound in terms of acceptable operating force.

5. Conclusions

We have conducted an experiment to find the accepted operating force of a button placed on each earpiece of in-ear type headphones. For buttons placed close to the speaker, on conventional earpieces, we concluded that normal dome and tactile switches are not well accepted due to their high operating force. Application of an operating force of approximately 85 grams is generally considered as most convenient. As such, we conclude that switches on in-ear type earpieces should preferably have an operating force of 85 grams or lower. In the Touch Headphones prototype we have met this requirement by using capacitive touch sensors.

6. References

[1] Jabra, "JABRA BT200 wireless headset" (and others), http://www.jabra.com/JabraCMS/EM/EN/MainMenu/Products/WirelessHeadsets/JabraBT200/JabraBT200, July 2005

[2] HP, "Stereo Bluetooth Headset" (and others), http://h10010.www1.hp.com/wwpc/nl/nl/ho/WF06c/A1-1693817-1694005-1694005-1694009-1694009-16023985.html, July 2005.

[3] Xymox technologies inc, "Tactile Feedback (dome switches)", http://www.xymox.com/tactile.htm, July 2005.

[4] Omron Electronic Components, "Tactile Switches", http://www.europe.omron.com/en/cor/ecb/home/productselector/Switches/tactileswitches, July 2005.

[5] i.Tech Dynamic, "Dynamic Bluetooth Clip Headset", http://www.itechdynamic.com, July 2005

[6] Kalat, J.W., *Biological Psychology – sixth edition*, Brooks/Cole, Pacific Grove, California, 1998, pp. 191-192.

[7] Jabra, "JABRA EarGels®", http://www.jabra.com/JabraCMS/NA/EN/MainMenu/Products/Accessories/JabraEarGels/JabraEarGels, July 2005