THE PROCESS OF OPTIMIZING MECHANICAL SOUND QUALITY IN PRODUCT DESIGN

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ABSTRACT
The research field concerning optimizing product sound quality is a relatively unexplored area, and may become difficult for designers to operate in. In some degree, sound is a highly subjective parameter, which is normally targeted sound specialists, if the sound has significant quality meaning to its context of use. This paper describes the theoretical and practical background of managing a process of optimizing the mechanical sound quality in a product design by using simple tools and workshops systematically. The procedure is illustrated by exploring a case study regarding a computer navigation tool (computer mouse or mouse). The process is divided into 4 phases, which clarify the importance of product sound, defining perceptive demands identified by users, and, finally, how to suggest mechanical principles for modification of an existing sound design. The optimized mechanical sound design is followed by tests on users of the product in its use context. The result of this article is a tangible, systematic process, which has the possibility of enhancing the knowledge about sound design in products and its cause and effect.

Keywords: Sound quality, process, mechanical sound.

1 INTRODUCTION
This article is a pilot study regarding the development process of a product design, with focus on how mechanical produced action sounds can be optimized in quality by focusing on users' subjective perceptions. The research project, called MechanicalSound+, is a starting point for further exploration and discussion within this research field. MechanicalSound+ tests the hypothesis regarding; ”with use of a systematic approach, it is possible to optimize the mechanical sound quality of existing products by focusing on the sound”. The theoretical and practical research is conducted via a case study and is targeted one specific product and demographical target group. Further research and exploration will verify the validity of the process in practical use in design practice.

In the area of product sound, the terminology is defined into four categories by Bernsen [1]:
1. Operational sounds
2. Action sounds
3. Signal sounds
4. Passive sounds

The field within designed product sound is a relatively new design research area. Studies have mainly been concerning re-produced operational sound in digital form, with use of trained listening panels in a controlled environment [2] [3] [4]. In these research projects, sound characteristics (also known as attributes) are used to define and rate the subjective perception of the operational sound in relation to objective, measurable characteristics. None of these projects deal with un-trained listening panels, and how to provide tangible guidance for product designers who have interest in optimizing the mechanical sound quality.

The methodology draws inspiration from DELTA's Filter model [5]. DELTA is a part of the Danish research and technology organization named GTS/ATG (Advanced Technology Group), and consults private and public businesses both locally and internationally. The Filter model describes the relationship between objective and subjective measurements when using a listening panel as a tool of verification. In the Filter model, objective measurements are conducted in the beginning of the process.

In MechanicalSound+, objective measurements are delimitated due to the purpose of conducting fast research using subjective parameters for systematic product sound optimization. Therefore, the focus is put upon the process of facilitating workshops with a tangible outcome for Product Development Departments (PDD). The outcome is perceptual demands identified by users of the product using a user-oriented methodology approach.

1.1. Market opportunities

Many product designers are only focusing on feeling and sight when developing products, and marketing strategists define it as 2D-branding [6]. By focusing on more senses, it is possible to create a differential advantage with increased sales as outcome [6]. This tendency of 5D-branding (branding for all senses) is a combination of service and product design. However, the 5D-branding aspect is not exclusively implemented into the product design alone, but it is normally a part of a system design solution [6]. Manufactures and developers can suffer economical consequences by ignoring the importance of the sound [7]. For instance, the Danish actuator manufacture, LINAK A/S, suffered mayor economical consequences due to noise in their hospital elevation products [7].

As a part of the screening process for MechanicalSound+, a survey [8] was conducted among 120 practicing Industrial Designers in Denmark. The response rate was poor (25 responded), and could be characterized by a lack of interest in sound design. Therefore, the survey was seen as a starting point containing inspiring data. The data indicated a gap between how designers work with sound in product designs, and in what degree they felt the sound parameter can be optimized in practice. 15 out of 25 considered sound design as a competing parameter within their business. 73 percent out of the 15 respondents asked felt that they ”in some degree” or ”in a strong degree” could optimize the sound in their product designs [8].

1.2. The designer’s environment

Within product development, the designer has significant power to focus the product design towards a specific goal. It is commonly known that in a structured development process, a Design Brief or list of demands controls this process [9], and can be seen as a contract between PDD and client. It prevents the designer from creating solutions which become irrelevant and not beneficial for the client. Typically, the designer’s role is to visualize a better solution than the existing situation, plan it, execute it, and, in some cases, facilitate the final stages of implementation [10].

MechanicalSound+ conducted research via a four-phased process, which is described in the following sections:

- Phase 1: Identifying the importance of sound
- Phase 2: Defining attributes
- Phase 3: Rating attributes
- Phase 4: Creating mechanical modifications and tests

2 MANAGING THE PROCESS

The process of sound quality optimization proclaims demands to the product developer regarding basic theoretical knowledge about sound and product development. MechanicalSound+’s outcome was a handbook with guidance for product developers to facilitate and execute workshops resulting in improved knowledge about optimization of mechanical action sounds in a specific product targeted a specific demographical user group. It is meant to be an inspirational platform and tangible toolbox for freely use and modification. However, it is not seen as a rigid tool, but more as an ongoing iterative tool. A case study concerning the optimization of a computer mouse’s action sound was used throughout MechanicalSound+ to conduct results for later data analysis and discussion.

2.1. Identifying the importance of sound

The starting point of the research was identifying target users, its context of use, and hereby the demographical importance of sound in the specific product. Numerous methodologies are able to gather this information, and fast situated interviews were proven being a beneficial tool. As Lyon states [11], it was found crucial to rate the importance of the sound parameter in the beginning of a project due to decisions regarding design and construction all have influence on the sound design [11]. Furthermore, analysis of the product structure in relation to its surrounding components was preferable to consider at this stage of the process. The mechanical sound can be caused by isolated settings of components (named generator) [11], or several combinations and relations of components.

It concluded a tendency of four users in average rated the product sound of their mouse to 3.75 on a scale from 1 to 5. The mechanical sound was important but not essential because other design parameters were rated higher. Due to the purpose of MechanicalSound+, the aim was to differentiate the mouse by its mechanical sound. The aim of the sound parameter was hereby rated 5 out of 5, which can be seen in figure 1.

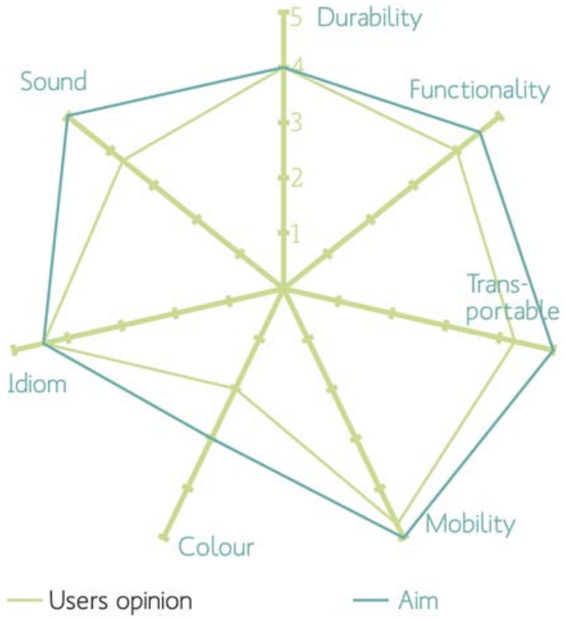

Figure 1. The rating of design parameters in MechanicalSound+.

2.2. Defining attributes

Designers can focus their development by defining various demands to the product (or product specifications) [9]. As a result, it is possible to verify the outcome (product) before final implementation to the market. A user-driven approach was used in MechanicalSound+ to define attributes describing the perceived sound characteristics. Afterwards, the attributes were rated and used as demands for subsequent mechanical modifications. The attributes are conducted in a five-people workshop situated in the product's context of use.

It has been proven beneficial to use a setup of tools prepared by the facilitator before executing the workshop. It was mainly writing tools, post-its, A1 paper map, and most important of all, products with diversity in mechanical action sound. In this experiment, it was positive that the facilitator was a part of the PDD for further documentation, development, and final tests.

With instruction from the facilitator, the workshop began. Here, it became important to constantly notice the dynamics of the listening panel, and observe how well users group and categorize the products. Non-artistic users may have difficulty in describing subjective parameters due to its intangible characteristics. Video material and pictures might become beneficial for later data analysis and documentation.

Figure 2. Users grouping computer mice in accordance to its sound characteristics (attributes).

The workshop resulted in four groups of attributes describing sound characteristics. The first group was named ”sharp, fast, and stress” which was evaluated in direct contrast to the other defined attribute ”lazy”. Another grouping was named ”round and smooth”, which also has an opposite attribute named ”hollow”. The attributes ”lazy” and ”hollow” were eliminated due to consensus of opinion in the listening panel of its direct contrast. Afterwards, the listening panel rated the products on an undefined scale exclusively in relation to the sound attributes. The results were used in selecting products with highly diversity in sound perception for the following workshop.

The attributes named ”sharp, fast, round, and smooth” are all perceptual descriptors of sounds in accordance to DELTA’s word classifications [5]. ”Stress” was the only attribute whose characteristic was described as affective responses to sound [5]. Many attributes are localized in the same word classes, but cannot be generalized into one group of sound descriptors in this type of product.

2.3. Rating of attributes

The following workshop had the purpose of rating the attributes defined with use of individual blindfolded listening tests exclusively focusing on the sound. Before conducting the results, the users needed to be validated as a useful human measurement tool. An individual blindfolded test needed to be carried out to eliminate all senses besides the ability of hearing. After validation, a scaling of the most accepted value, named X+, was located by the users on a similar undefined scale. The rating of the most accepted value was executed with the sound design of five other products as reference. This rating indicates a trend of what this specific user group accepts the most.

Each user rated the two attribute categories; ”sharp, fast and stress” and ”round and smooth” blindfolded but with the ability to;

1. Generate the stimuli (sound).
2. Scale the attribute value for each product.
3. Scale the most accepted value X+.

The two tests (each attribute category) were executed twice in order to validate the users’ responses. When facilitating the second round, the facilitator reorganized the position of the products. In figure 3, all users’ average values are represented (the ratings of both tests divided by 2) including the most accepted value X+ in the last column.

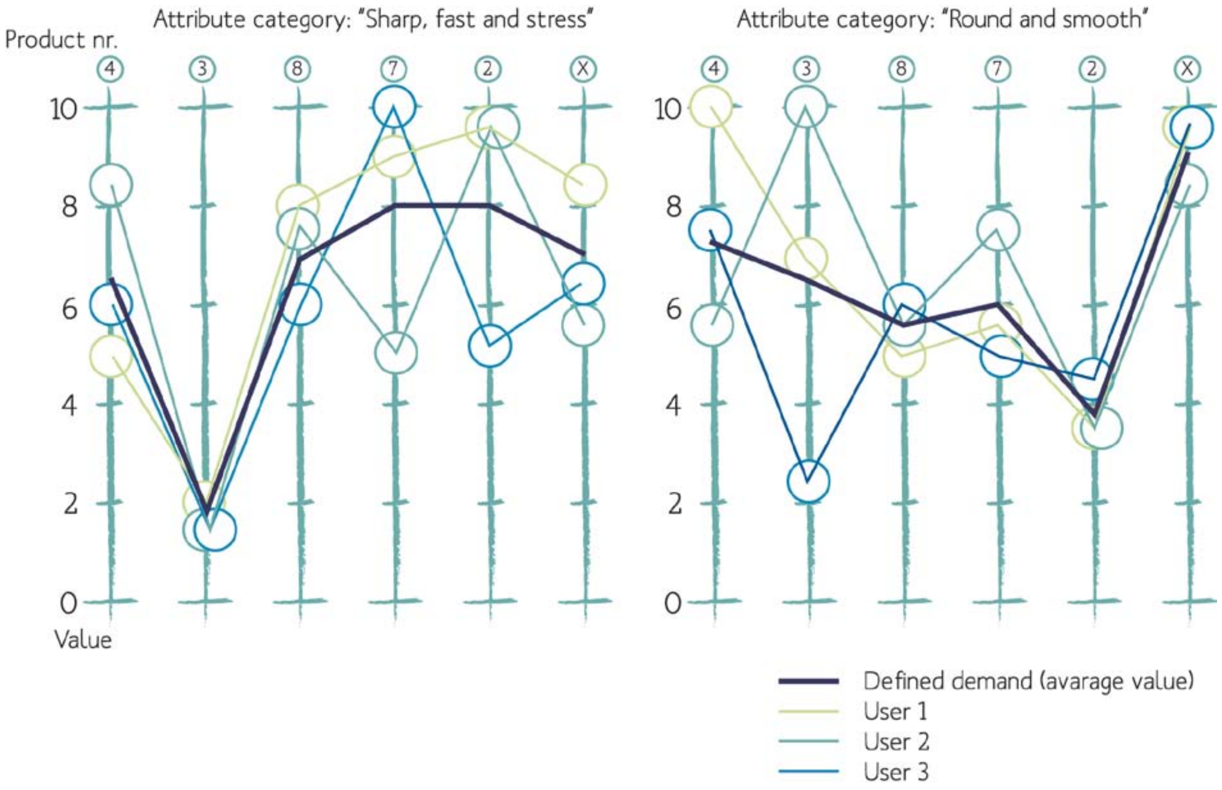

Figure 3. The ratings of 2 attribute categories by 3 users. The answers by users are the average value conducted from 2 similar tests. The thick purple lines indicate the overall average value from all users participating in the test.

Three out of four users did not have major variations in rating the attributes categories. One user had difficulty in making consistent answers and was excluded from further data analysis. The rating was segmented via photos and going from the lowest value of 0 to a maximum scale of 10. Here, the average value form first and second round of tests was put into a scheme containing all user responses. The rating of the most accepted value indicated an average of 7 in the attribute category ”sharp, fast and stress” and 9 in ”round and smooth”.

2.4. Creating mechanical modifications and tests

The two defined attribute categories with ratings were used as guidelines for targeting improved sound quality in the product design. In accordance with Lyon [2], the developer needs to identify the source of the sound and localize the mapping between design and perceptive parameters before making sound design modifications. This was carried out by analyzing the product, its components, and the relationship in between. Lyon [11] categorizes the passage of sound throughout a product into three groups:

- Generator (source of noise)
- Transmission path
- Surface reflection

Several products were detached and analyzed regarding the localization of the sound source. In this type of product, a micro switch was identified as the generator of the sound and of most importance at all. Many different types of micro switches were identified in other computer mice with high diversity in sound characteristic. The product volume, internal wall placement, tightening of overall assemblies/joints, and assembly of the PCB-board with the bottom part of the mouse all had influence in the transmission path. By decreasing the volume with fabrics, it was possible to create a sharper sound. Dampers in between the PCB-board and the bottom part reduced the sharpness of the sound, and lowered the sound level together with sound absorbing material inside the mouse. Surfaces decorated with absorbing material had minor effect on the sound. All relationships found can be seen in figure 4.

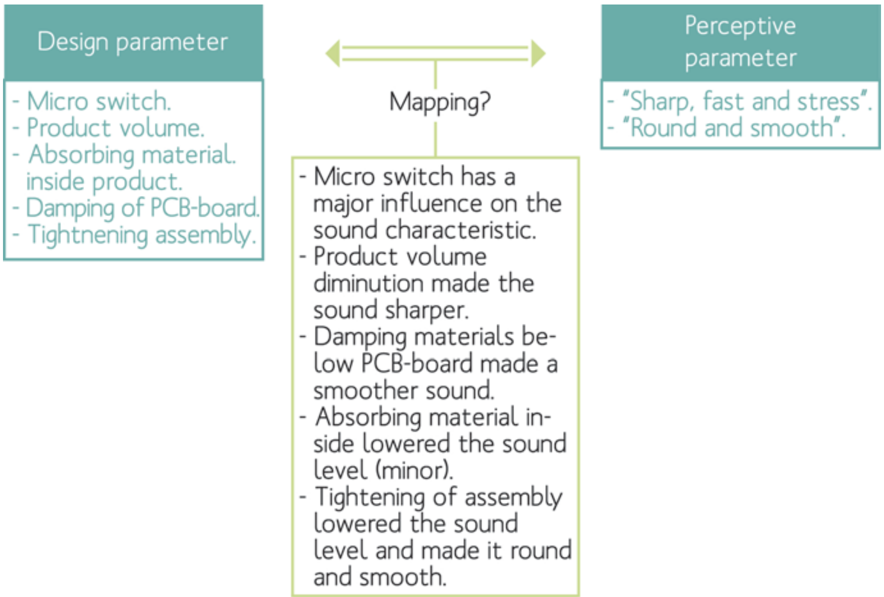

Figure 4. The mapping of design and perceptive parameters of computer mice, and what kind of influence these parameters have on the sound design.

Five similar products were modified, and the sound designs of two products were directly aimed at the users' identified ratings of the two attribute categories. The only differences in these two products were the loudness of the action sound. The remaining products were targeted a higher value in ”sharp, fast, and stress”, and another product a higher value in ”round and smooth”. The remaining mouse was not modified at all, and all modifications can be seen in figure 5.

Figure 5. The sound designs of five similar products were modified. A: filled with material reducing the product's volume. B: tightening the overall assembly using tape in all joints. C: replaced the micro switch. D: replaced the micro switch, dampener below the PCB-board and reduced the product's volume. E: no modifications.

The modified products were tested by 82 design students, and the results can be seen in figure 6:

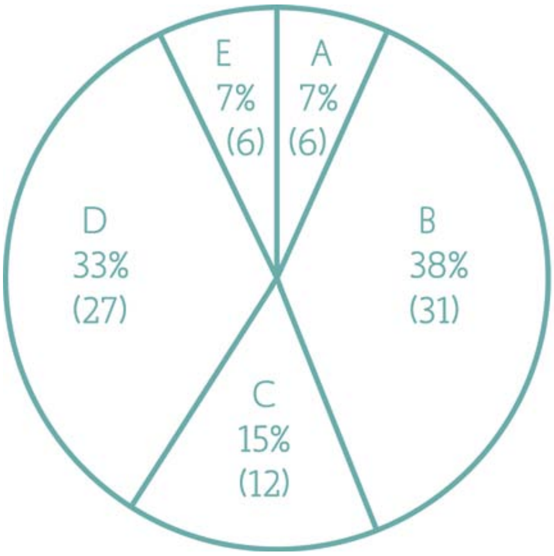

Figure 6. Test of five different sound designs with same product base (identical products from the beginning). 82 design students participated, and evaluated which product sound was the most acceptable in the given context of use (group rooms at Aalborg University).

As seen in figure 6, product B and D are evaluated most acceptable by the users. With knowledge from the conducted tests, it would be preferable to adjust the following design parameters in order to optimize the mechanical sound design in the computer mouse used in the test:

- Use the existing micro switch with which the product is manufactured.
- Tightening the overall assembly and joints using thermoplastic elastomeric or other rubber materials.
- Integrate dampers between the PCB-board and the bottom part of the mouse.
- Coating the inside of the top part with absorbing material.

These principles need to be tested using a prototype in further research for final validation.

3 CONCLUSIONS

A four-phased model for mechanical sound quality optimization has been explored throughout a case study concerning the action sound of a computer mouse. The process included a user-oriented methodology approach by including users identifying and rating the defined attributes categories followed by evaluation of the final sound design by design students. It can be concluded that it is seen possible for developers to optimize the existing sound design in a computer mouse by executing workshops systematically throughout the product development process. The sound of the micro switch was found highly important in modifying the mechanical produced action sound. Furthermore, the internal volume, the damping of the PCB-board, and the tightening of the overall assembly and joints were found relevant in this specific product researched in MechanicalSound+.

It is seen in other research projects regarding sound quality optimization that sound descriptors are exclusively in each product category and very much context and user dependent [12]. Another research project explored how to predict user responses to sound quality by setting up metrics and Acoustical Sensory Profiles [2]. The conclusion points out that it is very much product, user, and context dependent, and it is very difficult to generalize to other products, segments, and markets.

MechanicalSound+'s research results are based on minor statistically responses, and further research can, with a greater number of respondents and resources, conduct more valid data. Also, it would be beneficial to explore other methodologies and more complex product structures.

The outcome is seen as a possibility for improved knowledge and awareness within the PDD about how to identify which parameters that have influence on the mechanical sound design. In a product development process, the PDD needs to identify the importance of i.e. a mechanical produced action sound at an early stage of the process. If the sound has major importance to the users' quality perception, workshops and simple tests can be incorporated into the product development process.

The workshops and tests can become a time, resource, and economical demanding post in the project's overall structure. It is, therefore, important to evaluate the importance of the product sound contrary plausible outcome of quality improvement at the beginning of a project. If not, major economical consequences are plausible [7]. In the conducted case study, the mechanical produced action sound was exclusively targeted eliminating other important senses like seeing or/and feeling when using the mouse. Further studies can explore this relationship in between targeted senses and adjust the process presented in this case study towards a more holistic sensorial approach. The overall quality assessment is a combination of all senses affected by the product in-use, and hereby a possibility of greater quality improvement in the product design.

Sound is not the only subjective parameter at which designers target their products. It is a fine balance between all five human senses. The importance of other subjective parameters can be beneficial for the PDD to classify at an early stage of the process. A product's idiom and design is also a very subjective parameter, whereas a PDD can - with use of mood or style boards - create a platform of communication between designers and users to target users' emotional demands regarding i.e. aesthetic preferences. This case study differs from mood or style boards by creating tangible tools for designers to target their mechanical produced action sound towards with optimized quality perception as outcome by users.

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