Product Sound Design: An Inter-Disciplinary Approach?

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Product Sound Design:

An Inter-Disciplinary Approach?

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Abstract

The practice of product sound design is relatively new within the field of product development. Consequently, the responsibilities and the role of a (sound) designer are not very clear. However, practice shows that various disciplines such as design engineering, acoustics, psychoacoustics, psychology, and musicology contribute to the improvement of product sounds. We propose that sound design should be conducted by experts who have knowledge in the afore-mentioned fields. In other words, we suggest that product sound design should be an independent field that encompasses an inter-disciplinary approach.

Keywords

sound design; sound designer; product sounds; design processes; multi-disciplinary, inter-disciplinary

Our daily interactivity and experience with the sounds that products emit are various. One could have a desire for a car because of its sophisticated door and engine sound, or one may despise an alarm clock sound because it is too loud and too sharp. Using a vacuum cleaner may be too uncomfortable to one's ears, however the happy bell of a microwave oven may be the most expected sign for a late dinner. These examples illustrate the influence of product sounds on our reasoning, on our emotional state, on our purchasing decisions, and on our expectations regarding the product and its functionality.

Studies regarding product sound design and perception have also confirmed the complimentary role of auditory experience on how people perceive and respond to products (Lageat, Czellar, & Laurent, 2003; Vastfjall, Kleiner, & Garling, 2003; ven Egmond, 2006; van Egmond, 2008). That is, a well-designed sound enhances the product experience on ergonomic and hedonic levels. Conversely, unsatisfactory auditory experience will negatively influence one's emotional responses to and conscious judgments on a product. Therefore, in the last decade, more attention has been dedicated to improve the quality of product sounds and consequently the product experience (Lyon, 2000; Özcan & van Egmond, 2006; van Egmond, 2008).

Although designing sounds for products have become a rather acknowledged practice within the field of product development, the task of a designer with respect to sound design is not very clear. In an average sound design task, it is expected that the sound of a product is adequate to the product it belongs to (Blauert & Jekosch, 1997). For example, a kitchen extractor fan should sound 'powerful, yet inconspicuous'. However, for designers, achieving such a goal is not very straightforward. Designing product sounds entails an iterative exchange of expertise from various disciplines that are functionally different. In principle, designing sounds for products requires manipulation of the structural configuration of products—because a product sound is a consequence of moving product parts. Alternately, sound design entails sound synthesis for products that require . Primarily, an acoustical analysis is required to determine the physical character of the sound (i.e., spectral-temporal structure), which can then also be used for sound simulations (Lyon, 2001; Susini, McAdams, Winsberg, Perry, Viellard, & Rodet). A psycho-acoustical analysis reveals people's sensorial reactions to a sound in terms of pleasantness or comfort (Zwicker & Fastl, 1990). Furthermore, semantic associations of the created sounds need to be tested for the adequacy of the sound to the product (Blauert & Jekosch, 1997; Guski, 1997,). In some cases of sound design, musical knowledge is required to compose somewhat musical sounds (e.g., mobile phone ring tones, alarm clocks) (Schimmel, 2001). Thus, the fields of acoustics, psycho-acoustics, engineering, psychology, and musicology contribute to the improvement of the sound at different stages of a sound design process. The multi-disciplinary nature of product sound design makes the design practice too complicated for an average designer / design engineer. Therefore, the tasks regarding the sound design should be separated from the tasks of design engineers.

We propose that sound design, instead of being a multi-disciplinary practice that requires the simultaneous involvement of various experts, should be considered as an inter-disciplinary practice that is conducted by experts who have knowledge in the afore-mentioned fields. Thus, in this paper, we will focus on the contribution of various disciplines to product sound design. Furthermore, the responsibilities of a *sound* designer will be discussed and the plausibility of product sound design as an independent field will be argued.

Product sounds

Two types of product sounds exist: *consequential* sounds and *intentional* sounds. *Consequential* sounds are emitted by products as a result of their functioning. For example, hairdryer, vacuum cleaner, washing machine sounds are considered to be consequential sounds. Such products contain multiple sound producing parts such as running engines, rotating gears or fans, bouncing springs, pumping water, blowing air. The formation of the product sound is dependent on the type of action and the type of source in action. For example, if the product is electrically operated, it probably contains an engine and a gearbox. Attached to them may be a fan that has to rotate or blades that have to move and cut. A rotating fan may be used to blow or suck air. Moreover, the material, size, and the geometry of the product part also contribute to how the sound is formed. Consequential sounds are often informative about the product functioning cycle and listeners cannot intervene their occurrence. *Intentional* sounds are designed, implemented, and put by a sound engineer. Microwave oven finish bells, alarm clocks, oven setting feedback sounds are some of the examples. They are mostly digital and somewhat musical sounds often used in user interfaces. Such sounds are abstract by nature; however, listeners learn to attribute meaning to them as they are mostly designed to convey certain messages. Listeners also feel obligated to attend to intentional sounds due to their communicative nature.

Furthermore, product sounds can be discerned into six perceptually distinguishable sound categories (Özcan, van Egmond, & Jacobs, submitted). These categories are air, alarm, cyclic, impact, liquid, and mechanical sounds. Sounds in these categories vary in their spectral-temporal composition, material interactions that cause sound, and conceptual associations. In addition, the perceived character of a sound can be dependent both on perceptual and cognitive factors (Özcan & van Egmond, 2007; Özcan et al., submitted).

Defining the field of product sound design

Why design product sounds?

Design problems concerning product sounds are situation based. Although silence is preferred for some products (e.g., computer fans, dishwashers), the presence of a sound is almost compulsive when it comes to cars, espresso machines, or alarm clocks. For example, a computer is expected to be silent because it is a heavy-use domestic appliance which should function inconspicuously. However, the experience of a car ride may be complete with the proper auditory feedback that is responsive to certain user actions (e.g., acceleration or breaking) or that is suitable to the character of the car (e.g., sports car). Products such as alarm clocks exist merely because of their auditory function. Furthermore, because sound is a consequence of a functioning product, its presence can be complementary to user expectations regarding the product. For example, it may be the sound of an espresso machine that prepares a person to a tasteful Italian coffee. In summary, comfort, ergonomic use, functionality, or hedonic values may constitute the main reasons to design the sound of a product. Nevertheless, whatever the reason is, the main concern regarding product sound design is the suitability of the sound to the concept of the product (Blauert & Jekosch, 1997; Özcan & van Egmond, 2006).

Sound design within industry

Designed sound often indicates sophistication in the engineering of the product, thus increases the perceived value of the product. Especially automotive industry has dealt with the improvement of the sound of their products. To our knowledge, they have specifically designed the sound of the door-closing (Kuwano, Fastl, Namba, Nakamura, & Uchida, 2006), engine (Letens, 2002), gearbox (Bodden & Heinrichs, 1999) and tested the user responses to the changes in the sound quality (Blauert & Jekosch, 1993; Bodden, 1993; Bisping, 1997). Sound design can also be found in other product domains such as crunchiness of a crisp or the softness of the plastic bottle of a fabric softener are all designed to complement the product experience. Although there is an increasing interest in the sound design of domestic appliances, the sound design of the domestic appliances has been mostly restricted to noise closures and diminishing the loudness of domestic appliances (Lyon, 2000). In domestic appliances, added sounds are often used to communicate abstract meanings or provide feedbacks. The keystroke tones in mobile phones, the bell of the microwave oven, and the click of the mouse are some examples.

Available tools and methods

Both the industry and the academia are interested to develop tools and methods for the design of product sounds. Industry reveals only little information regarding the tools and methods used for the sound design practice. However, a well-known method to judge the suitability of the sound to the product is the sound quality assessment (Blauert & Jekosch, 1997). For that, a questionnaire is used that contains a list of adjectives that have potential to describe the sound in development. As a result, product developers are able to test upfront psychological effects of the designed sounds (see e.g., Kuwano et al. 2006, Letens, 2000).

Other methods have been developed to predict the perceptual space for the sound in development. For example, listeners' preference for noisy appliances could be predicted using psycho-acoustical data such as loudness, harmonicity, and noisiness (Susini et al, 2004). When diagnosing fault in product parts, acoustical measurements can be helpful (Benko et al.). Bodden (1997) suggests that such predictions and the auditory analysis of the product sound should be done considering the users and the context of use.

The application of product sound design

Sound is an integral property of the product. Any changes on sound require changes in the product. Thus, the application of product sound design is a part of the main product development process and should run in parallel to it. An iterative problem analysis and solution is conducted regarding the source of the sound (i.e., product and its parts). Özcan and van Egmond (2006) have suggested a prescriptive model for designing product sounds. The suggested product sound design process shares procedural similarities with those processes of product development proposed by Roozenburg and Eekels (1995)

Similarly, the process of product sound design consists of four main phases: problem analysis, conceptual design, embodiment design, and detailing (see Figure 1). In *problem analysis phase*, designers verbally discuss and auditorily exemplify the sound related problem. The examples can be created by recording the sound of the products or by demonstrating the problem with the presence of the working product in question. In *conceptual design phase*, designers auditorily sketch their conceptual ideas. Sounding sketches can be recordings of any object that has the potential to represent the sound desired. These sound examples may be ambiguous, and do not aim to represent the original sound. In *the embodiment design*, the ideas are materialized and parts-to-be-used are determined. Then, sounding models are produced that represent (and imitate) roughly how the product functions and will sound accordingly. As a communication tool, sounding model summarizes designers' ideas about the proposed sound and makes it easy to discuss the suitability and the feasibility of the proposed solution. In *detailing phase*, a prototype exits to test the functionality of the product. As the sound produced also represents the original sound of the product, sound quality assessments can be done using questionnaires. The results of which can be used to determine the final appropriateness of the sound to the product.

Bodden (1997) has suggested that for good auditory analysis, proper equipment is required. Signal acquisition should be done carefully by using multi-channel recording methods to capture more auditory information. Later, basic signal analysis methods (e.g., adopted from Zwicker & Fastl, 1993) are applied to understand the acoustic nature of the sound (i.e. spectral and temporal composition of the sound). Relevant modeling and editing techniques are used to simulate the desired sound. However, results work the best when sound and source are coupled for the sound quality evaluation.

Analyzing the acoustic property of the sound and determining the problem is the first step. Sound simulations already suggest the desired output of the design process. However, the next critical step is the materialization of the ideas. That is, the design team needs to formulate what product part needs to be changed or replaced, what product part actions need to be calibrated, and how the order of events should occur in order to offer the desired output. This may be an iterative process which requires high technical skills on components, structures, and assembly for the well-tuning of the sound (Lyon, 2000).

Major studies in the field of product sound design all agree on the psychological effect of sound on users (Blauert & Jekosch, 1997; Bodden, 1997; Lyon, 2000; Lyon 2003; Özcan & van Egmond, 2006; van Egmond, 2008). It is the user that determines the adequacy of the sound to the product. Therefore, especially in the last phase, but preferable throughout the whole design process, user input need to be considered. The use of questionnaires is one way of verifying the semantic and conceptual relation between the sound and the product. However, theoretical studies provide insight into conceptual network regarding product sounds and cognitive processes that underlie such network (Özcan & van Egmond, 2007; Özcan et al., submitted). This means that design team could incorporate such knowledge into auditory sketching and conceptual design of the sound.

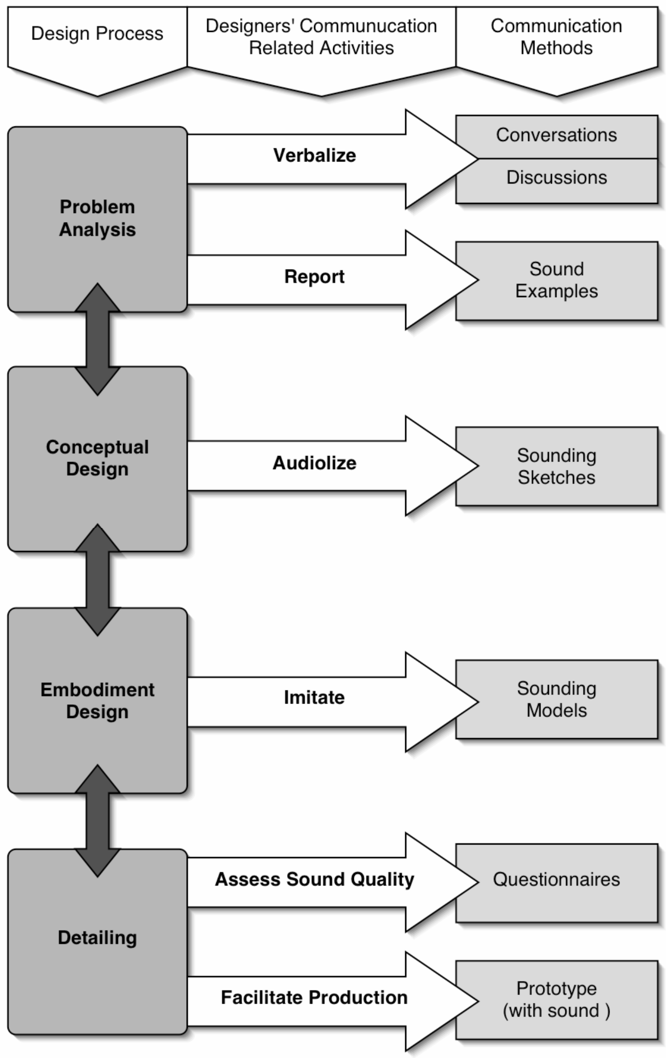

Figure 1. Proposed methods for product sound design related communication.

Disciplines contributing to product sound design

Any design process has the potential be multi-disciplinary. Experts from different fields may contribute to a design activity depending on the task and requirements. For sound design, three indispensable disciples provide knowledge: *acoustics*, *engineering*, and *psychology*. A sound design task cannot be completed in the absence of one of these disciplines. Figure 2 demonstrates how knowledge from these disciplines feed the sound design process and results in the main solution provided for the sound problem of the product. In the following paragraphs we will explain the individual contribution of these different fields of expertise.

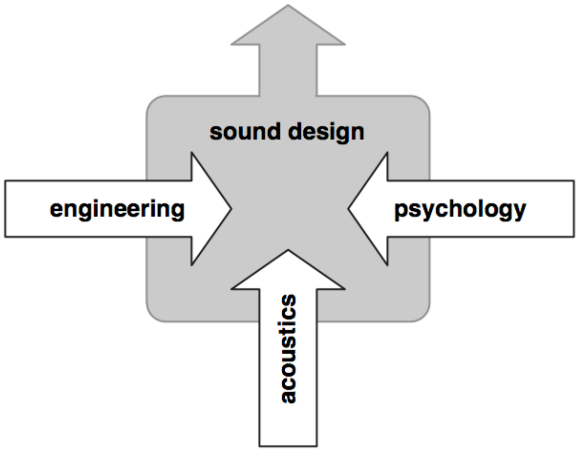

Figure 2. Main disciplines contributing to product sound design activity

Acoustics

Acoustics is the science that focuses on the sound phenomenon. It covers basic physical principles related to sound propagation and mathematical and physical models of sound measurement. Therefore, the medium in and through which sound travels, reflecting and vibrating surfaces, speed of sound, and other physical characteristics of sound such as sound pressure, wavelength and frequency are the topics of interest for the field of acoustics.

Sound occurs as a consequence of the energy release caused by objects in action. Although, the sound source and action determine the physical quality of the sound, *acoustics* does not investigate the source as a whole but the physical properties of the source such as the interacting materials, weight, size, geometry of the objects Furthermore, sound propagates over time because it is the result of time-dependent dynamic events. That is, the physical character (i.e., spectral-temporal composition) of a sound changes over time depending on the type of actions and sound sources. For example, a musical instrument produces a structured sound (due to the harmonic partials and temporal pattern). A shaver produces a noisy sound because it contains multiple sound producing events each creating different harmonic partials and occurring at different time frames causing temporal irregularity.

The field of acoustics provides techniques to analyze and simulate sound. First, basic acoustic terminology consists of frequency (variation rate in the air pressure), decibels (sound intensity), and amplitude (sound pressure). Frequency content of a sound and the intensity variations in time are visualized by a spectrogram. Furthermore, a sound wave represents the temporal tendency of sound propagation and the sound pressure over time. Thus, the spectral-temporal composition of a sound event can be visually analyzed and consequences of certain events can be precisely detected. Moreover, various sound modeling techniques have been developed in the field of acoustics. With the available computer technology, it has been possible to simulate sounding objects that are perceptually convincing (Cook, 2002; Pedersini, Sarti, & Tubara, 2000; Petrausch, Escolano, & Rabenstein, 2005; Rocchesso, Bresin, & Fernstrom, 2003).

When designing product sounds, understanding the acoustic nature of the sound event is compulsory. Acoustic analysis of the sound can be first done during problem analysis phase and can recursively occur until the problem has been defined. Furthermore, sound simulation can also be necessary to test upfront the perceptual effects of the desired sound.

Engineering

Engineering is the discipline through which abstract scientific knowledge takes on an applied nature. Regarding product sound design, especially mechanical engineering, electric-electronics engineering, and material sciences provide knowledge. Because sound is a consequence of interacting materials, relevant engineering disciplines deal with sound indirectly and rather focus on manipulative aspects of products. Therefore, various product parts, mechanisms, assembly structure, material interactions, the order of events occurring can all be engineered depending on the design requirements of the product and its sound.

Main focus in product engineering is on the functionality of the product. Thus, suggested alterations that are necessary to improve the product sound can only be done if it does not compromise the main functionality of the product or product parts. Engineers should have satisfactory knowledge on physics and mathematics, therefore are able to calculate the energy release as sound or as vibration. As a result, they can provide solutions in the form of noise closures or sound dampening techniques.

Furthermore, discipline of engineering provides various tools and methods to embody conceptual ideas and solutions to problems. Engineers and designers are well-supported on modeling, testing, and prototyping (Cross, 2000; Hubka & Eder, 1988; Roozenburg & Eekels, 1995).

Psychology

So far, the contributing disciplines have dealt with the physical aspect of sound and the object causing the sound (i.e., product). However, any sound has psychological correlates which may be on a semantic level or an emotional level (von Bismarck, 1974; Kendall & Carterette, 1995; van Egmond, 2004). Upon hearing listeners' main reaction to a sound is to interpret it. Such interpretations may sometimes be abstract, but they often refer to the source of the sound and the action, such as, crashing car or car passing by (Fabiani, Kazmerski, Cycowicz, & Friedman, 1996; Marcell, Borella, Greene, Kerr, & Rogers, 2000). Many experimental studies have also indicated that just by hearing listeners can describe the material, size, and shape of the sound (Hermes, 1998; Lakatos, McAdams, & Causse, 1997) Listeners are able to follow the changes in the spectral-temporal structure of the sound and perceive it as auditory events or sometimes as auditory objects (Kubovy & van Valkenburg, 2004; Yost, 1990).

The conceptual network for product sounds consist of associations on different levels (Özcan et al., submitted). Source and action descriptions occur the most and followed by locations in which products are used the most (e.g., bathroom, kitchen), basic emotions (e.g., pleasant-unpleasant), psychoacoustical judgments (e.g., sharp, loud, rough). In addition, source properties can also be identified (e.g., interacting materials or sizes of the products). Furthermore, listeners can associate the product sounds to more abstract concepts such as danger. Özcan and van Egmond (2005) have also shown that semantic or emotional judgments are sound type dependent. For example, alarm sounds are described mostly by abstract meanings such as 'wake up call'; however, impact sounds are described mostly by action and interacting materials.

These conceptual associations of sound indicate that a fittingness of the sound to the product or to the environment in which the sound occurs is judged. Therefore, a design team cannot overlook the cognitive and emotional consequences of the sound. In various stages of design, user input needs to be considered.

Hybrid disciplines: psycho-acoustics and musicology

Above we discussed the major disciplines contributing to sound design. However, some hybrid disciplines also contribute such as psycho-acoustics and musicology.

Psychoaoustics deals with the basic psychological reactions to the acoustic event. Often the following parameters are used to observe listeners: sharpness (high frequency content), roughness (fluctuation speed of the frequency and amplitude modulation), loudness (sound intensity), and tonalness (amount of noise in a sound). Although these parameters are supposed to be subjective, still a general conclusion has been made in the past regarding the threshold and limits of human sensation to sounds. Therefore, psychoacoustical algorithms have been presented to measure the above-mentioned perceived characters of sound (Zwicker & Fastl, 1990). These algorithms are used to measure the sound's perceptual quality and predict listeners' tolerance to sounds. Thus, they are predictive of sensory (un)pleasantness.

The contribution of musicology to product sound design comes when alarm-like synthesized sounds need to be designed. Composing music requires knowledge on theories about musical structures and compositions, tools to create harmonic and rhythmic sounds.

Responsibilities of a sound designer

To sum up, a sound designer needs to have knowledge and skills on three major disciplines (engineering, acoustics, and psychoacoustics) and also on hybrid disciplines such as musicology and psychoacoustics (see Figure 3). A sound designer is primarily an engineer who is able to manipulate the construction of a product and is skillful in applying physical and mathematical knowledge in order to analyze and model product structure while considering the consequences in terms of sound.

However, such an engineer should be able to interpret the physics of sound per se. Skills on acoustic analyses and ability to simulate sound are necessary. Furthermore, a sound designer should be able to link the structural properties of a sound to its acoustical composition. In addition, musical knowledge on how to compose synthesized sounds may be required.

Furthermore, an engineer solving sound problem of a product not only considers the physical aspects of sound and the sound source but also its psychological correlates. It is ultimately the user's vote that counts when judging whether the sound fits the product, its functionality and the context of use. Knowledge on psycho-acoustical analyses is required to predict the first user reactions only to sound. Later, semantic analyses need to be conducted with potential users to make sure the sound design is complete and appropriate to the product.

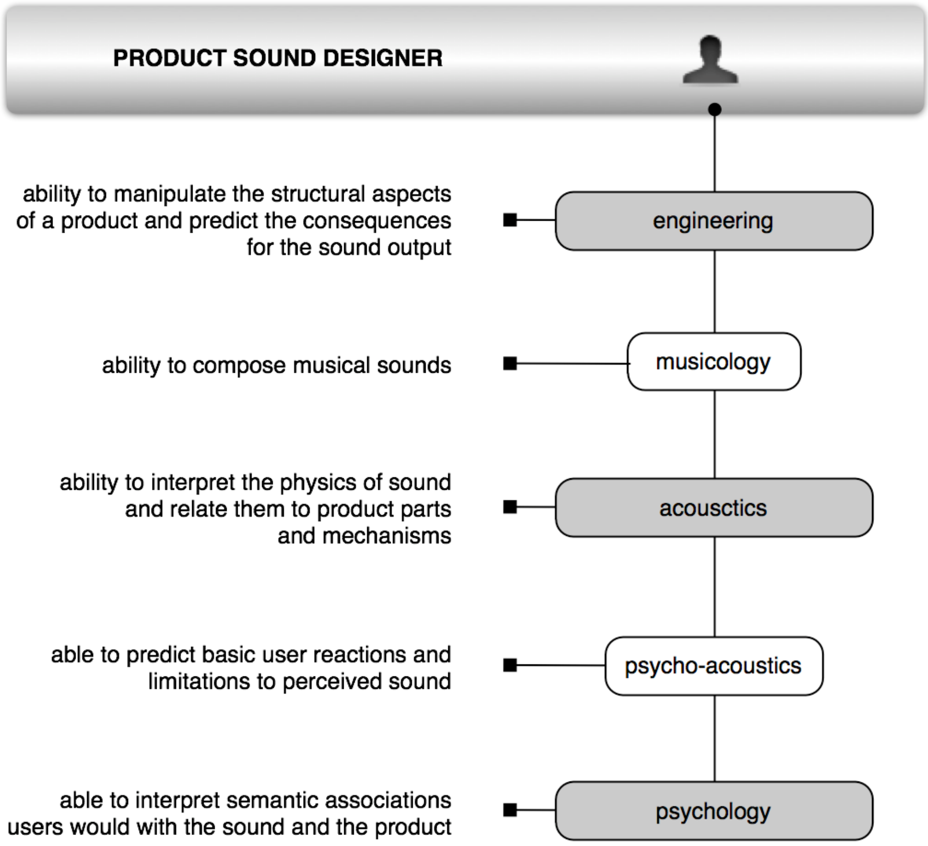

Figure 3. Professional domain of a sound designer

Conclusion: Is product sound design an emerging discipline?

Sound design practice has long been conducted by a team of designers and engineers who are individually experts in acoustics, engineering, and psychology. If at all a sound designer existed in a design team, this person was more a mediator who made sure that the team members communicated well with regard to the product and its sound and the project was well completed with the contribution from the above-mentioned disciplines. The contributions of the experts from different disciplines made the sound design task a multi-disciplinary task. However, product sound design consists of various recursive tasks. Thus, the sound design process often suffers from communication related problems and recursiveness of such a multi-disciplinary task may hinder the speed and proper application of the solutions. Therefore, instead of having experts from different fields designing the sound of a product, we suggest that a sound designer who has knowledge mainly in engineering and other supporting fields (acoustics and psychology) should take over the sound design task. Embedding the knowledge from different disciplines in one would make the sound design process an inter-disciplinary process rather than multi-disciplinary.

Considering the interest from both the industry and the academia, the tools and methods design specially for sound analysis and design, the body of knowledge that is required to conduct a simple sound design task, we can conclude that product sound design is definitely an emerging discipline. However, yet much needs to be done in order to for this newborn discipline to settle. One main suggestion would be to educate design students on this topic. Schools of industrial design and design engineering should start to include sound design in their curriculum. Furthermore, companies that manufacture products and product ideas could pay more attention the sound design task, consider it as part of the main design problem, and recruit experts—that is sound designers—who are knowledgeable in this field.

This paper has focused on the fundamental knowledge a sound designer needs to have in order to conduct a sound design task. We have segmented this knowledge in terms of (a) the physical aspects of the sound, (b) the psychological correlates of the sound, and (c) the engineering potential of the sound source. The available knowledge on product sound design is limited and the practice of sound design is often based on ad hoc solutions—not on established methods or theories. Consequently, we have constituted the domain of product sound design by reviewing literature on the related topics. Future studies could systematically investigate the process of sound design by observing designers' sound related activities on a purposely-chosen sound design task. Subsequently, after a sound design task has been completed, debriefing designers via interviews could provide further insight into the needs of sound designers.

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He has a background in acoustics, psycho-acoustics, experimental psychology, music theory, and music psychology. He obtained his PhD at the Nijmegen Institute for Cognition and Information (NICI, University of Nijmegen). At TU Delft, he leads a group on the perception and design of product sounds. The special interest of the group is in the sounds of domestic appliances and the use of sounds in user interfaces. The group investigates the perceptual, experiential, and functional properties of product sounds.