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How do industries turn design-intensive? Technological constraints and design conventions in the manipulation of product form

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Abstract

Historically, several industries have changed from solely being oriented towards technological innovation and industrial efficiency to suddenly having aesthetic product designs as a central competitive parameter. Previous research has looked into what characterizes innovation and competitive dynamics in design-intensive industries, but the question of how industries turn design-intensive have previously been overlooked, in spite of evidence indicating the strategic and economic importance of such changes. Through a longitudinal case study of the hearing aid industry in the years 1992-2013, it was found how industries turn design-intensive through a combination of visions for changing the socio-cultural associations of their products and technological affordances from the availability of new technological designs.

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Introduction

Companies such as Alessi, Bang & Olufsen, Artemide and Apple are well known examples of companies that have secured a strong competitive position through the use of innovative product form design. Design award agencies such as Red Dot Award, IF Design Prize, Good Design Award and the Janus Price today include award categories spanning industries not commonly associated with product form design and aesthetics, such as medical products and industrial appliances. Competition and innovation dynamics in design-intense industries follow different logics than technological industries (Cappetta, Cillo and Ponti, 2006; Delléra and Verganti, 2011) and the introduction of product form design as a focus within firms bears a significant impact on the strategic orientation of firms (Ravasi and Lojacono, 2005). Italian household good manufacturer Alessi transitioned from being an industrially driven company until a series of successful innovations in product form design changed the company and the role of product form design in its strategic

orientation (Rindova, Dalpiaz and Ravasi, 2011; Dalpiaz, Rindova and Ravasi, 2016).The work of Verganti (2003, 2008, 2009), have found how firms can reach the status of design-leadership in their industries through formulating broad visions of changing the socio-cultural meanings of their products. These firm-level observations beg the question of how and why such processes occur on an industry level.). Since the emergence of powerful design exemplars leading to design-intensity, historically have reflected remarkable shift in industries, theory on innovation and technological change should be able to account for such changes. In spite of the literature having identified several points of difference between technological and design-intensive industries, little has been done to understand how design-intensity is introduced within industries. Such processes will be denoted 'design-intensification' in this study. This study sought to shed light on this issue by exploring how design-intensification occurs on an industry level. Through analyzing design-intensification on an industry level, it was found how design-intensification can emerge from an industry wide vision of changing the socio-cultural associations of its products, triggered by technological shifts creating affordances for manipulating the designs expressions of products.

Review

The concept of 'design' has for long played an important role in theorization of technological change (Clark, 1985; Henderson and Clark, 1990; Tripsas, 1997; Baldwin and Clark, 2000; Frenken and Nuvolari, 2004; Windrum, 2005; Dibiaggio, 2007). The importance of product design have been found to move beyond a product level, as it holds implications for how firms, industries and markets are organized (Brusoni and Prencipe, 2001; Colfer and Baldwin, 2016). The type of design that has taken the spotlight of innovation research has been technological designs, understood as the way the components of a product are assembled (Clark, 1985; Henderson and Clark, 1990). In contrast to technological designs, researchers has recently started to theorize the role of product form design in processes of technological change (Rindova and Petkova, 2007; Verganti, 2008; Eisenman, 2013). 'Product form design' is defined as the overall shape, material, texture and color of a product (Krippendorff, 1989; Norman, 2013; Rindova and Petkova, 2007).

Product form designs influences how users understand and valorize the products they encounter (Verganti, 2008; Ravasi and Stigliani, 2012). Unlike technological designs that will tend to be selected by organizations in search for functional value (Baldwin and Clark, 2000), product form designs tend to be selected due to the socio-cultural, emotional and cognitive responses they provoke (Verganti, 2003; Verganti, 2008). Some industries are characterized by innovation being aimed at functional value through technology (Baldwin and Clark, 2000) or socio-cultural value through stylistic innovations (Cappetta, Cillo and Ponti, 2006). Even in industries dominantly oriented towards functional value, search for innovations in socio-cultural value can occur interdependent with a technological focus (Eisenman, 2013). In light of this, the process of design-intensification should be seen as a shift from product development to being a merely technical concern, to also being an aesthetic and socio-cultural concern.

While design-intensification on an industry-level is currently un-theorized, studies on firm level design-intensification could meaningfully provide guidance for the study. Researchers have suggested that radical innovation in product form design is driven by firms formulating cultural visions for the socio cultural meaning of their products (Verganti, 2008) or the forming of 'cultural intents' for the mobilization of cultural ressources (Ravasi, Rindova and Dalpiaz, 2012). The work of Verganti has found how radical innovation in product form design typically will have its antecedents in broad explorations of socio-cultural changes in society, leading to experimentations with new 'design languages' (2008). Dalpiaz, Rindova and Ravasi (2011) found that the mobilization of new cultural resources in strategy formation led to aesthetics and the socio-cultural meaning of products being a central part of strategy formation within the firm. While these studies each identify drivers that enhances our insights on the processes leading to such changes, one aspect remain overlooked: the material condition of possibility for manipulating the form of products.

The work of Eisenman (2013) calls for exploration of the role of 'endogenous factors' in constraining innovation in product form design by limiting certain manipulations of product form. 'Endogenous factors' are to be understood as limiting factors to product form design caused by the basic market expectations that audiences have to a given category as well as technological requirements for it to function. Understanding the nature and role of endogenous factors, will imply a focus on how such factors impact the search of firms

for technological innovation to overcome such limitations to innovation in product form design (Eisenman, 2013).In light of this, this study will explore the interaction between the cultural side of the phenomenon, envisioned product meanings and cultural intent, and the technological side of endogenous factors. The following question guided the study:

How does design-intensification occur in technological oriented industries?

And

Which role does technological innovation play in mitigating the constraining effect of endogenous factors in design-intensification processes?

Theory: Indicators tracing design-intensity

In the following section, the concept of design-intensity as an industry-attribute developed and empirically grounded through a previous theorization. Based on this conceptualization, it was possible to trace the process of design-intensification of the hearing aid industry to explore the role of limiting endogenous factors to product form design and technological innovation had impacted this process. Through a review of work related to the role of product form design in strategy, innovation and industry dynamics, three overall design-intensity indicators were derived. While other potential characteristics of design-intensive industries were observed, only factors also suggested to be present in technology-intensive industries were included.

A central observation in the literature is that product form design serves communicative purposes, due to carrying design expressions (Krippendorff, 1989; Verganti, 2008; Eisenman, 2013). In contrast to technological designs that seeks towards enhancing functional value, it is socio-cultural, emotional and cognitive responses that is sought for in the case of product form design, rather than functional value (Rindova and Petkova, 2007; Verganti, 2008; Talke et al, 2009; Eisenman, 2013).Innovating the design expression of product can serve the following strategic ends in innovation processes: 1) explaining the functionality of products (Hargadon and Douglas, 2001; Rindova and Petkova, 2007) 2) Creating excitement

around products, for example through designs emphasizing the novelty of products (Talke et al, 2013; Eisenman, 2013) and 3) Extending the functionality of products to not solely utilitarian aims, but also cultural and symbolic aims such as signaling personal identity, group belonging or social status (Ravasi, Rindova and Dalpiaz, 2012; Eisenman, 2013). In light of this, the level to which product form designs are introduced that aims at carrying out communicative functions can be taken as an indicator of design-intensity.

Converging designs. While the evolution of technological designs within industries tend to show the establishment of dominant designs (Anderson and Tushman, 1990), design-intensive industries have been found to instead to show the rise of 'converging designs' in design expressions (Cappetta, Cillo and Ponti, 2006; Delléra and Vergani, 2011). With innovations in terms of style and aesthetics, compatibility does not force industries into selecting a few dominant styles, but rather allows for the co-existince of several styles dominant market niches, in order to later spill over and blend together in the mass market (Cappetta, Cillo and Ponti, 2006; Delléra and Vergani, 2011). In technological industries, the work of Eisenman (2013) suggests that increases in design-intensity during periods of technological maturation, will lead firms seek towards differentiation, following 'logics of fashion', rather than compatibility. In light of these findings, an indicator of design-intensity is the degree to which product designs varies in terms of design expressions across competitors.

Data and Methods

The concept of the design-intensity and the question of how industries turn design-intensive have only been scarcely examined in spite of its considerable impact on firms and industries (Verganti, 2008; Talke et al, 2009; Rindova, Dalpiaz and Ravasi, 2011). Due the fact that these themes have not currently been explored, an identification of the relevant dynamics is required, why a qualitative research design was chosen (Eisenhardt 1989; Yin, 1998).

This paper is based on a broader research project on the evolution of the hearing aid industry. The hearing aid industry was found to be an ideal industry for the studying processes of design-intensification as it contains 1) a significant increase in design-intensity can be observed and studied in a distinct interval. 2) Endogenous factors of a product category provide a constraining factor for industry actors to innovative manipulate product form and 3) where technological innovation has been and/or still is a significant or dominant factor in competition between firms. The hearing aid industry is a high technological industry, with an FDA categorization as a medical product. Historically, the hearing aid industry has been characterized by a high level of end-user resistance, where stigma related to hearing aid use has been a considerable source of non-adoption amongst potential users (Kochkin, 1993, 2007). Throughout the history of the industry, this stigma has been addressed by the industry through innovations in product form design. Previous research have suggested that the strategic importance of innovation in product form design increases in contexts of consumption where the aesthetic and symbolic aspects of product value is of high importance to users (Eisenman, 2013). Due to the challenge regarding the stigma of hearing aid use, innovation in product form design can be expected to be a meaningful part of the strategic and commercial drivers of innovation in the industry, and therefore ideal for the study.

The interval chosen for the study was the years 1992-2013. The year 1992 was the year of the introduction of the *"completely-in-the-canal"* device, a device barely visible to the surroundings of the user. This innovation in hearing aid design reflected a contrasting approach to designing hearing aids than the one observed in the years 2003-2013 where devices again would be designed to reside behind the ear as well as employing different aesthetic means to avoid design expressions seeking to mimic human skin. The interval stopped in 2013 due to the introduction of wireless streaming between a hearing aid and a smartphone device. This point of termination is meaningful as this new technology reflected a discontinuity in terms of how industry professionals reported that the stigma of hearing aid use should be mitigated, with a focus on "consumer product functionality", rather than merely consumer product aesthetics.

The data set for the study consisted of a combination of archival data combined with interviews with informants having witnessed, or taking part in, the studied process (See below for data overview). Archival material for the study consisted of hearing aid trade journal publications. These magazines provided the researcher rich and real time insight into the product evolution in the industry in terms of technological change and product form design. Especially, the magazines provided a rich source of advertisements and product descriptions, given the researcher an idea about which product has been introduced, when they had been launched, their technological content as well as visual representations of their product form design. Finally, annual reports from the involved hearing aid manufacturers where collected to verify informant claims about the commercial success of the central product innovations in the interval, Oticon Delta and GN's ResoundAIR.

The combination of archival data and interview data enabled the researcher both to get a rich, in-depth perspective on the studied events as well as heightening the validity of the findings through triangulation. Archival data allowed for a detailed mapping of the studied process without the retrospective bias that retrospective interview accounts hold. Interviews were able to validate the archival findings of the researcher as well as provide background information on the archival observations. For example while trade journal publications provided detailed information about product innovations in the industry, interviews provided background information about how the development process occurred.

Interviews were semi-structured, following pre-defined questions. The semi-structured format was selected, due to it both fixing the interviews to the focal variables of the study while simultaneously remaining open to new possible sub-themes related to the pre-defined areas. Throughout the data collection process, interviews where continually refined towards gradually more specific questions, with some of the final interviews questions aiming at directly verify the empirical observations of the author. The interviews with representatives from non-Danish manufacturers were conducted through SKYPE.

While most interviews where retrospective in nature, retrospective bias was mitigated through several means. While interviews where retrospective in nature, this did not pose a considerable challenge, as the questions

had a very high level of materiality in terms of how a new technology enabled a given design, for example due to mitigating previous technological barriers. Such relationships are unlikely to change over time meaning that changes in the informants retrospective sense-making of the events bear less effect on their accounts. In addition, the findings where triangulated through several means. Source triangulation across informants within firms and across different firms where used. Methodological triangulation of interview data with archival sources to the highest degree possible, to the degree that trade journal publications and annual reports could support the information arrived at from interviews.

Finally interviews published on the online journal for hearing care professionals audiologyonline.com was used to give real time triangulation to the interviews conducted by the researcher in the years 2015-2016 during which the research process lasted. Finally, a historical narrative of the period was sent to the hearing aid historian and curator of the Eriksholm collection for validating the observations of the study.

The empirical analysis occurred in three rounds.

In the initial part of the analysis, I traced the three indicators of design-intensity throughout the interval to find out how and when the design-intensification of the industry had occurred. Communicative use of product form (Rindova and Petkova (2007); Eisenman, 2013) was traced by analyzing how promotion material and/or accounts from interview informants claimed that design expressions was created in the product attempting to mitigate the negative associations of hearing aid use. Converging design **(**Cappetta, Cillo and Ponti, 2006; Delléra and Vergani, 2011**)** was analyzed through comparing images of designs in advertisements and product launch announcements. Design-discourse **(**Cappetta, Cillo and Ponti, 2006; Khaire and Wadhwani, 2010; Eisenman, 2013) was traced empirically in terms of how the “Product News” section in industry trade press mentioned and emphasized the visual dimensions of product design.

Secondly, I analyzed was how central innovations in technological innovations and product form design in the studied period. By structuring advertisements, product descriptions and articles written about new products in a timeline, I mapped the product evolution within the studied interval allowing for systematic identification of central discontinuities in technology and product form design. In this phase of the analysis I

found how technological advancements had enabled radical design innovations in the interval. Of the various technological advancements that had played a part in the new designs, only some were taken into account, if they provided a reflected a discontinuity to previous advances.

In the third and final phase, I sought to identify the enabling mechanisms between technological innovation and innovations in product form design. For this purpose, interviews with informants were utilized to understand how the cultural intent of mitigating the stigma of hearing aid use had been catalyzed by new technological opportunities. This was found in relation to two overall forms of endogenous factors: 'Technological constraints' from functionality requirements and 'design conventions'.

Data overview			
Overview of interview informants			
Company	Informant	Number of interviews	Use in analysis
Oticon, Delta Oticon,	Industrial designer, external	2	Insight into the development and commercialization process of Oticon Delta
	Engineer	1	
	Technical manager	1	
	Product manager	1	
	Project manager	1	
	Engineer	1	
	Product manager	1	
	Product manager	1	
	Former product manager	1	
	Marketing	1	
	Marketing/audiology	1	
	Audiology/development	2	
GN Resound (former Danavox),	Industrial designer, internal	2	Insight into the development of ResoundAIR and the technological
	R&D director	1	

			requirements the design had posed.
SeboTek	The two directors of the company and developers of the PAC device	1 conducted with both, 2 published with both	Insight into the development and reception of the technological architecture: The receiver-in-the-ear
	2 Audiologists and 1 technical employee	3 published interviews	Triangulation of observations from interviews conducted by the researcher
Bernafon	Project manager	1 with both informants	Insight into the development of the device Brite
	Product manager		
	Industrial designer, external.	1	
Starkey	Sr. research manager	1	Insight into the development of the device Zon
	Audiologist	1	
	External industrial designer	1	
Phonak	Designer, internal	1 with both informants	Insight into the development of the Audeo product family
	Product manager		
The European Hearing Instruments Manufacturer Association	President	1	Aggregated perspective on the evolution of the hearing aid and the technological requirements for a hearing aid designs introduced in the interval.
Independent public speaker and author with some affiliation to Widex	Long time hearing aid user and public speaker on hearing impairment	1	
University of Southern Denmark	Medical audiologist, clinical hearing aid	1	

	dispenser and former product developer in GN Danavox		
Total:	28 conducted 5 published 33 in total		
Overview over Archival Sources			
Trade journals	The Hearing Journal, 1992-2013 (HJ), Hearing review 1995-2013 (HR): 429 magazines covering 273 product launches.		Advertisements, product launch announcements and articles on new products was used to gain insights on the product evolution of the industry in terms of product form design and technological content of products Finally claims and statements about product designs was used as an indicator of 'design discurse'.
Annual reports	Annual reports from GN Resound and Oticon in the interval 2002-2008		Information about the commercial success of the devices ResoundAIR and Delta.

Design-intensity in the hearing aid industry

In the years 2003-2008, the hearing aid industry witnessed a considerable increase in its level of design-intensity. Previous to the interval, the style of device typically seen as the most aesthetic or cosmetic was a style of device hidden within the ear canal. While hearing aids occasionally won design awards, typically in the case of breakthrough technology, it was something that was observed to occur very seldom. When manufacturers in advertisements where to describe the aesthetic qualities of a product, this was typically

done with terms such as "*miniature*", "*inconspiciuous*", "*invisible*" or "*discreet*". Within product segments, differences between products were difficult to observe, due to designs tending to show minimal variation. In the years 2003 and 2006, two products were launched that apart from being exceptionally successful commercially, provided powerful exemplars that drove design-intensity within the industry. These products were rapidly imitated by competitors' leading to the industry forming converging designs (Cappetta, Cillo and Ponti, 2006). Unlike previously, especially the periods 2006-2008 showed a considerable variety of product form designs, in terms of different shapes, colors and design expressions. This shift was not however only a shift in product form design. The shift included several technological innovations that rapidly gained industry wide diffusion, and most importantly for this study, typically was utilized in the same product launches that reflect novel design expressions.

Tracing of design-intensity indicators in the hearing aid industry 1992-2013		
Design-intensity indicator	**1992-2002:**	**2003-2013**
Communicative use of product form	Designs mainly taking skin or hair colors for camouflage or being designed so as to reside within the ear canal of the user The design of devices claimed by producers to (apart from surfaces hidden within the ear canal) to seeking to imitate the contours of human skin. Aesthetics only.	Designs often taking metallic colors resembling electronics, the paint of automotives or jewelry rather than parts of the human body. The design of devices claimed by producers to create stylistic and aesthetic expressions besides "*discreetness*" and "*comfort.* ", such as "*sleek"* or "*stylish*".

	News sections in trade press seldomly report hearing aids winning design awards	News sections in trade press report hearing aids winning design awards several times each year
Converging designs	Images of devices showing minimal variety in shape and color across competitors	Images of devices showing significant variety in shape and color across competitors
Level of design-intensity	**Minimal**	**High (relative to previous periodization)**

The transition to digital signal processing and design-intensification of the hearing aid industry (1996-2008)

In the previous section, findings were reported on the analysis of how the hearing aid industry changed from a minimal level of design-intensity to product form design and aesthetics being a significant industry concern. This leads to the question, how did this transition occur and which role did technological change and cultural intent play in the process? In the following, findings will be reported on the analysis tracing the variables of 'technological innovation' and 'product form design' throughout the interval. In addition to finding how design-intensification occur on an industry level, this part of the analysis enabled the researcher to identify the specific interplay between cultural intent and endogenous factors in design-intensification processes.

In early 1996, the world witnessed the introduction of the first two devices utilizing digital signal processing, the device DigiFocus from manufacturer Oticon and Senso from manufacturer Widex. With these events, a new technological regime had been opened up for the hearing aid industry. One of the several technological promises of this shift was an improved flexibility in terms of how the devices could be fitted to the specific hearing loss of the user as well as new opportunities for suppressing feedback. In 1998 the manufacturer GN

Danavox, now GN Resound, launched the device Danalogic. The device was the first fully digital product from the manufacturer, but came as a part of the second generation of products in the industry utilizing the new technology. The device was one of the first to harness the benefits of digital signal processing in terms of feedback cancellation.

The incremental technological innovations in the wake of the shift to digital signal processing had brought about significant improvements in the ability of devices to manage feedback. Advances in feedback suppression enabled devices to either increase the volume of amplification while keeping the ear of the user open, rather than closed with the ear mold as in the case of a traditional hearing aid. As we shall see in the following, this technological advancement offered distinct advantages in manipulating the form features of the device in order to create novel design expressions.

Timeline of the findings from tracing the central variables through the interval (1996-2008)				
Year	Firm	Technological innovation	Product form design/cultural intent	Enabling/constraining technological driver of product form design
1996	Oticon, Widex	Radical innovation: Digital signal processing is introduced.		
1998	GN Danavox, Danalogic	Incremental innovation: Digital feedback suppression systems		
1999	Resound, Avance	Failed modular innovation: Open-fitting thin tube.		Lacking capabilities in feedback suppression allowed only a minimal level

				of amplification
2003	GN Resound, ResoundAIR	Modular Innovation: Open fitting thin tube.	New design expression, mainly in terms of the tube and ear mold/Cultural intent: Avoiding prosthesis associations of traditional designs	Control of feedback and whistling enabled open-fitting
2003	SeboTek	Architectural innovation: Receiver-in-the-ear, closed-fitting. PAC		
2004	Vivatone	Receiver-in-the-ear, open-fitting. Vivatone: Combination	Industry wide imitation of the design expression of ResoundAIR	
2006	Oticon	Delta, Receiver-in-the-ear (RITE), Open-canal-fitting.	New design expression, mainly in terms of the body of the device / Cultural intent: Creating a	Same as ResoundAIR and removal of receiver from the body of the device led to a smaller instrument

			design that would "*Shed stigma*".	
2007	Oticon	Epoq, Radical innovation introducing wireless streaming between hearing aids and external devices	Initially intended as a traditional BTE, but eventually changed to RITE prior to launch in light of success of Delta	
2007-2008		Industry wide launches of receiver-in-the-ear devices with open-canal-fittings.	Industry wide attempts at radically changing the design expression of the hearing aid leading to a high variety in product form designs	

In **2003**, the industry however witnessed the introduction of two devices that introduced technology and design changes that later would leave a considerable mark on the industry. One was the BTE device

ReSoundAIR by hearing aid manufacturer GN ReSound. Another was a particular device launched by newcomer SeboTek, titled PAC.

In terms of technology, ReSoundAIR was a modular innovation. The thin tube, a nearly invisible tube transporting sound from the device to the ear, as well as the open fitting ear plug, each represented the first successful attempts at commercializing these adjustments to the traditional BTE architecture. Before the open canal ear mold/thin tube solution was commercialized by GN Resound, it was attempted by the US manufacturer Resound (that later was bought by Danish GN Danavox, changing its name to GN Resound). The attempt at an open-canal thin tube solution by Resound is reflected in the following ad from 1999:

<table>
<tr><td colspan="2">Comparison of avance and Resound AIR</td></tr>
<tr><td> 
</td><td>  </td></tr>
<tr><td>Resound avance, excerpt from advertisement,
Hearing Journal, 1999, 8</td><td>GN Resound, ResoundAIR, 2003</td></tr>
</table>

As implied in the title “hearing enhancer”, the device only allowed for a limited amount of amplification. The capabilities in digital signal processing did not allow for the required feedback suppression that the design required for it to provide any sufficient level of amplification (interview with former R&D director of GN Danavox). The US manufacturer Resound was later acquired by GN Danavox, now forming GN Resound. With the exploitations of digital signal processing, and the experience of newly acquired manufacturer in the open-fitting, thin-tube solution, GN Resound could in 2003 present a synthesis between the two in the form of ResoundAIR. The ability to utilize an open-fit, thin-tube solution enabled the industrial designer of the device to engage in manipulating the “*icon design*” of hearing aid, something that

previously was unexplored territory in the industry. When asked how the new design expression of ResoundAIR had emerged in the development process, the designer of ResoundAIR noted that the experimenting with novel components triggered the ideation of the new style of device.

"Interviewer: *What do you mean when saying that you "discovered the design device", was it an opportunity you sighted?*

Designer of ResoundAIR: *It is something that happens when you sit as a designer and work with some concepts then sometimes some things occur that totally make objects change in their expression. You suddenly get some opportunities with a smaller battery, new technology, fewer microphones, then you can "screw" the concept together in a new way. And then always something completely new happens. … we started playing with the elements and could see that we sat with something entirely different.*"

The ambition of ResoundAIR to create a light, comfortable and discreet behind-the-ear device for mildly hearing impaired users that otherwise would have resisted the use of amplification. This ambition as well as the identification of the means to realize it, emerged from micro-level experimentation in utilizing novel components in product design.

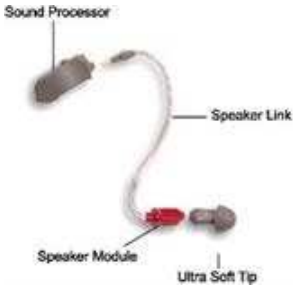
The device reported by informants, in business media and in annual reports that the device was exceptionally successful in terms of sales and profit margins. ResoundAIR was reported the bestselling product launched in the history of the company (interview with director, 2015). When informants from manufacturers were being asked about the antecedents of the design devices they launched in 2006-2008, ResoundAIR was nearly univocally emphasized as the frontrunner to this type of product.

Mere technological opportunity is however not a sufficient condition for firms to innovate in product form design. While ResoundAIR was enabled by advances in feedback management at the time, it was also driven by the intent of the designer to create a device departing from the prosthesis associations of traditional designs. Same year as the launch of ResoundAIR, the newly established US firm SeboTek had presented a novel device at the major audiological trade fairs (HJ, 2003, 5). The device, which the inventors and

directors of the company, had labelled the PAC, standing for “Post Auricular Canal”, later to be termed receiver-in-the-ear (RITE) or receiver-in-the-canal (RIC).


Sebotek, PAC, 2003

The device represented an architectural innovation on a technological level, where the receiver or speaker previously had resided within the body of the device, this component had now been moved into the ear canal, connected with a thin wire, leading from the body behind the ear to the speaker in the canal. The idea of a receiver-in-the-ear technology was not new, but had previously been tried by Philips already in the 90’es, but never became a commercial success due to the company not being “*able to provide reliable quality for this system*” (interview data with Brite product manager. The same account was given in a conversation with hearing aid historian Claus Nielsen, 2016,). In contrast to later devices utilizing a receiver-in-the-ear architecture, SeboTek utilized a closed fitting, placing the receiver deep in the ear canal, rather than the open fitting utilized by ResoundAIR allowing unamplified sound to travel through the ear piece. In a published interview, a Sebotek Audiologist explained that “*The key to the whole thing is they have the receiver down deep in the canal where it belongs.*”(interview, 2003, published at audiologyonline).



SeboTek PAC, *Hearing Journal*, 2003, 5

While the device did not bear the prototypical form features of a behind-the-ear hearing aid (BTE), there was no attempt at innovating the design expression as such. The developers told the researcher the background story of the device and how the ambition had been to improve the delivery and fitting process, both to ease the fitting-related workload of hearing aid clinics, but also with regard to hearing aid fitting in nations with less advanced instruments and infrastructure the handle the process of custom fitting devices to the individual user (interview with developers of PAC).

In spite of possessing the technological architecture that later would show instrumental in radically catalyzing the design-intensity of the industry, there had been no cultural intent of creating any aesthetics apart from when worn "on the ear", and that Oticon Delta was the first to introducing that dimension, manifest in the advertisements of PAC promising the device to be "virtually invisible" (Sebotek PAC ad, Hearing journal, 2004, 10) and in published interviews conducted close the launch of the device, it was emphasized that : "Nunley**:** *The biggest advantage is that this device has the cosmetic advantage of a CIC, and the functionality of a BTE*. " (interview, 2003, audiologyonline)[1].

In **2006,** hearing aid manufacturer Oticon A/S launched the hearing aid Delta that like ResoundAIR three years in advance, presented a remarkable commercial success (Oticon annual report for 2006). The device utilized a receiver-in-the-ear architecture, but unlike SeboTek's deep fitting, it utilized an open-canal fitting similar to ResoundAIR . In terms of product form design, it presented for the market a radical new design expression. Its triangular shape was unseen in an industry where designs typically had attempted to directly camouflage with the contours of the ear, a manifest in the stereotype "*The beige banana behind the ear*". With a particular triangular shape and easily exchangeable shells on the faceplate, available in a broad array of metallic colors and styles, Delta was the self-proclaimed hearing aid for people "*who hate hearing aids*" (advertisement, 2006).

[1] The *"cosmetic advantage"* should be interpreted as referring to invisibility as a CIC device resides deep within the ear canal.

Oticon, Delta, 2006

The development of Delta was initially driven by the vision of a team of three individuals with a cultural intent to create a hearing aid device that would tap into the base of potential users that resisted the use of amplification due to negative associations related to hearing aid use. Across informants from Oticon, Delta was reported to be an attempt to present a product radically departing from stereotypical perceptions of hearing aids, as explained by the project manager of the development of Delta:

"With its form language on the device as such, Delta was first and foremost to challenge the common image of how a hearing aid looks. … The focus of design, aesthetics, painting, something that looks different and attractive and not just looking like prosthesis, a big lump behind the ear. That is something Delta was one of the pioneers of" (interview, 2015).

The actual design of the device was the outcome of a cultural intent to create a hearing aid with a radically novel design expression. This ambition was reported as something that escalated as the process evolved. Initial in the process, this intent was present at a far lower degree. At the time, due to the immense success of open-fit, thin tube devices that ResoundAIR had commenced, merely making a small and discreet device was the initial aim, rather than the broader cultural intent later sought realized. Initially in the development phase, even a device residing completely inside the ear was amongst the considerations.

Later in the process, the technical head of the project came with the mechanical idea for the device, for utilizing a receiver-in-the-ear architecture combined an open-canal fitting. Following this point, the commitment and level of ambition regarding the novelty of the design expression increased and the industrial designer was addressed with a request for something "*rather untraditional*". As the industrial designer worked in collaboration with the engineers on the composition of components, the level of ambition increased. Finally a set of prototype models was suggested by the designer, resulting from the dialectical

process with the mechanical engineer, where the fact that "*it did not look like a hearing aid"* was the central criteria for the selection of the design. The product manager recalls from the stage:

"Interviewer: *Do you remember what struck you about that one*?

It had a lot more personality than the others. The other ones looked like hearing aids. So it went very fast that we chose it. … Delta was: Wow this is something completely different." (Interview, 2015)

The launch and rapid success of Delta led to a new period in the hearing aid industry where nearly all major manufacturers would launch receiver-in-the-ear claiming novel design expressions. The years 2007-2008 following the launch of Delta saw an industry wide trend from manufacturers launching devices with radically novel design expressions, utilizing an open-canal fitting, receiver-in-the-ear style.

In the period 2003-2008, product form design emerged as important competitive parameter. The industrial design of Bernafon Brite and Starkey Zon both described the drivers of the design briefs they received as driven by the increased design-intensity in the competition at the time. Instrument size was found to have been a competitive parameter for the entire interval, reflected in frequent advertisement claims of "*inconspicious*", "*invisible*" and when devices residing inside the ear canal was gaining wide diffusion, behind-the-ear devices were often framed as "*mini-BTE's*". After the successful launch of Delta, a new competitive design parameter was introduced, reflected in product launch announcements in trade journals and advertisements claiming products to be "*sleek*", "*beautiful"* and "*stylish*". This introduction of design as a new competitive parameter required firms to adopt the new technological architecture in order to compete on the product form design parameter. In the wake of Delta, Oticon daughter company approached their external design request from a design that was to be "*iconic*". The design agency involved in the design of Starkey Zon, launched two years after Delta, where requested a product form design that would live up to the new aesthetic standards in the competition between manufacturers (Interview with external industrial designer, 2016). The focus on design as a competitive parameter was reported to be the outcome of a newly recognized aspect of a hearing aids' value, namely the fact that it "*looked good in the hand"* or had "*hand*

value" due to it not being recognized that the first encounter with the hearing aid from the user was not when worn on the ear, but when held in the hand. The external industrial designer of Delta explained that

"*Since then there has come an understanding of that you evaluate the aesthetics of a hearing aid in two scenarios. How does it look in the hand and how does it look in the ear. In the daily use, how it looks on the ear may be more important, but in a sales situation, how it looks in the hand is of enormous importance*".

The recognition of "*hand value"* as a competitive parameter led to an industry wide imitation of Delta showing the emergence of convergent designs. Unlike dominant technological designs, these designs reflected a high level of variety, while similar in the sense that they aimed for attracting younger users by launching aesthetic hearing aids "*not looking like a hearing aid*". The Swiss daughter company of Oticon, Bernafon, launched in 2007 the device Brite, with the product manager of the device describing the range of innovations in product form designs in the period as a "*gold rush*". Same year, another major Swiss manufacturer, Phonak launched their device Audeo and the by the end of 2008, all major manufacturers had launched an open-canal fitting, receiver-in-the-ear device, most of which claimed highly novel design expressions and were frequently awarded design awards. One informant from US manufacturer Starkey, that joined the trend with their device Zon in 2008, emphasized the role of various technological advancements in the boom of innovations in product form designs in the period:

"*So what you see again is this perfect convergence of signal processing capabilities to reduce feedback and whistling, the ability to redesign the hearing aid putting the receiver in the ear to keep the ear open, reduce the mechanical packaging so its more attractive, injection molding techniques get better so that they easily can have things like bone lines and plastic and smarter design, power consumption gets low enough so you can go for smaller batteries and drive the size down. All of these things were sort of interacting with each other in that time period*."

The quote expresses one of the central observations in the initial phase of the analysis, namely that the design-intense period could not have happened at any time, but rather was dependent upon several technological developments happening prior to it. This "*convergence*" between technological improvements

and an increased novelty in design witnesses that technological products require certain technological pre-conditions in order allow product developers to manipulate certain form features.

This increase in design-intensity, implied that aesthetic product form designs became a competitive factor, through the new product value aspect "*hand value*", indicated by the rapid imitation of the ResoundAIR and Delta devices amongst most major manufacturers. All of these imitators utilized the same technological architectures as these devices, due to it being necessary for enabling the innovations in product form design that these new designs required. Later this, style of device became established as a dominant design within the industry, across a wide range of product segments. Initially however, it was adopted by manufacturers in order to fulfil the new competitive parameter of devices "*looking good in the hand*", rather than solely "*invisible on the ear*". The receiver-in-the-ear style rose rapidly in market share until reaching 50% of all devices sold in 2014 (Hearing journal, 2014, 6). Apart from the technological first mover Sebotek, the open-canal fitting, receiver-in-the-ear architecture was initially selected by manufacturers due to its ability to enable radical innovations in product form design within the industry. The selection of the style amongst manufacturers were driven by the immensely successful devices ResoundAIR (Open-fitting) and Delta (Open-fitting, receiver-in-the-ear) that led to an increased design-intensity within the industry requiring manufacturers to adopt the technology to be competitive in terms of the new parameter of aesthetics "*in the hand*". Since it was found that novel technologies played a considerable role in enabling the novel design expressions, the following stage of the research process sought to understand this enabling mechanism.

Endogenous Technological constraints: Expanding the space of possible design expressions through making traditional, functionality induced, form features redundant.

In order for a hearing aid to function, some design features are required, that constrain the opportunity of a designer to manipulate product form to create new design expressions. Some design features carries communicative content that functions as social symbols (Rindova and Petkova, 2007; Verganti, 2008; Eisenman, 2013). In the case of the hearing aid, it was the ear piece customized to the shape of the user's ear, connected to the device through a plastic tube that was seen as carrying a symbol of "*orthopedic*" and

"*prosthesis*", why manufacturers sought to alternative designs. The radical design innovation of the design devices was to create formal expressions not associated with characteristics such as "sickness", "old age" and "handicap" in favor of signaling being "active", "tech-savy" and "fashionable". The requirement of the custom molded tube would have constrained such efforts, but due to advances in feedback suppression in the wake of the transition to digital signal processing, the constraining factor of the custom ear mold and thick plastic tube was removed. Previous to 2003 and the launch of ResoundAIR, behind-the-ear hearing aids were commonly observed to be advertised without a tube and ear mold. Observed exceptions included advertisements not from hearing aid manufacturers, but firms specializing in producing ear molds particularly.

Differences in the design-expressions of behind-the-ear hearing aids	
Custom ear mold and thick tube	Open-canal fitting and thin tube
	

Illustrative example of the difference in design expression of behind-the-ear-hearing aids with a custom ear mold and thick tube and an open-canal, thin-tube design.

Across informants and manufacturers, the open-canal fitting, was reported as a central driver for the emergence of the "design devices". The requirements of a custom fitted ear mold were a barrier for the behind-the-ear device to be a carrier of design expressions to innovate the meanings associated with hearing aid devices. A former R&D director at GN Resound noted that "*those thin tubes that we have made, have them look much less orthopedic than they did back in the days*", indicating that a shift from a product form

design expressing sickness, would require a departure from the traditional ear mold. The designer of ReSoundAIR explained the researcher that an explicit focus in the design process were to develop something that departed from the prototypical form features of the behind-the-ear device, here accounted for by the designer as "symbol recognition":

"*Something that gives the hearing aid symbols is the ear mold, so when you take this* [holds up a classic BTE device] *there is recognition, but less so with this* [holds up a ResoundAIR device], *it's the same with ITE products. You have this symbol recognition. Often what gives the prosthesis characteristics are this one* [indicates the ear mold]. *You have something that has been molded for your body to reside within it. That says, this is a prosthesis"*

Exchanging the custom ear mold with the open-fitting was a central aspect of the intended manipulation the hearing aid product form in order to alter its associations of "*prosthesis"*. Prior to the launch of the devices, categorical positioning of the form of the device away from the prototypical features associated with stigma was an explicit focus in relation to pre-commercialization testing:

this one [holds up ResoundAIR], *we did measures on it and nobody can see what it is. So in this way you have removed peoples' preconceptions out of the equation*. … *nothing like this existed before. You could get some small hearing aids, that leaned towards it in size, you can see here* [shows prototype model], *the difference in size is not that big, but you have a big difference in the expression*."

In a later interview, the researcher was informed the researcher how icon design methods had been deployed:

"*I did some design studies were I tried to show people different products. … I could see that there was a very clear connection between the transparent ear mold that people could recognize"*

This modular change in technology, allowed the designer to change the design expression of the hearing aid, in terms of what he found was the most critical component with regard to departing from the "*prosthetic*" expressions of traditional devices, that due to the signal processing capabilities at the time, required a custom ear mold and thicker plastic tube for transporting sound.

By the same token, when asked whether the novel design expression of Delta's and later Brite's design could have happened before, informants were expressed considerable skepticism towards it being possible if faced with the necessity of utilizing a custom ear mold. The industrial designer of Delta explained that: "*you would constantly be split between the beautiful part of the device and the part that looked more like a medical device. Especially with the ear mold… it is clearly formed to a part of a body*". The product manager of Brite noted that "*it allowed us to come up with a completely different thing, cause when you have a regular ear mold with a tube then you are kind of limited. It allowed us to do really creative stuff*". The requirement of a custom molded tube posed a significant barrier to innovation the design expression of the BTE, as it was the carrier of the hearing aid "*symbol recognition*". Could the traditional ear mold not have been replaced with an open-canal fitting, the designer would have been less likely to identify the novel design expression as a meaningful opportunity.

Endogenous Design Conventions: Expanding the space for design opportunities through mitigating the constraining effects of market expectations.

Products developers will typically face design rules set by requirements for functionality (Baldwin and Clark, 2000). In the case of the hearing aid, also expectations to the physical size of products was found to be considerable constraint to the creation of new product meanings through manipulating the prototypical form features as these. A central enabling mechanism of the receiver-in-the-ear style in the creation of the designs innovations of the period 2006-2008 that was reported in the data was that the new architecture allowed product developers to reach a device size conforming to the expectations of the market, which would otherwise have been compromised with the experiments in product form design. In the design process of Delta, the designer reported this expectation as being a "*rule number one*" where the device was required to "*disappear on the ear*". The receiver-in-the ear architecture gave a rapid decrease in device size that allowed designers to carry out form experimentations that would otherwise have reflected a compromise with the expected size of devices.

Creating a product form design that departed from traditional shapes would require a compromise in size, a compromise seen as unacceptable in the hearing aid industry. Removing the speaker from the body of the device to the ear canal allowed products to reach a size that made that had them meet the threshold with regards to miniaturization and thereby allowing for the new aesthetic expressions to be a relevant contribution to the value of the product. Without this technological opportunity, the product would be expected to fail due to non-conformity to market expectations regarding instrument size. The technical manager of Delta explained conforming to market expectations regarding size was a crucial part, as it would otherwise cancel the value added to the product through the novel shape of the body:

"*How could you place the components so that you could deliver on size. Because if we made something that was not small enough, then it doesn't matter how it looks, you can make the most fancy design, but if it doesn't reach a certain threshold on size, then it is irrelevant."*

The triangular shape of Delta or the rounded, organic shape of Bernafon Brite was reported as not being the smallest possible shapes to give the devices, due to the priority given to the "form factor". The engineers behind Delta's mechanical design explained that "*Delta was not as small as possible. There was some air in the device. That was considered inappropriate to make a device that was not as small as possible*". The device broke with a design convention in the industry of using all possible means in order to minimize the size of the device. By the same token, in the case of the earliest follower of the Delta device, the project manager of Bernafon Brite noted that "*we knew at this time that it was not the smallest instrument that we could have built, but we said, We take this because of the form factor, because the rounded shape was definitely not the smallest we could have built, we could have done the instrument smaller using a more traditional shape*". While the experimental shapes given to the bodies of the devices required a compromise in size, the removal of the speaker from the body of the device to the ear canal gave a drastic advance in miniaturization that allowed prioritizing the "*form factor*" in contrast to reaching minimal instrument size. In a product category were compromising product size is seen as "*inappropriate*, the new technological architecture gave the developers a degree of "design freedom" enabling radical experiments with shaping the body of the device. The product manager of Brite explained that: *the form of the instrument was basically,*

allowed by the speaker unit being in the ear, it was basically a smaller instrument, and then we had space on our hands to play with shapes that are more iconic, more so than the "banana". The traditional shapes of hearing aid devices that have given rise to the stereotypical, caricatured the "*beige banana behind the ear*" reflected a way of designing the body of the device that reflected the minimal space requirements for a optimal partitioning of components. Since the prototypical shape was determined through miniaturization creating novel shapes of the body of the device would require neglects of instrument size. Had the designer of Delta not have had the opportunity available, it would have difficult to achieve the design expression arrived at in the case of Delta. The designer of Delta reflected: *"Ofcourse you could have made a new form on the hearing aid in itself. But it would of course be way bigger and not as discreet. It would probably be difficult to squeeze the things inside in an elegant triangle. If you even where to choose a triangle, as Delta was written into"*. As seen in the case of the shift from the traditional custom ear mold to the open-canal fitting, creating a device along the lines of Delta was reported as being severely technologically constrained, had it not been for the availability of the receiver-in-the-ear architecture.

Discussion: How do industries turn design-intensive?

For several decades, product design has been seen as central catalyst for change in industries and the dynamics of competition (Clark, 1985; Henderson and Clark, 1990; Anderson and Tushman, 1990; Tripsas, 1997; Baldwin and Clark, 2000; Brusoni and Prencipe, 2001; Frenken and Nuvolari, 2004; Windrum, 2005; Dibiaggio, 2007; Colfer and Baldwin, 2016). While the literature previously has focused on technological designs, this highlight the importance of product form design to include in the study of how industries evolve. More specifically, the study points the attention to an overlooked form of industry change, namely the emergence of design-intensity within industries. Previous studies have found how several drivers of design-intensification on a firm level (Verganti, 2008; Rindova, Dalpiaz and Ravasi, 2011; Eisenman, 2013). This study found how certain technological innovations can allow product developers to manipulate the material form of products, a necessary condition of possibility for design-intensification of an industry. This study suggests the emergence of design-intensity to require a particular state-of-affairs in the technological evolution of an industry as a trigger of powerful design exemplars. Such powerful design exemplars were

found to furthermore drive design-intensity through introducing new competitive parameter, leading the industry wide adoption of the technology required to manipulate the material form of products towards desired design expressions, thereby also impacting the technological evolution within an industry. In the case of the hearing aid industry, it was found how a range of technological innovations in the preceding years had enabled product developers to overcome technological constraints and design conventions in order to innovate the design expression of the hearing aid. It was found how the highly successful exemplars, ResoundAIR and Delta led to the introduction of a new design related aspect of product value that became a new competitive parameter which competing manufacturers quickly responded to. The introduction of 'hand value', led product level competition from being a merely technical concern of functionality and miniaturization to also being an aesthetic concern. It was however found how the realizations of concerns, had to work around endogenous factor related to technical concerns related to functionality and design-conventions related to miniaturization. The emergence of new aesthetic concerns, not only led to an increased level of design-intensity within the industry, but also led to the selection of a new dominant design, the open-canal, receiver-in-the-ear architecture. This was due to the fact that this architecture was the most beneficial in order to mitigate the technological constraints and work around the design conventions that limited the potential for the design expression of the hearing aid to be altered..

The bulk of literature on how firms can identify and exploit opportunities in product form design has mainly occurred in industries already characterized by a high level of design-intensity, such as fashion, interior design and household equipment (Verganti, 2003, Verganti, 2008; Cappetta, Cillo and Ponti, 2005). The findings of this study advance this discussion by shedding new light on how design-intensity is introduced within industries. Furthermore it was found when such transitions potentially can occur, by showing how such shift in some periods will be unlikely due to constraints to altering the material form of their products. Design novelty is typically a result of changing the prototypical features of a product (Talke et al, 2009). This study suggest that departing from prototypical product features can face technological constraints and design conventions that will limit the potential of product developers to create innovative design expressions. The novel technological architecture of the open-canal, receiver-in-the-ear style gave designers freedom in

terms of giving new shapes to the devices. In addition it was found, that the new technological opportunities led designers to experiment in ways with assembling components in a way that the new design expression could emerge from.

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