About the cover
'the black eye and a glass bowl'
'black eye' (karagöz fasulyesi) is a type of bean grown in Beypazari, which is a town and district of Ankara Province in the Central Anatolia region of Turkey.

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Meanings of Materials

PROEFSCHRIFT

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Discovering, making and communicating meaning is our full-time job.

MARK JOHNSON

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Introduction

All living things and lifeless things around us share one property in common: materials. They give substance to products that we touch, see, smell… Bones, skin, wood, metal, plastics and glass are only a few examples of the materials universe. Materials have been studied in science and engineering for years. Nevertheless, questions regarding our experiences with materials have rarely been studied, since technical factors have dominated material decisions. How do we experience materials around us? When do we think that a certain material is modern, elegant, sexy, feminine, or professional? This research illuminates the intangible face of the material domain.

Whilst it is acknowledged that functional aptness is still a key factor for a product's success in the market, there is a growing interest and recognition for the more intangible side of products. *Does it feel good to touch? Is it luxurious? Does it express my life-style? Is it convenient for my cozy and friendly room? Is it high-tech?* In other words, the symbolic (Dorfles, 1966), or the expressive function of the product (Mono, 1997), has gained greater importance and value in contemporary design discourse. On the other hand, developments in technology, the emergence of new interests, new life-styles, and new trends have led to an era in which users interact with products having an increasing diverse range of colours, materials, shapes and functions. Without a doubt, in this present dynamic era it is not easy to ensure that the message of a product interpreted by users will be same message intended by the designer. In this sense, to be capable of designing products that properly express their intentions, designers should understand the links between product specifications and meanings. In addition, they should *understand other people's understanding* (Krippendorff & Butter, 2008) instead of using merely their own intuitions or gut feelings in the formation of meaning (Chung & Ma, 2001; Hsu, Chuang, & Chang, 2000; Warell, 2004). As Krippendorff insists (2006), placing meanings into the centre of design considerations provides designers with a unique focus and expertise that other disciplines do not address.

Offering distinctive characteristics and attributes, *materials* are a key factor in product design not only for improving *use* and *function*, but also for contributing to (or creating) the *meanings* that people attribute to products. Hodgson and Harper (2004) state that materials considerations are pervasive in design, being the substance through which designers' intentions are embodied. Likewise, Gant (2005) emphasizes that the strategic use of materials is one of the most influential ways through which designers engender deeper, more emotive connections between their products and their users. Scholars in the domain of materials and design all conjoin on the significant role of materials in creating product values and meanings (Arabe, 2004; Ashby & Johnson, 2002; Conran, 2005; Cupchik, 1999; Doordan, 2003; Ferrante, Santos, & de Castro, 2000; Fisher, 2004; Gant, 2005; Lefteri, 2001; Ljungberg & Edwards, 2003; MacDonald, 2001; McDonagh, Bruseberg, & Haslam, 2002; Sonneveld, 2007; Van Kesteren, 2008; Zuo, Jones, & Hope, 2005). The starting point of this research stems from the following statement: designers need insights into the role of materials for creating particular meanings attributable to products. This statement requires a deep understanding of the key variables affecting the meanings we attribute to materials.

Main Goal of the Thesis

Developments in materials science and manufacturing technologies have enhanced the variety of applications for materials. People encounter versions of a particular product made of different materials or the same material embodied in different products. This has led to an unavoidable transformation of meanings attributed to a certain material. A single material, polypropylene for instance, may be evaluated differently when it is embodied in kitchenware rather than an office accessory. Manzini (1986, p. 3), in his book *The Material of Invention*, also emphasizes that new technologies have radically altered the meanings that once endowed materials with cultural and physical depth. Accordingly, traditional sayings such as *wood is cozy*, *metal is aloof* or *plastic is cheap* are less relevant and strict in today's design practice. Materials obtain different meanings in different products. Therefore, designers who aim to select a material that will contribute to the meaning they intend to convey in a product are confronted with the difficulty that the materials universe is immense. No simple rules exist for explaining meaning-material relationships. In other words, it is not possible to locate a design method that will guarantee material 'x' will evoke meaning 'y' in product 'z'.

The goal of this thesis is to explore how materials *obtain* their meanings and how materials cooperate with other elements of product design (such as form, function, use, and users) for expressing certain meanings. In asking 'how', the intention is not to refer to the cognitive process that take place in the mind of the beholder, but rather to understanding the key variables that affect the attribution of meanings to materials. The ultimate aim is to support designers in systematically incorporating meaning considerations into their materials selection processes.

Structure of the Thesis

The three main questions addressed in this thesis are:
How do people appraise materials?
How do materials obtain their meanings?
How can product designers involve meaning considerations into their materials selection processes?

To answer these questions, the thesis is divided into three main parts: (1) materials experience, (2) attributing meanings to materials, and (3) [meaning driven] materials selection in product design (Figure 1).

PART I Materials Experience

Part I deals with the first research question: how do people appraise (or evaluate) materials? Chapter 1 is an introductory chapter in which the significance of materials in product design is briefly explained with a number of product and material examples. The chapter underlines the role of materials for conveying meanings and eliciting emotions, which are defined in the chapter as the *intangible characteristics of materials*. Chapter 1 addresses the *terms* used by various scholars in order to emphasize the intangible side of materials within design discourses. In Chapter 2, after a brief summary of the product experience domain, descriptive items of materials are collected through a set of studies. These items are classified into seven descriptive categories, which are comprehensively clarified in the chapter. The categories relate to the three experiential components in product experience (aesthetic experience, experience of meaning, and emotional experience). Based on these categories, the chapter proposes the establishment of a new term for design discourse: materials experience.

Part I concludes that materials are used for creating certain experiences. Furthermore, although the significance of materials in creating experiences is emphasized in a number of existing sources, they fail to identify characteristics of materials that lead to their use in constructing meaning. It is emphasized that research stressing the intangible characteristics of materials, and the integration of these aspects into materials selection sources, can provide a considerable contribution to the product design domain.

PART II Attributing Meanings to Materials

In the second part, focus is directed towards one of the components of materials experience: *meaning attribution*. Chapter 3 commences with a literature review on meaning creation.

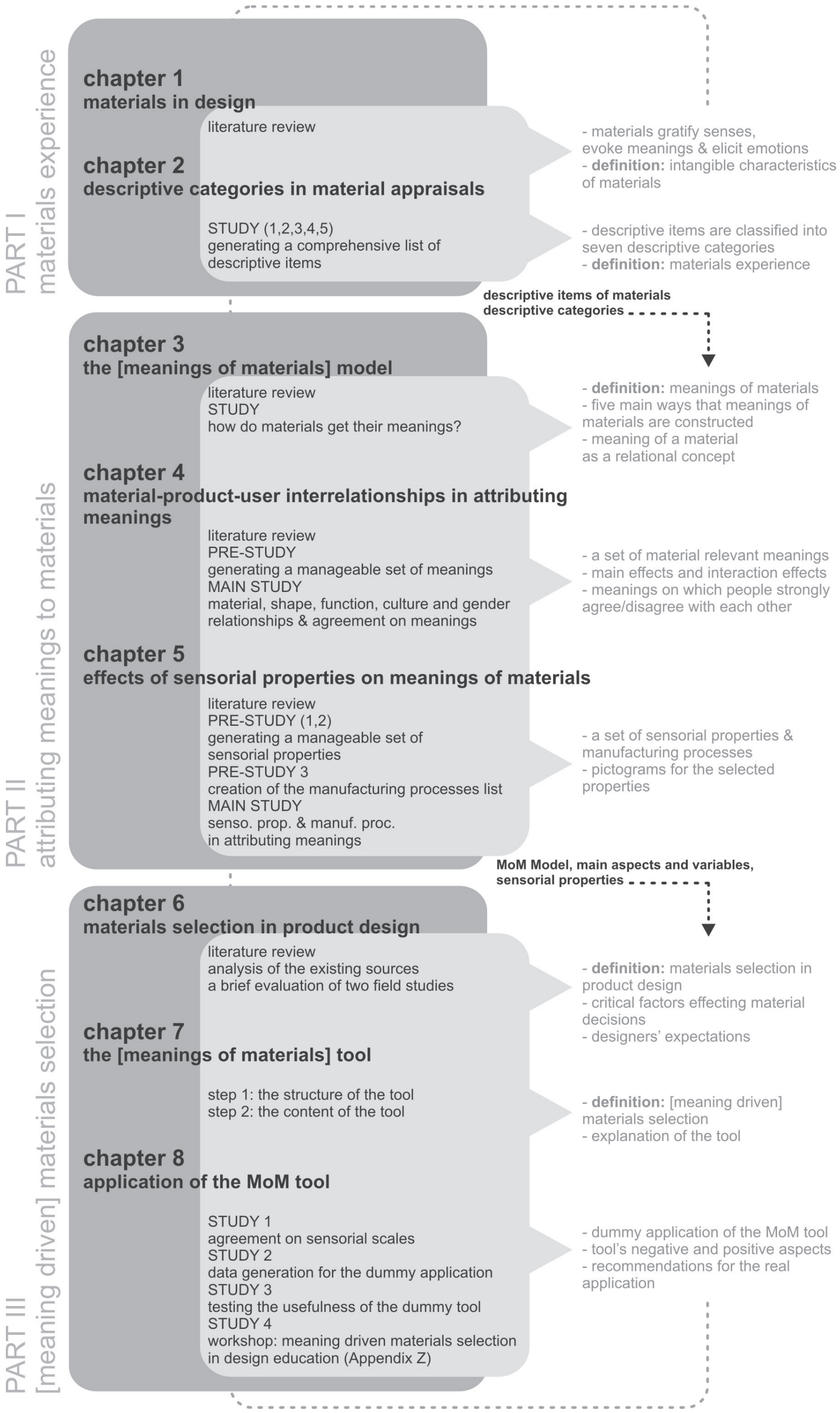

Figure 1. Structure of the thesis with an overview of the conducted studies.

The chapter consists of three conjoined studies, which are performed to identify the key variables in meaning attribution to materials. Five main structures describing the relational properties in attributing meanings to materials are identified. These structures explain the various ways in which materials can obtain their meanings. Based on the detected structures, a model for *meanings of materials* that covers the key variables in meaning attribution is created. *User*, m*aterial* and *product* are defined as the main components of the model. In Chapter 4, the role of the *product* and the *user* in attributing meanings to materials is tested and verified through a study in which participants were asked to evaluate eight products made of plastics and metal. Furthermore, the level of agreement among participants of the study on certain meanings is explored at the end of the chapter. Chapter 5 focuses on two aspects of the main components of the model: *sensorial properties* (as a material aspect) and *manufacturing processes* (as a product aspect). The main aim of the chapter is to identify the sensorial properties of materials and manufacturing processes that are effective in creating expressive meanings.

The main conclusion of Part II is that designers who intend to create certain meanings through the materials of their products are confronted with the difficulty that there is not a one-to-one relationship between material properties and intended meanings. Combinations of different properties evoke particular meanings for specific contexts and users. This conclusion led to the creation of the Meanings of Materials (MoM) model. The main question asked at the end of this part is: how can we convey these findings and the MoM model to designers in such a way that it supports and enhances their activities of creating meaning through materials selection?

PART III [Meaning Driven] Materials Selection

A tool for supporting designers in their task of involving meaning considerations in *materials selection* is developed in Part III. The tool is developed with reference to two main sources: (1) insights into (a) materials selection methods and tools, and (b) current studies on materials in design; and (2) (a) the Meanings of Materials (MoM) model, and (b) aspects established earlier in the thesis found to be effective in attributing meaning to materials. These two main sources are used for the aim of creating a list of criteria for a *meaning driven materials selection* tool. In Chapter 6, on the basis of a comprehensive literature review and interviews conducted with professional designers, first a set of critical factors in materials selection for product designers is identified. Next, various sources used by product designers for selecting materials are listed. Three recently established tools for material selection are briefly explained at the end of the chapter. Tools and sources are evaluated in terms of their suitability for product designers' material selection processes. The main advantages and disadvantages are revealed. The necessity for a new approach to materials selection in product design, based on meanings of materials, is emphasized in the chapter.

Chapter 7 proposes a new approach defined as meaning driven materials selection. Following an outline of the approach, the [Meanings of Materials] tool is developed as an interactive tool aiming to assist designers in understanding the key aspects effective in attributing meanings to materials in an inspiring way. The process of conceiving and developing the [Meanings of Materials] tool is presented intensively in the chapter. The last chapter of the thesis, Chapter 8, comprises the application and evaluation of the [Meanings of Materials] tool. The chapter concludes with an extensive discussion on the positive and negative aspects of the tool and recommendations for further applications.

PART III concludes that even though certain modifications are required, the proposed [Meanings of Materials] tool achieves the goal of transferring the main findings of the research into the domain of design practice. The thesis ends with a section on Findings and Implications, which reflects on what has been achieved and what the further possible research directions can be.

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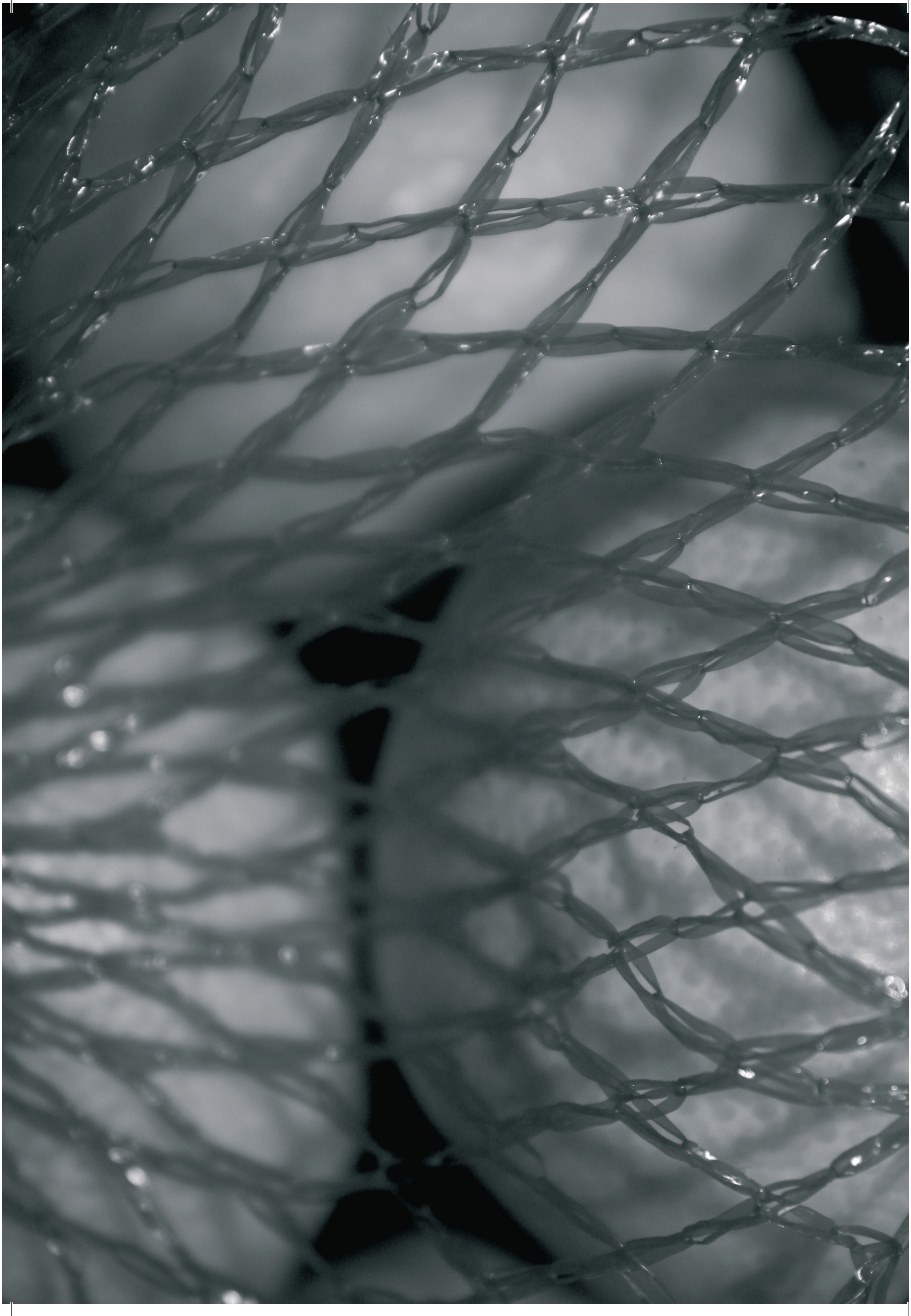

PART I
materials experience

The first part of this thesis proposes the establishment of a new term for design discourse: *materials experience*. Product designers, in order to convey certain product values, need to enrich their understanding of the product experience and the whole set of activities involved in it. Materials, being an interface between products and people, play a significant role in the product experience. In the first chapter, the role of materials in the domain of product design is briefly discussed. The chapter presents a number of examples in which materials are selected not only for technical benefits but also for gratifying senses, conveying particular meanings and eliciting emotions. At the end of Chapter 1, it is concluded that materials, like products, are used for creating experiences. This statement is the basis for exploration in Chapter 2, in which descriptive items on materials are collected in a set of studies. These items are classified into seven descriptive categories, each of which is comprehensively clarified in the chapter.

Chapter 1 is based on:

Karana, E. & Kandachar, P. (2006), *Effects of New Materials on Industrial Design and Societies: From Industrial Revolution to Concept of Smartness.* Paper presented at the Future Design Conference, Seule, South Korea.

Karana, E. (2006), *Intangible Characteristics of Materials in Industrial Design.* Paper presented at the 5th International Design & Emotion Conference, Goteborg, Sweden.

1

materials in design

1 Introduction

> "… The ages in which man has lived are named for the materials he used: stone, bronze, iron. And when he died, the materials he treasured were buried with him: Tutankhamen in his enameled sarcophagus, Agamemnon with his bronze sword and mask of gold, each representing the high technology of their day."
>
> Mike Ashby (2005, p. 4)

Design can be defined as "*the human capacity to shape and make our environment in ways without precedent in nature, to serve our needs and give meanings to our lives*" (Heskett, 2005, p. 5). Needs were basic in early ages, when materials were used as tools to enhance the capacities of humans for hunting and sheltering, and for general survival. The natural world provided a diverse source of materials to accomplish these largely functional aims. However, a problem emerged: how to improve these tools by making them more durable, less fragile, less liable to impact forces, etc. Humans seek out forms for artefacts that are appropriate for particular purposes. In other words, product forms eventually become very closely adapted to the needs of humans (Heskett, 2005). Changes in forms have been largely derived from the use of new materials; materials have been used to improve the functional utility of objects and have made possible the embodiment of new forms for established needs. Thus, the entire history of mankind's design of products is closely linked to the history of materials.

Materials, offering distinctive characteristics, are key factors in design for improving products. They do not only affect use and function of products, but also contribute to the creation of meanings and particular experiences. Taking this as a starting point, this chapter addresses the role of materials in product design, not only for functional benefits but also for creating meanings and eliciting emotions.

2 Materials in product design

Form Follows Materials[1]

The impact of increasing scientific knowledge about the nature of materials has provided considerable changes and developments in tools and methods used for processing materials. Advances in materials have resulted in new forms and designs for new products in everyday use (Chapman & Peace, 1988). In other words, new materials stimulate designers to seek out new forms and usages of objects. The encouragement that materials afford to designers and the product designs that result inevitably affect people's ways of living, environments and cultures.

The most obvious effects of materials on industrial design were certainly observed after the Industrial Revolution, when production machinery was installed for manufacturing in various industries (particularly the pottery, automotive and textile industries). The Industrial Revolution brought a shift in design and manufacturing thinking away from single components, towards collections of units and sub-assemblies. It provided the processing of different materials in a single production line, which affected the nature of products. In seeking designs appropriate for sub-assembly, for instance, a dramatic change was made in the materials content of cars, to the extent that many late 1980s cars bear little resemblance to late 1950s models (Forester, 1988). Another example sector fully influenced by the emergence of new materials and manufacturing technologies was the American porcelain dinnerware industry. It virtually disappeared because it was not able to grow beyond traditional styles and it could not battle with newly produced materials such as plastics.

Dormer (1990) explains, by way of three cultural phenomena, changes in material use in the late 20th century marked by the prevailing use of plastics. Firstly, there appeared a move away from heavy products to lightweight ones. Secondly, the gap in differences between natural and manmade materials was narrowed. Finally the third trend, a retreat from non-renewable resources, marked the beginning of research for re-usable materials, and included new generations of plastics in almost every industry. In the relationship between design and materials, plastics have become one of the most versatile materials, stimulating designers to create new shapes, new solutions and new mechanisms for existing needs (see Figure 1 for example).

Figure 1. Silicon garlic peeler.

Sparke (1983) states that perhaps more than any other single material it is plastics that have encouraged designers and manufacturers to move towards aesthetic simplicity (of form) in mass-produced artefacts. On the other hand, Katz (1978) claims that plastic objects are curved because polymers need to flow within the moulds and corners are difficult to produce. In other words, she argues that instead of inciting designers to create new forms, plastics, because of their physical properties, actually force designers to create similar forms that are capable of being easily removed from mould tools. Plastics, nevertheless, have inevitably led to new approaches to form and function in design. Ashby and Johnson (2002) emphasize that the form of any product and the process used for embodying that product are strongly influenced by the nature of the material from which the product is made. Designers and manufacturers constantly try to resolve the interrelation between a form and methods used for creating that form. They look for ways to optimize the materials- form- process relations.

Products require a set of parameters to be met by materials (e.g. handles of kettles are made of nonconductive materials to protect people's hands, Figure 2). Mayall (1979) talks about the psychology of materials, which refers to the kinds of affordances a material offers. Norman (Norman, 2002, p. 9) directly explains the affordances of materials: "*Glass is for seeing through, and for breaking. Wood is normally used for solidity, opacity, support, or carving...* ". Thus, every material fulfills a particular function and this inevitably affects designers' material choices.

Figure 2. Examples of kettle handles made of three nonconductive materials.

Certain manufacturing processes require particular materials to support ease of manufacture. A material may be convenient for a process and thereby a material- process relationship may affect the form of a product (Figure 3). Design in plastics, for instance, is also heavily influenced by the ability to cut in metal to form mould tools. In other words, achievements in metal technology have to some extent dictated what can be achieved in plastics.

Figure 3. Each material is convenient for a different process, which results in different forms.

Alternatively, Clemenshaw (1989) argues that the extreme malleability of plastics creates a demand for more creativity in shaping metals to realize very demanding moulds. Therefore, a material not only affects design objects made of that material, but also the objects made of other materials. In addition, materials can drive technological developments in manufacturing processes, directed at enhancing the form possibilities that can be achieved with those materials. The plug container in polished stainless steel designed by Stephen Newby is a good example, presenting metal in a form that we are not used to seeing in metal products (Figure 4). The manufacturing process allows inflation of the stainless steel without moulds (Lefteri, 2006).

Figure 4. Plug container in polished stainless steel, designed by Stephen Newby.

Materials gratify senses

High-tech styling in the 1980's was defined as plastic products with bright artificial colors and surface textures. When plastics first emerged, however, the tactile experience of plastic artefacts was generally unsatisfactory for people (Walker, 1989). Plastics were warm and soft in touch, but not brilliant, not heavy and not as hard as porcelain or iron. One of the most popular strategies adopted by designers seeking to enliven the surface qualities of plastic was to pattern it- often copying natural materials such as wood or marble (Dormer, 1990). This approach did not go on for long. In the 1950's, just the opposite philosophy prevailed among the public, with the introduction of Tupper's[2] new products, which were flexible, light in weight and soft to the touch (Clemenshaw, 1989). When people interact with products their senses are in contact with the product materials, which mainly deliver visual and tactile stimuli (Giboreau, Navarro, Faye, & Dumortier, 2001; Sonneveld, 2004). In other words, designers use materials to create sensorial experiences with products. Figure 5 shows a translucent porcelain lamp designed for visual experience.

Figure 5. The Cibola Pendant Light made of translucent porcelain, by Scabetti (Dominic Bromley).

Throughout design history, chairs have been one of the products that have been designed as symbols of their own place and time (Colombo, 1997). Materials have strongly influenced the forms of chairs and have been a convenient tool for designers to create sensorial experiences particularly to gratify tactual senses (Figure 6).

Figure 6. Examples of materials used for creating tactual experiences in chair design.
Blow Lounge Chair, made of polyurethane foam, by Foersom & Hiort- Lorenzen; Vermelha, made on a steel frame and bound with acrylic based rope covered with cotton, by The Campana Brothers

Materials evoke meanings and elicit emotions

As explained briefly in the previous paragraphs, materials affect various aspects in product design such as form, function, manufacturing technologies, etc. and they are used for creating sensorial experiences. In addition to these aspects, materials are used as the symbols of beliefs; they convey meanings and elicit emotions. Sonneveld (2004) emphasizes that material properties are often used to characterize people, for example weak, strong, hard, soft, flexible, rigid, etc. Accordingly, product personalities can be characterized by the physical properties of applied materials.

According to Heskett (2005, p. 84) objects and environments can be used by people to construct a sense of who they are - to express their sense of identity. Materials embodied in objects and used in environments also contribute to the constructions of self-identity. Charles Eames' Lounge Chair 670 & Ottoman 671, for example, was a symbol of a businessman who merged office and home, and thus work and leisure, in a manner that prevailed in America in the late 1950's (Colombo, 1997). The idea was obviously supported by the combination of plywood, leather and aluminum (Figure 7).

Figure 7. Materials associated with businessmen in early 50's, Lounge Chair and Ottoman, by Charles Eames.

Krippendorff (2006) explains that ladies wear high-heeled shoes because they are said to look elegant and make a woman's legs look longer: "*when a woman comes home from a formal occasion, the first thing she changes are the uncomfortable shoes she wore essentially to define herself for others*" (p. 49). In other words, even though they are ergonomically unsuitable for walking even normal distances, high-heeled shoes are used to convey a sense of identity. Coming back to the materials world, a number of product examples exist for which the designer's material preference is led mainly by conveying an idea of 'self identity' for the user, even though the chosen material is not the most convenient for the intended form, use or ease of production. The Wooden iPod exemplifies one of these cases (Figure 8). The designer Joshua Driggs specified African Padauk wood for the product. Driggs explained the idea behind the Wooden iPod as follows: "*I have never liked the white finish. I am also applying a wood finish to just about everything on my desk to have a matching set. And the iPod was not excluded.*" When he was asked if it was still possible to 'scroll' with the click wheel, by dragging one's finger over the new wood surface, he answered, "*I used a very thin and strong double-sided tape to hold the click wheel and select button in place. Also a* *good air-less contact is necessary to ensure that the touch-sensitivity of the click wheel is preserved though the thicker coating on top*"[3]. Apparently, wood neither provided an added functional value in comparison to the original material specified by Apple, nor was it the most appropriate material to reproduce an iPod form.

Figure 8. Wooden iPod designed by Joshua Driggs.

Lately, the Golden iPod (Amosu 24ct Golden iPod) was introduced to the market. The product was promoted as "*Covered in hardened mirror gold, users can stare triumphantly at their beautiful, golden visage while rocking out to the new [fill in harp pop star of choice]*"[4]. It was not a pop star but a famous football player, David Beckham, who became associated with the Golden iPod. His teammates pooled together to get him a unique iPod Touch that was both covered in gold and custom engraved[5] (Figure 9).

Figure 9. David Beckham's Golden iPod.

Materials can be symbols and legacies of design approaches to support form and function. For example, Art Nouveau is associated with wood, bronze, and iron, and Streamline with steel and aluminum. Wood, ceramics and stone, for example, are very often used in Zen design, which is considered as a balance between detail and ease of use, particularly in East Asian cultures such as Japan, China and Korea (Figure 10).

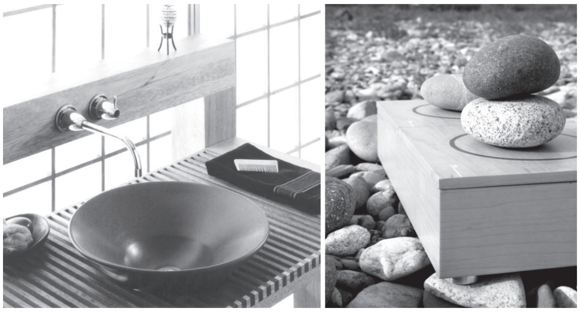

Figure 10. Materials associated with Zen Design.

Materials can be used for conjuring up different associations. Marcel Wanders, for example, designed the Foam Bowl which was created by dipping a sponge form into fluid porcelain clay[6]. After drying, the piece is fired in an oven where the sponge burns away leaving only the porcelain in its place. The physical properties of porcelain enabled the designer to successfully implement this production technique and to create a sponge association with the aesthetic properties of the material form that remained (Figure 11).

Figure 11. Foam Bowl designed by Marcel Wanders.

The material used in a product can elicit various emotions such as surprise, disgust, disappointment, curiosity etc. Desmet (2002) showed that material is one of the product characteristics that surprise people, together with shape, product function, size and construction. Ludden (2008), in her doctoral research, focused on surprise experiences that are elicited by incongruent sensory information in products. In several experiments, she explored visual- tactual incongruities, which are elicited mainly through choices of product materials. An example product with visual- tactual incongruities is a vase that looks like a crystal vase but is in fact made out of plastic (polycarbonate) (Figure 12). Owing to its material, the vase is much lighter than people would expect.

3 Intangible Characteristics of Materials

Beyond selecting a material that meets a functional need, questions regarding meanings and ideas matter to designers: Is it luxurious? Is it convenient for a cozy and friendly room? The examples given in this chapter show only a few attempts in which materials are selected not

Figure 12. Plastic (polycarbonate) vase that looks like a crystal vase (Ludden, 2008).

only for their physical characteristics but also for their intangible values, i.e. meanings they evoke or emotions they elicit.

Can a material have an intangible character? Or can a meaning be embedded in a material? Several examples can be given where the meanings conjured by a material **act as if** they are intrinsic characteristics of that material. The value and durability of dinnerware, for instance, was associated with the rigidity, coldness and weight of ceramic for a long time. Ceramic still seems to be the most hygienic, long-lasting and valuable material for dinnerware (Lefteri, 2006). Metal connoted precision and was used to emphasize technological superiority and high-level engineering for years (Arabe, 2004). Wood is warmer and cosier than many other materials and carries associations of craftsmanship. Ljungberg and Edwards (2003) also talk about the specific qualities expressed through materials. They state that a plastic remote control does not give the feeling of high quality compared to a heavier version with a metallic case. In all these examples, meanings are conventionally attached to materials by people. In other words, materials do not have meanings unless we interact with them in a particular context. Recognition of a material and a prevailing use of it stimulate the emergence of those meanings to behave as if they are material's intrinsic qualities.

Certainly, materials have a history, which helps us to assign meanings to them even when they are not embodied in products. In the past, manufacturing technologies were limited. A certain material was used in products with generally similar forms and functions (such as ceramics prevailingly used for dinnerware, or metal embodied in sharp edge forms for machinery). Improvements in manufacturing technologies and materials science have stimulated new materials and forms in product design. Now, metal can appear in organic forms and high-tech ceramics are used in electronics. As a result of this, a material is "like an actor, it can assume many different personalities, depending on the role it is asked to play" (Ashby & Johnson, 2002, p. 73).

According to Manzini (1986), there has become a 'loss of recognition' of materials since the introduction of plastics. Many new kinds of plastics have emerged in the last decade. Each has different properties and is used in a variety of products. Lefteri (2006, p. 7) explains how the definition of plastics has changed, from being an environmental 'criminal' to a material that comes from nature and returns to nature with the emergence of ecological plastics. In brief, the meanings fixed to a material have loosened. Histories of materials are shifting. As stressed by Wilson (1988), children whose first experience of the world comes from Toys 'R' Us may develop a different set of material values than adults who grew to maturity surrounded by wood, stone, and metal.

In that sense, in order to convey their intentions properly, designers should understand how a material possesses its meaning in different products. In existing literature on materials and design, the significance of this intangible side of materials is mentioned in various ways, such as: the second and third order materials characteristics (Hodgson & Harper, 2004), emotive- stage materials characteristics, softer criteria of materials' considerations, invisible characteristics (Lefteri, 2005), less tangible issues of materials (Conran, 2005), qualitative properties (Edwards, 2002; Jee & Kang, 2001), non-active or passive functions of materials (Deng & Edwards, 2007), non- technical issues of materials (Ferrante, Santos, & de Castro, 2000), material image, metaphysical aspects of materials, non- physical properties of materials (Ljungberg & Edwards, 2003), material personality, personal dimensions of materials (Ashby & Johnson, 2003), intrinsic cultural meanings of materials (Manzini, 1986), expressiveness of materials (Rognoli & Levi, 2004), subjective dimensions, essential and indicative character of materials (Rognoli & Levi, 2004), and perceived characteristics of materials (Zuo, Jones, & Hope, 2005).

Even though the importance of these aspects is emphasized, only a few researchers (Ferrante et al., 2000; Hodgson & Harper, 2004; Ljungberg & Edwards, 2003; Rognoli & Levi, 2004; Zuo et al., 2005) have conducted studies on the subject and proposed ways of linking intangible characteristics to designers' materials selection processes. However, there is currently no materials selection source that focuses on understanding and applying the intangible side of materials within product design (Conran, 2005; Deng & Edwards, 2007; Hodgson & Harper, 2004; Karana, 2004; Lefteri, 2005; Lovatt & Shercliff, 1998; Sapuan, 2001; Van Kesteren, 2008).

To sum up, designers select materials not only for physical benefits but also to convey their ideas and give character to their products. Product designers may have several questions regarding the intangible aspects of materials that arise during materials selection, such as "Does the selected material support the intended meaning of the product?", "Does it fit the target user group?", or "what kinds of associations can it evoke?". The objective of this introductory chapter was to emphasize the role of the intangible side of materials for the design domain. Considerable advantages for the product design domain may be realized through research focusing on the integration of intangible aspects of materials with designers' materials selection processes.

Endnotes

1 Form follows function, the phrase made famous by the architect Louis Sullivian, is a principle associated with modern architecture and industrial design in the 20th Century, which states that the shape of a building or an object should be predicated by or based upon its intended function or purpose (Holm, 2006). The phrase was adapted to the materials domain by Ashby and Johnson (M. Ashby & K. Johnson, 2002).

2 Tupperware brand products made their debut in 1946. Tupperware now reaches nearly 100 markets around the world with its colourful plastic products, especially for kitchen wares (source: Tupperware website)

3 http://money.cnn.com/2005/07/05/technology/personaltech/wood_ipod/index.htmi

4 http://gizmodo.com/gadgets/gadgets/amosu-24ct-golden-ipod-finally-254312.php

5 http://www.telegraph.co.uk/sport/football/international/england/2296139/David-Beckham-century-gift---a-golden-ipod.html

6 http://www.mattermatters.com/search.asp?Mode=Product&ProductID=98±

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Karana, E. & Van Kesteren, I. (2008), Materials affect: The role of materials in product experience In P. M. A. Desmet, J. V. Erp & M. Karlsson (Eds.), *Design and Emotion Moves*. UK: Cambridge Scholars Publishing.

2

descriptive categories in material appraisals

1 Introduction

A variety of factors, including *form* and *function*, *user characteristics*, and *context of use*, can be influential in our experiences of products. Several studies consider the effects of one or more of these factors on product experience (see e.g. Desmet, 2002; Govers, 2004; Van Rompay, 2005). Besides the other factors involved in *product experience*, materials can be utilized by designers to convey the intended meanings and ideas (Karana, 2006) as briefly exemplified in the previous chapter, or they are used to support other product aspects (e.g. form and function) with the purpose of underlining the existing meaning of a product (Arabe, 2004; Crilly, Moultrie, & Clarkson, 2004; Hodgson & Harper, 2004; MacDonald, 2001; Sapuan, 2001).

Throughout this chapter it is assumed that *materials experience* is a part of product experience and plays an important role in how we experience products. Therefore it is argued that the particular emphasis on *materials experience* will provide a valuable contribution to the product design domain. The main aim of the study reported in this chapter is to identify the descriptive categories in people's material appraisals (i.e. people's evaluations of materials) and to link these to the three experiential components in product experience: aesthetic experience, experience of meaning and emotional experience. After a brief summary of the product experience domain, descriptive items on materials are collected through a set of studies. These items are classified into seven descriptive categories, each of which is comprehensively clarified in this chapter.

In the following section, the product experience domain is recapitulated. The section highlights similarities between experiencing a product and experiencing a material. Based on these similarities, materials experience, as a new term for the product design domain, is proposed. In the third section, the adopted methods for collecting descriptive items about materials are described. An explanation of how the descriptive items were distributed into seven categories is given in the fourth section. In the fifth section, the study is summarized and the descriptive categories are used to support a more detailed definition of materials experience.

2 From product experience to materials experience

Product experience, in several sources, is proposed as a general concept that encompasses other more specific experiential concepts such as aesthetic and emotional experiences (Dewey, 1980; Hekkert, 2006; Overbeeke & Hekkert, 1999). Hekkert (2006) describes the three components in product experience as: (1) aesthetic experience (gratification of the senses), (2) experience of meaning (attribution of meanings to products) and (3) emotional experience (the elicitation of feelings and emotions). In Hekkert's words, "*while interacting with a product, a person (observer) first comes across the artefact, senses it, perceptually analyses it, compares it with the previous cases, classifies it into a meaningful category, and consequently interprets and appraises it*" (p. 159). Correspondingly, while describing a material in a particular context, besides the technical characteristics, one can talk about its colour, transparency and softness (sensorial characteristics) or the material's utility for hygienic environments and its appropriateness for several kinds of applications (how we 'use it'). Furthermore, one can emphasize its modernity, sobriety, robustness, prettiness; one can tell how a material conjures up grandparents, high-technology, or certain foods (classification into a meaningful category), or how someone gets happy or bored by materials (evoked emotions) (Karana & Van Kesteren, 2008). Put differently, just as in product experience, aesthetic, meaning and emotional experiences are pervasive in the discourse on materials in design.

Several studies emphasize the effects of user characteristics on product experience. They mainly state that next to aspects of product design such as form, function, colour, etc., characteristics of users inevitably shape the product- user experience (Alcantara, Artacho, Gonzalez, & Garcia, 2005; Hsiao & Chen, 2006; Margolin, 1997; Van Rompay & Hekkert, 2002). Some studies also underline how context of use influences the product experience. How we use a product, what type of product it is, or in which context we experience it, can play a crucial role in attributing meanings to the product (Cupchik, 1999; Mottram, 2004; Opperud, 2004; Schliemann, 1998; Smets & Overbeeke, 1995). Materials experience can also be influenced by user and context of use next to the material properties (Margolin, 1997; Rognoli & Levi, 2004; Suri, 2002; Williams, 2007). A material may evoke the meaning 'elegant' when embodied in kitchenware, but it may look 'cheap' or 'kitsch' when used for office accessories; or certain materials may be valued differently by different users of different cultures.

Based on a number of similarities to product experience, one can talk about materials experience. The main aim of this chapter is to answer the question, can we find descriptive items related to the three components of product experience within people's materials experience? The chapter reports on a series of interrelated studies performed to answer this question.

3 Collecting descriptive items

A thorough exploration of the descriptive items about materials, followed by a categorization of these items, was regarded as essential for identifying the main verbalizations of people (product designers and users) regarding materials in daily use. Descriptive items were collected from a variety of sources: magazines, other publications (books, published interviews, articles, journal papers), structured interviews and questionnaires. In preparation for the collection of descriptive items, and to collect as many descriptive items as possible, a list of considerations was drawn-up to guide the collection process.

- People may have an idea about a particular material (mentioned in Chapter 1 as meanings of materials behaving as if an intrinsic material property) even before its embodiment in a product.
- Materials may exist in various states in particular circumstances. As well as with a raw state of a material in nature, we may encounter its moulded version embodied in a sitting unit. Descriptive items can vary with these different material states. Evaluating a material as it was (that is, as a raw material), as a material sample, or embodied in a particular product may each influence people's descriptions.
- According to Crothers et al. (2004), changes in form affect product perception and overall descriptions. Likewise, the form of a single material sample may also be influential on how people evaluate that material; hence it may be crucial to include materials in different forms.
- Not only vision, but also other sensorial aspects including touch, sound, smell and taste can play vital roles in the appraisals of materials. For this reason, providing tangible samples of materials for evaluation, rather than 3D models on computer screens or 2D printed representations, may have the effect of augmenting people's descriptions.
- Evaluations of materials can differ depending on the profession of the participants performing the evaluation. For instance, while a designer may take a focus on the sensorial characteristics of a material, an engineer may habitually talk more about the technical characteristics of a material. Therefore, in order to enlarge the initial list of descriptions as much as possible, it can be valuable to incorporate participants from various domains (e.g. engineering, social sciences, applied sciences, etc.) in addition to the design domain.
- The diversity of descriptive items can be expected to be notable when participants

come from a design domain, and especially when a product under evaluation is their own design. Designers can be more descriptive about products for which they went through the materials selection process themselves or took place in an advisory committee for the ultimate selection.

- A few studies in the design domain have shown that expertise in a specific domain such as industrial design, engineering, medicine, etc. may be influential on the product appraisals of people from those domains (such as recognition and appreciation of a novelty in the domain) (Mondogon, Company, & Vergara, 2005; White & Smith, 2001). Thus effects on the variety of material descriptions collected can be expected: descriptions gathered from design students can differ from those provided by professional designers.
- Descriptive items may show incongruities that reflect the cultural background of appraisers (Desmet, 2002; Van Rompay, 2005). In other words, appraisers whose cultural backgrounds differ may offer quite different descriptive items for the same material.

Based on the considerations presented above, a series of five studies was conducted to collect a large sample of descriptive items about materials. Table 1 gives an overview of the studies.

Table 1. Summary of the five studies conducted to collect descriptive items.

	study 1	study 2	study 3	study 4	study 5
source	50 design students 8 professional designers	50 design students 8 professional designers	15 design students 8 professional designers	15 students from other disciplines	magazines books published interviews
stimuli	materials as words	materials as samples	materials in products	materials in products	materials in general

One of the important decisions made prior to the studies was on the kinds of materials that would be evaluated through the research. Most materials selection sources describe different kinds of materials in relation to their possibilities for engineering applications, principally because most of these sources originate from an engineering domain. For the present research, five material families were chosen on the basis of three criteria: materials that (1) are generally preferred by designers for use in their products, (2) are recognized straightforwardly by the public owing to their prevalence in general use, and (3) occur generally in materials selection sources. Wood, glass, ceramics, metal and plastics fitted well to these criteria and were chosen as the materials to be evaluated across each of the studies.

Although the first four studies were conducted with students at Dutch universities, their nationalities were not always Dutch to provide some cultural variety.

Study 1: Materials as words

Method

Participants

Fifty senior design students (26 male, 24 female), who had completed at least three years of the Bachelor in Design Education within the Faculty of Industrial Design Engineering of Delft University of Technology, and eight (4 male, 4 female) professional designers practising in the Netherlands voluntarily participated in Study 1.

Procedure

The participants were asked to describe (react to) the five materials - wood, glass, ceramics, metal and plastics- presented as written words with no accompanying pictures, samples or products. The study was conducted individually. Participants were instructed that there was no restriction on the form of the descriptive items they would offer, and that they could use sentences, adjectives, nouns, etc. They received a single-page questionnaire containing two open-ended questions: (a) How would you describe this material?, (b) How does it feel? Answers in Dutch were translated to English. All answers were analyzed and the descriptive items were collected.

Results

A total of 188 descriptive items were collected in Study 1. The descriptive items comprised technical and sensorial aspects of materials as well as some expressive meanings such as 'modern', 'sexy', and 'feminine'. The results of Study 1 showed that people have ideas about a particular material even before its embodiment in a product. The results are discussed more extensively in the overall evaluation section, together with the results from the other four studies.

Study 2: Material samples

Selection and Preparation of the Material Samples

To increase the variety of the descriptive items, a range of materials samples from each material family was sourced for Study 2 (for plastics: ABS, PP, PS, PU, PE, PC, PA (nylon); for wood: pine, oak, beech, black cherry; for glass: frosted glass, colored glass, Pyrex (borosilicate glass used in laboratory equipments, telescope mirrors), silica glass; for metal: stainless steel, aluminum alloys, copper, iron, zinc alloys; for ceramics: glass ceramics (cookware), and unglazed ceramic samples).

The physical form of the material samples was an important consideration. Relations between product form and attributed meanings to that form have been studied extensively by design researchers (Crothers et al., 2004; Hsiao & Chen, 2006; Muller, 2001; Van Rompay, 2005).

According to these studies, some specific form features (e.g. size, geometry, etc.) affect the overall impression of a product. For instance, rounded geometries can be used to suggest that a product has a warm and friendly character (Janlert & Stolterman, 1997), or products with a complex geometrical form can appear more high-tech (Chung & Ma, 2001). In one study it was shown that a material sample having either a rounded or sharp-edged form can be influential on people's attribution of meaning to the material (Karana, Van Weelderen, & Van Woerden, 2007). It was therefore important in Study 2 to use samples in different forms to increase the number and variety of descriptive items. Material samples were collected and re-formed into sharp-edge (plate) and rounded (ball) forms (Figure 1). A third sample type, in the form of a bowl, was also used in Study 2. The main reasons for using a bowl sample were its similarity of form and its compatibility with the different material families. In addition, bowls do not carry supplementary elements such as buttons or handles, and could be made of a single material type (no material combination).

Method

Participants

Fifty senior design students (22 male, 28 female) from the Faculty of Industrial Design Engineering of Delft University of Technology and eight (4 male, 4 female) professional designers practising in the Netherlands voluntarily participated in study 2.

Procedure

The study was conducted individually. Each material sample belonging to a single material family was given one-by-one to each participant. Since the participants could handle and manipulate the samples during the evaluation, they were asked to verbalize their descriptions aloud (think aloud protocol). The questions were similar to those used in Study 1. The descriptions were recorded and then deciphered in order to collect the descriptive items.

Results

The number of collected items from Study 2 was 304. Not surprisingly, the materials samples provided descriptive items that were not mentioned in Study 1. For a given material, the descriptive items differed with changes in the form of the sample. For instance, while the metal plate was often associated with factories and found aloof, the metal ball was appraised as warm and modern. A detailed evaluation of the descriptive items can be found at the end of this section.

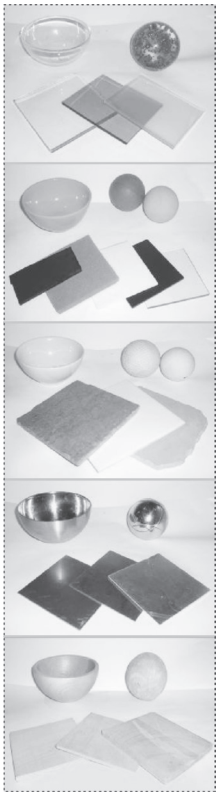

Figure 1. Material samples and bowls used in Study 2.

Study 3: Materials in products evaluated by designers

Selection of the product categories

It was expected that people would use the widest range of descriptions for materials embodied in their own products, owing to long-term personal experiences with those products. Moreover, the function and the use of products, as well as their form, were anticipated to affect the descriptions. Two related studies (Study 3 and Study 4) were conducted to test these predictions. In Study 3, disregarding product function, use and form, the participants were asked to select five of their own products, each made from a single material family (wood, plastics, ceramics, glass and metal). The participants were informed that there was no restriction on the function of the selected products. In Study 4, the participants were requested to select three types of products: (1) a small electronic product, (2) a product with a well-defined, distinct function such as 'for sitting'/'for storing'/'for eating'/ for lighting' or 'for writing on', and (3) a large electronic product (a full account of these product categories can be found in the description of Study 4).

Furthermore, for both studies, the participants were asked to select products with materials that they liked and disliked, and products that they considered their favourites. The reason for involving these additional categories in studies 3 and 4 was an assumption that people are eager to talk about the things they like or dislike. The full set of product categories used in study 3 were: (1) 'a product with a material you like', (2) 'a product with a material you dislike', (3) 'a product that is made of ceramics', (4) 'a product that is made of glass', (5) 'a product that is made of metal', (6) 'a product that is made of wood', (7) 'a product that is made of plastics', and (8) 'your favourite product'. Professional designers were asked to select one product for which they were actively involved in the materials selection process, and to additionally describe the materials embodied in that product.

Method

Participants

Fifteen master students (5 male, 10 female) within the Faculty of Industrial Design Engineering of Delft University of Technology and eight (5 male, 3 female) professional Dutch designers voluntarily participated in Study 3.

Procedure

The participants were informed with a letter about the product categories, alerting them to the products they were required to select prior to the research commencing. Study 3 took the form of an interview lasting approximately one hour, held at the home of each participant. The participants were asked to describe the materials of their selected products by answering the following interview questions: (a) How do you describe the material of this product?, (b) What do you like or dislike about the material?, (c) Why do you think the designer chose this material?, and (d) What would you change in this product- in terms of materials- if you were the designer?

The rationale behind (c) and (d) was that the participants were expected to be more descriptive if asked to assume an empathic approach. In other words, by acting as if they were the designer of the product, participants would be forced to ponder more deeply the material of the product and evaluate more critically the various aspects influencing materials selection. The interviews were audio recorded and analyzed in order to derive the descriptive items of materials.

Results

The overall number of products involved in Study 3 was 167 (e.g., picture frames, teapots, bowls, mugs, ashtrays, mobile phones, remote controls, hair brushes, plates, perfume bottles, mp3 players, DVD players, lighters, cameras, computer mousse, guitars, etc.). Two of the participants stated that they could not decide on their favourite product, therefore they did not select products for that category. In total, 216 descriptive items on materials were collected in Study 3.

The experiment was quite satisfying with regard to the number of new descriptive items that were collected. The participants emphasized technical properties of the product materials, such as heat conductivity, water-proofness, high impact resistance, etc., attributable to the intended use and function of the evaluated product. The issue of descriptive items being affected by whether the selected product was the participant's own design- or not- was elaborated. Professional designers were more descriptive about the products for which they were involved actively in the materials selection process. Of the total 216 descriptive items, 127 came from the professional designers.

Study 4: Materials in products evaluated by non-designers

In literature there are several studies revealing the differences between designers and non-designers in terms of their product appraisals (Bloch, Brunel, & Arnold, 2003; Lin, Lin, & Wong, 1996; Mondogon et al., 2005). The findings of these studies indicate that people with a design background are trained to verbalize their impressions about artefacts and that they develop a broad vocabulary for describing product variants. In Study 4, focus was given to the differences between non-designers and designers regarding their materials evaluations. The expectation was to collect new (different) descriptive items from non-designers (that is, from people whose profession is other than design).

Selection of the product categories

To be able to explore the assumption that material descriptions from designers and non-designers are different, six product types based on the following three distinctions were selected for evaluation:

- A functional product versus an 'emotional product': (product 1) a product with a distinct function and (product 2) a favourite product;
- A product mainly touched during use versus a product mainly looked at during use:

(product 3) a small electronic product and (product 4) a large electronic product;
- A product that is liked versus a product that is disliked: (product 5) a product made of a liked material and (product 6) a product made of a disliked material.

With the first distinction, the aim was to collect data about the differences between a functional product and an 'emotional product'. However, it was not desirable to influence the participants' descriptions by making the distinction obvious. Therefore, no definite words related to 'function' or 'emotion' were mentioned to the participants. Instead, four functions of products were defined, namely an object used for sitting, storing, eating or writing on (such as a table or a coffee table), and for lighting. The product type chosen to explore material descriptions of products that people have an emotional bonding with was their favorite product. The second distinction required two product types that were similar, but which differed in their user interaction. 'Electronic products' was chosen as an overall category, within which a sub-categorisation of 'small electronics' and 'large electronics' was made. 'Small electronics' was characterized as a product type that could be carried easily by people. This product type allowed an assessment to be made of the participants' impressions of materials used in electronic objects that they touched frequently everyday. The product type, 'large electronics' referred to products that could not be carried easily by users, and which instead are mainly looked at during use. The distinction between material descriptions of products that are liked and those that are disliked was mentioned directly to participants. With this distinction, the aim was to identify which material characteristics dominate people's descriptions of products. The participants were asked to describe two products with materials that they liked and disliked.

Method

Participants

Sixteen participants (11 male, 5 female) attended Study 4. Seven participants were students within the Technical University of Delft (three in architecture, two in applied sciences, one in aerospace engineering, one in civil engineering) and one was a student of medicine. Eight participants were employed in various jobs: programmer, advisor, policeman, researcher (four) and entrepreneur/ DJ.

Procedure

The participants were informed with a letter about the product categories, requesting them to select products in advance of the research. The study was conducted individually and took place at the home of each participant. No payment was given for participation and sessions lasted approximately one hour per participant. The participants answered the same questions posed for Study 3. Sessions were audio recorded and analyzed to collect descriptive items on materials.

Results

The participants selected 96 products (e.g. mobile phones, hair dryers, coats, sofas, beds, chairs, coffee machines, mp3 players, lamps, wallets, laptops, book-shelves, hand bags, palm PCs, coffee tables, sun glasses, etc.) falling within the defined categories. The total number of collected descriptive items on materials was 120.

Contrary to expectations, no clear differences were present between the descriptions of materials given by designers and non-designers in terms of the variety of the collected items. Not surprisingly, non-designers were found less expressive and capable in verbalizing their feelings about artifacts in comparison to the design students in Study 3. Even though the participants were asked explicitly about the materials of the products, it was apparent that they focused on the products more generally rather than just the materials aspect. Most of the descriptive items given by the participants therefore related to product form, function or use. However, for some particular functions (e.g. in the product type 'small electronics') the participants showed interest in the sensorial properties of materials, whereas for 'large electronics' they mostly identified technical aspects of the materials. For an extensive evaluation of the results, see Karana and Van Kesteren (2008).

Study 5: Collecting descriptions from related sources

Table 2 shows the sources which were explored in Study 5 with the aim of collecting descriptive items for explaining materials use within products.

Results

A total of 367 descriptive items were collected from the sources consulted in Study 5. The number of the collected items was significantly higher than in the previous studies, because

Table 2. Sources explored in Study 5.

content	source
50 interviews	International Design (ID) Magazine (Issues: Feb 2003, Jan/Feb 2004, Mar/Apr 2004)
40 product descriptions	International Design (ID) Magazine (Issues: Jul/Aug 2005; May/Jun 2005, Mar/Apr 2005(Vol 52); Jan/Feb 2004, May 2004, Jun 2004, Jul/Aug 2004, Sep/Oct 2004, Nov 2004 (Vol 51); Feb 2003, Apr 2003, Jun 2003 (Vol 50))
12 interviews	London Design Museum Website
5 interviews	Design Magazines - Juicy Salif by Philippe Starck (Alessi) - Watch by Philippe Starch (Fossil) - Senseo by Joost Alferink (Philips & Douwe Egberts) - Heineken bottle by Ora Ito (Heineken) - iPod by Jonathan Ive (Apple)
231 product descriptions	Materials for Inspirational Design Series - Metal (44 product descriptions) - Plastics (76 product descriptions) - Ceramics (36 product descriptions) - Wood (40 product descriptions) - Glass (35 product descriptions)

most of the explored sources in Study 5 put emphasis on the technical aspects of materials. Moreover, because English was the language in most of the explored sources, several of the descriptive items collected were synonyms of previously collected items. For instance, the items indigenous (referring to local), sturdy (referring to robust) and vulgar (referring to rude) were collected for the first time through Study 5.

Overall evaluation: Classifying the descriptive items

In studies 1 – 5, materials were presented in various modalities (as words, as samples, in products) and appraised by different groups of participants. The last study (5) was a thorough exploration of existing material related sources. The main aim of the studies was to generate a comprehensive list of descriptive items for exploring people's materials experience. In order to create the list, the collected items from each study were merged. After eliminating similar items (e.g. cold was mentioned in all five studies and counted only once in the final list), the final list consisted of 687 items (Appendix 2.1).

The list of items was thoroughly analyzed with the cooperation of experts in the fields of technical properties of materials (a material engineer), sensory characteristics (e.g. sound expert, smell expert) and product experience. The full 687 items were classified into seven descriptive categories, drawing upon the related literature summarized in Section 2: (1) use descriptions, (2) manufacturing process descriptions, (3) technical descriptions, (4) sensorial descriptions, (5) expressive/ semantic descriptions, (6) associative descriptions, and (7) emotional descriptions. Figure 2 indicates the distribution of the 687 items over these seven categories. Certain items with multiple meanings were counted in more than one category (e.g. 'cold' was used for sensorial and expressive /semantic categories). Figure 2 shows that the sensorial (n= 200) and expressive/ semantic descriptions (n= 219) are close in size. The expressive/ semantic category has the largest size among all the categories. Only 33 distinct manufacturing process descriptions were collected, which is the smallest size among all the categories. The next section addresses the definitions of the seven descriptive categories in relation to materials experience.

4 Seven descriptive categories in material appraisals

Use descriptions of materials

Use descriptions of materials refer to a specific product or a unique environment in which a material is employed for a particular purpose. Participants sometimes correlated a material to use circumstances and gave descriptive items related to the appropriateness of that material to the circumstances that they mentioned. This quotation from one of the conducted studies is a good example of a use description raised in the studies: "this material is used in slippery floorings in order to avoid accidents". The participant indirectly reveals that the material has a non-slippery tactual feature, which is a sensorial property. Nonetheless, instead of explaining the material by directly referring to its sensorial properties, the participant emphasizes the end use (application) of the material.

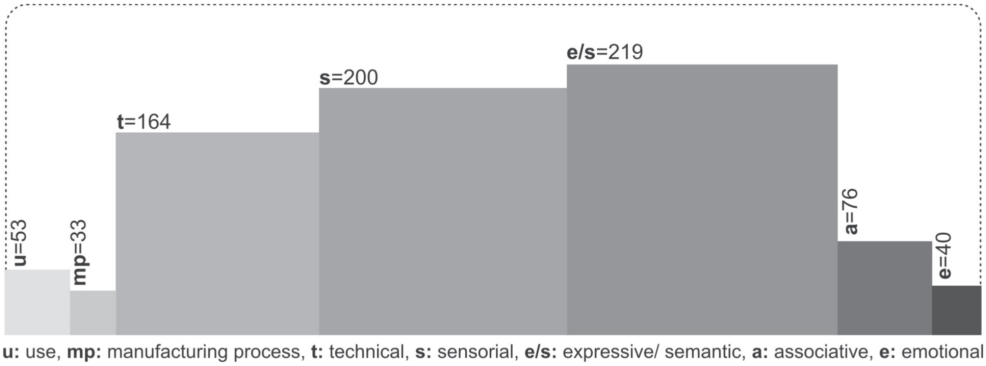

Figure 2. Distribution of the entire set of items (n= 687) over the seven categories.

Since form and function are two of the most important product appraisal aspects, descriptions regarding the form- function- materials interactions were also counted as use descriptions. The following are further examples of use descriptions of materials: for take away lunchboxes, used as a structure material, used as a construction material, used in kitchens, used in bathrooms, used for toys, useful, functional, used as a living room material, for organic forms, for eating from, for everyday products, for model making. It can be seen that the use descriptions have some phrases in common, e.g. 'for', 'used as', 'used for', 'used in'. These phrases were beneficial for identifying and differentiating use descriptions from associative descriptions. However it was quite a challenge to draw precise borders between use and associative descriptions. To complicate matters, it was noted that material descriptions change over time on the basis of the duration of use and personal significance. For instance, when asking participants to describe a material sample, they mainly explained the sample with the aid of probable use scenarios based on their knowledge or previous experiences (e.g. this material is used as a structure material). However, when the participants were asked to describe materials of their own products, their explanations are primarily related to the values of those materials for them personally, or how useful they are in contexts that they have experienced first-hand.

Manufacturing process descriptions of materials

Manufacturing refers to the making of things for use and sale by using tools or manual labor. In industrial design, the term refers to a vast range of human activity, from hand craft to high tech, which is commonly applied to industrial production, in which raw materials are transformed into finished products on a large scale. The manufacturing of a product involves many intermediate processes required for the production and integration of individual product components, such as joining (assembly) and finishing (e.g. surface treatments including glazing and painting). The Cambridge Engineering Selector (CES) contains information for the most commonly used 19 joining processes, 20 shaping processes and 23 surface treatment processes, which were used for distinguishing manufacturing process descriptions in this study.

The choice of manufacturing process depends basically on the material, on the intended form, on the required size, precision and surface finish. The descriptive items on the list related to manufacturing processes of materials basically focusing on two critical points: (1) the manufacturability of the material by means of a particular process (e.g. injection mouldable material) and (2) the probable process used for the primary production of the appraised product (e.g. moulded). The first point is connected to the technical characteristics of a material, which enable or rule out the application of certain production techniques. The second point is a direct reference to a manufacturing process by which a material becomes embodied into a component. The participants were able to perceive the type of manufacturing process or surface treatment used through the help of sensorial characteristics of the products (e.g. the wall thicknesses, mould (production) lines, surface texture, etc.). In other words, manufacturing process descriptions of materials are related both to technical properties of materials and to the intended aesthetic experience. Therefore a dilemma was encountered involving whether a particular descriptive item expressed a sensorial characteristic or a manufacturing process. Instead of making this choice for each item, the decision was taken to categorize all items expressing the applied production or treatment techniques for the appraised product (e.g. glazed, polished, galvanized, etc.), and also the shaping and joining processes (mass produced, cast, moulded, glued, etc.) as manufacturing process descriptions.

Technical descriptions of materials

When a material is sought by name in any kind of selection source, such as an online database, a handbook, etc., the technical data on the material is the most easily accessible. Such data is largely numeric; that is, it is quantifiable. Each material can be thought of as having a set of technical properties, which can mostly be directly derived from the chemical structure of the material. These properties form a multitudinous list. Materials selection sources compile the most important properties required for engineering design. Ashby (2005), as an example, offers some technical materials properties entitling them as 'design- limiting materials properties'. Ashby's list was utilized for identifying the technical items in the research. Strength, impact resistance, heat conductivity and reflection coefficient are some examples from the technical descriptions list.

Sensorial descriptions of materials

Descriptive items making reference to interactions between materials and users through the five senses- sight, touch, smell, taste and hearing- were defined as sensorial descriptions, such as smooth, cold, flowing (tactile aspects) and matt, translucent, shiny, red (visual aspects). Sensorial descriptions are especially related to one of Hekkert's experiential components: aesthetic experience (gratification of the senses) (see Section 2). Following his definition, sensorial descriptions must also encompass perceptual analysis of the sensorial inputs, not just straightforward reporting of sensory information. Therefore, descriptive items referring to gratification of the senses (aesthetic experience), such as beautiful surface and ugly colour, fall under the category of sensorial descriptions of materials.

In some particular cases sensorial items can be defined both technically (quantifiable) and subjectively. Hardness clearly exemplifies one of these cases. Hardness is resistance to indentation and scratching and it is directly related to the technical properties of materials as H. Softness is related to stiffness (S) - or rather, to lack of stiffness. The stiffness of a material in a given shape is defined as proportional to its modulus E, another technical material property. S = EH: Consequently, if S is small, the material feels soft; as S increases it feels harder (Ashby, 2005). Even though the hardness/softness of a material can be measured and quantified, the conception and perception of hardness or softness can vary from person to person. The measured hardness of a material may not necessarily match with people's perceived hardness of the same material.

Sensorial items can also be used as expressive/semantic items. *Cool*, for instance, with its dictionary definition, expresses a moderately cold temperature, somewhere between warm and cold, or lacking in warmth (Merriam- Webster Online). Alternatively, *cool* in daily language may manifest a not hasty, deliberate, self-possessed and dispassionate manner. In the context of materials, *cool* can either represent the perceived coolness of a material as lacking in warmth (sensorial), or metaphorically represent the unflustered or unemotional impression left by the material (expressive/ semantic). With this in mind, the items cold, warm and cool were included in both the sensorial and expressive/ semantic lists, depending on their contexts raised by the participants.

Expressive/semantic descriptions of materials

Semantics, deriving from sema (sign), refers to the aspects of meaning that are expressed in a language, code or other form of representation (Wikipedia). Semantics is also defined as the connotative meaning arising from subjective cultural and/or emotional colouration, in addition to the explicit or denotative meaning of any specific word or phrase in a language. Rooted in the semantics of language, product semantics is a theory developed in the 1980s by Reinhardt Butter and Klaus Krippendorff. They introduced the idea of a product as a text with levels of meaning. They define product semantics as "*the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design*" (1984). To sum up, product semantics deals with how people attribute meanings to products, which is similar to one of Hekkert's experiential components: experience of meaning (attribution of meanings to products) (2006).

The meaning of a product derives from the totality of its form, material, function, colour, etc. Thus the semantic dimensions of a product focus on the following questions (Vihma, 1995): *What does the product represent? How is the purpose of a product expressed or presented? In what kind of environment does a product seem to belong?* The answers to these questions cover the product's pragmatic (practical) dimension regarding its purpose and function. Mono (1997) divides the semantic functions of a product into four groups: (1) to describe purpose, mode of operation, (2) to express properties, (3) to exhort reactions, and (4) to identify a product, its origin, kinship, location, nature or category. It is useful to consider an example product, in this case a vacuum cleaner (Figure 3), to discuss the semantic functions of a product further. The product describes a mobile machine due to its visible wheels and roller; it expresses a friendly and gentle manner because of its curved top surface, smiling face figure and the separation of the body into two sections by two different colours (as the black part looks like the hat of the machine). Furthermore, there is a one clear exhortation in this product: the transparent part of the vacuum pipe, which is an exhortation to lift the handle and see the vacuumed pieces flow through the machine. The product and the manufacturer are identified by the name- Henry. Mono emphasizes that it is sometimes difficult to distinguish among the four functions. For instance, identifying can overlap with expressing, and exhortation can overlap with description.

Figure 3. The Henry vacuum cleaner.

Materials can be used to build one or more of the semantic functions of a product. For instance, the transparent material of the vacuum pipe contributes to the exhortation function of the Henry vacuum cleaner, whilst the red shiny plastic expresses a warm and friendly character. Likewise, a particular material can be used as a means of identity for a particular product. 'Neoprene bottle holder' exemplifies one of these cases (Figure 4). Herein, a material is used for identifying a specific brand (in this case BUILT NY), based on the use of a unique material within a given product sector.

In this way, it is possible to refer to a material's expressive semantic functions in a certain product. Various properties of materials may be combined in order to communicate semantic functions. For example, there may be a correlation between weight, thickness and slimness of a material, and the association of good or poor quality (MacDonald, 2001). For the purposes of this present research, *expressive semantic descriptions of materials* elucidate the qualities that a specific material expresses. In other words, the kinds of meanings we attribute to materials after the initial sensorial input.

When people explain what a particular material expresses (to them), they frequently use

Figure 4. Neoprene bottle holders.

words similar to those used for describing a person; e.g. the metal surface looks elegant and aloof. Put differently, these expressive items are mostly personality characteristics, defined as "*stable and durable, non- physical qualities of a person on which he/she discriminate him/herself from others*" (Govers, 2004, p. 11). Products are suggested to have certain personality characteristics, on the basis that people use human personality characteristics to describe their impressions of a product (Govers, 2004). However, we assume that it is not easy to talk about a permanent or intrinsic material personality or an expressive meaning. A common thread throughout this study is that the expressive meaning of a material differs depending on the product in which the material is embodied. On the other hand, some expressive meanings appear to transcend product sectors and 'behave like' an intrinsic material characteristic, such as 'wood is cosy' or 'metal is modern'. In this study, all personality characteristics, e.g. aggressive, sexy, modern, sober, etc. were counted as expressive/ semantic descriptions.

Associative descriptions of materials

Associations in the context of products are defined by Ashby and Johnson (2002) as the things a product reminds us of, the things a product suggests. The associative descriptions of materials require retrieval from memory and past experiences, and finding the things a particular material brings to mind, such as the association of porous polyurethane foam with a piece of cheese, or the association of colourful, transparent, resilient plastics with childhood jellybeans. The items under this category mostly started with *I associate this material with*, *this material reminds me*, or *it is like*, etc. Williams (2007) in his article, The iPod and the Bath Tub, states that everybody perceives the iPod as clean because its materials reference is a convention of cleanliness that everybody interacts with everyday: a bathroom. He adds that people associate the iPod's pure white surface and smooth touch material with the shiny white porcelain of a bathtub and the reflective chrome of the faucet on a washbasin (Figure 5).

Osgood et al. (1957) emphasize that a basic distinction must be drawn between the meanings of a sign and its associations. According to them, white is the most common association

Figure 5. The iPod's material is associated with cleanliness and bathtubs.

of black, but it does not follow that white means black. The same notion is useful for separating associations and expressive meanings (semantics) in material appraisals. However, the conducted studies showed that some material associations are made in response to certain qualities of materials conveyed as expressive meanings, such as associated with high quality, toy- like, business- like, associated with factories, etc. These associations are commonly used by people for describing a particular material and will be included in further studies.

Emotional descriptions of materials

Emotional descriptions of materials are defined as the subjective feelings of people (Desmet, 2002) towards a material (that is, how a material makes us feel). People's emotional responses, delineated also as reactions to meanings, are triggered by our thoughts, beliefs and attitudes about the situations or events (Demirbilek & Sener, 2003). Thus, an emotion is a result of a cognitive process, which arises often unconsciously and automatically (Desmet, 2002). Desmet defined a set emotions often elicited by product appearance. These were useful in this current research as a base for grouping emotional descriptions of materials. "*This material is boring*" or "*this material surprises me*" are two examples of emotional descriptions of materials.

5 Discussion

The main question of this chapter was: Can we find the items related to aesthetic experience, experience of meaning and emotional experience in people's material descriptions? Following a series of five studies, it was possible to classify collected descriptive items of materials (n= 687) into seven descriptive categories. Items referring to aesthetic, meaning (semantic) and emotional experiences were found within the categories. The first three categories (use, manufacturing process and technical) are not experiential categories. They are mainly related to the performance of the material, its utilitarian application and its processing. However, it should be recognized that there is a link between use and associative descriptions, and between manufacturing process descriptions and sensorial descriptions. The fourth category (sensorial descriptions) refers directly to aesthetic experience. The fifth and sixth categories (expressive/semantic and associative descriptions) jointly comprise the experience of meaning. The seventh category (emotional descriptions) refers directly to emotional experience. Figure 6 summarizes the findings of the studies reported in this chapter. It depicts the three types of stimuli used in the five studies: materials as words, material samples and materials in products, and the seven descriptive categories found in materials appraisals. On the basis of the experiential categories found in people's material descriptions, a definition of materials experience can be offered: materials experience is the whole series of effects elicited by the interactions between people and materials in a particular context.

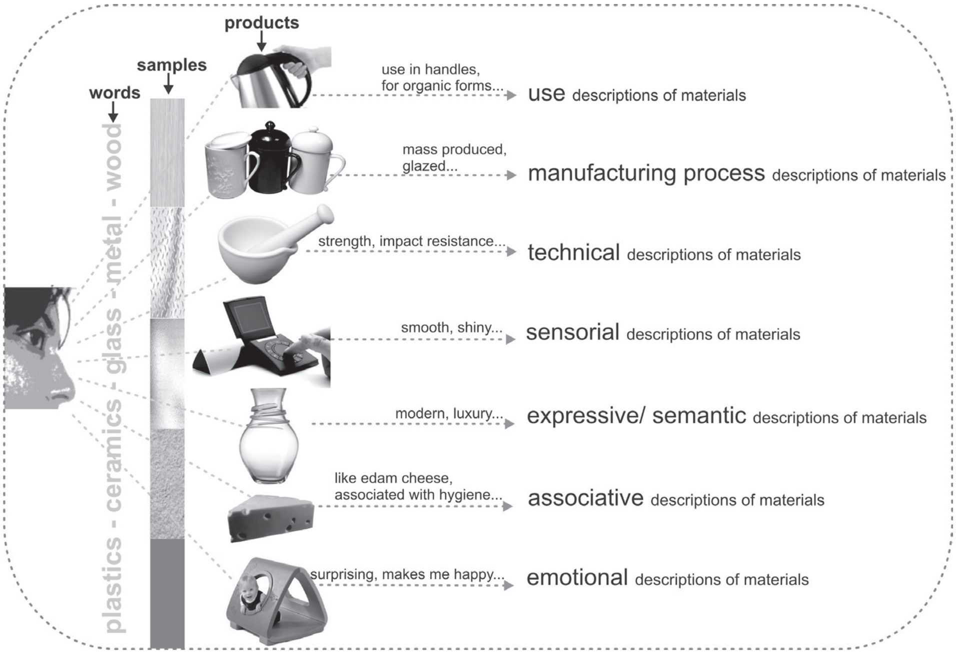

Figure 6. Seven descriptive categories in people's material appraisals.

Endnotes

1 An extensive description of this study can be found in Karana and Van Kesteren (2008).

2 One of the most important materials selection software databases is CES: Cambridge Engineering Selector (1992). It is a remarkable tool centered on methods developed by Mike Ashby and colleagues at Cambridge University (UK) and Granta Design. It combines three principal functions: (1) straightforward search for information, material properties, process methods, suppliers, and so on; (2) a systematic approach for analysis of material and process information and optimal selection; and (3) modeling of complex properties such as creep or fatigue, or of process cost.

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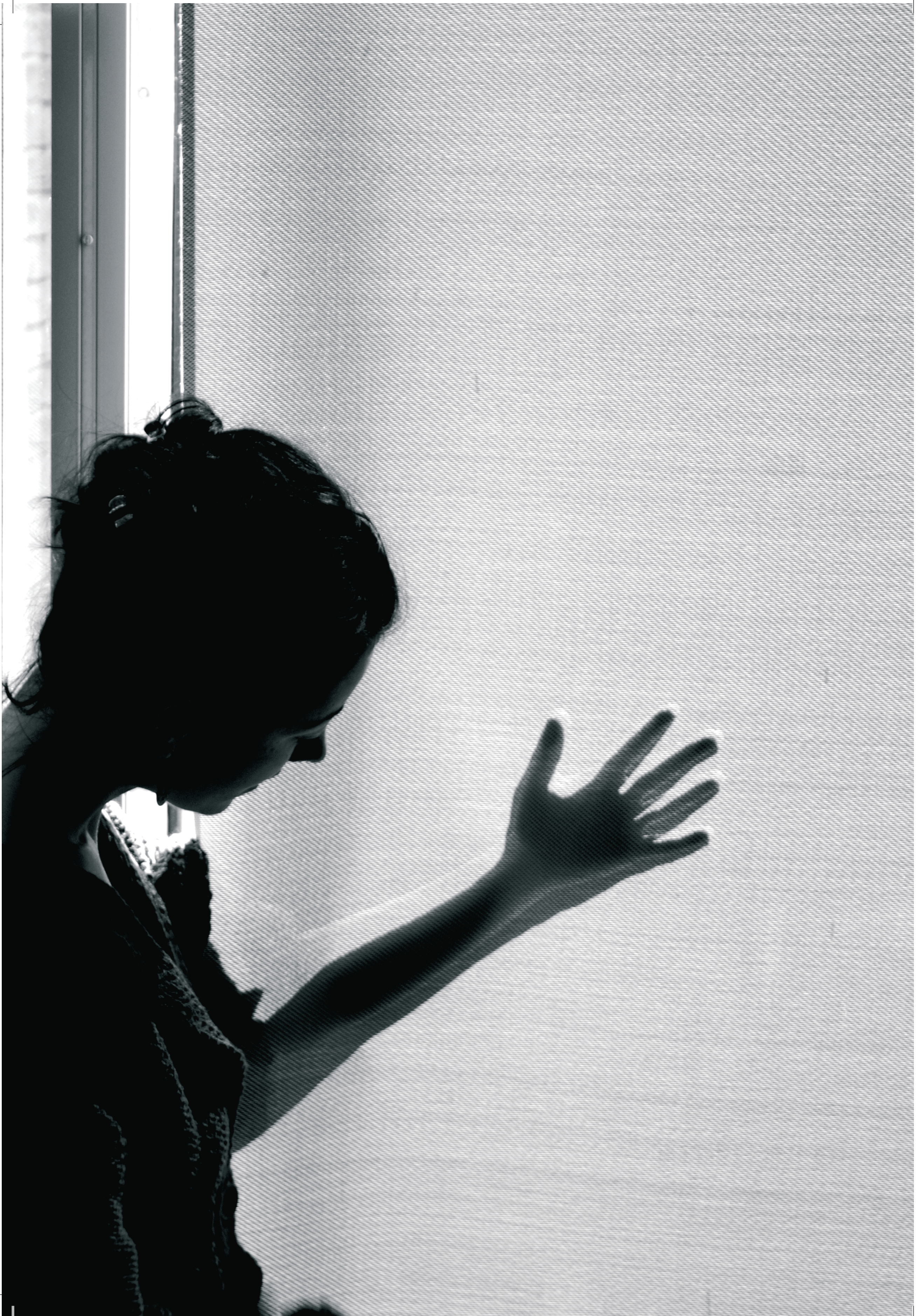
General Conclusion :: Part I

People encounter a world of different materials everyday: they touch materials, associate them with other things, attribute meanings to them, love some and hate others. The series of studies reported in this chapter were a first attempt at defining materials experience and descriptive categories in people's material evaluations. The classifications of material descriptions collected through the studies were taken as a basis for the remainder of the research and are utilized at different stages throughout the thesis.

The studies showed that when people are asked to evaluate a material, the descriptions they offer may be related to technical and sensorial properties of materials, or to intangible characteristics such as meanings (e.g. modern, cozy, sober) or emotions (e.g. love, fear, surprise). The findings of the studies provoke an interesting question: Why do people utilize 'use descriptions' for one material and other descriptions, such as sensorial, for another material? Giving a simple answer to this question is impossible, as researchers in the design field generally agree that the appraisal of a product (and its embodied material) is based on the consumer's past experiences and their personal tastes, interests, moods, etc. (Crilly et al., 2004; Krippendorff & Butter, 1984; Vihma, 1995). Additionally, the appraisal of a material must take into account the product and its context of use.

One of the most interesting findings of the studies reported in the second chapter was that people tend to describe materials in terms of their sensorial properties and the meanings they evoke. 'Meanings' was the descriptive category most frequently used. Obviously, we attribute meanings to materials and these meanings play an important role in our appraisals of materials. The second part of the thesis focuses on these meanings by exploring the kinds of aspects that affect the meanings we attribute to materials, i.e. when we think that a particular material expresses a certain meaning.



PART II
attributing meanings to materials

In the previous chapter, descriptive categories in people's material appraisals were identified in order to relate them to the three experiential components in product experience: aesthetic experience, experience of meaning and emotional experience. A total of 687 descriptions were collected and classified into seven descriptive categories: (1) use descriptions, (2) manufacturing process descriptions, (3) technical descriptions, (4) sensorial descriptions, (5) expressive/ semantic descriptions, (6) associative descriptions, and (7) emotional descriptions. The fourth category refers to the aesthetic experience. The fifth and sixth categories (expressive/ semantic and associative descriptions) comprise the experience of meaning. The last category (emotional descriptions) is related to the emotional experience. It was concluded that the experience of materials, or *materials experience*, unfolds along similar lines as the experience of a product as a whole, and can thus be defined as the series of effects elicited by the interactions between people and materials in a particular context. Now in Part II, we focus on experience of meaning and aim to answer the following question: How do materials obtain their meanings?

Chapter 3 is based on:

Karana, E. and Hekkert, P. (2008), *Attributing meanings to materials*, 6th International Design & Emotion Conference, Hong Kong.

3

the [meanings of materials] model

1 Introduction

Products convey meanings. A kettle may look *sober* or a tea cup may strike one as *traditional* or *nostalgic*. A product may be attributed different meanings through the material it is made of. Simultaneously, a particular material may bring to mind different meanings when used in different products. How a material is evaluated and what kinds of meanings it expresses may have a strong influence on people's appraisals of products. In this chapter, we aim to find the key variables in meaning attribution to materials.

This chapter consists of three joined studies with three different groups of people, involving a thorough assessment of 75 products and their materials. In the next section, different perspectives on how meanings are created, how materials are used for creating meanings, and what we mean by 'meanings of materials' are discussed. In the third section, three focus group studies used to generate data are described. On the basis of the focus group results, the fourth section identifies five ways in which materials obtain meanings. The findings are finally used to build a model covering the key variables that jointly contribute to a material's meaning.

2 Creation of meaning

There are many definitions of meaning stemming from different disciplines, each dealing with language, psychology, behavior and experience. The proponents within disciplines do not always agree with each other, with the result that many more definitions within a single domain become engendered (Osgood, Suci, & Tannenbaum, 1957). Nevertheless, definitions of meaning, in general, are apt to simplify how humans tend to relate one thought to another. In linguistics, meaning is the content carried by words or signs exchanged by people when communicating through language. Meanings may take many forms, such as evoking a certain idea, or denoting a certain entity.

One who is interested in meaning creation encounters three main perspectives in literature: (1) a perspective taking the object as the center of meaning creation, (2) a perspective taking the individual as the centre of meaning creation, and (3) a perspective taking the interaction between object and individual as the centre of meaning creation. We will not try to prove one of these perspectives is better than the others. Because, firstly, to be capable of making a rigid comparison between these perspectives requires an intensive exploration and understanding of each perspective beyond what is feasible for this thesis. Secondly, each perspective partly focuses on different kinds of meanings (e.g. functional meanings, figurative or expressive meanings) to different extents (Van Rompay, 2005). Nevertheless, it is important to briefly review the main ideas behind the three perspectives, in order to explain the approach adopted for the studies reported in this thesis.

Object- centred perspective

According to the object- centred perspective, meanings are primarily conveyed through the object. This approach embraces direct perception, which is simply defined as the detection of information in an environment without recourse to inference or memory. Direct perception originates from *Gibsonian Psychology*, which is usually termed *Ecological Psychology*. Gibson (1979) and the proponents of the ecological view stress that knowledge of the world is unaided by inference, memories, or representations. Gibson argues that stimulation brought about by objects is very rich and provides such a precise specification of an environment or entity that a perceiver needs only to detect this information, and not to elaborate on it. According to the Gibsonian approach, it is not what is inside the head that is important, but rather what the head is inside of (Michaels and Carello, 1981). Accordingly, Gibson introduced his well-known term 'affordance' as a quality of an object, or an environment, that suggests to an individual how to perform or achieve an action (Gibson, 1979).

The methodology used for understanding the meaning creation followed at the beginning of the 20th century divided 'the object' of study into a set of elements that could be analyzed separately with the objective of reducing the complexity of this object and understanding the parts of a whole (Sternberg, 2003). Contrary to this methodology, the school of Gestalt practiced a series of theoretical and methodological principles that attempted to understand the object as a whole. The fundamental principle of Gestalt theory is the law of prägnanz (German for conciseness), which states that we tend to structure our experience in a manner that is regular, orderly, symmetric, and simple (Wertheimer, 1938). In line with prägnanz, Gestalt psychologists attempt to propose a number of laws (Gestalt laws) that hypothetically allow us to understand our inborn tendencies in perceiving the world and its objects (Wertheimer, 1938). The *Law of Symmetry*, for instance, supposes that symmetrical images are perceived collectively in spite of distance, or the *Law of Similarity* proposes that the mind groups similar elements (which might depend on relationships of form, colour, size or brightness) into collective entities or totalities (Wertheimer, 1938). According to both Gibsonian and Gestalt approaches, perception of the environment is direct and both approaches focus on perception-action related meanings, not figurative ones. However, while the Gestalt approach explains direct perception in terms of the functioning of the nervous system, and accepts memory as the primary internal contributor to perception, the Gibsonian approach assumes that meanings are not limited to a present instant captured by a retinal snap-shot. The stimulus, or information received through vision, takes the form of a transforming optic array (optical flow or transpiring event) (Michaels and Carello, 1981). Perception is simply the detection of this information and an ongoing activity of knowing the environment and entities contained within. In brief, according to the object- centered perspective, meanings of objects are not attached to a specific perceptual system and they are primarily related to the formal properties of objects such as lines, shapes, colours, etc. This approach rejects the dualism of individual and environment/entity.

Individual- centred perspective

In contrast to object- centered perspectives, individual- centred theories conceive of perception as primarily mediated and indirect. The information detected from an environment and objects is processed with the intervention of memories and representations. In this respect, proponents of the individual- centered approach assume that objects represent information and what matters is how individuals process this information; thus meanings are considered as the constructs of the mind (Van Rompay, 2005).

Researchers became increasingly interested in the individual- centred approach in meaning creation with the rise of cognitive science, which accepts the mind as having a certain conceptual structure. Neisser (1967), one of the most influential names in cognitive psychology, defines cognition as all processes by which sensory inputs are transformed, reduced, elaborated, stored, recovered, and used. According to proponents of the individual-centred approach, these processes operate even in the absence of physical stimulation, such as through images and hallucinations (Josephs, 2000). In other words, physical stimuli and their associated features are not primarily necessary to evoke meanings. Instead, individuals' motives (goals, needs or instincts) and memories lead to meaning attribution. Accordingly, sensation merely communicates the formal sensorial characteristics of objects and environments, but does not extend to meaning attribution. A single sensation cannot identify an object, thus sensations must be combined with others contained in memory for an object to be properly identified and a meaning attributed (Michaels & Carello, 1981).

The role of memorizing images and associating them with certain meanings is emphasized in Peirce's theory of signs and semiotics, which deals with meaning creation through the process of signs detected by individuals. According to Peirce, a sign, once we recognize it as a sign, has an effect on our minds, such that we call to mind what is being referred to, even though that thing is not present to perceive. Particular associations of emotion, mode or tone are evoked (Atkin, 2006). Semanticists differ on what creates meaning in an expression. For example, a bag is a container used for carrying items. This is a bag's primary function, which is its *literal meaning* or *denotation*. But a bag may also have many figurative associations such as how it is used in special events as a luxurious accessory, or how it is associated with a certain group of people. These refer to a bag's *figurative function* or *connotation*. In semantics, the relation of signs to situations and behaviors is called (sociological) *pragmatical meaning*, and the relation of signs to other signs (linguistic) *syntactical meaning* (Osgood et al., 1957). Both philosophers and psychologists have tended to be more interested in *semantical meaning*- the relation of signs to their significates. Semantical meanings gave rise to the theory of *product semantics*. Developed by Reinhardt Butter and Klaus Krippendorff in the 1980s, product semantics introduces the idea of a product being reducible to a text level of meaning. It mainly deals with how we attribute meanings to products. According to product semantics, we appraise a product in order to place it into a personally meaningful category. When we first perceive a product, attention is drawn to signs that help to identify and categorize the product (Krippendorff & Butter, 1984). Concerning meaning systems in product experience, a designer assumes the role of sender of messages (in the form of a product) and users assume the role of receivers of the message.

In order to know what a given sign denotes, the mind needs some experience of that sign and a community must agree on the meanings a sign (or sign systems) evokes. Van Rompay (2005) in his doctoral thesis mentions these meanings as learned meanings, which exist in a social meaning system as a context for mediating cultural knowledge. Opperud (2004) states that people interact with the world and participate in social activities, which lead to a continuous construction of common cultural and social meaning systems. Accordingly, if a child, for instance, visiting the house of his mother's old friend, is told that people living in that house are quite wealthy and highly educated, the child is introduced to a meaning system that later helps him/her navigate and appraise products associated with *wealthy* and *highly educated* meanings in a certain social and cultural context.

Interaction- centred perspective

In the third perspective, interaction- centred, it is stressed that neither individuals nor objects, but instead the interaction between individuals and objects, gives rise to certain expressions (meanings). According to one of the most influential proponents of the notion, Merleau-Ponty (1962), perception has an active dimension and our body is also a permanent condition of experience. He also underlines that a perceived object is inextricably tied to its environment (or background). Only after we integrate within an environment can we turn our attention towards particular objects within that environment and experience all the perspectives and meanings that objects can evoke. Merleau-Ponty emphasizes that our bodily involvement with things is always provisional and indeterminate. Therefore, our attention towards a particular object does not operate by clarifying what is already seen, but by constructing a new Gestalt oriented towards the object.

In concordance with Merleau-Ponty, Dewey (1980) stresses that interactions between individuals and their environment are the central point of meanings. He further claims that our symbolic expression and interaction are tied intimately to the pervasive aesthetic characteristics of all experience. Dewey takes experience in its broadest sense and calls it situation. In his words, situation is not just our physical setting, but the whole complex of physical, biological, social and cultural conditions that constitute any experience. According to Dewey, pervasive characteristics are not properties of objects, instead, the entire situation is characterized by pervasive qualities, and objects are distinguished in an experience out of the background of a pervasive qualitative whole (Johnson, 2007). Dewey explains his argument with an artwork from Picasso. He states that there is not a single quality (or qualities) which make a particular painting a Picasso. Instead, the overall impression of a painting defines it as a Picasso, "*the quality of the whole permeates, affects and controls every detail*" (in (Johnson, 2007, p. 73)).

Basing his argument firmly on Dewey's perspectives, Johnson (2007) argues that meaning is grounded in bodily experience; "*it arises from our feeling of qualities, sensory patterns, movements, changes, and emotional encounters*" (2007, p. 70). He adds that meaning is not limited only to bodily engagements, but that they are always the start and end points. The crucial importance of experience- *an ongoing flow of qualities and qualitative changes*- is often emphasized in Johnson's studies.

> So, we are living in and through a growing, changing situation that opens up toward new possibilities and that is transformed as it develops. That is the way human meaning works, and none of this happens without our bodies, or without our embodied interactions within environments that we inhabit and that change along with us (Johnson, 2007, p. 83).

According to Lakoff and Johnson (1980), embodied interactions may share a similar recurring structure of (or within) our cognitive processes. These structures are called image schemas and emerge from our bodily interactions, linguistic experiences and historical contexts (Johnson, 1987). The authors define image schemas as dynamic embodied patterns that take place in and through time. Johnson (1987), for instance, in the following passage, explains the dynamic nature of the *verticality schema* and how image schemes play a role in meaning creation.

> The verticality schema, for instance, emerges from our tendency to employ an up-down orientation in picking out meaningful structures of our experience. We grasp this structure of verticality repeatedly in thousands of perceptions and activities every day, such as

> perceiving a tree, our felt sense of standing upright, the activity of climbing stairs, forming a mental image of a flag-pole, measuring our children's heights and experiencing the level of water raising the bathtub. The verticality schema is the abstract structure of these verticality experiences, images and perceptions. Experientially based, imaginative structures of this image- schematic sort are integral to meaning and rationality (Johnson, 1987, p. XIV).

Summing up, proponents of the interaction-centred approach have not merely taken attention to the embodiment of meaning in overall experience but also to the patterns of feelings and to the nature of qualities that explain how things and experiences become meaningful to an organism. According to the interaction- centred approach, experience comes to us as "*unified wholes (gestalts) that are pervaded by an all encompassing quality that makes the present situation what and how it is*" (Johnson, 2007, p. 73).

Conclusions

Three perspectives on the construction of meanings from artefacts were reviewed in this section. It should be recognized that theories discussed under each perspective (object-centred, individual-centred and interaction-centred) acknowledge the contributions of others. The aim was not to show that one perspective is better than the others, but to explain the main notion followed in this thesis. Throughout the research, we accept the interactional approach as the primary notion, taking both object and perceiver into account in meaning attribution. Our main assumption is that meanings of materials are not fixed properties, but materials obtain different meanings in different interactions between people and materials, in different contexts, and these meanings can change over time. However, we assume that there are some patterns that pervade the attribution of a meaning to a material in a particular context for a particular group of people.

In our view, we attribute meanings to materials on the basis of the characteristics of a situational whole in which materials are experienced (as put forward by Dewey and Johnson). In this thesis, *characteristics of a situational whole refer to a meaning evoking pattern* in materials experience. A material's technical and sensorial properties, the product it is embodied in, its context of use, our memories, previous experiences, cultural values and emotions inevitably affect the kinds of meanings we attribute to that material. Taken together, these aspects may construct a meaning evoking pattern for an individual. In the research reported in this thesis, the aim is to support designers in the creation of intended meanings of materials. Taking all the previous points (in line with the interactional perspective) into account, we will not provide designers with certain ways for creating meanings, but make them realize the versatile and dynamic character of meanings of materials, stimulate them to detect the characteristics of situational wholes (or meaning evoking patterns) for each meaning-material relationship, and make them understand the key variables in a meaning-evoking pattern.

3 Meanings of materials

The study of meanings has been considered crucial in design thinking since the 1950s and early 1960s (see e.g. Dorfles, 1966; Osgood et al., 1957); Maldonado, 1961; Gugelot, 1962). Nevertheless, issues concerning meaning have always been difficult to pinpoint due to their subjective and dynamic character; that is, meaning attribution is influenced by people's (designers' and users') experiences, socio-cultural backgrounds, intentions, contexts, and the passing of time (Cupchik, 1999; Krippendorff & Butter, 1984; Mono, 1997; Oehlke, 1990; Vihma, 1995). Therefore, it has proved challenging to arrive at universal meanings attributed to a product based on that product's qualities, and to explore the attribution of those meanings with quantifiable techniques. In this regard, the book '*the measurement of meaning*' has been a pioneering study, in which the authors (Osgood et al., 1957) deal with the nature and theory of meaning and present a new and objective method for its measurement, which they call the *semantic differential*.

Semantic differential is not a specific test, but rather a general technique of measurement that can be adapted to a wide variety of problems in various areas. It has been used in a number of studies in design research to obtain the affective responses and attributed meanings to products; such as, table glasses (Petiot & Yannou, 2004), chairs (Desmet, 2002; Van Rompay, 2005), commercial products (Mondragon, Company, & Vergara, 2005), mobile phones (Chuang, Chang, & Hsu, 2001), cars (Desmet, 2002; Hsiao & Wang, 1998), micro electronic products (Chung & Ma, 2001), footwear design (Alcantara, Artacho, Gonzalez, & Garcia, 2005), kettles (Hsiao & Chen, 2006), mascots (Lin, Lin, & Ko, 1999) and so on. In these studies, the most frequently used product feature was *form*. Accordingly, the main aim was to find out the links between the significant form features of products and the affective responses of users. Throughout this research, we use semantic differential in order to explore meanings- materials relationships in material appraisals.

The researchers listed in the previous paragraph have contributed to the development of methods and tools for the evaluation of meanings carried by product features. The number of studies focusing on meanings expressed by products increased starting from the 1990s. For instance, Mono's book '*design for product understanding*' (1997) attempts to support product designers by developing a language of forms based mainly on the semiotic approach. Following the same approach, Vihma (1995), in her doctoral thesis '*product for representation*', has measured and evaluated various product features (e.g. technical and ergonomic data) for a semantic analysis of products. The aforementioned studies emphasize the necessity of understanding the translation of product features into attributed meanings, with the aim of guiding designers to create more comprehensible and user-friendly products.

In user-product interaction, several factors can be effective in attributing meaning to products (e.g. the product form, material, function, color, its context of use and its user, etc.). When we (first) perceive a product, we try to place it into a meaningful category and thus our attention is drawn to those signs emanating from the product that can help us to identify and categorize it (Krippendorff & Butter, 1984). Materials, being the substance of products, can deliver such signs. They affect the experience in user-product interaction. In the previous chapter materials experience was defined as *the whole series of effects elicited by the interactions between people and materials of products in a particular context*. Van Rompay (2005, p. 19), in his doctoral thesis on *product expression*, states that "*people talk about products in terms of expressive characteristics reflecting personality traits such as modesty and pride*". When people are asked to describe a certain material, they frequently refer to its expressive characteristics and these characteristics are grounded in different aspects of materials (and products). A particular material of a product, for instance, might express professionalism predominantly through its shiny, robust and smooth properties and the product's sharp edged geometry. Herein, shininess, robustness, smoothness and sharp-edge geometry cooperate and jointly contribute to a material's expressive character. Expressive characteristics (variously called figurative or abstract characteristics, see (Blank, Massey, Gardner, & Winner, 1984)) are not factually part of a materials' physical entity or appearance (i.e. a material is not literally feminine or masculine). An expressive character (or meaning) of a material is based on the interactions between an individual and his/her environment, including the product and its material, and can change over time.

In materials experience, in addition to expressive meanings (e.g. modern, sexy, sober, etc.) certain associative descriptions, which require retrieval from memory and past experiences, can also express particular qualities of materials, such as *toy-like*, *business-like* and *associated with factories*. These descriptions are commonly used in material appraisals and behave like expressive characteristics. Accordingly, meanings of materials in this research consist of expressive/semantic and specific associative characteristics, both of which are used for defining the qualities of materials. **Meanings of materials** are what we think about materials, what kind of values we attribute after the initial sensorial input in a particular context.

4 A study on how materials get their meanings

This section reports on a study that had the aim of revealing what kinds of aspects play a crucial role in people's attribution of meanings to materials, i.e. what the key variables of a meaning evoking pattern are. The study consisted of three focus group studies, each with different types of participants. The first study was conducted with academics with a specialty in materials in design and product experience, the second study with professional designers and the final study with non- designers. With the second study, we aimed to find out certain differences between design practitioners and designers in academia. After these two studies, a third study was conducted in order to explore the differences between designers and non-designers in their meaning attribution to materials.

The same procedure was followed in all three studies. Each group was asked to focus on the materials of products, and select five products that expressed pre-determined meanings particularly through their materials. The meanings selected for this study came from five conceptually different sets of meanings (see Chapter 4 for an extensive explanation): *aggressive*, *nostalgic*, *professional*, *sexy* and *toy-like*. The instruction was explained with an example: "*For instance, you found several products expressing the meaning 'sexy'. You should particularly focus on the material of these products and select one, of which the material plays a dominant role in conveying this meaning.*" The participants were informed that they could bring a visual representation of the product if it was not possible to bring the product itself.

In all three studies, the participants were invited to a focus group discussion. They were asked to bring the products (or visual representations of the products) to the focus group. To start off, the participants were first asked to group the products based on their meanings. In this way we could get a first impression on the similarities and differences of material properties belonging to the same meaning category. Next, the participants were asked to explain their choices. In doing so, the participants contributed to each other's descriptions and commented on the points they agreed on or not. They were encouraged to discuss the relations between products, materials, and associated meanings. After that, the products were evaluated separately, with the participants being asked if the same product would express a different meaning if it were made of another material. Throughout the focus group sessions, various aspects that play a role in the attribution of meanings to materials were discussed intensively. Discussions were audio-recorded and analyzed after the sessions.

Study 1: material appraisals by design academics and researchers

Participants

Seven design researchers participated in Study 1. Four were senior PhD students in their last years of research and two were Assistant Professors, all at the Faculty of Industrial Design Engineering of Delft University of Technology. One participant was working as a consultant on material advice.

Results

The participants explained their selections starting with the most difficult ones for them. *Aggressive* was stated as the most difficult meaning to convey through materials because they believed that aggressiveness is more related to the use of a product than to its material. Moreover, form and function of a product very much determine the aggressiveness of its material. All participants brought products that have potentially harming effects during use, such as a needle, a stapler, a fork, a model making knife, etc. (see Figure 1). Their choices thus reflected the literal meaning of *aggressiveness*, in terms of *behavior that is intended to cause harm or pain*.

Figure 1. Examples of aggressive products/materials.

According to the participants, products conveying *toy-like* and *professional* meanings were rather easier to find. All of the selected *toy-like* products were made of light and colourful plastics. In those products, plastics were mostly appraised as surrogate materials, replacing metal, wood, etc. that was used in the first, original versions of these products. The participants mentioned that a particular combination of certain material properties might evoke professionalism. The strong and lightweight coated aluminium used in a bottle was evaluated as professional by one of the participants (Figure 2). The same material could be appraised differently (i.e. as less or non professional) if it was heavy. The participant argued "*We know that this bottle is very durable and strong, which conflicts with its lightness. The combination of these two material properties- lightness and strength- conveys the professional meaning in this particular product.*"

Figure 2. An example of a professional product/material.

Most of the participants agreed on the pleasing effect of the *sexy* products when they experienced them tactually. On the other hand, the material of a golden flashy g-string, which was brought by another participant, was not considered *sexy* by the other participants. In this case the intention and the message were conveyed through the product materials in a very unsubtle way, which was found irritating. Appreciation of a material as *sexy* was found to be very personal, and expressed individuals' interests more so than other meanings. Moreover, attributing the meaning *sexy* to a material was found to be very context dependent. The biggest diversity in materials emerged in products selected for the meaning *nostalgic*, which is dominated by personal experiences. Nevertheless, a common property among the selected *nostalgic* materials was that they were all made of natural materials arising from plants or animals, such as wood, leather, stone, bones, etc. and carried a 'sign' referring to the past and representing the product's age, such as scratches on leather, or the smell of wood.

Study 2: material appraisals by professional designers

Participants

Four professional designers from a Dutch design company participated in this study.

Results

All of the participants agreed that a material of a *professional* product clearly supported the technical function and the use of that product. Moreover, the participants associated professionalism with coldness and distance, which led them to select metallic products. The context in which a material is experienced was mentioned as an important aspect. For example, the material of a product used in an office environment can be appraised as more professional compared with its use in a kitchen. The participants added that in professional products, it is rare to find a combination of more than two materials. They gave a few specific material names considered professional, such as Kevlar, titanium, smart materials, etc.

A leather armchair, a furry handcuff and a silk woman's dress, which were selected for the category *sexy*, were each made of materials soft to the touch. Two of the designers did not find the fluffy handcuff sexy at all. One of them explained that the object was apparently designed for sending a sex message to a specific target group: "*I don't find it sexy because I am opposed to this idea or I am not supporting a kind of sexual experience which involves handcuffs*". Another designer added that "*rather than sexy, I find it gay-like*". These comments are similar to the ones for the 'g-string' in the first study (Figure 3).

Figure 3. Polarised explanations were given for the g-string and the handcuff.

In the category *sexy* materials, there was one product for which the material was very different to the other selected products: a light bulb. In contrast to the other selections, which directly or indirectly referred to the experience of sex, the bulb metaphorically represented the designer's personal reflections on sex. In her words, "*the bulb is very delicate… you* *should handle it very carefully because it can break easily… and its semi-transparency gives it a mysterious feeling in that you can not completely see what is happening inside. And although the material is not soft, semi transparency gives the softness effect as well*". One of the designers emphasized that the leather chair, the fluffy handcuff and the bulb were combinations of a 'soft' and a 'hard' material, since they all carried a metal detail in their bodies (Figure 4).

Figure 4. Examples of sexy materials.

The designers associated *aggressiveness* with roughness (Figure 5). They looked for materials or products that could injure the user in an unexpected way. A very rough surface of a wall, for instance, might hurt bare hands if they are accidentally rubbed against it.

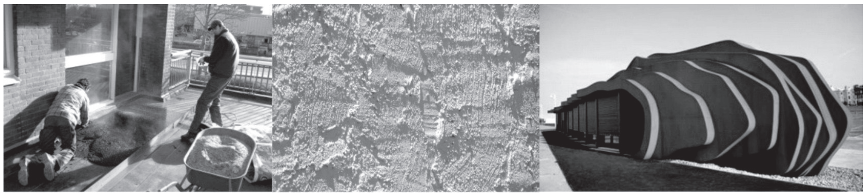


Figure 5. Examples of aggressive materials.

Even though shape obviously played an important role in conveying the meaning *toy-like* (such as for the classic rubber duck), when designers were asked to imagine the same products made of metal, they said that the product would hardly express the meaning *toy-like* (Figure 6). Importantly, it was very difficult for the participants to avoid the effect of colour on their product selections. In their words, colour was one of the major factors affecting the overall impressions of products and it was almost impossible to look beyond colour and to evaluate materials and products irrespective of their colour.

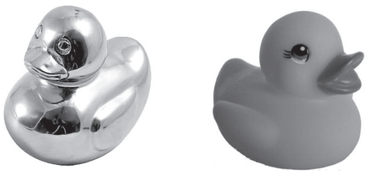


Figure 6. A rubber duck would express a different meaning if it was made of metal.

In general, the designers emphasized that their expertise could have been especially influential in interpreting the meaning *professional*. They stated that because of their design backgrounds, they could detect details related to high-tech manufacturing processes or expensive materials, both of which may be influential on communicating professionalism. Additionally, because the participants follow new events in the design domain, they could recognize a product made of a novel material and appreciate it. In contrast, the interpretation of sexiness, for instance, may be less affected by the participants' expertise and reliant more on personal tastes (or individual differences).

Study 3: material appraisals by non-designers

Participants

Four non-designers participated in this study: two secretaries, one electronic engineer and one software programmer.

Results

Metal appeared for the first time in the materials category *sexy*. The product in question was a sugar bowl made of a round shaped shiny metal (Figure 7). It had a matt plastic nipple-like brim, clearly expressing a sex related image. The participant explained his choice, "*The combination of these two materials- very shiny metal and matt plastic- contributes to the sexiness. Especially the plastic brim emphasizes the nipple form. If it was made of one type of material, the effect could be weaker I guess.*" Similar explanations for the effect of combining materials (or creating contrast by using two different materials) were made in Study 2 (see handcuff and bulb).

Figure 7. Example of a sexy product/material.

One of the participants explained that "*products that imitate existing ones look toy-like to me. The imitated aspect can be related to either function or material. Because plastics are used for imitating other materials, I think light plastic versions of originally metal (or wood, glass, ceramics) products convey the meaning toy-like.*" Following this 'definition', the participant suggested to change a product's category (a lamp) from *aggressive* to *toy-like* (Figure 8). The lamp, which was brought to fit the category aggressive, was appraised as *toy-*

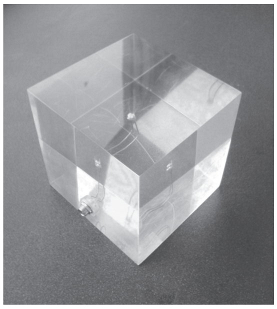


Figure 8. A lamp considered toy-like because of its glass-like plastic material.

like after discussions. They emphasized that "*It is meant to be a lamp but not functioning very well. It is meant to be glass but it is plastic. Shortly, it is imitating a glass version which probably works better. Therefore, it is definitely toy-like.*"

For the designers in Study 2, use of a novel material was often a sign of *professionalism* in products. Moreover, production details and good surface finishes affected the designers' decisions. Conversely, non-designers in this study associated professionalism with materials that fulfill their functions well in certain products. They did not mention production details, surface finishing or use of novel materials in their appraisals of materials.

5 Overall Discussion and Model Building

In general, the participants of all three studies emphasized that it was challenging to evaluate just the materials of a product in comparison to the entirety of a product. They recommended a modification in the task as 'select a material that is aggressive' instead of 'select a material of a product that is aggressive'. The important role of *differences* among users in attributing meanings to materials was emphasized throughout the whole discussion. Associations with a unique event (like Christmas) or a person (like grandmother) led to personal attachments with certain products. Moreover, context of use was one of the main aspects mentioned in meaning attribution to materials.

Figure 9 shows the products selected by each group for the given meanings. We could not observe major differences in the selected products between Studies 2 and 3. We were expecting to find differences between these two groups in their interpretations of *professionalism* in materials, but only a minor difference was observed. In contrast to the designers (Study 2), non-designers (Study 3) did not mention new materials (or material families) in their attribution of professionalism in materials.

Even though characteristics of products and materials obviously 'collaborated' to convey particular meanings, the characteristics involved depended on the intended meaning. For the

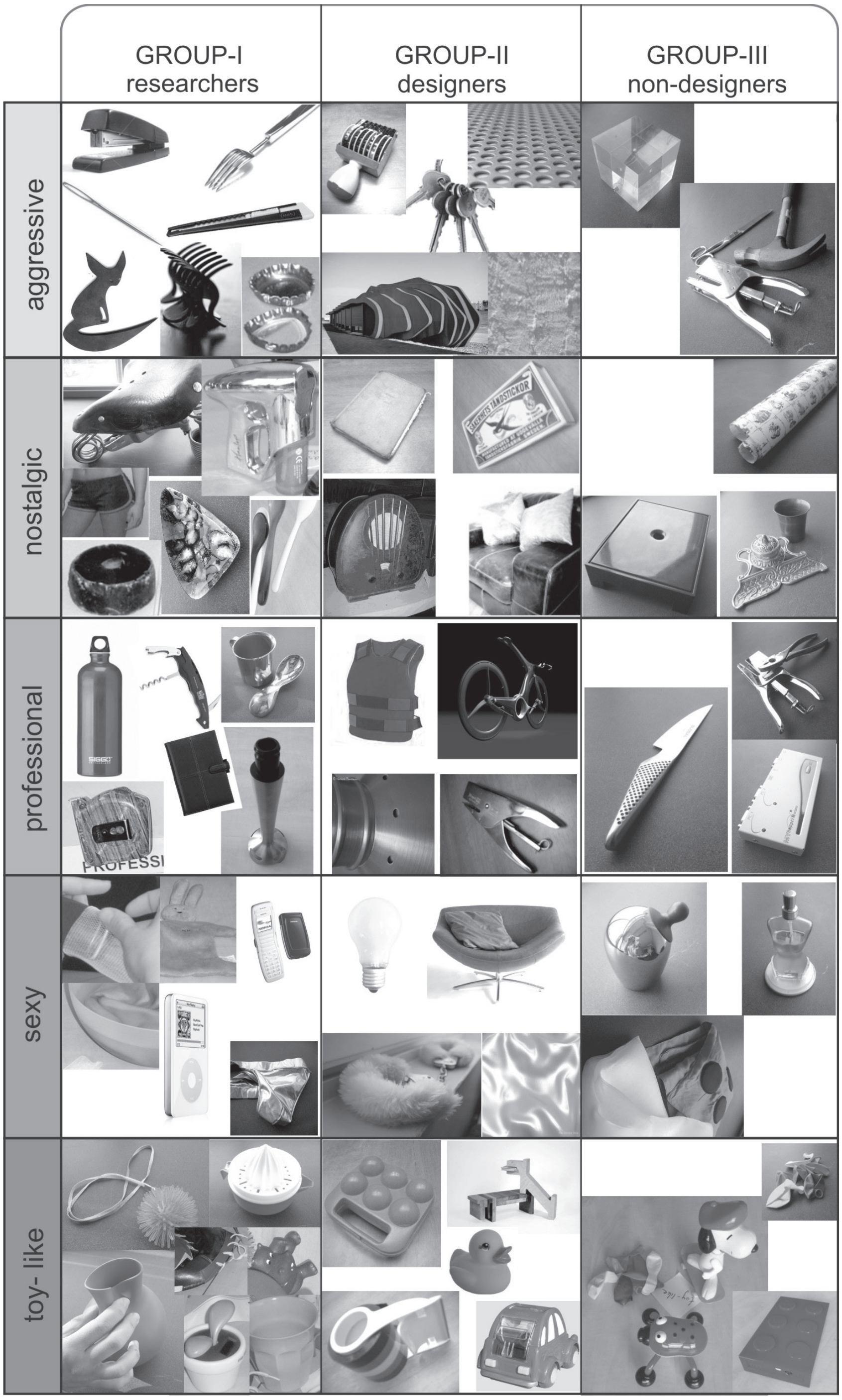


Figure 9. Selected products in the three studies.

meaning *toy-like*, for instance, the lightness of a material and the rounded geometrical shape of the product worked together to convey the meaning, whereas for the meaning *aggressive*, the hardness and coldness of a material and how it was used were the prominent

characteristics. Moreover, one of the most important findings of the study was: *materials obtain their meanings not only based on their technical and sensorial properties, but also through the products they are embodied in, through the users who contact with these products, and how or in which contexts these products are used*. We can elaborate on this result by identifying five main ways that meanings of materials are constructed.

(1) Meanings of materials based on material properties

'Material properties' cover the characteristics that distinguish a material from other materials. A material can be different from another material through its unique technical properties including strength, elasticity, heat conductivity, etc. that makes us place this material in a particular material family, such as metal. Users experience technical properties of materials as sensorial properties. In other words, sensorial properties of materials appear as moderators in material-user interaction, and they help us to appraise a material and attribute meanings to it. Summarizing, material properties refer to technical and sensorial properties of materials. With meanings of materials based on material properties, two different scenarios can be observed: (1) the material family (e.g. metal, plastics, glass, etc.) has a main effect on a material's meaning, and (2) a particular sensorial property of a material (e.g. glossiness, roughness, softness, colour, etc.) has a main effect on a material's meaning. In the first case, meanings attributed to a material family often become regarded as an intrinsic material quality, such as metal is cold and distant or wood is warm and homely. In the second case, a particular sensorial property (or set of properties) results in a certain meaning being assigned to a material. For example, smoothness and semi-transparency of a material might together connote sexiness, in which case both plastics and glass can obtain the meaning sexy (Figure 10). The material properties found effective in attributing meanings to materials can be summarized as follow:

Aggressive: hard and strong (materials that allow jaggedness in products), metallic colours, black, cold, rough

Nostalgic: natural materials (paper, leather, wood), old materials (Bakelite, copper)

Professional: new materials (Kevlar, smart materials), cold, smooth, dark colours (black), metallic

Figure 10. Smoothness and semi-transparency in two product/material examples.

colours, few materials, combinations of certain technical properties for enhancing function (e.g. combining strength and lightness)

Sexy: smooth, silky, velvet-like, fluffy, skin-like, semi-transparent, glossy, combinations of materials for emphasizing a part of a product

Toy-like: smooth, light (weight), bright colours (red, blue, green, yellow, orange)

Relationships between these detected sensorial properties and the given five meanings will be further explored in Chapter 5.

(2) Meanings of materials affected by product aspects (e.g. shape and function)

In a number of sources, it is emphasized that the selection of a material cannot be separated from the choice of shape (Ashby, 2005; Budinski, 1996; Edwards & Endean, 1990; Roozenburg & Eekels, 1995), which is in itself determined by the function of a product and the constraints of manufacturability. The shape and function of a product in which materials are embodied affects how we evaluate materials. A single kind of plastic, for instance, can be perceived as sober when it is embodied in an office accessory, and toy-like when embodied in a household product. Likewise, a material can be perceived as aggressive in sharp-edged products, or aggressive because the material is formed into repetitive shape elements associated with 'teeth' and 'biting', and therefore bring to mind aggressive behaviour (Figure 11).

Figure 11. Repetitive shape elements in example products.

In order to obtain a shape, material is subjected to manufacturing processes. According to Ashby (2005), the interaction of function, material, shape and manufacturing process lies at the heart of materials selection processes. How a material is processed or what kind of manufacturing techniques are used may have an important effect on the attribution of meanings to materials. This effect is not a direct one, but rather it is through the shape and sensorial properties that arise as a result of manufacturing processes. For instance, a polishing process (which is a surface treatment process) affects the surface quality of a material, and as a consequence may change the meanings attributed to that material. In another example, a particular process applied to a material, for example vacuum forming, might cause a very thin wall-thickness, which in turn might change the material's perceived quality.

(3) Meanings of materials affected by user characteristics

The assessment of products and their materials, and the attribution of meanings thereto, are related to past experiences and personal tastes of users (Krippendorff, 2006; Krippendorff & Butter, 1984; Mono, 1997). Moreover, demographic differences such as age, gender, education, income, etc. and cultural backgrounds may affect how people appraise materials and what kind of meanings they attribute to them. Ljungberg and Edwards (2003) explain the changing value of materials for various cultures, such as Scandinavian, Middle European and Mediterranean, with the example of villas made of wood. Although they are quite popular in Scandinavia, in Middle Europe such houses are often met with skepticism. According to Dormer (1990), who presents another example, some particular cultures do not favour plastics as kitchenware because it contradicts their understanding of what plastics are and how they perform. In the studies reported in this chapter, we observed that the attribution of the meaning nostalgic to a material entails recall of memories that are endearing to an individual's life. As a result, any material in any product has the possibility to be nostalgic: it is a matter of individuals' experiences (Figure 12). Likewise, a material may evoke the meaning sexy for an individual who associates that material with his/her personal sexual experiences.

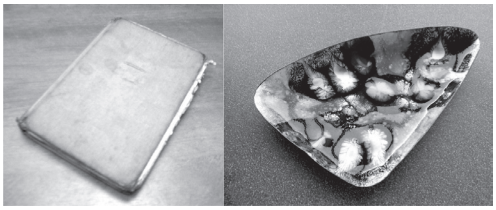


Figure 12. Any material can be nostalgic for a particular individual.

(4) Meanings of materials affected by interaction and use

The consequential experience of using a material/ product or how we interact with it can be very influential in appraisals of materials. Returning to a previous example, people associate an unexpected harm effect of a product or material with aggressiveness. Materials are appraised in a particular use scenario and possible effects or consequences are predicted through previous experiences. A rough wall, for instance, is expected to hurt the skin, or a heat-conductive metal handle of a pan is expected to burn one's hand during use (Figure 13). Fisher (2004) emphasizes how plastic objects start their life delighting us with their pleasurable sensorial properties such as smoothness and glossiness, and, after a short time, how they begin to disgust us with the deterioration of their properties such as changing colour, taking the smell of the 'food' they contain, etc. Meanings attributed to a certain material can be derived from these kinds of use and interaction cases.

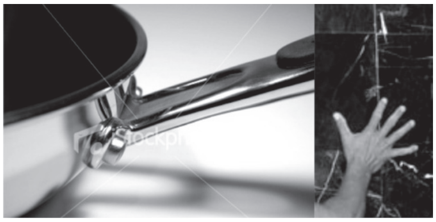


Figure 13. Materials can be appraised based on particular use scenarios.

(5) Meanings of materials affected by context

People give meanings to things on the basis of situations and contexts (Johnson, 2007; Mono, 1997; Osgood et al., 1957). Krippendorff (2006) explains that a dictionary usually lists several meanings of a word. Competent users of the dictionary know which meaning applies to a given situation on the basis of the context in which the queried word occurs. Krippendorff emphasizes that *artefacts mean what their contexts permit* (p. 59). A material, for instance, can be appraised differently in daylight or in subdued light. Considering the effect of light on material perception, some clothing shops provide changing rooms equipped with lights that can be set to daylight or night light in order for customers to see how fabrics of clothes are perceived under different illuminations. Poelman (2005) also emphasizes the role of context in meaning attribution and divides context into two main categories as *internal context* which is the combination of product aspects such as form, materials, etc. and *external context* which refers to an environment or a situation in which the product is used.

Over the last decade, the variety of applications for materials in product design has increased remarkably. A particular material may be embodied in a kitchen appliance as well as in an office accessory. Even though the technical qualities of the material remain the same in both applications, the expressive meanings attributed to the material may differ considerably. Reciprocally, different materials used in a similar context may obtain similar meanings (see Figure 14).

Figure 14. Materials used in an office environment can be appraised as professional.

Meanings of Materials Model

The Meanings of Materials (MoM) model in Figure 15 depicts the dynamic action between a user and a material in which the material obtains its meaning. A **user** with his/her particular characteristics interacts with a **material** of a product, appraises it and attributes a meaning (or meanings) to it. The attributed meaning will be (partly) based on the material's technical and sensorial properties and is affected by aspects of the **product** in which the material is embodied. A material's meaning can change, depending on the user-material interaction, which is affected by use and time. The model shows that each component has a number of aspects (e.g. shape, manufacturing process, gender, expertise, etc.) that can influence the meaning attribution to materials. Finally, the **context** in which the material of the product is appraised may have a considerable effect on meanings attributed to materials, and is therefore shown as enclosing the entire process of user attribution of meanings to materials.

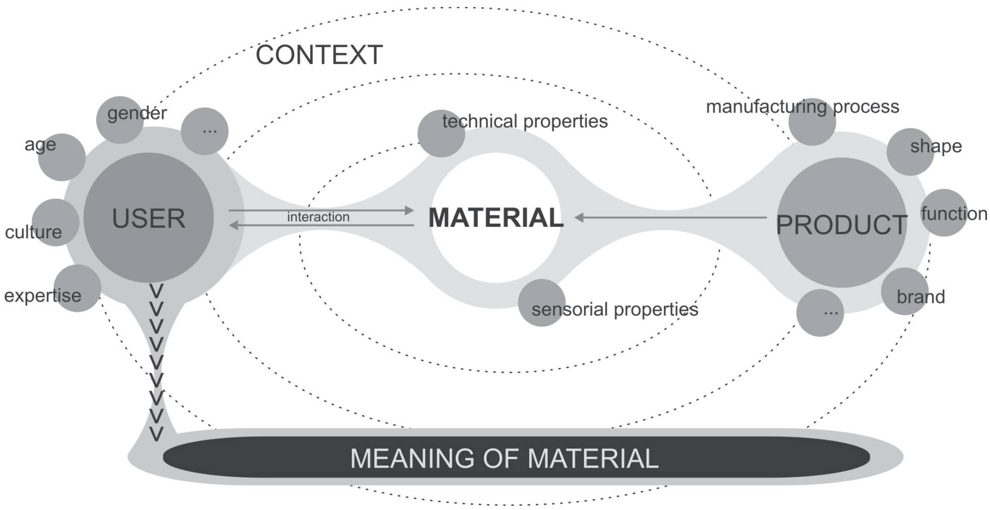


Figure 15. Meanings of Materials Model.

6 Conclusion

The main goal of this chapter was to explore *how materials obtain their meanings*. To answer this question, first current approaches in literature were reviewed to establish descriptions of how meanings in general are created. On the basis of the definitions found in the related literature, we concluded that an expressive character (or meaning) of a material is based on the interactions between an individual and his/her environment, shaped by the qualities of the entire context and open to change over time. *Meanings of materials* are what we think about materials: they are the values we attribute after the initial sensorial input in a particular context.

Following the literature review, a series of three studies was conducted in order to explore the kinds of aspects that play a crucial role in attributing meanings to materials. These qualitative studies were an initial attempt to understand particular meaning-material relationships. Certain sensorial properties of materials can be effective in how materials obtain their meanings. While hard and smooth materials, for instance, are mostly associated with professionalism, soft and semi transparent materials are found sexy. However, it is vital to note that a meaning of a material is influenced by some other factors, including the product in which the material is embodied, how it is used in a particular context, and who the user is. Moreover, the degree to which each aspect contributes to the creation of a particular meaning of a material depends on the type of meaning (e.g. an age related meaning such as nostalgic, or a quality related meaning such as professional). Therefore, it is not easy to define a one-to- one relationship between certain materials and particular meanings.

On the other hand, the results of the studies showed that there are some patterns (characteristics of situational wholes) that affect the meanings we attribute to materials. To be capable of finding these patterns within particular situations, designers should be familiar with the key factors in attributing meanings to materials. Our attempt is to identify, draw attention to, and present the interrelations of these factors. In the next chapter, we aim to show the practical effects of some of these factors (which we may also identify as components of the MoM model).

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Chapter 4 is based on:

Karana, E. and Hekkert, P., (*submitted*), Material-Product-User Interrelationships in Attributing Meanings.

4

Material-Product-User Interrelationships in Attributing Meanings

1 Introduction

In the previous chapter, a model was established that presents *meaning of a material as a relational concept in which material, product and user jointly play a role in a particular context*. In building an intended meaning of a material, these factors are structured and linked to each other. Every factor consists of a number of aspects (e.g. *user* covers aspects including gender, expertise, educational level, personal characteristics, culture, etc.) that might individually play a crucial role in meaning attribution in particular cases. Thus, the challenge for verifying the importance of some of these factors in a quantitative study is in selecting those aspects that are likely to significantly influence how people experience materials.

In this chapter, the main aim is to confirm that (1) a product's aspects (such as shape, function, brand, etc.) affect what kind of meanings are attributed to the material(s) of the product, (2) the appraisal of a material is affected by who the user is, (3) the effect of a certain aspect may vary depending on the material itself (material family). Shape and function were selected as product aspects, whilst gender and culture were selected as user aspects with reference to the related literature. The chapter reports a study conducted with sixteen Chinese (eight females; eight males) and sixteen Dutch (eight female; eight male) participants in order to explore the effects of the selected aspects on meanings of two material families: plastics and metal. Significant differences between two cultures in their material appraisals were found, which are explained in this chapter. At the end of the chapter, we also explore the reliability of such material appraisals by looking into the level of agreement on the meaning scales among Dutch and Chinese participants.

Materials and Shape

People interact with plenty of physical objects every day and these objects share one property: form, which is the boundary of matter by which we distinguish these objects from each other and their environment (Muller, 2001). A designer decides the form, which is realised as a product via appropriate manufacturing processes. Thus, form includes material- manufacturing process- shape interactions (Ashby, 2005). Shape refers to the external two-dimensional outline or appearance of something; thus shape determines an object's boundary abstracting from other aspects such as colour and material (Chen, 2005). In particular, shape does not depend on the size of the object.

A number of scholars have conducted studies on the effects of shape on people's product appraisals (see for instance Chen, 2005; Chung & Ma, 2001; Hsiao & Chen, 2006; Petiot & Yannou, 2004; Van Rompay, 2005). A set of studies exploring the alterations in attributed meanings to materials due to differences in geometrical shape has recently been carried out (Karana, Van Weelderen, & Van Woerden, 2007). Three material types- metal, plastic and glass- were mapped to four selected geometrical shapes (rounded, sharp-edged, organic and hybrid) in Photo Works and Maya software (Figure 1). These twelve models were shown one by one to sixteen students of the Faculty of Industrial Design Engineering of Delft University of Technology, via a computer screen. After each model, participants were asked to specify to what extent the presented model expressed pre-determined meanings such as toy-like, professional, etc. The meanings were presented with five- point scales.

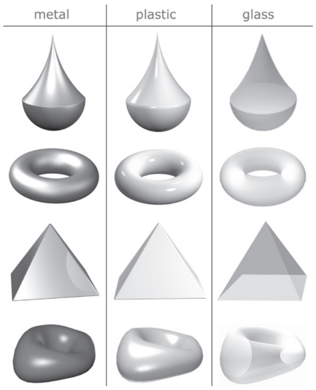

Figure 1. Mapped geometrical shapes used in a previous study (Karana et al., 2007).

The results of the conducted study indicated that there exists a relationship between geometrical shapes and the meanings people attribute to materials. People associate particular materials with certain shapes. These associations are mostly due to a prevailing use of a material in a certain shape used in daily experienced products. While plastics allow more organic forms in mass production, metal can be easily produced in sharp-edged or rounded geometrical shapes. Likewise, to see an organic product made of glass may surprise users more than seeing the same shape in plastic, thereby affecting the attributed meanings to these particular materials in these cases. In the mentioned study, not every geometrical shape was found equally effective in meaning attribution to all materials. In other words, different combinations of shapes and materials can have different effects on attributed meanings. However, significant differences were obtained in attributed meanings to materials embodied in sharp-edged and rounded forms. In the focus group studies (Chapter 3) the geometrical shape of a product was also mentioned as a crucial variable in materials experience. Taking both of these prior studies into consideration, it is predicted that any given material will be appraised differently in rounded and sharp- edged products. We expect that a material of a rounded shape product is perceived as more feminine, cozier and more toy-like than of a sharp-edged product.

Materials and Function

We expect that users would interact differently with different kinds of products, and that this would influence the way people describe the materials of which those products are made. For example, people might not take a material's expressive meaning into consideration if a material is mainly used for its physical superiority in a product (such as a plastic handle of a pan), and, people might emphasize the materials of products they have an emotional bonding with (such as a fabric cover of an old notebook). Other examples are the difference in perception of materials in products that are mainly touched during use compared with those that are mainly looked at during use, or the differences between products that are liked or disliked. In another previous study (Karana & Van Kesteren, 2008), to be able to explore the assumption that people use different descriptive items to evaluate the materials of products with different functions, we selected six product types which were explained in a previous chapter (See Study 4 in Chapter 2). The results of the study showed that the type of a product, according to the six identified categories, influences the quantity and the variety of the descriptive terms used by participants for describing the product and its materials. We found that for products with emotional bonding, people use a larger number of sensorial descriptions compared to the functional products. A clear difference in product descriptions between small products and larger products was also noticed. The small products elicited more sensorial descriptions than the larger ones. The reason behind this result is explained in the study as daily experience with *big electronic* products does not usually provide tactual interaction, holding or grasping. Therefore, the low tactual contact with these products might explain the participants' lower number of sensorial descriptions of material properties.

Similarly, in the focus group studies reported in the previous chapter, the type of product, namely what a product affords, was often mentioned by participants as an important aspect influencing how people appraise materials. For instance, how a product fulfills the required function and what kinds of results occur during and after use were found particularly effective in the attribution of *aggressiveness* to products and to the materials of these products. Summarizing, it is predicted that a single kind of material might be appraised in a different way in different products. For instance, we expect that a material might be perceived as more ordinary when it is embodied in a household product than in a personal product.

Materials and Gender

According to Johnson (2007), an experience reveals *four recurring qualitative dimensions of all bodily movements: tension, linearity, amplitude, and projection* (p. 22). He gives a number of examples enlightening the effects of gender differences on experience with regards to these four dimensions of bodily movements. He mentions two sources on phenomenological and sociological analysis of girls and boys. The first one (Strauss, 1966) reports the differences between two genders in early ages (e.g. five years old) in the manner of *throwing* things. It reveals that "*boys tend to throw a ball with sweeping, forceful motions that occupy more of the full space available to them, both vertically and laterally, and that involves more of their whole body and its potential force*"; whereas girls do not make any use of lateral space (p. 23). In the second source (Young, 1980) how culture often teaches girls to confine their movements is discussed. Young states that "*girls traditionally were not supposed to take up space, nor were they supposed to inject their entire bodily presence into a situation*".

Brewer and Bassoli (2006) explored the ways in which gender can constitute an important factor for emerging types of interfaces. In another study, women showed greater intensity of both positive and negative affective responses to changes in situations than men (Lukas, 2007). Johnson (2007) emphasizes that the mentioned socially and culturally imposed differences have gradually changed, and they will most probably cease to exist in the future. However, these few examples just imply how two genders experience things differently based on their physical abilities, social and cultural norms. Accordingly, in this study, it is expected that the gender of a user influences the evaluation of materials.

Materials and Culture[1]

The assessment of the qualities of products, their materials, and the attribution of meanings thereto, are related to people's past experiences and personal tastes, which to a large extent manifest in culture (Krippendorff & Butter, 1984; Mono, 1997; Oehlke, 1990). Findings of a previous study (Karana, 2004) conducted with sixty Turkish people revealed that there are significant associations on shape-material and material-product relationships among Turkish people. Their associations of certain materials with particular products expressed the effects of their cultural values. For example, a 'wooden box' was associated with a 'chest' that is traditionally used for storing a bride's trousseau.

Because every culture has its own way of living, it is expected that the value of a certain material might show differences from culture to culture. Ljungberg and Edwards (2003) explain that in Scandinavian countries, since wood is very common, a house built of stone is typically perceived as more expensive and prestigious than a wooden one. The authors emphasize that the enterprises of the Scandinavian villa producers to export the wooden villas to Germany did not work since German people also think that wooden houses are inferior and simpler than houses built of stone or concrete. On the contrary, in Mediterranean countries, wood is perceived as more valuable and luxurious material, perhaps because in these regions it is quite rare (in comparison to Scandinavian countries).

Another cultural effect appears in the appraisals of metal products. The results of the study of the Turkish participants revealed *metal* to be regarded as formal and less domestic compared with wood and ceramics (Karana, 2004). The participants associated metal with factory environments and mass production. They believed that metal is a convenient material for producing technological objects, which should be durable and strong. In contrast, Swedish people use metal (stainless steel) in kitchen worktops and sinks and they believe that it is prestigious. Partly this is because metal is used in premium branded products such as Bang & Olufsen, in which aluminium gives a cold and somewhat Nordic product identity (Ljungberg & Edwards, 2003).

According to Dormer (1990), some cultures do not favour plastics as kitchenware because it contradicts the common understanding of what plastics are and how they perform. For example, people of a certain culture may fear that a plastic cooking pot might melt under heating (Dormer, 1990). In the study of Turkish people, 52 out of 60 participants stated that they did not prefer plastic kitchenware since they found it cheap and dangerous for health owing to its man-made chemical origins (Karana, 2004). Soentgen (1997) claims that whereas the origin of plastics is not widely known by the public, everybody is familiar with the origin of wood. The more people know about a material regarding its origin and manufacturing techniques, the more confident they feel while using the products made of this material in daily life (Karana, 2006). Therefore, people might tend to prefer traditional materials for their everyday use objects. Clemenshaw in his book of *Design in Plastics* (1989), made a quotation from Kenji Ekuan, a famous Japanese industrial designer, who explained that Japanese people had so entirely based their sensitivities upon the transience of time that they even included their own deaths in their natural calendar, and they keep transience in mind in everything they do. They reflect this approach to every aspect of their life, including products. *So, "they feel not only uncomfortable with, but they even hold a horror of this thing called plastic that denies death; that even when death of use/function finally comes, death is not reflected in a change of shape or similar deterioration".*

Considering the number of examples given above, it is predicted that cultural varieties lead to differences in attributing certain meanings to materials. We, for instance, expect to find differences between Asian and European cultures on appraisals of plastic products.

2 A study for exploring the material, shape, function, culture and gender relationships in meaning creation

In this section, a study is conducted in order to explore the effects of the above listed aspects on attributing meanings to materials. Before the main study, a pre-study was conducted to generate a manageable set of material relevant meanings (i.e. meanings likely to be evoked by (or expressed through) materials of products).

Pre-study: generating a manageable set of meanings

In Chapter 2, 219 meanings of materials were collected. To ensure the validity of the further studies, it is convenient to deal with a manageable number of meanings instead of 219, which is too large. Furthermore, because the set will be used for measuring spontaneous responses of users on materials, the items of the set should be clear, understandable and relevant for material appraisals. Considering those points, three stages were followed in the pre-study. These stages were mainly aimed at reducing the number of meanings to a manageable amount: (1) cleaning the list of items (76 meanings were retained from the original 219), (2) selecting the most material-relevant meanings (38 meanings were retained from the remaining 76), and (3) classifying the 38 meanings based on their conceptual similarities. Ten meanings expressing different concepts were selected from the 38 classified meanings for the main study.

Stage 1: cleaning the list of items

In this stage, ambiguous and redundant items were eliminated from the list of 219 items.

a. *Items with more than one meaning:* '*Cool*' exemplified one of these cases. *Cool*, with its dictionary definition, expresses the moderately cold, between warm and cold, or lacking in warmth. Alternatively, *cool* in daily language may manifest a not hasty, deliberate, self-possessed or dispassionate manner. Whilst our focus is on materials, cool can either represent the real coolness of the material as lacking in warmth, or metaphorically represent the unflustered or unemotional behavior of the material.

We dealt with a similar complexity due to the ambiguity of some novel technical terms. For instance, 'smart' is to have or show quick intelligence or ready mental capability like *a smart student, or to be* fashionable and elegant, as in *a smart suit, a smart restaurant. On the other hand, 'smart' is a particular type of material developed in the last twenty years, defined as* a material that has the capability to both sense and respond to environmental stimuli, as well as being capable of active control of its response (Karana & Kandachar, 2006). For this reason, 'smart' can also be used for explaining the 'smartness' of a material as an intrinsic technical quality. These kinds of items having more than one meaning (e.g. cold, warm, cool, smart, natural, etc.) were excluded from the final list of meanings.

b. Items with identical meanings: There were a number of items conveying similar denotations.

For instance, *homey is often used for explaining that a material is* cozy and homelike. *However, cozy, domestic and associated with homes or associated with living rooms were also in the list. The familiarity with an item and its frequency of use were main selection criteria in that case. For instance, in the study reported in Chapter 2, the participants used 'cozy' or 'associated with homes' more frequently than 'homey'. Thus we included cozy, domestic and associated with living rooms instead of homey in our final list.*

c. Items regarding associations: Osgood et al. (1957) emphasize that a basic distinction must be drawn between the meanings of a sign and its associations. According to them, *black* does not mean *white* even though this is the most common association. Following the same notion, we also separate associations and meanings in material appraisals. Someone can associate a dark wood with her/his grandmother, which does not denote 'grandmother' to be the meaning of the material. However, some associations did express certain qualities of materials, such as *associated with high quality, toy-like, business-like, associated with factories,* etc. Therefore, these sorts of associations were included in our meaning list.

Stage 2: Selecting the more material-relevant items

Materials can in some cases be more influential in creating particular meanings than the other factors in product design (such as form, function and use). In order to create a meaning of *sexy*, for example, a designer can firstly make use of *form* instead of *material*, and subsequently use material for enhancing the existing meaning mainly created by form. In other cases, the material of a product can be the most effective factor for attributing meaning to a product, such as the case of 'high-tech'. This study aims to explore which meanings of materials play an important role in product design.

Method

Participants

The participants (N= 28; 14 male, 14 female) were Dutch doctoral students (n= 21) with a design background (and who had taken at least four major design courses) and senior master students (n= 7) at the graduation stage in their final year of masters study, all within the Faculty of Industrial Design Engineering at Delft University of Technology. The participants contributed to the study voluntarily.

Procedure

The study was conducted individually. The study took 15-20 minutes for each participant. The participants were given a booklet with 76 items (meanings), each of which was presented with a five- point rating scale. The participants were instructed to mark only one box for each item. In a written instruction they were asked to imagine a product/ products which carry the meanings (items) represented in the booklet. They specified to what extend a material could be effective in attributing those particular meanings to a product/ products. The items and the introduction were presented together with Dutch translations.

Results

A *One Sample t-* test was executed to compute the significance levels of the items. The mean score and the standard deviation of each item are presented in Figure 2. The dotted horizontal line in the figure indicates the overall mean score for all 76 items (M= 3.45). The individual items with a mean score equal to or higher than the overall mean score were selected for further studies. 38 items had a mean score equal or greater than the overall mean score. These 38 items can be found in Table 1.

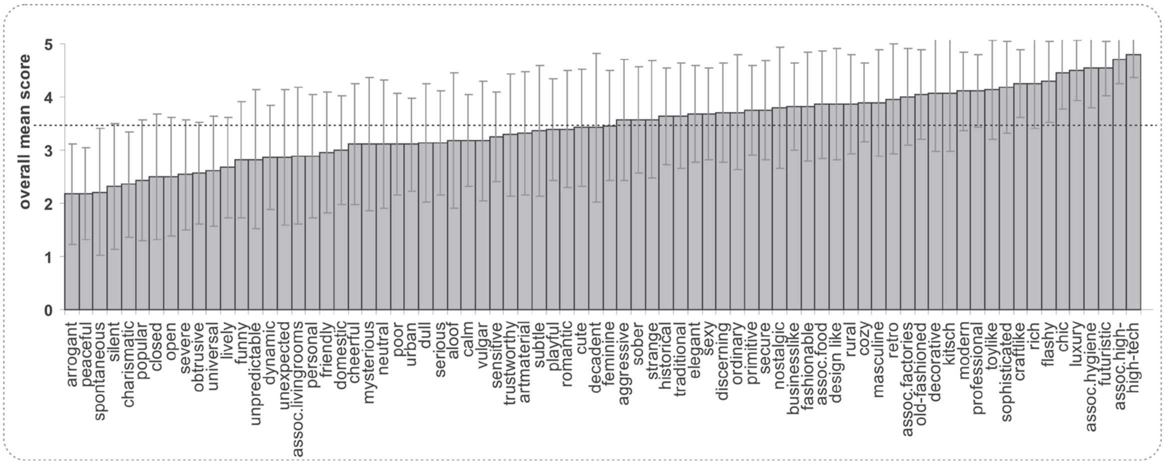

Figure 2. Analysis of material-relevant items.

Table 1. Selected 38 material-relevant items.

Aggressive	Fashionable	Primitive
Associated with factories	Feminine	Professional
Associated with food	Flashy	Retro
Associated with high- quality	Futuristic	Rich
Associated with hygiene	High-tech	Rural
Business- like	Historical	Secure
Chic	Kitsch	Sexy
Cozy	Luxury	Sober
Craft- like	Masculine	Sophisticated
Decorative	Modern	Strange
Design like	Nostalgic	Toy like
Discerning	Old- fashioned	Traditional
Elegant	Ordinary	

Stage 3: classifying the conceptually similar items

Evidently, some of the highest scoring items in Figure 2 are conceptually similar. For instance, the items *historical*, *primitive*, *old- fashioned* and *modern* are all related to 'age', whereas, the items *chic*, *rich*, *luxury* and *elegant* refer to 'quality'. At this stage conceptually close items were classified. In this way, we aimed to obtain a more concise and concentrated set of meanings for use in further research.

Method

Participants

The participants (N= 22; 10 males, 12 females) were senior undergraduate students (final year of bachelor) or masters students at the Faculty of Industrial Design Engineering of Delft University of Technology. All participants were Dutch and none of them had participated in previous studies. They were not paid for their participation.

Stimuli

The stimuli for the study were ten bowls made of five different materials (wood, plastics, metal, glass and ceramics). At first, fifty various bowls were collected. They were then grouped based on their material families. Afterwards, from each material family, it was decided to select two representative bowls, which were preferably quite different from each other. The main reason for using bowls for this study was their similarity and simplicity in form and their variability and availability in different materials. In addition to this, bowls do not carry supplementary elements of form such as buttons or handles. Each bowl is made of only one type of material (no material combinations) (Figure 3).

Figure 3. Collected bowls for Study 2.

Procedure

The ten bowls were presented one by one in a randomized order to each participant. The participants were simultaneously given a booklet containing the 38 previously selected items (meanings). Each participant was instructed to rate the presented bowl by pointing out to what extent the material of the bowl expressed the given meanings. A five-point scale was used, ranging from 'not at all' to 'very much', to report their ratings. The study was performed individually and each participant was allowed to handle the presented bowls during the entire evaluation process of 38 items. The task took approximately 15-20 minutes for each participant.

Results

All the scores from the participants were transferred into data sheets in order to perform a factor analysis to classify the 38 meanings. This analysis provided a rotated component matrix (Table 2), which is a representation of the factors subsuming those meanings that are conceptually related. As shown in Table 2, the analysis revealed six factors with eigenvalues greater than 1.00. The horizontal dotted lines in the matrix represent the borders between the factors. Factor 1 is characterized by high loadings of 'age' related meanings like *nostalgic*, *primitive*, *historical*, etc. On the second factor, 'striking' meanings such as *flashy*, *strange* and *aggressive* have high loadings. For the third factor, 'quality' related meanings (e.g. *luxury*, *chic*, *elegant*, etc.) are grouped. The fourth factor, which we name 'cool', consists of only three meanings: *fashionable*, *design like* and *sexy*. Factor 5 is distinguished by high loadings of 'serious' meanings such as *masculine*, *business like*, and *professional*. Finally two seemingly disparate meanings are grouped under the last factor: *associated with food* and *retro*. The last factor was not considered in the final evaluation due to its uncertainty for interpretation.

For each of the five factors, two meanings were selected that were considered most likely that designers would intend to express them in a design. For instance, attributing a meaning of *modern* to a material may be more intentional than a meaning of *old-fashioned*. Likewise a meaning of *flashy* may be more intentional than *kitsch*. This was the major principle for our selection. Furthermore, meanings like *cozy* and *toy- like* do not clearly reflect the essence of their grouping. For example, even though *cozy* seems not conceptually related to 'age', it appears under this factor. On the other hand, although some meanings express a certain characteristic of their group, they are conceptually different from each other. *Professional* and *masculine* exemplify such a case. They both express the 'serious' factor but in different ways. Furthermore, some meanings have high loadings on other factors (e.g. modern also has a high loading on the fourth factor).

On the basis of these concerns, one or two (clearly different) representative meanings were selected from each group: *futuristic* and *cozy* from 'age' factor, *sober* and *strange* from 'striking' factor, *elegant* and *toy-like* from 'quality' factor, *sexy* from 'cool' factor, *professional* and *masculine* from 'serious' factor. We found the opposite poles of some meanings in the list (such as masculine- feminine, strange- ordinary, etc.). Opposite poles of others, which were not mentioned in the list, were obtained from the semantic scales created by Osgood et al. (1957). The final set of meanings taken forward into the main study is presented with their semantic opposites in Table 3.

Table 2. Factors indicating the correlated items.

Rotated Component Matrix[a]

		Component					
		1	2	3	4	5	6
age	craft-like	,861					
	historical	,859					
	rural	,836					
	traditional	,801					
	primitive	,781					
	nostalgic	,755					
	futuristic	-,690					
	old-fashioned	,677			-,545		
	assoc. with factories	-,641					
	modern	-,613			,589		
	high-tech	-,606					
	cozy	,605					
striking	sober		-,766				
	flashy		,704				
	strange		,695				
	kitsch		,680				
	ordinary		-,613				
	secure		-,607				
	aggressive		,600				
	discerning		,591				
quality	luxury			,797			
	chic			,790			
	rich			,768			
	toy-like			-,625			
	elegant			,569			
	assoc. with high quality			,550			
	sophisticated			,465			
	decorative			,451			
cool	fashionable				,753		
	design-like				,681		
	sexy				,573		
serious	masculine					,760	
	feminine					-,757	
	business-like					,589	
	professional					,531	
	assoc. with hygiene					,453	
	assoc. with food		-,521				,580
	retro						,544

Extraction Method: Principle Component Analysis.
Rotation Method: Varimax with Kaizer Normalization.
[a] Rotation converged in 8 iterations.

Table 3. Used nine meanings with their semantic opposites.

aggressive - calm	frivolous - sober	ordinary - strange
cozy - aloof	futuristic - nostalgic	sexy - not sexy
elegant - vulgar	masculine - feminine	toy-like - professional

Main Study

The aim of the main study was to confirm that (1) a product's geometrical shape, (2) a product's function, (3) the gender of the individual who appraises the material of a product, and (4) the cultural background of the appraiser, each affect the meanings attributed to the material(s) of a product. Furthermore, it is posited that the effect of a certain aspect on the overall expression of a product may vary depending on the material family. These assumptions are explored in this study.

Method

Participants

The participants were sixteen Chinese (eight male, eight female; mean age 25.4 years, range 23-30 years) and sixteen Dutch (eight male, eight female; mean age 24 years, range 21- 28) undergraduates of Delft University of Technology. Students of design oriented departments are expected to be more familiar with the general features of a variety of products, which may lead to occurrences of 'learned' associations between those features and expressive meanings (Van Rompay, 2005). For this reason, an attempt was made to invite participants who had not received any design education (e.g. architecture, art schools, etc.). A special emphasis was also put on the number of months (or years) that the Chinese participants had spent outside of China. All of the Chinese participants were exchange students in their first six months in the Netherlands. All of the subjects participated voluntarily.

Stimuli

Two types of materials, which are predominantly used in mass produced daily products, were selected to be included in this study: plastics and metal. A market search was carried out to identify two types of products with two different functions, made of plastics and metals, produced in rounded and sharp- edged shapes. A number of products answering one (or two) of our criteria were encountered. However, it was difficult to find the two variants of a same product made of metal and plastics. Because different materials require different manufacturing processes, varieties in forms attributable to production details were observed. For this reason, special emphasis was placed on finding simple products with a minimum number of production details. The critical issue was to select products that would allow participants to easily perceive the differences between material types and geometrical shapes. Following these concerns, a *waste basket* was the first product found in two different geometrical shapes and in two materials.

A waste basket is a mass produced product used as a temporally container of waste in kitchens (or bathrooms and toilets) of houses and offices. They are mostly made of metal or plastics. Even though a waste basket is not considered as a personal product, it may contribute to the image of an environment (or the person who lives in that environment) along with other products. After selecting a 'waste basket' as the first product type, we began to look for products that are not for the household but instead may be considered more personal and require more tactual interaction with users. A lighter, which is a small portable device used to create a flame, met these criteria. We were able to find lighters in two different forms, made from similar kinds of metal and plastics as used in the waste baskets. Figure 4 depicts the stimuli used in this study.

Figure 4. Stimuli used in the study (four waste baskets, four lighters).

Procedure

The participants were individually invited in a room at the Faculty of Industrial Design Engineering. They were presented with the eight products one by one. Together with each product, the participants were given a page with 7-point bi-polar scales presenting the nine meanings (Table 3). The participants were informed beforehand that they would study eight different products made of plastics and metal. They were asked to evaluate *to what extent the material of the presented products expressed the given meanings*. Before starting the actual study, an example scale was presented. Although there were no time limits, the subjects were instructed to base their judgments on their first impression. The eight products and nine meanings were presented in a random order. The sessions took approximately 15 minutes for each participant. All meanings and instructions were presented both in English and in the participants' mother tongue (Dutch or Chinese) (Appendix 4.1).

Results

The presumed effects of the selected aspects on meanings of materials were analyzed by a 2 (function) X 2 (shape) X 2 (material) X 2 (gender) X 2 (culture) multiple analysis of variance (MANOVA) with the nine meanings as dependent variables. All 2-way interactions were included in the analysis. All significant main effects and 2-way interactions ($p < .05$) are presented in Table 4.

Table 4. Multiple analysis of variance summary table.

	dependent variable	F	Sig.
Function	aggressive*	11,738	,001
	elegant*	31,153	,000
	frivolous	7,482	,007
	futuristic*	36,606	,000
	ordinary*	98,003	,000
	sexy*	54,976	,000
Shape	cozy*	11,850	,001
	elegant	6,932	,009
	masculine*	15,811	,000
	sexy*	17,439	,000
Culture	cozy*	61,712	,000
Gender	aggressive	5,412	,021
	ordinary*	20,876	,000
	sexy	6,980	,009
Material	elegant*	11,357	,001
	frivolous	5,125	,024
	futuristic*	21,760	,000
	masculine	3,876	,050
	sexy	6,108	,014
	toy-like*	32,040	,000
Function x Shape	elegant*	11,357	,001
	sexy*	15,369	,000
Function x Material	toy-like	7,121	,008
Culture x Function	futuristic	9,012	,003
	ordinary	4,475	,035
	toy-like*	13,241	,000
Culture x Shape	cozy	6,552	,011
	futuristic*	10,753	,001
	masculine	4,186	,042
Culture x Material	elegant	5,368	,021
	sexy*	16,735	,000
Gender x Material	futuristic	9,012	,003
	sexy	4,184	,042
	toy-like	5,499	,020
Material x Shape	futuristic	3,944	,048

$p < .05$ (Note: (*) efects with $p \leq .01$)

Main effects

Starting with *product effects*, FUNCTION has main effects on almost all related meanings except for cozy, masculine and toy- like. The materials of lighters are found more *elegant*, more *futuristic*, more *frivolous*, more *aggressive*, *sexier* and less *ordinary* than the materials of waste baskets (see Fig. 5a). SHAPE has main effects on *cozy*, *elegant*, *masculine* and *sexy* meanings of materials. Expectedly, the materials of rounded shape products are appraised as cozier, sexier, more elegant and less masculine than the materials of sharp- edged products (see Fig. 5b). Coming to the second main factor, *user effects*, the main effects obtained for GENDER were on the attribution of the meanings *aggressive*, *ordinary* and *sexy* to materials. Males, in general, found the materials of the presented products more aggressive, sexier and less ordinary than females (see Fig. 5d). With regard to CULTURE, main effects were only obtained on *cozy*. In general the Chinese subjects perceived the presented materials as cozier than Dutch subjects (see Fig. 5c).

MATERIAL type was found to have main effects on six meanings (out of nine), excluding *aggressive*, *cozy* and *ordinary*. Overall, metal was perceived more *elegant*, more *futuristic*, more *frivolous*, *sexier* and less *toy-like* than plastics. Interestingly, plastic is perceived more masculine than metal (see Fig. 5e).

Interactions

The first two interactions show how a change in shape and material influence the main effect of FUNCTION on meanings of materials. FUNCTION X SHAPE interaction was obtained for the meanings *elegant* and *sexy* (Figure 6a-b). The participants appraised the materials of waste baskets as more elegant when they are produced in a rounded shape. However, the materials of lighters were perceived as more elegant in a sharp-edged shape. While a rounded shape has a large influence on attributing sexiness to waste baskets, it is less effective in perceiving lighters as sexy. The only FUNCTION X MATERIAL interaction is presented in Figure 6c, showing that plastics, as compared to metal, is perceived as much more toy-like in waste baskets than in lighters.

The GENDER X MATERIAL interaction was significant for the meanings *futuristic*, *sexy* and *toy-like*. Figures 6d, 6e and 6f reveal that these interactions are due to the differential effect of the two MATERIAL types. As followed in the figures, for females whether a product is made of metal or plastics is more important in attributing the meanings *futuristic, sexy* and *toy-like* than for males. MATERIAL X SHAPE interaction only reached significance on the meaning *futuristic*. The figure 6g reveals that rounded shaped plastic is perceived as more futuristic than sharp-edged plastic, whereas metal is perceived more futuristic when it is in a sharp-edged form.

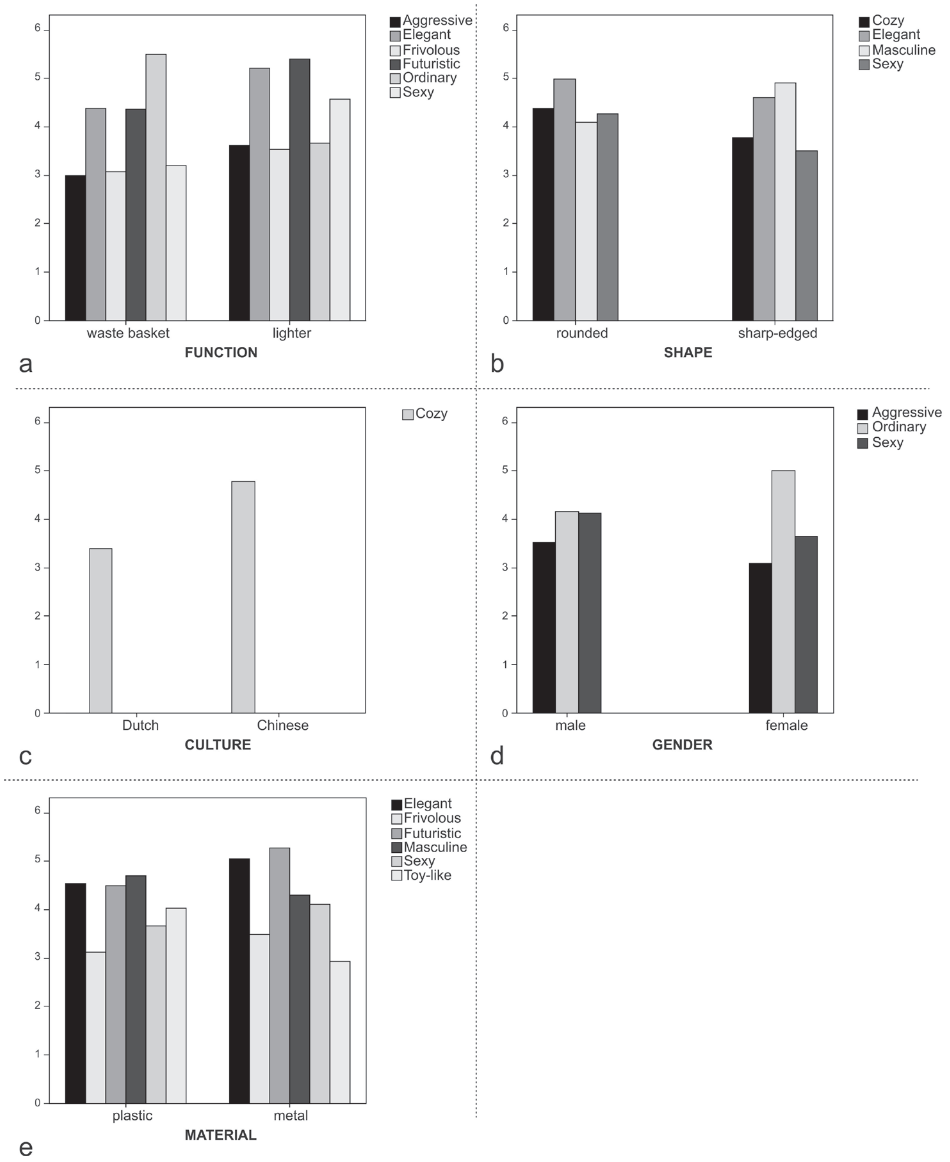

Figure 5. Main effects of function, shape, gender, culture and material.

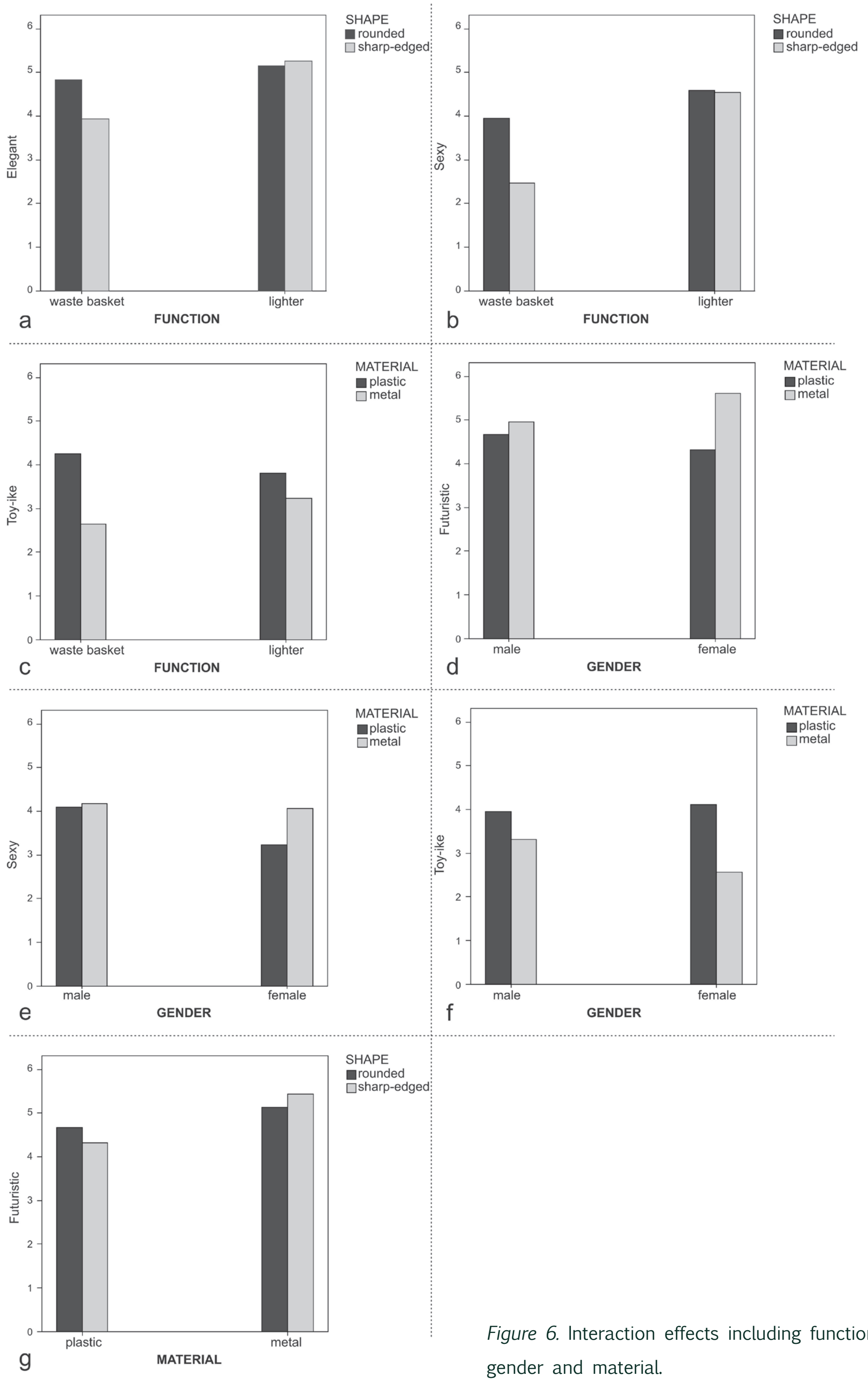

Figure 6. Interaction effects including function, gender and material.

CULTURE was implicated in three significant two-way interactions, with SHAPE, MATERIAL and FUNCTION (see Figure 7). A CULTURE X FUNCTION interaction was observed for three meanings: *futuristic*, *ordinary* and *toy-like* (Figures 7a, 7b, and 7c). Materials of waste baskets were appraised as relatively much less futuristic and much more ordinary by Dutch participants than Chinese participants. The Dutch participants found the materials of waste baskets more toy-like than the materials of lighters. In contrast, the Chinese participants found the materials of lighters more toy-like than the materials of waste baskets.

For Dutch participants, a difference in geometrical shape of a product had relatively more effect on attributing the meanings cozy and masculine to materials than for Chinese participants (Figures 7d and 7f). Interestingly, while sharp-edged products were found more futuristic by Dutch participants, Chinese participants saw rounded products as more futuristic (Figure 7e). A CULTURE X MATERIAL interaction was obtained for the meanings *elegant* and *sexy* (Figures 7g and 7h). Similar to the CULTURE X SHAPE interaction effect, for Dutch participants, differences in the materials of a product had more effect on attributing the meaning elegant to a material than for Chinese participants. Finally, the Chinese participants found plastic products sexier than metal, whereas Dutch participants thought that metal products were sexier than plastics.

Discussion

The results of the study supported the contention that meanings of materials in a particular context are shaped by interactions of certain aspects of materials, products and users. One of the most important findings of this study was that all aspects tested in this study show main effects for some of the given meanings, but not for others. Material, itself, affects the attributed meanings for six out of the nine meanings. The product aspects, SHAPE and FUNCTION, have a similar and relatively stronger effect on attributing meanings to materials, respectively four and six significant main effects, than GENDER and CULTURE, with only three and one significant main effect, respectively. For certain meanings, such as *futuristic*, *elegant* and *sexy,* more main and interaction effects were obtained than for other meanings (Table 4). Their assessment is apparently more affected by the aspects (i.e. shape, function, gender and culture) varied in this study. This may be explained by participants' easy associations of materials with futuristic, elegant and sexy products. *Frivolous*, in contrast, was less affected by changes in shape, function, gender and culture. This may be a result of the participants' unfamiliarity with the term *frivolous*. Relatively few effects of the various aspects on the aggressiveness of materials were observed. This is most likely due to circumstances also experienced in the focus groups studies, where participants connoted aggressiveness with the anticipated harmful effect of the product (i.e. a literal rather than metaphorical meaning of aggressiveness). The participants might have focused mainly on an anticipated result of an interaction with the lighters and the waste baskets, rather than other material and product aspects such as shape or sensorial properties of materials. This may explain why the materials of lighters were found more aggressive than materials of waste baskets.

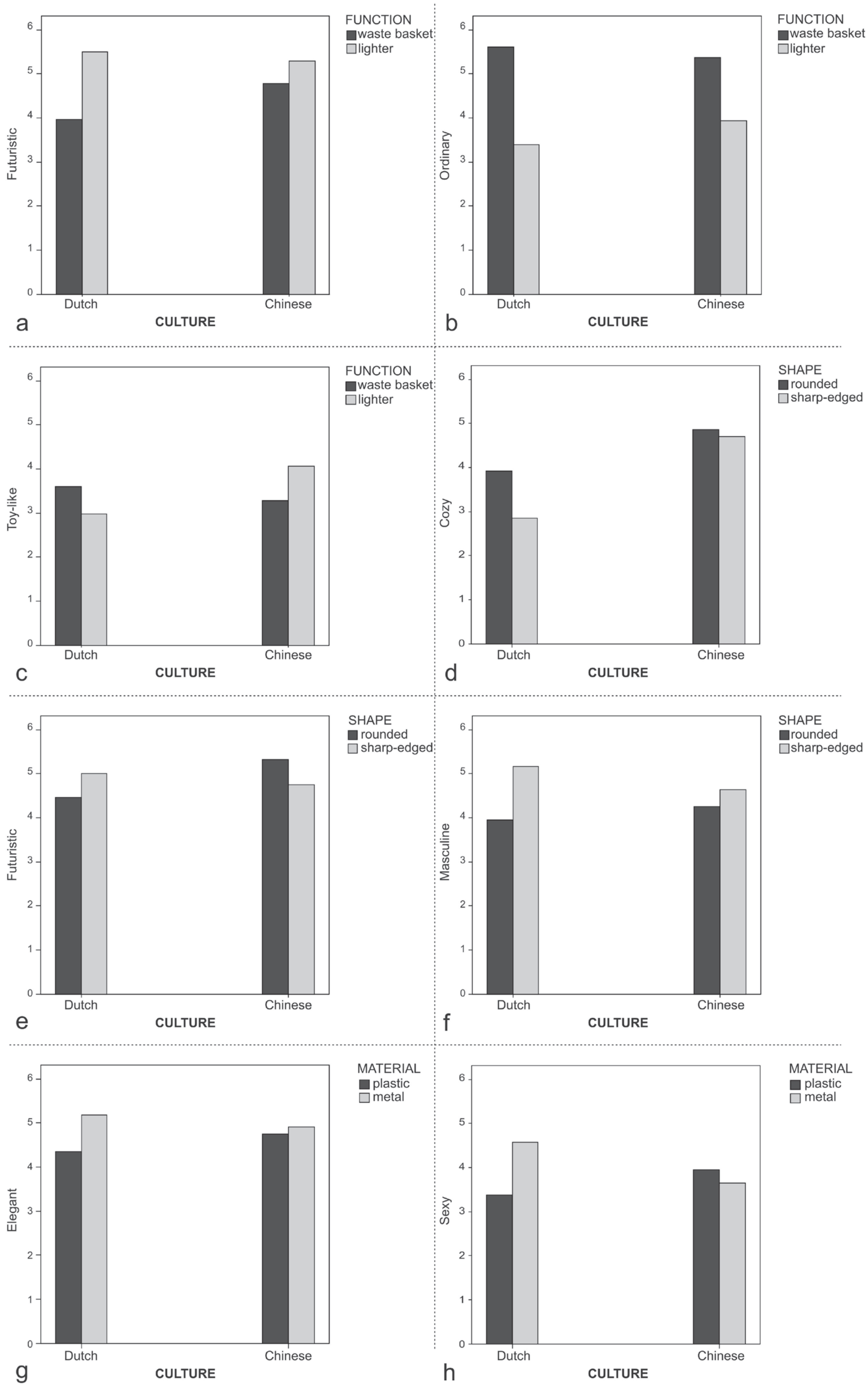

Figure 7. Interaction effects including culture.

In the introduction of this chapter, we discussed the findings of a study demonstrating that women show a greater intensity of both positive and negative affective responses (Lukas, 2007). Likewise, according to another study, women are more successful than men in judging emotional meaning from nonverbal cues (e.g. facial expressions, formal properties of artifacts) even with minimal stimulus information (Hall, 1984). Our study generated similar results. Females' reactions to the material variance were greater than males' reactions. In other words, whether a product was made of metal or plastic made a greater difference to females' evaluations. A significant gender difference was observed for the meaning *ordinary*; females found the materials in general more ordinary than males. In order to find a product or a material ordinary, a user is expected to be familiar with it. In that respect, the female students in our study may have been more familiar with the products and the materials used (particularly within households). On the other hand, it is difficult to explain gender differences as to attributing the meaning *aggressive* to materials. Seemingly, the potential harm effects of the given materials were higher for males than for females; or males might have rated the aggressiveness of the materials metaphorically. Shortly, although we did find a few main effects for GENDER, they are hard to explain.

A crucial question stems from the overall findings of the study: were participants able to evaluate the materials of products, as a specific aspect, or did they evaluate the products in general, covering many aspects? Although they were asked to evaluate the materials of the products, it is known that other product aspects affect the overall impression of a product. Therefore, one can interpret the main effects obtained from this study as the changes in the overall impression of the products with respect to the changes in shape, function, gender, culture and material. In this sense, using two types of materials was a wise attempt to show how material interacts with other aspects (two-way interactions) and the effects of these interactions on certain meanings.

A number of interesting 2-way interaction effects was found. For instance, a significant SHAPE X CULTURE interaction for the meaning *futuristic* was obtained. The Chinese participants found the materials of rounded shapes more futuristic than the materials of sharp- edged shapes. It was just the opposite for Dutch participants who, in general, appreciated metal more than plastics (e.g. metal was found sexier, more elegant and more futuristic than plastics). This result can be supported by the previously mentioned example of Swedish people regarding their impression of stainless steel as prestigious and valuable, based on associations with metal-based Bang & Olufsen products. The differences between the two cultures in their evaluations of metal and plastic were as predicted. However, we expected to find a more negative approach towards plastics from Asian people. This unpredicted result may be explained by the fondness of Asian cultures on natural and organic forms, which are mainly associated with plastics. It may also be partly explained by an expanding number of plastic products in Asian markets, which make Asian people more familiar with this material family. A particular culture might also be more familiar with a product, which may affect the culture's approach to a certain material embodied in this product. In informal discussions after the study, for instance, some Chinese participants indicated that they had never seen the kinds of lighters used in this study before.

Another important point is that although the study was devised to see how certain aspects interact with two types of materials for expressing particular meanings, the occurred differences might have been the result of different sensorial properties. In other words, if a matt metal (as like matt plastics) had been used instead of a glossy one, the results might have been different; or, instead of black plastic, if grey was selected the results again might have differed. It may also explain why plastic was found more masculine than metal in this study. Glossiness and colours may play important roles for how people appraise materials and products. The effect of various sensorial properties including glossiness on materials' meaning will be explored in the next chapter. For this study, a special attempt was made to select 'ordinary' versions of products (e.g. not painted with flashy colors, not surprising with extraordinary material properties).

It should be recognized that even though we made a speculative discussion on the findings of this study on the basis of common knowledge, the main answer of *why these two cultures, for instance, attribute different meanings to materials* still remains fuzzy.

3 Agreement on meanings

While evaluating the results of the study reported in the previous section, we realized that people can agree with each other on one particular meaning of a material, while their agreement level on another meaning might be low. In the latter case, we suppose that other aspects (such as user differences) may be more influential on conjuring up some other meanings (e.g. a material can evoke the meaning 'nostalgic' for an individual, whereas another individual might not agree on that). We assume that meanings of materials on which people agree strongly with one another might be easier to associate with certain material properties and product features. In other words, we may be able to define some meaning evoking patterns in commonly raised material- meaning relationships. This assumption led us to assess the results of the study (reported in Section 2) from an alternative perspective, in order to find out the meanings on which people significantly agreed with one another. Since CULTURE generated some significant results in the study, we found it interesting to compare agreement levels of two cultures (Dutch and Chinese) on the meaning scales.

Results

In order to assess the agreement among participants, intraclass correlation coefficients (R_i), an index of the reliability of the ratings, were calculated for each meaning scale. The R_i statistic was found more appropriate than the often applied mean Pearson product moment correlation because the latter ignores the extent to which two independent raters disagree on any single rating (Hekkert & Van Wieringen, 1996). The R_i statistic can be employed to measure the data using only one participant's assessments at a time. When there is more then one participant (as in the study, which featured ten participants), in order to estimate inter- rater reliability, a *single measure intraclass correlation* is computed. Besides the overall agreement, the agreement among Dutch participants and Chinese participants were calculated separately. Table 5 presents the results of the R_i statistic.

Table 5. Degree of agreement between participants on the meaning scales.

	Dutch N=16		Chinese N=16		Overall N=32	
	(Ri)	**Sig**	**(Ri)**	**Sig**	**(Ri)**	**Sig**
aggressive - calm	,14	,002	,01	,328	,01**	,012
cozy - aloof	,22	,000	-,04	,894	,05	,008
elegant - vulgar *	,33	,000	,16	,000	,24	,000
frivolous - sober	,13	,003	-,01	,507	,05**	,015
futuristic - nostalgic *	,40	,000	,12	,004	,20	,000
masculine - feminine	,26	,000	-,03	,613	,08	,001
ordinary - strange *	,46	,000	,21	,000	,33	,000
sexy - not sexy *	,50	,000	,28	,000	,32	,000
toy-like - professional *	,21	,000	,16	,001	,14	,000

* Scales on which within-group and overall group agreements were both significantly high
** N= 31 for these two scales: one participant's ranking was removed because it had zero variance

The intraclass correlations on each scale reveal that agreement among Dutch participants was generally considerably higher than among Chinese participants. Agreement on five scales - [elegant- vulgar], [futuristic- nostalgic], [ordinary- strange], [sexy- not sexy] and [toy-like- professional] - was significant for both the Chinese and Dutch participants. The highest agreement was obtained on the [sexy- not sexy] scale for both the Dutch and Chinese participants (R_i= .50 and R_i= .28). Agreement on the [ordinary- strange] scale was also relatively high for both groups (R_i= .46 and R_i= .21). The Chinese participants' lowest agreement was on [cozy- aloof], [masculine- feminine] and [frivolous- sober] (R_i= -.04, R_i= -.03 and R_i= -.01). Agreement among the Dutch participants was relatively low for [aggressive- calm] and [frivolous- sober] (R_i= .13 vs. R_i= .14). The overall agreement among participants (N= 32) was high except for three scales: [aggressive- calm], [cozy- aloof] and [frivolous- sober] (R_i= .01, R_i= .05 and R_i= .05). Agreement on the [ordinary- strange] scale was the highest in overall assessment (R_i= .33).

Discussion

Interestingly, agreement among the Chinese participants on all of the scales was in general very low and it was consistently lower than agreement among the Dutch participants. This result is an indication that the meanings presented in the study were not easily recognized and associated with materials by Chinese people. This result could be tentatively explained with Wittgenstein's (1980) definition of meaning as the results of conversations, collaborations and histories of coordinations among people, always maintaining a social context. Thus the *meaning* of a particular meaning and the signs evoking this meaning can be more lucid for a specific culture. Dutch people, for instance, tend to use the expression 'gezellig' (which does not have an equivalent word in English) in order to emphasize the coziness of a surrounding or a situation. This may lead to the development of a conventional understanding and association of a meaning with particular signs. Accordingly, it can be expected that Dutch people would agree with each other on coziness of a room (or an artefact). However, the meaning cozy might be too unfamiliar for Chinese people that they would not recall a particular experience that helps them to find out the signs required for conjuring up certain associations related to this meaning. In the line of this example, we might assume that certain meanings are not identified (not talked about or do not have long histories) in particular cultures and that as a result material properties and product features cannot easily be associated with those meanings. No agreement on the [masculine- feminine] scale among the Chinese participants, for instance, was astonishing while Dutch participants agreed more strongly with each other on this scale. This disparity may be partly explained by the different interpretation of the qualities associated with men and women in these cultures.

Dewey (1980) elucidates that "*experienced situations are the soil from which the objects, properties, and relations of our world grow*". Adapting to our discourse, all materials and products have experiential stories, which are woven into social and cultural histories (Krippendorff, 2006). It is to be expected that certain cultures are more familiar with certain materials than others (e.g. Bamboo is of high cultural significance in East Asia; whereas it is not very commonly used in Western Europe). Schivelbusch (1979) explains that new materials and technologies evoke 'a sense of loss' in those who experience them; but sometime after, people develop 'a new set of perceptions' and accept replacements as 'natural', or even desirable. Being familiar with a material with regard to its qualities and sensory patterns through experiencing it in various situations, the individuals of a culture might inevitably have a common idea about the values and meanings of the material. Put differently, the more the individuals of a culture are familiar with a material, the more they agree on the meanings the material evokes. Consequently, one might be tempted to assume that low agreement levels of Chinese participants on the meaning scales might be the result of their unfamiliarity with the chosen materials or products. As it has been mentioned previously in this chapter, some Chinese participants indicated that they had never seen the kinds of lighters used in the study before.

Another interesting result of the study was that levels of agreement in overall evaluation (N= 32) on some meanings were very high, indicating that the patterns that evoke these meanings were similar for both cultures. *Ordinary*, *sexy* and *elegant* were three of these meanings. Surprisingly, agreement on the sexy scale within both cultures was the highest among other scales. Furthermore, the two cultures also agreed with each other on this meaning (R_i= .32). The reason behind this result might be an easy association of a certain property (or properties, such as rounded shape and glossiness of material surfaces) with the meaning sexy. Seemingly, the patterns evoking a sense of sexiness in materials are similar for both cultures. It might be suggested that people do not easily relate *aggressiveness* and *soberness* to materials in general. As emphasized in the previous chapter, aggressiveness, for instance, is more associated with the harming effects of a product that occur during or after use. Thus, aggressiveness is very much related to shape (such as sharp cutting edges), function and use. Therefore, a low agreement level on the meaning aggressive was less surprising to us.

As a closing remark, the findings of the study showed that some meanings are more easily associated with material and product features. The meaning evoking patterns behind two of these meanings (sexy and elegant) will be explored in Chapter 8.

4 Conclusion

Summarizing, the study reported in this chapter supports our assumption that people's understanding of a material's meaning is grounded in certain aspects mainly related to the product the material is embodied in, the material itself with its descriptive physical and sensorial properties, and the characteristic of the user who experiences the material. The study aimed to investigate the effects of shape and function as product aspects, and gender and culture as user aspects, on the attribution of certain meanings to two material types: plastics and metal. The effect of function on meanings of materials also implied that other types of products, which were not included in this study, might generate different results. Moreover, different use circumstances and different contexts can contribute to the creation of different meanings. Therefore, it is difficult to generalize the findings of the study in order to propose definite ways for creating particular meanings through materials.

On the other hand, whilst people may agree strongly with each other on one meaning, they may disagree strongly on another meaning. We assume that sensorial properties of materials can be one of the most crucial aspects of evoking patterns that lead to the attribution of meanings to materials with high levels of agreement amongst people. On the basis of this assumption, the focus in the next chapter is made towards sensorial properties of materials.

Endnote

1 The results of the focus group studies reported in Chapter 3 showed that the expertise of a user may affect attributing certain meanings to materials. The three expertise groups showed differences in perceiving professionalism in materials. Both designers and non- designers, for instance, emphasized that an innovative use of a material in a product can be recognized and appreciated more by people with design backgrounds. Considering this, we first selected expertise as a user aspect to test our model. We conducted a study in line with the Main Study explained later. Sixteen undergraduates of the Faculty of Design Engineering and sixteen undergraduates of different faculties (not design related) of Delft University of Technology evaluated eight products (Figure 4). All students were Dutch and they were in their second or third years of study.

No significant difference between the two groups was found (Appendix 4.2), and it could be concluded that the level of expertise may not play a significant role in the attribution of meanings to materials. This result might, however, also reveal that the level of expertise of participants was not discriminative enough to find significant differences. In order to assess the effects of expertise in attributing meaning to materials, we recommend using professional (experienced) participants rather than students in further studies.

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5

Effects of Sensorial Properties on Meanings of Materials

1 Introduction

The previous chapter investigated the effects of shape and function as product aspects, along with gender and culture as user aspects, affecting the attribution of certain meanings to two material types: plastics and metal. This chapter focuses on two aspects of materials, which are regarded as two of the most important aspects in the materials and design domain: sensorial properties and manufacturing processes. The two main assumptions of this chapter are: (1) *people commonly focus on specific sensorial properties for attributing certain meanings to materials,* and (2) *particular manufacturing processes can be used for creating particular sensorial experiences, which can change the overall impression of materials and products.*

In Chapter 3, it was stressed that technical properties of materials are experienced through sensorial properties by people. In other words, sensorial properties of materials appear as moderators in material-user interaction, and they help us to appraise a material and attribute meanings to it. In this way of meaning construction, two different scenarios were suggested: (1) the material family (e.g. metal, plastics, glass, etc.) has a main effect on a material's meaning, or (2) a particular sensorial property of a material (e.g. glossiness, roughness, softness, color, etc.) has a main effect on a material's meaning. In the first case, meanings attributed to a material family often behave as if an intrinsic quality of that material, such as metal is cold and distant or wood is warm and homely. In the second case, a particular sensorial property (or set of properties) results in the assignment of a certain meaning to a material. For example, smoothness and semi-transparency of a material might together connote sexiness. In this example, both plastics and glass can obtain the meaning sexy. The first case (material type) was tested in the previous chapter (Chapter 4). Metal and plastic products were compared, and the main effects of material type on the attribution of the meanings *elegant*, *futuristic*, *sober*, *sexy* and *toy- like* were obtained. In this chapter, we explore the second case, i.e. a particular sensorial property of a material affecting a material's meaning.

In Chapter 3, it was also emphasized that how a material is processed or what kind of manufacturing techniques are used may have an important effect on the attribution of meanings to materials. For instance, combining materials in certain ways (e.g. using decorative joining like sewing or invisible joining like gluing) or special surface treatments (e.g. covering layers, polishing, etc.) may play an important role in how we appraise materials and products. However, any effect that a manufacturing process has on a material's meaning was established as indirect, i.e. people perceive a process or a surface treatment with the help of sensorial characteristics (e.g. wall thicknesses, mold (production) lines, texture, etc.). Thus, the second relationship explored in this chapter is the effects of manufacturing processes, conveyed through sensorial experiences, on the meanings people attribute to materials.

Sensorial properties of materials and manufacturing processes

Sensorial properties of materials were broadly explained in the previous chapters. Briefly, the properties describing the interaction between materials and users through our five senses (sight, touch, smell, taste and hearing) are defined as *sensorial properties.* They include tactile aspects like smooth, cold, and flowing, or visual aspects like matt, translucent and shiny. In literature, sensorial properties of materials are recognized as one of the most important aspects of materials in determining the affective responses of users (Fenech & Borg, 2006; Mono, 1997; Rognoli & Levi, 2004; Sonneveld, 2007; Williams, 2007; Zuo, Jones, & Hope, 2005). Most of these sources conjoin at the point that some basic elements of *touch* and *vision* foreshadow a specific meaning for a material. For instance, the smoothness of a surface can evoke the meaning elegant (Zuo et al., 2005) or a shiny chrome surface can be associated with high-tech or futuristic as in Terminator 2 for a molten metal bad guy (Williams, 2007). On the other hand, as conveyed throughout this research, it may not be easy to assert that a material of a product is friendly due to its silky soft touch and its matt visual property. But it may be claimed that *softness* and *brightness* together with the other product aspects (like shape and function) are considered by designers for ascribing meanings to materials.

Manufacturing involves making things for use and sale, by using tools or manual labour. In industrial design, the term refers to a vast range of human activity, from hand craft to high tech, which is commonly applied to industrial production, in which raw materials are transformed into finished products on a large scale (Fenech & Borg, 2006). The manufacturing of a product involves all intermediate processes required for the production and integration of the product components, such as joining and finishing (surface treatment) processes including glazing and painting. The Cambridge Engineering Selector (CES) contains information for the 19 most commonly used joining processes, 20 shaping processes and 23 surface treatment processes, which were adopted for denoting different manufacturing processes of interest in this study.

2 Studies

In Chapter 2, an exploration was made of how people experience materials, through the collection of descriptions about people's material appraisals. Of the total 687 descriptions, 200 were related to sensorial experiences of materials. Furthermore, 33 of the 687 descriptions referred to manufacturing processes including applied production or treatment techniques for the appraised product (e.g. glazed, polished, galvanized, etc.), shaping and joining processes (mass produced, cast, moulded, glued, etc.). We consider that every single property alluded to in the 200 descriptions can be influential in a particular context. On the other hand, we assume that particular sensorial properties and manufacturing processes find more popular use by designers in creating certain material experiences. In order to achieve our main goal of identifying these commonly used properties, we first need a convenient number of properties to be used in further studies. For this reason, before the main study to be reported in the chapter, we first conducted a set of pre-studies with the aim of reducing the number of properties from 200 to a more manageable number.

Pre-Study 1: Creating a manageable list of sensorial properties (from 200 to 21)

In Pre-Study 1, the extensive list of collected sensorial descriptions (n= 200) was narrowed down by experts on particular senses (e.g., expert on touch, expert on sound, expert on smell). First, the experts were interviewed individually. Before each interview, they were requested to bring a list of properties regarding their sensory domains (about touch, about smell, etc). They evaluated their own list of properties by focusing on materials, and identified those properties that were more relevant to materials. Then they were given the list with 200 sensorial descriptions of materials and asked to select those that related to their pre-selection list. In this way, at the end of all of the individual interviews, the original 200 items were grouped into five categories based on their relevance to a sensory domain. After that, each expert compared their own list with the list that we gave to them. They selected the sensorial properties that they found very relevant for creating meanings of materials. Finally they identified combinations of descriptions related to a single sensorial property (e.g. *massive*, *airy* and *hollow* were gathered under *massiveness* property).

The selected properties were discussed once again with all of the experts and two industrial designers, to remove properties that might be 'tricky' (difficult) to comprehend by designers. For instance, instead of "sounds like a rainstorm when you scratch it" or "sounds tinny", we used *scratchiness* of a material, *dampened* (or *resonant*) sound of a material and *low* (or *high*) *pitch* sound of a material. Only a few descriptions related to *taste* (e.g. bitter, sweet) and we found these irrelevant for material appraisals of products. For this reason, taste related properties were not included in the sensorial list.

While selecting the properties, we realized that some particular technical (or quantifiable) properties of materials are used by people as a sensorial property. *Elasticity* and *stiffness* are two of these cases. These are technical properties of materials referred to by designers, who may be more familiar with these terms for describing the flexibility of a material or a material's resistance to elastic deformation. Similarly, *strength*, which is a technical property, is used very often by designers for referring to tough or ductile qualities of a material. To take these three common and interchangeable technical-sensorial properties into account (elasticity, stiffness and strength), we added them to our list of properties. Ultimately, 21 properties were selected for the main study (see Table 1).

Table 1. Preliminary list with selected 21 sensorial properties with Dutch translations.

brittleness (brittle- unbreakable) / *broosheid (broos- onbreekbaar)*
colourfulness (colourful- colourless) / *kleurrijkdom (kleurrijk- kleurloos)*
dampened / resonant sound of the material / *bedompt/ resonerend geluid van het materiaal*
darkness (dark- light) / *donkerte (donker- licht)*
ductility (ductile - tough) / *vervormbaar (kneedbaar- taai)*
elasticity (high-low) / *elasticiteit (hoog- laag)*
glossiness (glossy- matte) / *glans (glanzend- mat)*
intensity of colour (intense- mild) / *intensiteit van de kleur (intens- zwak)*
low/ high pitch sound of the material / *laag- tonig/ hoog- tonig geluid van het materiaal*
massiveness (massive- airy- hollow) / *massiefheid (massief- luchtig- hol)*
odorous (natural- oderless- fragrant) / *geruigheid (natuurlijk- geurloos- geurig)*
reflectiveness (reflective- non reflective) / *spiegeling (spiegelend- niet spiegelend)*
roughness (rough- smooth) / *ruwheid (ruw- glad)*
scratchiness (scratchy- not scratchy) / *krasbaarheid (krasbaar- krasvast)*
softness (soft- hard) / *zachtheid (zacht- hard)*
stickiness (sticky- not sticky) / *kleverigheid (kleverig- niet kleverig)*
stiffness (stiff- flexible) / *stijfheid (stijf- flexibel)*
strength (high- low) / *sterkte (hoog- laag)*
transparency (transparent- translucent- opaque) / *transparantie (transparant- melkachtig- ondoorzichtig)*
warmth (warm- cold) / *warmte (warm- koud)*
weight (light- heavy) / *gewicht (licht- zwaar)*

Pre- Study 2: An online survey (from 21 to 13)

The purpose of the second pre- study was to select the sensorial properties (out of 21 properties) that designers consider influential in attributing meanings to materials. An online survey was conducted for this purpose.

Method

Participants

The survey was sent to 50 professional Dutch designers who were informed about the survey in advance. There were 28 (12 female; 16 male) valid responses for the evaluation process. The average age of participants was 33. All participants had at least 4 years of experience in product design.

Meanings

We required a manageable number of meanings that could be understood and evaluated easily by designers. In Chapter 4, 38 material relevant meanings were selected from a list of 219 expressive meaning descriptions. Conceptually related meanings were then grouped under five factors. The meanings used in this pre-study were selected on the basis of these depicted factors. Firstly, one representative meaning from each factor was selected: *futuristic* from the 'age' factor, *flashy* from the 'striking' factor, *luxury* from the 'quality' factor, *fashionable* from the 'cool' factor, and *professional* from the 'serious' factor. Additionally, a second meaning, which was obviously different from the first meaning and which designers may commonly aspire to, was selected for each factor: *cozy*, *sober*, *toy- like*, *sexy* and *masculine*.[1]

Procedure

A survey was carried out online. It contained 11 pages including a brief introduction page. On each page, a meaning item (one of 10 selected for the study) and 21 sensorial properties (see Pre-Study 1) were presented in a randomized order (see Appendix 5.1 for an example). The participants were asked to select the properties that they found effective in creating the given meaning. They were allowed to choose more than one property for each item. By clicking the next button, they were able to move to the next page consisting of another item and the same sensorial properties, though presented in a different order. All properties and meanings were translated into Dutch.

Results

A *One Sample t- test* was executed to compute the significance levels of the ratings. The overall mean score for 21 properties (M= 3. 5) is indicated by a dotted horizontal line in Figure 1. The properties with mean values equal to or higher than the overall mean score were selected as properties perceived as the most effective for constructing meanings. According to the test results, designers identified 13 properties to be effective in meaning attribution to materials.

Sensorial properties and related parameters

In this section, the 13 sensorial properties are classified under correlated parameters based on related literature. Three main sources were used: *expressive- sensorial atlas* by Rognoli and Levi (2004), *tactual experience guide* by Sonneveld (2007) and *Sensation and*

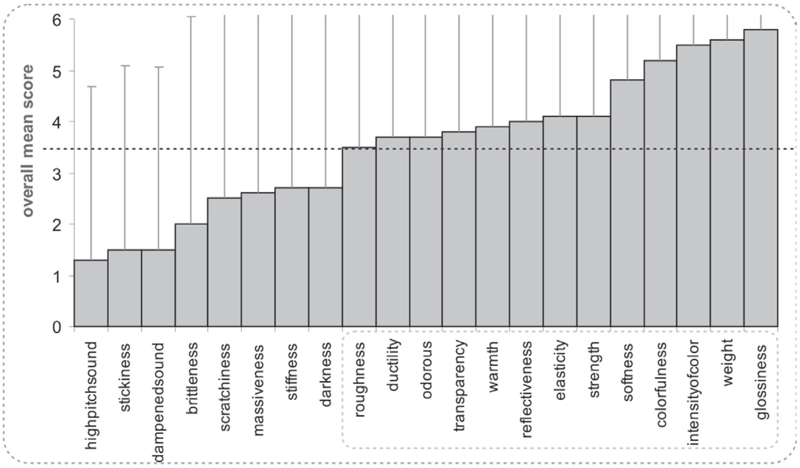

Figure 1. Selection of the effective sensorial properties.

Perception book by Goldstein (2002). The aim is to have an overview of the dominant sensory modality (or modalities) in materials experience. The 13 properties were classified first into three sensorial modalities: *tactual*, *visual* and *olfactory* (Figure 2). *Tactual* refers to what one physically experiences through touch when interacting with environments (Sonneveld, 2007), or in our case materials. When *tactual* is compared with *touch*, it is more related to *experience* than touch, which refers to the *act* of touching and of being touched (Sonneveld, 2007). It includes thermal sensations as well as sensation of force, pressure and friction (Rognoli & Levi, 2004). Ductility, elasticity, roughness, softness, strength, warmth and weight were gathered under the tactual modality.

In Figure 2, the properties related to the three sensorial modalities are further grouped under related parameters. For instance, ductility, elasticity, softness, strength and weight are *pressure and force* related properties (Van Kesteren, 2008). Warmth is related to thermal diffusivity (a combination of thermal conductivity and specific heat) and is grouped under the *temperature* parameter in the table. Roughness is concerned with *friction* of a surface (Rognoli & Levi, 2004), which also affects stickiness. It should be recognized that roughness can also be evaluated by sense of vision. However, in this study we consider roughness (or smoothness) of a material as being most critically appraised through the sense of touch.

The stimulus for vision is light, and the visual process begins when visible light enters the eye and forms images on the retina (Goldstein, 2002). The properties related to light and seeing are gathered under the *visual* modality. Glossiness, reflectiveness and transparency are three effective visual properties that are linked to 'reflection coefficient', 'index of refraction' and 'surface roughness'. In other words, these three properties are connected to each other and they are grouped under the *light reflection* parameter in the figure. In a similar way, *intensity of colour* and *colourfulness* are classified under *colour* parameter.

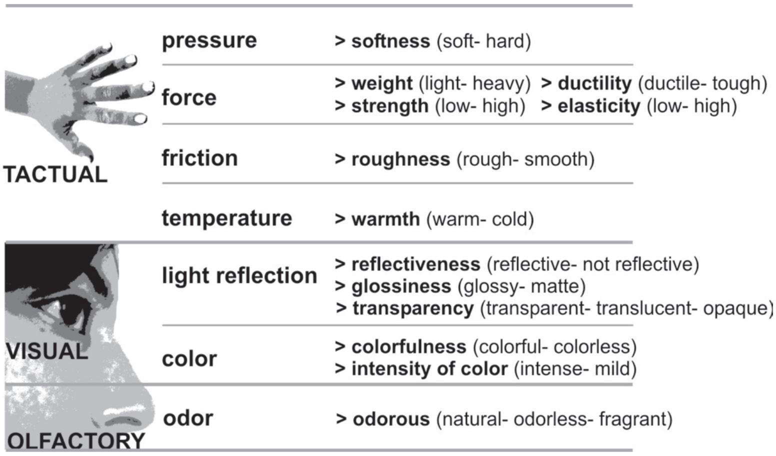

Figure 2. Sensorial modalities and parameters found effective in attributing meanings to materials.

Olfaction, which is also known as olfactics, is the sense of smell and the detection of chemicals dissolved in air (Goldstein, 2002). Following this definition, the olfactory modality covers smell- related properties in the figure. The detected chemicals in olfaction, generally at very low concentration in air, are called *odour*. *Odourous* properties take place under the odor parameter.

Discussion

In Pre-study 2, it was found that the sensorial properties effective in attributing meanings to materials are mostly related to visual and tactual sense modalities. *Glossiness* (5. 8) was regarded as the most effective sensorial property in meaning attribution by Dutch designers. Other effective properties related to sense of vision were *intensity of colour* (5. 5), *colourfulness* (5. 2), *reflectiveness* (4. 0) and *transparency* (3. 8).

Softness (4. 8), *strength* (4. 1), *elasticity* (4. 1), *warmth* (3. 9), *ductility* (3. 7) and *roughness* (3. 5) were touch- related material properties selected frequently by designers. *Weight* (5. 6) had the second highest mean score after glossiness in the overall evaluation. Not surprisingly, *strength* (4. 1) was found relatively more effective in creating meanings than the similarly grouped properties *ductility* (3. 7) and *brittleness* (2. 0). The mean score of *elasticity* (4. 1) was notably different from *stiffness* (2. 7). This result confirmed our assumption that designers are more familiar with some technical terms than related sensorial ones.

The smell of a material (odour) was initially in our list of properties. Some industries such as the automotive industry have recently increased pressure on their material suppliers to reduce the smell of synthetic materials (Oliver and Catharine, 2005). Likewise, designers have been increasingly aware of values created through olfactory experience (e.g. the leather smell of a car interior, or the natural smell of a wooden chair). The material property *odourous*

(3. 7) appeared as an effective property in our final list.

Sound- related properties, that is, the dampened/ resonant sound of a material (1. 5) and the high/low pitch of a material (1. 3), had rather low mean scores in comparison to other sense modalities. There are two possible explanations for this finding. The first is that designers may not understand the terms *dampened*, *resonant* and *pitch* sound. An alternative explanation is that designers may think that sound is indeed not effective in creating meanings unless people experience the entire product. On the other hand, it should be recognized that the aim is not to disregard a property which can be valuable in a particular situation. Instead, we aim to select the properties that are, first, used often by people while describing materials, and second, commonly used by designers for expressing certain ideas through materials. Therefore, we recommend further studies particularly focusing on smell and sound and their effects on expressive meanings of materials.

Pre-Study 3: Creation of the manufacturing properties list

In order to have a manageable list of manufacturing processes to explore in the main study, first the list of collected manufacturing process items (n= 33) was analyzed to create categories based similarities and differences between processes. The main division of Ashby utilized in the CES was adopted for a preliminary classification process. We were able to categorize all 33 descriptions under three main categories: (1) shaping processes, (2) joining processes, and (3) surface treatment processes. In the CES there are more processes listed than in our list. Most are very detailed processes and they are difficult to be recognized through sensorial properties of products. On the other hand, we did not want to ignore any process that was not mentioned in the appraisals of materials and products, as it could plausibly have an effect on meaning. Therefore, our own list of processes and the list provided from CES were analyzed by four experts on materials and manufacturing processes from the Faculty of Industrial Design Engineering of Delft University of Technology. They were asked to go through both lists and select the ones that could affect a products' appearance in a way that can be perceived easily. They named some main categories that were not listed in CES, such as material combinations, decorative joining, etc. These categories were suggested to be very effective in creating sensorial experiences and meanings. *Material combination* is a product property rather than a material's sensorial property. Specific processes are required in order to combine materials. Therefore material combination was included in the manufacturing processes list. The final list consisted of eight main categories covering certain important manufacturing processes, with material combination as an individual category. Table 2 shows the list of processes that was used in this study.

Main Study

In total, 13 sensorial properties and 9 manufacturing process categories were selected in the pre-studies. In the main study, we further investigated the importance of these 13 sensorial properties in meaning attribution to materials and looked for properties that might have

Table 2. Manufacturing process categories (and sub-processes) used in the main study.

shaping	- production volume (handmade, mass produced) - shaping through moulding (blow moulding, vacuum moulding, press molding, etc.) - shaping for details (milling, injection molding, etc.)
joining	- functional (visible) joining (screw, bolt, etc.) - decorative joining (sewing, snap fastener, etc.) - invisible joining (glueing, welding, laminating, etc.)
surface treatment	- polishing (sanding, burnishing, etc.) - covering layers (printing, glazing, painting, etc.)
	- material combinations (plastics+metal, metal+wood, wood+plastics, etc.)

been overlooked in the pre- studies. In addition to this, we aimed to determine if people found the 9 process categories effective in attributing meanings to materials; or, if certain properties and processes played a more important role than others for creating particular meanings. For this study, participants were asked to select materials (preferably embodied in products) expressing the five given meanings- *aggressive*, *nostalgic*, *professional*, *sexy* and *toy-like.* These meanings had been used in Chapter 3, in which the results of a conducted study had been tentatively concluded with a set of relationships between sensorial properties of materials and these five meanings. Herein, we aimed to make these tentative results more concrete with a quantitative study. The participants were asked to appraise the materials of their products first verbally through interviews and then on paper through the list of sensorial properties and manufacturing processes presented by five- point scales. In total, 125 products were collected and analyzed.

The main goal of the study was to identify the most important properties and processes based on product and material evaluations by people. In order to get reliable results, it was crucial to present the items in a way that would prevent wrong or ambiguous interpretations. Therefore, all items of both lists (sensorial properties and manufacturing processes) were visualized with a graphical software program. Every single sensorial property was represented with three visuals demonstrating two opposite ends and one moderate level of the property (e.g. transparency was represented with three modalities: (1) *transparent*, (2) *translucent*, and (3) *opaque*. With this approach, the participants were able to consider all variants of a certain property whilst evaluating products based on that property. Special attention was given to the representation of the properties, by using interchangeable supportive elements, such as a ball for representing colour and transparency. All properties were presented in a similar virtual environment. Each main manufacturing process was represented with at least three visuals referring to commonly known sub-processes. Invisible joining, for instance, was represented with three visuals related to gluing, welding and laminating. For production volume, used for asking whether a product was produced in large quantities or not, only two sub-processes were visualized: hand-made production and mass- production.

For certain processes, instead of showing the process itself, we preferred to show the end-result, which was thought to be more explanatory. This was because people most of the time are not familiar with the process itself, but rather what it offers in an end product. In some circumstances, the result of a process can be noticed or realized in the overall representation of the product, such as in an injection moulded cup. However, printing on a surface, for instance, can be showed with a small piece from a product. For the former case we preferred products that typified a given manufacturing processes. For example, shaping through moulding was illustrated by three pictures (1) a bottle (for blow moulding), (2) a bathtub (for vacuum moulding) and (3) a pot (for press moulding). The visuals were checked by experts before conducting the study. A pilot study with four participants was also conducted for testing the readability of the created visuals. A few of the manufacturing process visuals were redesigned as a result. In the pilot study, we realized that to represent certain properties with three visuals showing three levels was not sufficiently clear for the participants, because people are more familiar with (or commonly use) certain terms related to particular properties. Therefore, for these kinds of properties, we used both terms (expressing two polar levels) adjacent to the visual representations. Roughness, for instance, is a property used for describing the rough and smooth quality of a surface. We represented roughness with three visuals including a smooth surface, moderately smooth surface and a rough surface. Next to these three representations, we decided to write roughness as *roughness (smoothness)*, based on the concerns explained above. Figure 3 presents the final visual representations of all the properties and processes used in the main study.

Method

Participants

A total of 7 PhD students and 18 MSc students (14 female; 11 male) from the Faculty of Industrial Design Engineering of Delft University of Technology participated in the study. All participants were Dutch and they voluntarily participated in the study.

Procedure

The participants were informed with a letter explaining the requirements of the study one week in advance. They were asked to select five products expressing five given meanings (i.e. *aggressive*, *nostalgic*, *professional*, *sexy* and *toy- like*) particularly through their materials. The given instruction was explained with an example: "*For instance, you found several products expressing the meaning 'sexy'. You should particularly focus on the material of these products and select the one for which the material seemingly plays a major role in conveying the meaning 'sexy'.*" The participants were informed that they could bring a visual representation of the products if it was not possible to carry the product itself.

First the participants were asked to evaluate the materials of their products and to verbally explain the motives underlying their selections. The reason for this was to find out if any mentioned property did not appear on our list of properties. After the verbal appraisals

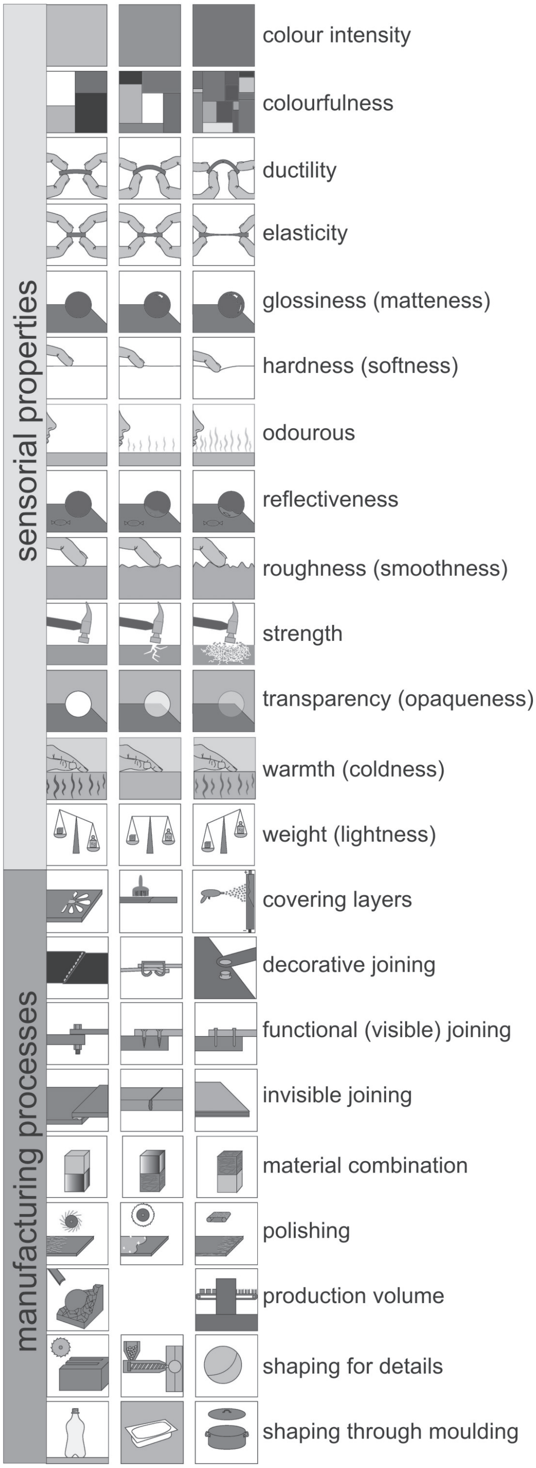

Figure 3. List of properties and visual representations used in the main study.

of each product, the participants were given questionnaires with visual representations of sensorial properties and manufacturing processes. Each item (property or process) was presented with a five-point scale. Participants were asked to indicate the importance of a given property for the meaning that their product conveyed.

Results

A total of 125 products were evaluated both qualitatively by analyzing verbal appraisals, and quantitatively with a statistical analysis of the scale ratings.

Qualitative results

The participants in general talked about particular sensorial properties such as glossiness, roughness, transparency, and softness. As expected, instead of giving certain process names, they commonly mentioned the results created through particular processes and which could be recognized easily, such as prints and visible production lines. They mentioned that certain manufacturing processes play a very crucial role in creating particular meanings (i.e. luxurious, elegant and rich). Two new properties not presented in our list of properties were mentioned several times by participants during the verbal appraisals: texture and wall thickness.

Not surprisingly, people associated certain materials with certain meanings, and these associations are similar to the findings obtained in Chapter 3. Particular sensorial properties were found effective in attributing meanings to materials in individual assessments of meanings. Table 3 lists the common associations between meanings and material properties obtained from the verbal appraisals of the participants. The table also includes a set of products selected for each meaning. The products in the table show that people associated metal and plastics with all five meanings. In other words, meanings attributed to metal and plastics can vary more easily over different products than, for example, glass and wood. While glass was mainly associated with the meaning *sexy*, wood was associated very much with nostalgic products.

Quantitative results

All data collected from the five point scales were transferred into data sheets. One Sample t-tests were performed in order to test if the mean scores of individual properties and processes differed significantly from the overall mean. Table 4 depicts the results obtained from the t- tests. Bold items in the figure show the properties that are significantly above or below the overall mean score (n= 2, 99). *Hardness* (3, 84) appears to be the most important property in the overall evaluation. *Roughness* (3, 82), *glossiness* (3, 67) and *colorfulness* (3, 69) follow hardness in ranking. *Odourous* (2, 11) obtained the lowest mean score indicating it was not considered important. Surprisingly, transparency was rated significantly below the overall mean score.

Table 3. Summary of the verbal appraisals with a set of product samples.

	product samples	associated materials	associated properties
aggressive		metal (stainless steel) plastics rubber	rough, hard, cold, glossy dark colours (black) material combinations (metal and dark coloured plastics)
nostalgic		metal (copper, iron, bronze) natural materials bakelite ceramic wood	patterns heavy, warm dark colours (brown)
professional		metal (titanium, stainless steel, silver) plastics	smooth, hard, cold matte, semi-transparent dark colours brushed, coated mass-produced
sexy		metal glass plastics textiles (satin)	smooth, hard/soft cold/warm, glossy/matte semi-transparent light colours (white) intense colours (crimson)
toy-like		plastics (latex, pp, pe) rubber	smooth, light, strong (unbreakable) ductile, elastic primary colours (red, blue, green, yellow) colour combinations

Table 4. Results of the One Sample t-test.

Test Value = 2.99	Mean	df	Sig. (2-tailed)	Mean Difference
Colourfulness (+)	3,69	124	,000	,698
Colour intensity (+)	3,50	124	,001	,506
Covering layers	2,72	124	,078	-,270
Decorative joining (-)	2,33	124	,000	-,662
Ductility	3,15	124	,307	,162
Elasticity	2,71	124	,067	-,278
Functional joining (-)	2,53	124	,002	-,462
Glossiness (+)	3,67	124	,000	,682
Hardness (+)	3,84	124	,000	,850
Invisible joining (-)	2,50	124	,003	-,486
Material combination	3,13	124	,382	,138
Odorous (-)	2,11	124	,000	-,878
Polishing	3,14	124	,299	,154
Production volume (-)	2,32	124	,000	-,670
Reflectiveness	3,13	124	,339	,138
Roughness (+)	3,82	124	,000	,826
Shaping for details	2,84	124	,308	-,150
Shaping through molding (-)	2,46	124	,000	-,526
Strength (+)	3,34	124	,017	,354
Transparency (-)	2,56	124	,005	-,430
Warmth	3,10	124	,412	,114
Weight (+)	3,32	124	,021	,330

No manufacturing process received a significantly higher mean score than the overall mean. Decorative joining, functional joining, invisible joining, production volume and shaping through moulding notably received scores below the overall mean.

Figure 4 shows the mean scores of properties separately for each of the five meanings and the ranking of properties based on their overall mean scores. The properties in general are found less influential in attributing the meaning *aggressive* to materials (2, 75). Participants indicated that they found *aggressiveness* difficult to express through material properties. In other words, they were not able to associate *aggressiveness* easily with certain material properties of products. On the other hand, *toy- like* (3, 11) and *professional* (3, 25*)* meanings were readily associated with material properties.

Furthermore, particular properties were found to be very effective in the assessments of specific meanings. While colour intensity and colourfulness were two leading properties in *toy- like* products, hardness and strength received the highest mean scores in attributing *aggressiveness* to products, and roughness received the highest ratings for the meaning *sexy*. As expected, certain manufacturing processes were also found relatively effective in *professional* products, such as invisible joining, functional joining and shaping for details.

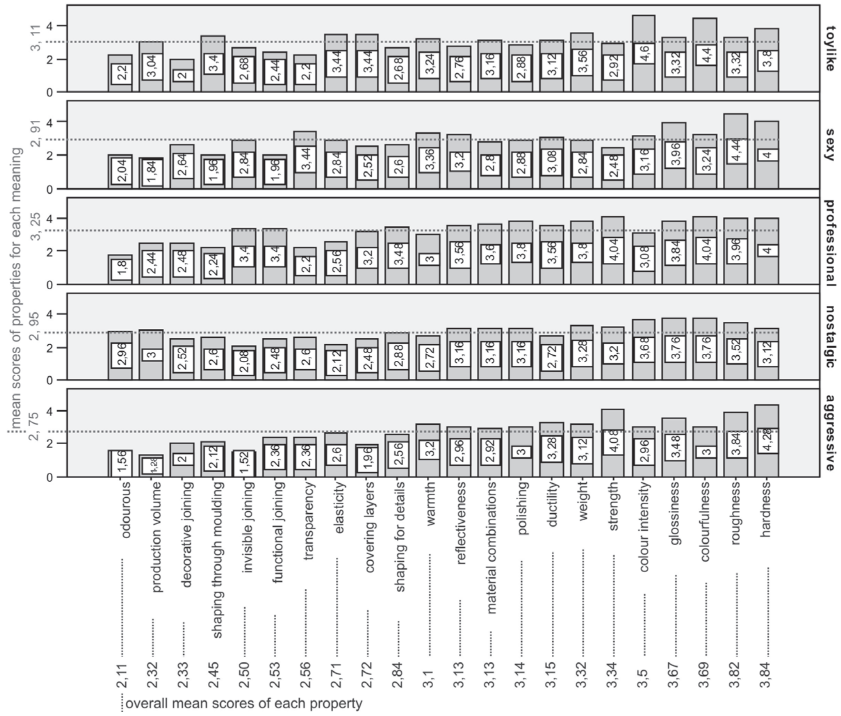

Figure 4. Mean scores for sensorial properties indexed against five meanings.

3 Discussion

In general, the participants mentioned that other product properties such as geometrical shape and colour played a crucial role in the overall impression of a product. Accordingly, the effects of a material on a product's meaning were found to depend much on the particular product in which the material was embodied.

There were noticeable differences in the selection of products based on a particular meaning. When selecting toy- like products, for instance, the participants looked directly for light, brightly coloured plastics. The pervasive use of a material for a certain product category helped them to construct easy associations between a material and a meaning. On the other hand, for the meaning *aggressive*, shape very much influenced their decisions. In some circumstances, similar to the studies reported in Chapter 3, the participants thought about the ramifications that occur during or after use of a product, such as a hurting effect of a rough surface, or a burning sensation of a poorly insulated kettle handle. Herein, *context of use* appeared as an effective factor in meaning attribution to materials. In some other cases, such as for *nostalgic*, the participants mostly looked for materials that were popular 50 years ago. Their decisions were inevitably affected by their personal experiences and backgrounds. As a consequence, some materials considered nostalgic would not be so for another *user*.

Most of the sensorial properties in our list appeared to be important in the overall evaluation. As expected, some properties were found more important than others (e.g. glossiness vs. warmth). However, a few properties received lower ratings than expected, such as transparency and elasticity. Although one may construe lower scoring properties as less important than those properties receiving scores above the overall mean score, it should be recognized that every single property may become crucial in particular circumstances. The smell of an old notebook, for instance, can be very valuable for its owner for recalling memories. *Texture* and *wall thickness* were often mentioned to be noteworthy factors in meaning attribution. These properties can therefore be explored in future studies.

The value of manufacturing processes was generally emphasized in creating meanings through sensorial experiences. However, we expected higher mean scores in the overall evaluation. In the informal discussions with the participants after their participation in the study, we realized that even for our participants (design students and design researchers), certain processes were not easy to recognize in products although their visual representations were found clear. Being a surface treatment process that is easily recognized through vision and touch, *polishing* appeared to be the most important manufacturing process in the overall evaluation. Overall, sensorial properties received generally higher mean scores than manufacturing processes (Figure 5).

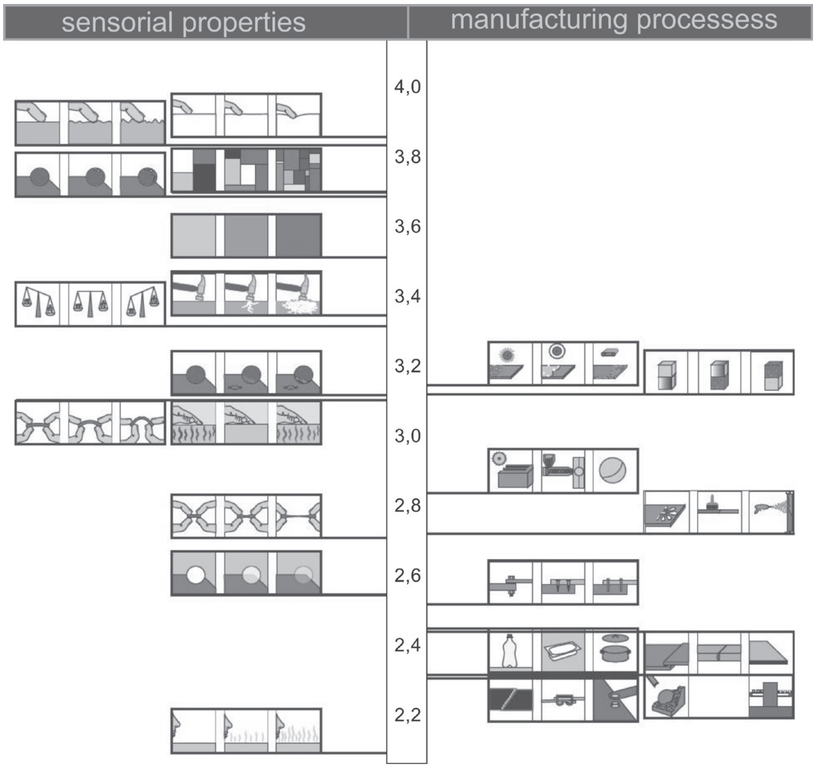

Figure 5. Comparison of sensorial properties and manufacturing properties in overall ranking.

According to the design researchers who participated in the study, the judgment of a particular manufacturing process requires a more focused assessment of a product. Subsequently, they recommended us to make our participants evaluate only one product in more detail in further studies. They added that even though the visual representations were lucid, it was a challenge to understand all sub-processes and to evaluate them in order to assess the implications of the main processes on the participants' products. Moreover, for some cases particular sub-processes were found very important, such as *sewing* under decorative joining, or *injection moulding* under shaping for details. The participants stated that those kinds of sub- processes could be presented individually. Colour was another important factor in the overall evaluation. However, the participants, in general, found it difficult to assess the colour of materials for two main reasons: (1) some mentioned that colour is not a property of materials in their selection, but an additional design consideration (colouring), and (2) in some cases, the selected product was made of more than one material, each having a different colour. Thus, the overall product could be evaluated as colourful, but not the material. These kinds of situations were confusing for the participants. Briefly, even though colour was regarded as one of the most important properties in the overall evaluation, separate studies are required to explore the effects of colour on material meanings.

4 Conclusion

People are primarily impressed by formal qualities of products, and certainly for many product areas, their appraisals of products and purchasing decisions are visually and tactually dominated. Inevitably, sensorial properties of materials play a crucial role in meaning attribution to materials. In general, it is impossible to determine a one-to-one relationship between a certain property and a meaning. Different combinations of properties result in different meanings of materials. However, particular properties, obviously, are more commonly used than other properties for constructing certain associations (e.g. glossiness vs. odourous). The detection of these associations can be valuable for designers in their materials selection activity.

The studies presented in this chapter showed that manufacturing processes create certain sensorial experiences in particular contexts that might affect how we appraise materials and products. Although the assessment of the effects of manufacturing processes on the meanings we attribute to materials is rather difficult in comparision with the effects of sensorial material properties, designers should be aware of the effects of manufacturing processes and involve them in finding meaning evoking patterns in their materials decision-making.

Author note

I gratefully acknowledge the help of Floris van der Merel, Miriam Bachet, Djurre Feldberg and Marnix Kichert in creating the *pictograms* used in the studies conducted in Chapter 5.

Endnote

1 This pre-study was conducted before the study reported in Chapter 4. In the study reported in Chapter 4 we aimed to create a set of semantic scales. In this pre-study the aim was to select a list of meanings which are conceptually different from each other, which can be recognized by designers easily and which designers may commonly intend to create. The lists of meanings used in these two studies are overlapping, but not completely the same.

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General Conclusion :: Part II

In Chapter 3, first, three perspectives in meaning creation were reviewed (object- centered, individual- centered and interaction- centered) and the main notion followed in this thesis was stated as the *interactional approach*, which takes both object and perceiver into account in meaning attribution. Accordingly, our main assumption was explained whereby materials obtain different expressive characteristics (or meanings) in different contexts. Thus, meanings of materials are not fixed properties. Furthermore, the meaning of a material in a particular context may change over time. On the other hand, we assume that there are some patterns that pervade situations in materials experience. A material's distinctive sensorial and physical properties, how it is shaped, how it is used, by whom it is used, etc. may define a particular pattern for a meaning(s) of this material.

Taking these considerations into account, a study was conducted to detect the main components of the meaning evoking patterns in materials experience. Five ways of meaning construction were defined in the processes that lead to attribution of meanings to materials. On the basis of these five ways, we developed the Meanings of Materials (MoM) model, which presented the meaning of a material as a relational concept in which certain material properties, products in which the material is embodied, how products are manufactured, how they are used, by whom, and in which context they are used, are jointly effective. The effects on meanings of material type, product and user were verified in Chapter 4.

The findings of the study in Chapter 3 also showed that particular material properties can be associated with certain meanings, such as shiny and hard materials with the meaning professional, or smooth and soft materials with the meaning sexy. This qualitative analysis was further explored with quantitative studies in Chapter 5. The most commonly used sensorial properties in attributing meanings to materials were listed. Effects of manufacturing processes on sensorial experiences, which indirectly affect meanings of materials, were also explored in Chapter 5.

In brief, the findings of the studies conducted in Part II one more time remind us that in order to understand the roots of a material's meaning, designers should look beyond obvious properties and avoid constructing one-to-one relationships between material properties and meanings. They should understand how certain aspects interact with each other in order to create a particular pattern for expressing a certain meaning. How can we convey this idea to designers, in order to support them in routine inclusion of meaning considerations into their materials selection processes? The next part of the thesis seeks an answer to this question.

PART III
meaning driven material selection

In the third part of this thesis, a tool for supporting designers to involve meaning considerations into their *materials selection* is developed. The evolution of the tool is based on two main sources: (1) insights into materials selection methods and tools, and current studies on materials in design (Chapter 6); and (2) the [Meanings of Materials] model and the key variables found effective in attributing meanings to materials in previous chapters. The idea of *meaning driven materials* selection is explained in Chapter 7. The chapter also explains the different stages followed during the tool creation. Part III ends with Chapter 8, in which a dummy application of the tool is tested.

Chapter 6 is based on:

Karana, E., Hekkert, P., Kandachar, P., (2008), Material considerations in product design: A survey on crucial material aspects used by product designers. *Materials and Design*, 29, 1081-1089.

6

[meaning driven] materials selection

1 Introduction

The starting point for developing a materials selection tool is to understand the current activities and approaches followed by designers and to find out the drawbacks as well as advantages of the existing tools and methods. There are several tools used in materials selection processes by designers. However, they are mostly engineering based tools, which are dominated by numerical (or technical) material data that is mostly of use in embodiment or detailed design phases of new product development. On the other hand, product designers consider certain aspects such as product personality, user- interaction, meanings, emotions, etc. in their material decisions. In this regard, existing tools and methods do not fully support designers in their materials selection processes, and especially not in the concept creation phase of new product development. New studies, which are reviewed in Section 3, have been conducted in order to support designers in their materials decision-making on the aforementioned aspects. However, the studies illuminate only a part of the greater whole and mostly focus on a single sensorial modality such as touch.

This chapter first describes the traditional view of materials selection in product design and addresses the existing tools and methods used for selecting materials. After a critical assessment of how designers select materials, what kinds of information they seek for, and what the existing tools and methods are, a list of guidelines for a materials selection source for designers is proposed. The necessity for a new vision for selecting materials in design, concerning alternative approaches (such as design for interaction, multi sensory design, etc.) is highlighted.

2 Product Design Process

Product design can be defined as the idea generation, concept development, testing and manufacturing or implementation of a physical object or service. Product designers are educated to follow a systematic approach in order to conceptualize and evaluate ideas and translate them into functions, forms and materials, etc. (Hubka & Eder, 1992; Pahl & Beitz, 1996; Pugh, 1981; Roozenburg & Eekels, 1995). They make this translation in a sequence of design phases. The sequence usually consists of three main phases: (1) concept creation, (2) embodiment design, and (3) detailed design (Ashby, 2005; Pahl & Beitz, 1996).

Ashby (2005) briefly explains these three phases as follow: at *the conceptual design stage* all options are open, that is, the designer considers the alternative ideas (regarding target market), working principles or schemes, and comes up with preliminary ideas fulfilling the design requirements. *Embodiment design* takes a function structure and seeks to analyze its operation at an approximate level, sizing the components and selecting materials, which will perform properly in the ranges of stress, temperature and environment etc. suggested by the analysis. The embodiment stage ends with a feasible layout, which is passed to *the detailed design stage*. Here specifications for each component are drawn up; critical components may be subjected to precise mechanical or thermal analysis; optimization methods are applied to components to maximize performance; materials are chosen, the production methods are analyzed and the design is costed. The phase ends with detailed production specifications.

3 Materials Selection in Product Design

The selection of a material for a specific application is a thorough and lengthy process, because almost always more than one material is suited to an application. Designers aim to select the most appropriate material(s) from a list of candidate materials. Many scholars in the field of materials and design put more emphasis on the technical properties of materials, manufacturability possibilities, economical requirements, availability, and environmental issues in materials selection (See Appendix 6.1 for a review of different sources defining the effective material aspects for materials selection processes).

Ashby and Johnson (2002) identify four main approaches followed by designers while selecting materials: (1) analysis, (2) synthesis, (3) similarity and (4) inspiration (pp. 127-132). In the first approach, designers use precisely specified inputs and well established design methods on databases of materials. This method is defined as *selection by analysis*. The second approach basically depends on past experiences, recovered by seeking a match between features, intentions, perceptions or aesthetics desired from a new design, and design solutions stored in a database of product *cases*, which is called *selection by synthesis*. If the designer looks for materials with selected attributes matching with those of another existing material, the method is the third approach, called *selection by similarity*. And finally, if the designer visits stores, viewing products and materials to seek ideas in a serendipitous way, until one or more are found appropriate for the project at hand, the method is the fourth approach, called *selection by inspiration*. Each of the methods has some strengths and weaknesses, and one of them may suit for one project, whilst another may suit a different project. Ashby and Johnson recommend designers *to combine all the methods for a more powerful selection*.

In most of the materials selection sources, an analytical approach is followed (Ashby, 1999; Cornish, 1987; Farag, 1989). In an analytical approach, a set of objectives and constraints are defined. Afterwards, the properties of a number of existing materials are analyzed based on the defined objectives and constraints. The candidate materials are then selected. Ashby and Cebon (2007) sum up the materials selection activity in four main steps (1) translate the design requirements as constraints and objectives, (2) screen the material world to identify materials that cannot do the job, (3) rank the materials that can do the job best and (4) explore the top rated materials. In that sense, materials selection is carried out (consciously or not) as a design activity, involving the phases *concept creation* (by formulating material objectives and constraints, and arriving at candidate materials), *testing* and *comparing* candidate materials, and making a *detailed selection* with technical specifications.

The four steps described by Ashby and Cebon (2007) summarize the traditional materials selection approach promoted in engineering design. Constraints and objectives are mainly determined by technical requirements and materials are selected accordingly. In product design, however, materials should not only fulfill technical requirements but also appeal to the user's senses and contribute to the intended meaning of a product. These concerns are introduced to the domain of design with alternative approaches such as *design for interaction* (Hekkert, Lloyd, & Van Dijk, 2009), *pleasure in design* (Jordan, 2000), *design for emotions* (Desmet, 2002), and *multi sensory design* (Schifferstein & Desmet, 2008). However, designers tend to invent their own ways (or just use their own intuitions) particularly in putting these concerns into practice in their material decisions (e.g. *selecting materials for emotional experience*), because there exists no common systematic approach for supporting designers in involving this 'intangible' side of materials into their selection processes (Arabe, 2004; Hodgson & Harper, 2004; Karana, 2004; Ljungberg & Edwards, 2003; MacDonald, 2001; Sapuan, 2001; Van Kesteren, 2008; Zuo, Jones, & Hope, 2005).

In Part II, the meaning of a material was presented as a relational property involving interactions between users, products and materials. These interactions cover many aspects such as technical, functional, aesthetic, etc. Product designers are responsible for considering these interactions in order to use materials efficiently to transfer certain meanings. In other words, materials are selected for creating certain experiences with their physical entity as well as intangible characteristics. Following this notion, **materials selection in product design** in this thesis is defined as the selection of appropriate material(s) for designed products by considering related design criteria such as manufacturing processes, availability, cost, function, shape, use, as well as meanings, associations, emotions, characteristics of users, cultural aspects, etc.

In the next section, two previous studies conducted to explore *how product designers select materials* and *what methods and sources they use to support their material decisions* are reported. These two studies involved interviews with 20 Turkish (Karana, Hekkert, & Kandachar, 2008) and 13 Dutch (Van Kesteren, 2008) professional designers. Based on the findings of the studies, first a set of key criteria in materials selection for product designers are identified. Next, a number of sources used by product designers for selecting materials are listed and three current tools are briefly explained at the end of the section. Tools and sources are evaluated in terms of their suitability for product designers for each step of materials selection activity. Their main advantages and disadvantages are revealed based on this evaluation. The necessity for a new approach in materials selection is emphasized.

A brief evaluation of two field studies on the materials selection expectations of designers (Karana et al., 2008; Van Kesteren, 2008)

The act of materials selection in product design involves the definition of a set of design requirements and converting them to a list of viable materials and processes. As mentioned before, the choice of a material starts at the conceptual stage when a very broad class of materials is identified as possible (or candidate) materials. This involves what may be called a pre- selection process. Existing *manufacturing facilities* or *availability* of a certain material can be determinants of materials selection at this stage. During the concept creation phase, unless technical requirements are defined at the outset of the project, product designers consider technical properties at an overview level and not in detail.

At the end of concept creation, product designers usually explain their preliminary ideas with *example products* (existing products) and *material samples* to their clients (Van Kesteren, 2008). Example products are used as crucial references of ideas in early design phases (Pasman & Stappers, 2001). When designers complete the conceptual period and proceed to the 'embodiment' and 'detailed design' phases, they begin to concentrate on manufacturability and issues of resource accessibility more intensively (Ashby & Johnson, 2002). They seek to determine if existing manufacturing processes are appropriate for the selected material, if the selected material is easily accessible, and if the *cost* of overall production is reasonable.

Apart from the predefined constraints related to availability, cost and existing manufacturing facilities, in most cases, designers start with a definition of a *product category* such as a medical product, equipment for military, a bathroom accessory, etc. A preliminary set of material requirements is usually listed based on the defined product category. For instance, if it is a military product and the user is determined as *soldiers*, the candidate materials are expected to be light, matte, resistant to open air conditions and alterations of heat. These material properties mainly respond to issues of utility and the physical function of the material. Functional needs can be more easily translated to a *technical requirement(s)*. Therefore, designers can easily access required data on the functional uses of materials.

In addition to the product category, product designers in most cases consider a *target market* in which they aim to attract certain people to their product. A target market can be people of a certain age group, a specific culture, gender, expertise, etc. Defining a target market plays an important role in determining ways for transferring certain meanings and ideas and eliciting emotions. People from a specific socio- economic group, for instance, may appraise a material as more valuable than people from another socio- economic group. Herein, the intangible characteristics of materials- involving the perceived values and cultural meanings, trend issues, associations and emotions evoked by materials (Karana, 2006) - play an important role in the product designers' decisions on materials. Designers use their own intuitions and gut feelings in order to select the best material(s) fulfilling the *intangible characteristics* of their products. The final materials decision is essentially the best match the designer can propose to achieve a certain product character. An in-house designer gave the example below (Karana, 2004):

> As far as I am concerned, it is perceptional dimensions that are very crucial in my material decisions. Especially in certain sectors, which clearly reflect the current trends such as home accessories, you can see materials' role in conveying particular ideas. Specific materials or sensorial properties certainly become trendy. Transparency is an example. I believe that I- MAC's success is a result of a very clever use of a transparent material. Likewise, rubber, for instance, is frequently used in promotional products nowadays. Because of its velvet-like texture, it feels warm and friendly, and you feel like touching to a natural material (such as skin). These kinds of considerations are very important in selecting materials (Gamze Türkoglu Güven, TASARIM ÜSSÜ).

Another designer explained how a material can be used for astonishing people (Karana, 2004). According to him, people may prefer products that astonish them. He emphasized that one of the most important ways for accomplishing astonishment is through '*material choice* '.

Sensorial properties of materials are found as one of the most vital aspects designers can harness for expressing certain ideas and notions through the materials of products (Karana & Van Kesteren, 2008). For instance, with the purpose of creating a *modern* product (which is an intangible characteristic) and selecting the most appropriate material that will contribute to this meaning, designers firstly consider a material providing a grey, shiny and smooth surface, which is usually associated with modern products. Product designers usually rely on common knowledge for relating certain sensorial properties to certain meanings, as in the example of creating a *modern* product. One designer gave the following explanation (Karana, 2004):

> In our sector (bus design), from our experience we know that bright materials are always perceived as *cheap*. Conversely, the main indicator of the quality products is their matt

> surfaces. Let's look at today's trends; inner coatings of Audi are completely made of matt materials. Designers are reflecting these kinds of considerations without using a written source but by benefiting from their own experiences. (Kenan Erdinç, MAN Türkiye)

In this sense, product designers need *inspirational sources* in order to see the *varieties in material properties*, or to see which kinds of properties are modified or used for creating meanings. Designers consider the potential effects of product materials on people's senses, or their use in different cultural groups, etc. However, they cannot easily translate their intentions into *a distinct list of material properties*. Above all, the intention of the designer should be appropriately aligned to the target market. For this reason, designers should *understand what their target group thinks* about a certain material- meaning relationship. A distinct list of material properties might also be useful for *comparing different user groups* by asking their thoughts on those properties of materials. People may explain their feelings about a material more easily by using a distinct list of material properties (Van Kesteren, 2008).

Product designers expect materials selection to take relatively little time in comparison to their entire design process (Ashby & Johnson, 2002; Karana et al., 2008; Pedgley & Norman, 2007; Van Kesteren, 2008). Designers believe that, in a limited time span, they cannot spend time for selecting *new* materials; as a consequence, they prefer to select traditional materials, which can be an obstacle to achieving innovative design. Therefore, designers would benefit from a tool that provides *new material ideas in a short period of time*.

Designers require materials data that can be readily and easily updated (Karana, 2004). In a study of designers, most (15/20) stated that communication between industrial designers of different companies (e.g. Vestel, MAN Turkey, Tasarim Ussu, etc.) was weak. They gave reasons including competition among the designers and the firms, who each endeavour to secure the largest market share. Three of the interviewees mentioned the idea of a *material platform* where designers can discuss about new materials and *share their experiences* on material choices for certain cases. In addition, the *renewal of data* in a given materials source is a very significant point, allowing designers to follow improvements and trends regarding target markets. Accordingly, most of the designers in the study (16 out of 20) used the Internet as a source in their material searches. The two major motives for opting to consult Internet sources were (1) up-to-date information can be found, especially on new production technologies and material innovations, and (2) accessibility of the source is easy and it does not take too much time.

Most existing material sources contain technical data, which is largely numeric. On the other hand, designers mostly prefer *images* (of sample materials and example products), supported with *a little text-based information* (Karana, 2004; Van Kesteren, 2008). This approach is expected to provide a more comprehensible technique for *comparing materials* and thus be supportive to designers' aims of selecting amongst a variety of candidate materials.

Current sources and tools for selecting materials in product design

The main sources consulted to assist systematic materials selection are materials databases- both published and software versions. In addition, product designers prevailingly use design fairs and conferences as inspirational sources for new material ideas (Karana, 2004). In Appendix 6.2, sources used by product designers in materials selection are listed.

Scholars in the design domain have recently developed new methods and tools that guide designers particularly in creating sensorial experiences through material choices. One of these tools is *The Matrix* developed by Zuo et al. (2001). The main aim of the Matrix is to understand how people respond to the sensory properties of materials. The tool provides guidelines, particularly for matching textures of materials to human aesthetic and perceptual expectations. In the Matrix, a dimension-lexicon system is proposed to summarize the material texture description (Zuo et al., 2005). According to this system, the description of a material texture can be summarized into four dimensions: *geometrical dimension* (e.g. irregular- repetitive, plain- bumpy, etc.), *physical-chemical dimension* (e.g. warm- cold, mist- dry, etc.), *emotional dimension* (e.g. cheerful- dull, comfortable- uncomfortable, etc.), and *associative dimension* (feather-like, silky, etc.). The developers of the Matrix conducted studies to find relationships between these four dimensions. Figure 1 presents the results of one of these studies. The Matrix in the figure shows that non-sticky, hard, slippery and dry textures are perceived as comfortable, safe, elegant and cheerful. However, one of the most important drawbacks of the tool is that even though the roles of product aspects, context of use, and user characteristics in material experience are emphasized (Zuo et al., 2005), data is mainly generated by asking people to describe material samples[1]. Therefore, the Matrix stimulates designers to set one-to-one relationships between texture properties and intangible characteristics. Furthermore, some descriptive items (such as elegant) which are expressive semantic descriptions, are confusingly presented under the emotional dimension in the matrix.

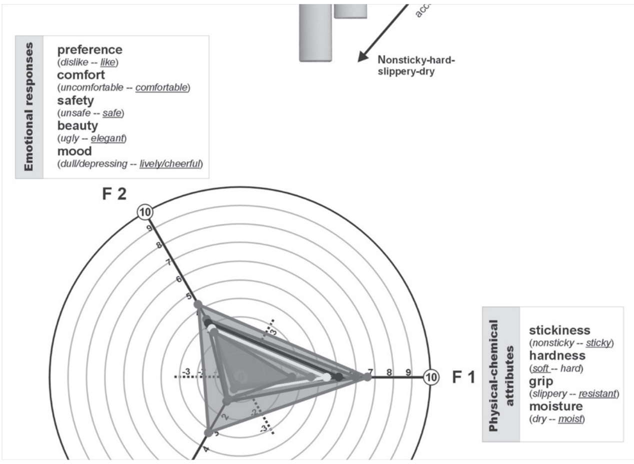

Figure 1. The *Matrix* developed by Zuo et al. (2005).

Developed by Saakes (2007), *Skin* is a tool to support designers for creating and reviewing materials, colours and textures on physical product prototypes (Figure 2). Materials, colours and textures are projected onto foam models (which must be white or another light colour) and which are made to evaluate preliminary ideas for product form. Using Skin, designers are motivated to include material considerations into early design phases to enhance creativity and idea generation. Moreover, they are encouraged to digitally explore materials and textures. The purpose of Skin is for designers to examine mainly how their products will look when embodied in real materials. Skin therefore primarily focuses on the sense of vision and aims to support designers in creating different textures; however, it does not guide designers in creating meanings through choices of materials.

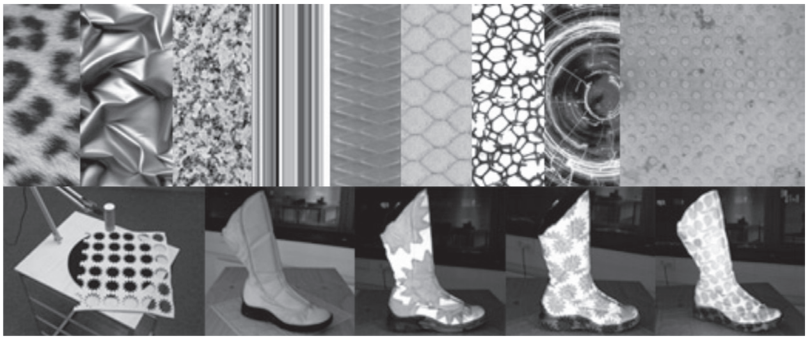

Figure 2. Skin developed by Saakes (2007).

Van Kesteren (2008), in her doctoral thesis, developed three tools focusing on different aspects of user-product interaction in materials selection (Figure 3). The first tool (picture tool) defines user-product interaction via pictures of example products. In her words, the aim is to bridge the desired product personality and the required materials properties. The second tool (sample tool) provides designers with materials samples with wide range of sensorial properties. The last tool (question tool) supports designers in structuring a conversation based on sensorial experiences with products by using question prompts. Designers are offered a sheet that relates sensorial properties with physical properties. After testing the usefulness of the tools, Van Kesteren discussed that designers did not use the sheet (question tool) because it contained too much text and was thus unappealing. The three tools were proposed to support designers in enhancing their materials vocabulary and familiarity, especially on the sensorial properties of materials. The presentation of materials embodied in products through use of *the picture tool* was an important attempt to bridge ideas of product personality and material choices, but the tool is limited to examples that attempt to propose one-to-one relationships between sensorial properties and personality characteristics.

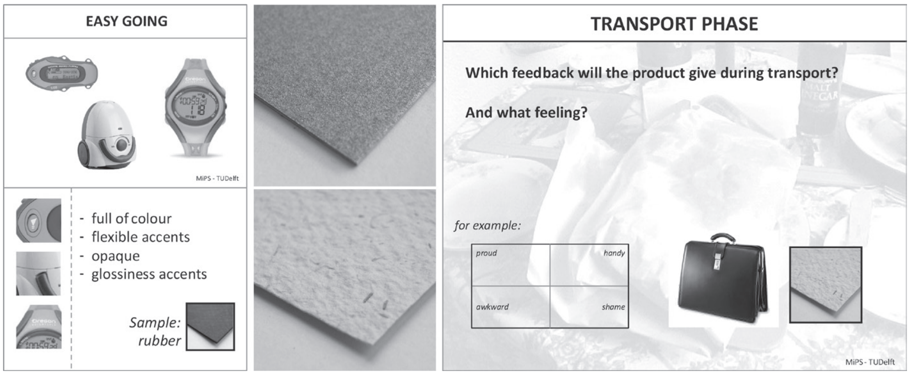

Figure 3. Picture, *sample* and *question* tools developed by Van Kesteren (2008).

4 Conclusions: Evaluation of Existing Tools and Methods

Materials selection is not a single activity with a definite place within the design process. It starts at the very beginning of a project (concept creation) and results in the design specification (embodiment) of a product. Data for material properties are needed at every stage in design. However, the nature of the data needed in the early stages differs greatly in its level of precision and breadth from that needed later on (Ashby, 1999; Mangonon, 1999). For example, at the conceptual design stage, the designer requires approximate data for the widest possible range of materials. All options are open: a polymer may be the best choice for one concept, a metal for another, even though the function is the same and both are plausible concepts. The problem, at this stage, is breadth. A crucial question stems from that point: *how can the vast range of data be presented to give the designer the greatest freedom in considering alternatives?* (Ashby, 1999, p. 8)

The rising speed of computing made databases increasingly attractive to assist materials selection. Computers allow fast presentation of materials property data or charts and graphs arising from the selection of a class of materials that have properties within a specified range. A widespread feature of databases is that they all have defined identifiers (that is, they are based on named materials and processes). The user defines the material type, such as polypropylene, and the databases find and display data associated with a given identifier. Most of the databases are efficient with their ability on storing, sorting and retrieving data (Ashby, 2005). However, they mostly require experience in materials or sufficient background knowledge on material properties in order to specify a range for a certain property.

The need for involving intangible aspects into materials selection processes leads designers to more inspirational sources such as presentations from suppliers, fairs, conferences and material exhibitions. Design InSite and Material ConneXion (See Appendix 6.2), for instance, are found useful to product designers in their material decisions, by providing different product examples and material samples. Particularly in the concept creation phase, in which designers focus on the character (or meaning) of their products, these ‘example and sample’ sources are preferred for materials selection activities based on *similarity and inspiration* methods (Karana, 2004). However, designers do not follow any systematic approach while using these methods (Ashby & Johnson, 2002; Karana, 2004; Van Kesteren, 2008).

To sum up, existing materials selection tools can serve a useful function in giving up-to-date information on engineering aspects of materials (technical, physical, quantifiable). This kind of data is mainly needed in embodiment and detailed design phases. In that sense, by stressing the importance of aesthetic experience and meaning considerations in material decisions, the new generation of tools and methods mentioned in the previous section provide valuable contributions to the design domain. However, they have limitations because they either focus on a certain sensory modality (such as touch), or they tend to propose definite links between certain formal material properties and meanings attributable to materials. Product designers also gather information about their target group while setting up criteria for materials selection (Karana, 2004; Van Kesteren, 2008), which is an activity not usually incorporated into the aforementioned tools. In this respect, it is inevitable to use other guidelines to support material decisions in design practice. The overall evaluation of this chapter is as follows:

Critical factors affecting material decisions in product design

- product (shape and function of the product)
- technical requirements
- existing manufacturing facilities
- availability of the material
- cost (material and manufacturing process)
- time
- sensorial properties of materials
- intangible characteristics of materials (meanings attributed to materials, emotions evoked by materials, cultural values and trends)

Designers’ expectations

- following innovations
- following trends for certain target groups
- renewed data
- sharing experiences with other designers
- understanding material properties (a list of important properties)
- understanding the target group for a product
- inspirational sources (product and material pictures, samples)
- comparing materials
- comparing approaches of different user groups
- visual representation of materials backed up with minimal textual information

Endnote

1 Currently, Zuo and his colleagues undertake material evaluations in a product context and offer a consultancy service to industry to evaluate the materials/textures of industrially produced products (source: http://www.material-aesthetics.com/main.asp)

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Chapter 7 is based on:

Karana, E., Hekkert, P., Kandachar, P., (*submitted*), Meaning Driven Materials Selection (1).

7

The [Meanings of Materials] Tool

1 Introduction

In the chapters in Part I and Part II, research on the key variables in meaning attribution to materials was reported. The main conclusion was that designers who intend to create certain meanings through the materials of their products are confronted with the difficulty that there is not a one- to- one relationship between material properties and intended meanings. Combinations of different properties evoke particular meanings for specific users within specific contexts. This conclusion led to the creation of the Meanings of Materials (MoM) model. The model presented the *meaning of a material* as a relational concept in which *material*, *product* and *user* are jointly effective. Furthermore, a set of related aspects were identified and tested in a series of studies, such as sensorial properties, manufacturing processes, shape, function, gender, age, expertise and culture. The main question of this chapter is: how may the findings from Part I and Part II assist designers in manipulating meaning creation in materials selection?

In the previous chapter, the need for a tool to support designers in systematically involving meaning considerations in their materials selection processes was emphasized. The current chapter describes the development of such a tool.

2 The [Meanings of Materials] Tool

Throughout this research we confirmed that a meaning of a material can not be reduced to a single property or a single sensory domain. Furthermore, it was concluded that a meaning of a material is evoked by the interaction between product aspects (such as shape, function) and material properties, with respect to how and in which context it is used and who the user is. Therefore, it is not possible to define simple design rules for a certain material-meaning relationship. Nevertheless, we also saw that there are some patterns that identify how materials obtain their meanings. A material, for instance, may express *professionalism* when it is smooth and dark (coloured), when its used in an office environment and when certain technical properties are combined for enhancing its function (e.g. combining strength and lightness) (see Chapter 3). We assume that a designer who can understand these relationships (which we may call 'meaning evoking patterns') can more deliberately (or systematically) manipulate meaning creation in materials selection processes. In order to make designers capable of finding these patterns, a tool should first familiarize designers with the key aspects (such as shape, user, manufacturing processes, etc.) that play an important role in attributing meanings to materials. The tool should convey the idea that many meanings can be attributed to many materials dependent on different products and contexts.

The three major aims of a proposed [Meanings of Materials] tool are: *(1) to familiarize designers with the main components (or factors) of the Meanings of Materials model, (2) to show which aspects (under main components) play an important role for certain meanings (such as sensorial properties, gender, culture, shape, etc.),* and *(3) to stimulate designers to find the relationships (or patterns) between these aspects and meanings.* In this way, we aim to encourage designers to systematically involve meaning considerations in their materials selection processes. This approach is termed **meaning driven materials selection** in this thesis. For the three goals listed above, we aim to provide designers with a collage of material examples (as material samples or materials embodied in products) that have been selected by a number of individuals who think that each material example expresses a certain meaning. In this way, the intention is not to provide designers with explicit design rules but rather to encourage designers to make their own conclusions by analyzing the selected materials.

The following two sections report on the two main steps that were followed in developing the Meanings of Materials tool: (1) the structure of the tool (order of actions), and (2) the content of the tool (generating data and presenting the outcome). In the last section of the chapter, the proposed tool is summarized.

Step 1: The structure of the tool

The thesis has established that an underlying need is for designers to be supported in their materials selection activities at early stages of the design process (i.e. concept creation). The tool was therefore required to be informative, inspiring and appealing to designers. In order to achieve this, a level of interactivity in the tool was sought: the aim was to construct a database derived from a number of people who were asked to select materials expressing certain meanings. They are asked to provide a picture of the materials they selected and to explain why they thought that the material they selected expressed the given meaning. Then, they were asked to appraise the selected material in terms of sensorial properties via five point scales.

In approaching the proposed tool, designers were expected to have in mind the meaning(s) they would like to create through the material(s) of their designs. From this standpoint, it was important to provide designers with a number of material examples presented alongside explanations made by the individuals who selected the materials and pointed out their associated meanings.

In the completed MoM tool, designers can navigate through selected materials and explanations. Furthermore, the MoM model and a list of important sensorial properties of materials are presented in the tool to guide designers in their analysis of the selected materials. The main assumption is that: even though each case (comprising a single person's explanation of the meaning they attribute to a certain material) is unique, designers will be stimulated to combine the cases and identify meaning evoking patterns. The materials selection process, aided by the MoM tool, is intended to finalize with an idea(s) of a material(s) conveying a certain meaning.

Throughout the research in this thesis, certain meanings were identified in the assessment of particular properties of materials across a number of studies. These meanings were revealed through the collection of descriptive items from a variety of sources (see Chapter 2). A total of 76 meanings were identified as material relevant meanings that designers are likely to want to convey through the materials of their products (see Chapter 3). The MoM tool incorporates these 76 meanings in order to guide designers at the beginning of their materials selection processes. A designer, with an intention in mind, is first encouraged to browse through the meanings and see if his/her intention is similar to (or the same as) one of the offered meanings. The designer can then access the examples and results from previous studies about a meaning that he/she is interested in, or can require a new study if there are no examples or results about the intended meaning (or a closely related meaning) in the tool. Thus, a new study is conducted and the results are added to the database. The designer can also require a new study to expand the data about a particular meaning already existing in the tool. For instance, a designer who intends to create a *feminine* product and who wishes to select a material(s) that expresses the meaning *feminine* can find that the tool consists of data about feminine materials selected by a narrow group of people. The designer may want an additional study in order to see, for instance, what Mediterranean people think about materials that express femininity. In this way, the MoM tool is conceived as a growing database of material meanings obtained from ongoing studies. Figure 1 summarizes the order of actions followed in the MoM tool as (a) a designer's request, (b) data generation, and (c) outcome evaluation.

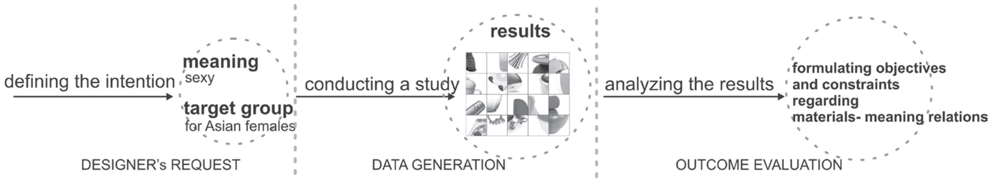

Figure 1. Order of actions followed in the MoM tool.

Step 2: The content of the tool

With the MoM tool, we aimed to provide designers with a variety of material (and product) examples, along with data on material sensorial properties (ranked on the basis of evaluations) and explanations of the MoM model components. The content of the tool was developed accordingly.

Data generation

Data are proposed to be generated through the results of different studies conducted online with groups of people who are asked to select materials expressing particular meanings[1]. People who participate in the study are given the following three tasks: (1) select a material that you think is 'X' (such as sexy, feminine, modern, etc.), (2) provide a picture of the material you selected, and (3) explain your choice and evaluate the material on the given sensorial scales (Figure 2).

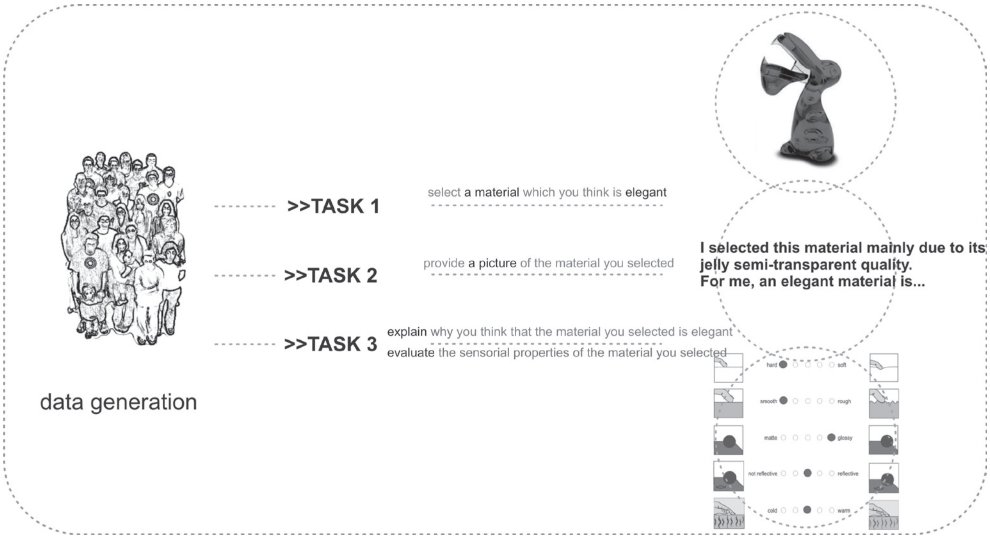

Figure 2. Process of data generation for the tool.

TASK 1: select a material...

In the previous studies reported in PART II, participants were asked to select objects expressing certain meanings particularly through their materials. It was noticed that the task was quite a challenge for participants, since they were supposed to look beyond the totality of objects and instead focus only on the contribution of materials to the objects' meanings. While designing TASK 1 for the tool, this point was taken into consideration and a special attempt was made to define a task that would be comprehensible even for non-designers, and which would lead them to material rather than object evaluations. Accordingly, the task was defined as: *select a material which you think is X* (X: a meaning such as sexy, futuristic, etc.)

An explanation page was prepared to provide participants with more detailed information about how to select a material expressing the given meaning (Figure 3). The explanation points out that the selected material could be embodied in an object or in a part of an object (such as a handle of a kettle). Differences in terminology between *object* and *material* are also explained in two additional pages with the help of examples (Figure 4). The participants are reminded that if they do not possess the material themselves, but instead noticed it in a magazine, internet, etc., and if they think it is a good example for the given meaning, they could still select that material as long as they are able to provide visuals of the material (pictures, photos, etc.) at a later stage.

TASK 2: provide a picture of ...

Combining several pictures into a visual whole makes it possible for designers to represent not just one object or idea, but something more multifaceted like a mood or a context (Govers, 2004). Designers usually use visual collages to define their target group and deduce certain product characteristics (such as form, colour, etc.) from these collages (Muller, 2001). In addition, designers prefer to transfer an idea (or a mood, or a context) to a client (especially if he does not have a design background) using visual representations (Van Kesteren, 2008).

On the basis of these considerations, the participants are asked to provide pictures of the materials they selected. On an additional page, they are instructed that the *pictures* may either be photographs taken by themselves or others, or any type of visual (photo, modelling, etc.) taken from the Internet, magazines, or a similar source (Figure 5). They are asked for a supplementary detailed picture in cases where the selected material is not embodied in an object's whole, but in a part of it. In other words, two pictures are needed if the object is made of more than one material: one for the entire object and one for the part made of the material that expresses the given meaning.

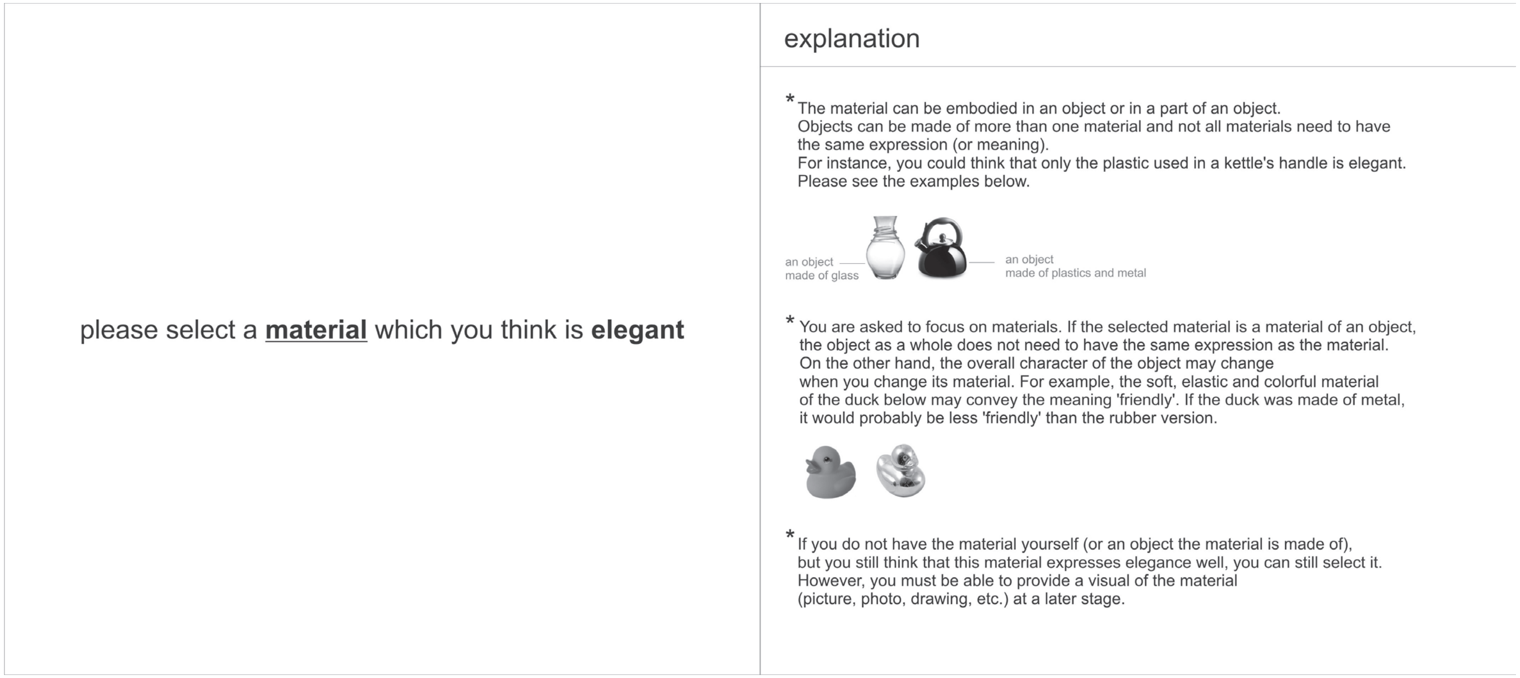

Figure 3. Task 1 and the first explanation page.

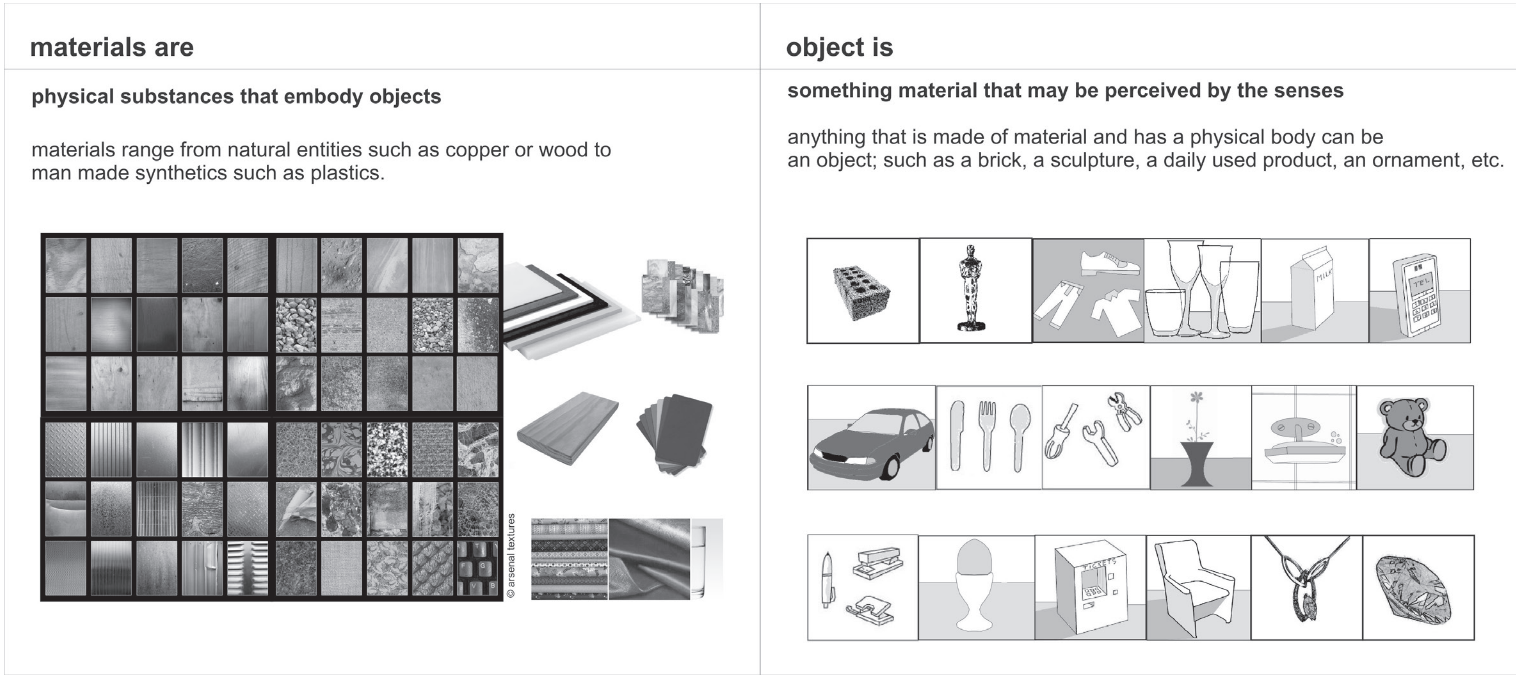

Figure 4. The second explanation page of TASK 1.

please provide a **picture** of the material you selected

explanation

* the pictures might be either the photographs you took or taken by others, or the visuals (such as pictures, photos, modeling, etc.) you found in the Internet, magazines, and similar sources.

* if the material you selected is embodied in an object, and this object is made of one type of material (that is the material you selected), only one picture which shows the entire object is sufficient.

glass which is embodied in a vase was selected
one picture is enough in that case

* if the material you selected is a part of an object made of more than one material, please also provide a picture of that part showing the material you selected clearly

metal which is embodied in a kettle made of plastic and metal was selected
two pictures are required in that case

Figure 5. TASK 2 and the explanation page.

TASK 3: evaluate the material...

Finally, the participants are asked to evaluate their selections. The appraisal of the selected materials is done in two ways: first verbally, by responding to an open ended question, and second with a list of sensorial properties presented with pictograms and five point scales. The aim of the open verbal explanation is to provide designers with more specific information concerning the reasons behind each individual's selection. After the verbal explanations, the participants are asked to assess the sensorial properties of the selected materials (provided from the previous chapters), presented with pictograms and five point scales. A fundamental question emerges at this stage: are people able to appraise the materials of their objects in terms of sensorial properties? A study was conducted to answer this question and finalize the list of sensorial properties to be included in the tool (See Chapter 8).

Outcome Evaluation

(1) Collection of the materials and objects

Here, the main idea is to support designers in identifying meaning evoking patterns regarding materials of products in an inspirational way. It is proposed that displaying the selected materials altogether in a single image might enhance the probability of designers detecting the similarities and differences among the materials. For this reason, the collected pictures from the participants are presented as a collection, in which designers first see all the materials associated with a certain meaning in zoomed views (thumbnails). When a zoomed view is clicked, the entire image appears.

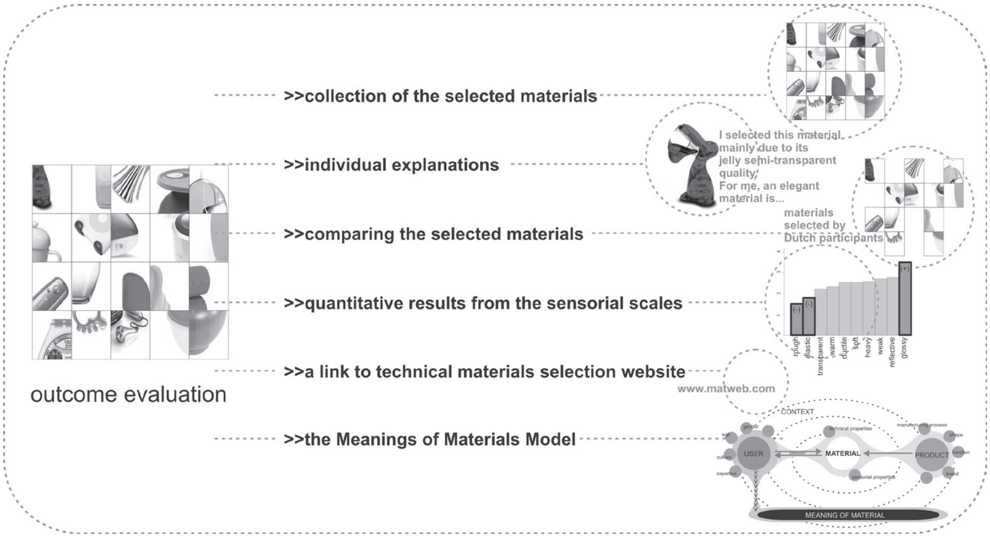

Figure 6. Evaluation of the outcome of studies undertaken for the MoM tool.

(2) Individual explanations of the participants

The MoM tool provides designers with the verbal explanations made by each individual who participated in the data generation studies. When a designer clicks on an image of a material presented in the MoM tool, besides the picture of the entire object, he/she finds the rationale of the individual who selected the material. The aim is to communicate to designers the participants' main motivations in their material- meaning selections.

(3) Comparisons of the selected materials based on certain group divisions

This information type is provided to allow designers to limit the results of the MoM tool to only those meanings offered by a certain target group, such as materials selected by females or males, materials selected by Asian people, etc. Designers are able to compare the results of the sensorial scales and to see significant differences between the compared groups' selections.

(4) Quantitative results from the sensorial scales

This part of the MoM tool presents material ratings based on sensorial scales. The results are presented with a graph ranking the properties according to their mean scores. The most important properties for the given meaning are determined. In this way, designers first become familiar with the properties that may have a general effect on the meaning of a material, and second develop an appreciation of the properties that play a crucial role in attributing the intended meaning.

(5) A link to a technical materials selection website

Designers are provided with a link to a technical material selection website where they can find detailed information about the technical properties of materials. The reason for inclusion of the technical link is the premise that it provides a good way to find out about those materials that deliver sensorial properties found to be significant in the overall evaluation.

(6) The Meanings of Materials Model

The Meanings of Materials (MoM) Model provides designers with the factors (or components) that play a central role in an individual's materials judgment. These factors (material, product, user and context) are briefly explained, and the probable key aspects of each factor as well as their underlying variables are listed. Manufacturing processes, for instance, is a product aspect and therefore presented under the product factor. A list of key processes that might affect people's aesthetic experiences with materials is offered (see the list in Chapter 5). We expect the model to be used as a guideline and a checklist by designers to formulate their thoughts and ideas, and define the meaning evoking patterns that will lead to materials choices.

3 Summary of the MoM tool

An important difference of the MoM tool compared with existing materials selection tools and methods is that it was proposed to be a growing database, augmented by data generated from continual studies. In addition, the MoM tool was intended to be an inspiring *interactive* alternative materials selection resource that has appeal to product designers. Summarizing, the purpose of the tool is to support designers (1) *to understand the key variables in meaning attribution to materials* and (2) *to define the patterns behind a particular material-meaning relationship*. The tool offers visual and textual inspiration for various types of products and materials related to intended meanings. Designers are encouraged to navigate through the material examples and read the explanations for each meaning case.

There are four strong points of the tool expected to be found useful by designers. First, designers need *to summarize and document* the findings of fieldwork related to a target group (Van Kesteren, 2008). The MoM tool is expected to answer this need by offering a collage of materials alongside ratings of the materials against sensorial scales. Together these are expected to lead to easier discussions with people involved in a design project, such as product designers from the project team, material suppliers or clients. Furthermore, the list of sensorial properties is expected to enhance designers' *vocabulary about materials,* which is expected to be helpful in summarizing and documenting a study's results.

Second, the interpretation of the results is left to designers. This means that although the quantitative data is presented for addressing the high rated sensorial properties, designers are expected to (1) be stimulated by the collage of materials, (2) pick up the useful or relevant points for their designs with their own intuition and creativity, and (3) define the meaning evoking patterns in their own way. We expect not only the similarities but also the differences between the selected materials to be *inspiring for designers*.

The last point is that the online application of the tool is expected to provide *a growing database*. The outcome of every study conducted to enhance the MoM tool is added to the tool's database. Thus, designers might either navigate through the results of an existing study, or request a new study to be performed. The proposed tool was visualized in this chapter (Figures 2-6). The next chapter focuses on the realization of the proposals. Data is generated for a dummy application and the outcome is tested with 24 junior designers and discussed with 4 senior designers.

Endnote

1 The group of people who participate in the study can be specified by the designer, who wishes to learn about a particular target group (such as Chinese females). In that case, the study must be administered to the appropriate sample population who fulfill the required specification for data collection. How can we invite people for their participation? The final tool is planned to be an online database. In online studies,

attracting the appropriate target audience often requires advertisement. There are various methods used to attract participants, such as bulletin boards, mass emails, advertisements in commercial areas, mail, monetary incentives, and discounts on company products (Groves et al., 2004). These methods often help in attracting willing participants, who provide better quality data than reluctant participants (Sharp, Rogers, & Preece, 2002). Nevertheless, there are two main disadvantages of online studies: (1) the response rate can be limited because not everyone has access to the Internet (Sharp et al., 2002), and (2) younger people are more likely to respond to online invitations, which is a hinderance for studies requiring the participation of older people (Groves et al., 2004). Despite these disadvantages of online studies, invitation methods seem appropriate for the development of a preliminary tool. However, a finalised version of the tool will require more detailed planning for the collection of better quality data from intended target groups.

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8

Application of the MoM tool

1 Introduction

In the previous chapter the [Meanings of Materials] tool was presented as an interactive tool aiming to assist designers in understanding the key aspects effective in attributing particular meanings to materials in an inspiring way. The proposed tool consists of three main actions: (1) a designer's request (made by designers about a certain meaning-material relationship), (2) data generation (a group of people is asked to select a material expressing the given meaning and report their selections), and (3) outcome evaluation (made by designers themselves to assess the results of the research). The tool is based on the following assumptions:

(1) people can rate materials on sensorial scales,

(2) people can select materials expressing certain meanings,

(3) people can verbally explain why they think the material they selected expresses a certain meaning and they can provide visuals of the selected material,

(4) the outcomes of the tool are inspirational to designers in their preliminary material decisions.

These four assumptions are explored and tested in this chapter. First, a study is conducted to examine if non-designers are able to evaluate materials with regard to their sensorial properties, using five-point scales. Next, a second study is conducted in order to test the data generation part of the tool, which requires participants to select a material expressing a particular meaning. Then the participants are asked to report their selections through pictures of the selected materials and verbal explanations of the motives behind their selections.

The results of this study are used for the 'outcome part' of the tool, which is tested by 24 master students from the Faculty of Industrial Design Engineering at TU Delft. Finally, the tool's positive and negative points are reported and recommendations are made for further development and applications of the tool.

2 Study 1: Agreement on sensorial scales among non-designers

One of our main assumptions for the proposed tool is that non-designers can reliably evaluate the materials of products with regard to their sensorial properties. As mentioned in the previous chapter, instead of just using a scale with verbal labels, visual pictograms to clarify the given sensorial properties are provided. In this study, we test (1) the comprehensibility of the properties by non- designers and (2) the reliability of their assessment of materials on the given sensorial scales. These two aims are investigated by measuring the level of agreement among a group of non- design students on the sensorial properties of ten different materials.

Sensorial scales

The scales on which participants of the study would significantly agree with each other would give an indication of the sensorial properties to be used in further applications of the Meanings of Materials tool. In other words, another objective of the study was to finalize the sensorial properties list to be used in guiding designers in manipulating meanings of materials.

The dominant effect of colour in attributing meanings to materials was emphasized in a number of studies throughout this research (see Chapter 5). Nevertheless, it should be recognized that colour can either be a material property (such as the *colour of wood*) or applied to a material by an additional finishing process (e.g. painting, printing), and thus can be considered a product aspect. The participants in Chapter 5 came up with a similar distinction in arguing that it was difficult to assess the colour of materials for two reasons: (1) some mentioned that colour is not a property of materials in their selection, but an additional design consideration (colouring), and (2) in some cases, the selected product was made of more than one material, each having a different colour. In addition, the colour of a material or a product is a result of its surface properties, its transmission properties, and its emission properties, all of which contribute to the mix of wavelengths in the light leaving the surface of the object (Muller, 2001). The perceived colour is then further conditioned by the nature of the ambient illumination, and by the colour properties of other objects nearby. Hence, colour perception is a rather complex phenomenon and requires more detailed exploration. Accordingly, the interpretation of the colour of selected materials in the tool was left to designers and colour was omitted from the list of sensorial properties in this study.

The odour of a material was also removed from the list on the basis of the results of one of

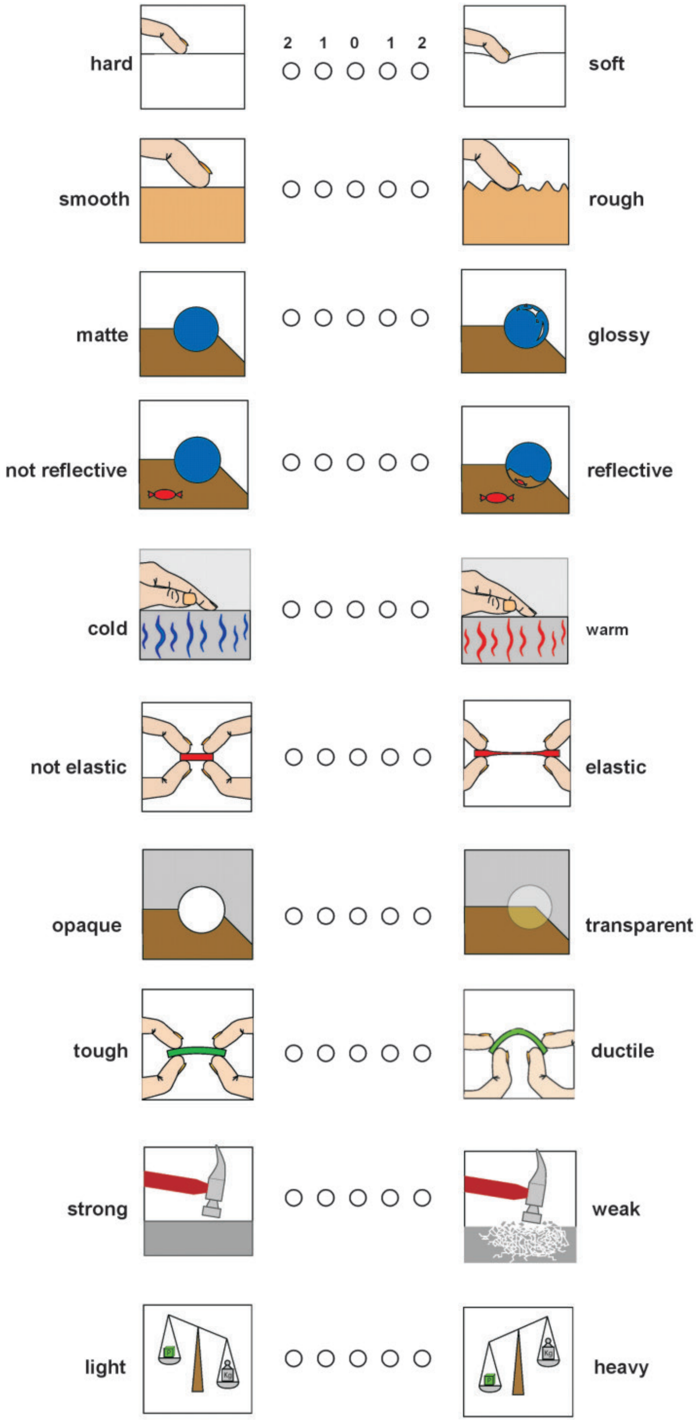

Figure 1. Sensorial properties used in Study 1.

the previous studies in the thesis (e.g. odourous modality received a significantly low rating in the overall evaluation reported in Chapter 5). The remaining sensorial properties used in this study are presented in Figure 1.

Participants

The participants were 10 university students (5 female; 5 male; mean age 25.5 years, range 20- 27 years, 6 Dutch; 4 Turkish) from different departments of Delft University of Technology. None of the departments was design oriented (e.g. applied science, aerospace engineering, etc.). They participated in the study voluntarily. If high levels of agreement among non-designers were achieved, our main assumption would be supported.

Stimuli

The stimuli for the study were 8 products made of different materials. Of the products, 6 were clearly made from a single material family: a glass vase, a wooden pepper- shaker, a ceramic vase, a ceramic teacup, an elastomer pan holder and a plastic spaghetti spoon. The other two products each spanned two material families: a teacup made of ceramics and plastics, and a cheese grater made of metal and plastics (Figure 2). An attempt was made to select products that provided sufficient variation in material sensorial properties. None of the products carried additional elements such as buttons, screens, etc.

Figure 2. Stimuli used in Study 1.

Procedure

Each participant individually evaluated the materials of the products. The products were presented one by one in a randomized order to each participant. After each product, the participants were given an evaluation sheet consisting of a list of ten five-point bipolar scales tied to sensorial properties of materials (Figure 1). The order of the scales was also randomized on each evaluation sheet. The materials of the products manufactured from two materials were separately evaluated. Thus, in total, ten materials were evaluated. All written instructions were presented in English. The task took approximately 10-15 minutes per participant.

Results

In order to assess the agreement among participants, intraclass correlation coefficients (R_i), an index of the reliability of the ratings, were calculated for each sensorial scale. In Chapter 4, we used intraclass correlation coefficients (R_i) for calculating the level of agreements on meanings (see Chapter 4 for more detailed information). The results are presented in Table 1. On all scales, agreement among participants was significant. With regard to the [opaque- transparent] scale, agreement among participants was very high (R_i= .86). Agreements on the [matte- glossy] (R_i= .69), [reflective- not reflective] (R_i= .66) and [tough- ductile] (R_i= .63) scales were also relatively high. Relatively low levels of agreement were obtained for the [smooth- rough] (R_i= .42) and [strong- weak] (R_i= .36) scales.

Table 1. Degree of agreement between participants on the sensorial scales.

	Intraclass Correlation (Ri)
cold- warm	.55
elastic- not elastic	.50*
hard- soft	.49
light- heavy	.55**
matte- glossy	.69
opaque- transparent	.86
reflective- not reflective	.66
smooth- rough	.42
strong- weak	.36
tough- ductile	.63

p< .001
* N= 7; three component variables had zero variance and were removed from the scale
** N=9; one component variables had zero variance and was removed from the scale

Discussion

The results of the study reveal that participants were able to reliably assess the sensorial properties of materials on the given scales supported with pictograms. However, agreements on some scales (such as [opaque- transparent], [matte- glossy], [reflective- not reflective] and [tough- ductile]) were higher than the others (such as [hard- soft], [cold- warm], [elastic- not elastic] and [light- heavy]). This may be partly explained by the ambiguity and subjective interpretation of the meanings of some tactual properties. For instance, while *opaque* (a visual property) clearly refers to materials which entirely obstruct the passage of light, *cold* (a tactual property) can refer to an unfriendly, aloof manner of a material (although the 'warmth' pictogram clearly shows warm/cold as a thermal property to avoid metaphorical interpretations). These kinds of ambiguous properties can be interpreted differently by each participant. The evaluation of the glass vase's softness may exemplify one of these cases. Even though vertical motion is required for the perception of softness of a material (as visualized by the pictograms), three participants evaluated the glass vase as moderately soft. It explains that people may evaluate softness of a material as pleasant to touch, not harsh or offensive to the sight, or not exciting by intensity of colour. Similar to the glass vase, the ceramic vase (Eggshell vase) was also evaluated as fairly soft by two participants. We assume that shape might also be effective on the interpretation of some sensorial properties of materials (e.g. rounded materials can be evaluated softer than sharp edged materials).

The relatively low level of agreement on the [strong- weak] scale can be explained similarly. In materials science, the strength of a material refers to that material's ability to resist an applied force – measured in specific terms including compressive strength, tensile strength, impact strength and shear strength. A strong or a weak material, therefore, can be visualized in various ways. At the beginning of this research, a set of studies was conducted in order to collect descriptive items about materials (Chapter 2). In these studies, it was noticed that people use 'strength' as a sensorial property (although it is a technical property) and it often refers to the capability of a material to withstand suddenly applied loads (impact loads) in the manner of brittle failure. Thus, if an object or a material is weak, it cannot resist a sudden stroke and breaks or smashes easily. The [strong- weak] scale was conceived according to this definition, and emphasized through the chosen pictogram. However, even if a material is not brittle it can still be weak (e.g. it may not be able to withstand a shear force). We realized that the evaluation of the elastomer pan holder was very challenging for the participants in that respect. While some of the participants considered it as weak because it could be torn off, others evaluated it as strong because it could not be broken into pieces by a hammer stroke (as visualized in the pictograms).

Differences in levels of agreement on the given scales can be further explained by the types of products used in this study. As mentioned before, an attempt was made to select products that provided sufficient variation in material properties. Nevertheless, the selected products did not exemplify the varieties (i.e. the possible extremes) of some properties. Except for one material (in the glass vase), nine of the materials embodied in the products used in this study were opaque. Therefore, the participants might have found it easy to evaluate the given materials on the [opaque- transparent] scale and this can be an additional reason behind the high level of agreement on this scale. On the other hand, all ten materials used in the study had different surface roughness. In a similar argument, because of the variety, the participants might have found it difficult to evaluate the comparative roughness of the materials.

It was interesting that two participants evaluated the metal of the cheese grater as semi-transparent due to its perforations for grating. It once more reminds us that it is difficult to ensure that a participant focuses on a material of a product rather than the product itself. Another interesting point was that when the participants were asked to evaluate the roughness of the black teacup material, some of them found it reasonably rough due to its dotted pattern, but some of them considered it as smooth because of the smooth inner surface of the cup. Likewise, while some participants evaluated the metal part of the cheese grater as rough, one participant rated it as smooth (e.g. "I can see that the metal is smooth particularly on the edges of the product. However, they made these holes on it for functional requirements. The product can be rough but not the material”). In short, the types of products used in this study might have had a crucial effect on the variety of levels of agreement on the sensorial properties.

Lastly, the results of this study might be an indication that perceptions of some sensorial properties can be more affected by the type of user-product interaction and by other sensorial properties (or other sensory domains). The warmth of a material, for instance, can be influenced by thermal conductivity, and also by its surface roughness and even by its colour. Roughness of a material, similar to warmth, is not always easy to evaluate since various aspects can be effective in perception of roughness. For instance, how people touch an object (with a finger or hand, by grasping or rubbing), the speed of his/her hand or fingers across a surface, and the force exhorted between his/her fingers and the surface can all be influential in roughness perception (Zuo, 2003). In addition, roughness can also be evaluated visually (visual roughness). On the other hand, purely visual properties are *only* perceived by vision. Transparency, for instance, is evaluated solely through one’s eyes (although environmental effects, such as light, can affect the perception of transparency). Consequently, it can be tentatively assumed that the interventions of other aspects (other sensorial properties, other sensory domains, environmental effects, or the interaction type) have less impact in the perception of visual properties than in the perception of tactual properties. This may also explain the relatively low level of agreement on the tactual properties.

In short, in spite of a few unexpected cases, high levels of agreement in the overall evaluation show that it is methodologically sound to ask participants to evaluate their selected materials on the basis of the sensorial scales provided. Nonetheless, it should be recognized that it is not easy to provide designers with very accurate results. Therefore, the ultimate interpretation of the sensorial properties of the selected materials must be left to designers. On the basis of the findings, no amendments to the pictograms were deemed necessary for the dummy application of the tool.

3 Study 2: Data generation for the dummy application

This study was conducted with the aim of answering three questions. First, are the tasks involved in using the [MoM] tool comprehensible for people with different cultural backgrounds and expertise? Second, are people able to practically provide pictures of the materials they select? Third, can people explain their material selections in their own words and evaluate them using the sensorial scales? Above all, the goal of the study was to generate data for the dummy application of the tool. Two studies (Study 2a and Study 2b), each focusing on a different material meaning, were conducted simultaneously with 48 participants.

Meanings

The two meanings used for the studies were 'elegant' and 'sexy'. In the study reported in Chapter 4, a significant CULTURE X MATERIAL interaction was obtained for *elegant* and *sexy*. GENDER X MATERIAL interaction also reached significance on the meaning *sexy*. Elegant and sexy were two of the few meanings affected by all key aspects in this study in Chapter 4. In addition, throughout the whole research, in several studies *sexy* was found to be one of the most personal meanings attributable to materials. Moreover, it was considered that the two meanings *elegant* and *sexy* are likely to be intentionally expressed by designers through their creations. Subsequently, the effect of culture on attributing the meaning *elegant* and the effect of gender on attributing the meaning *sexy* to materials were explored in this study.

Participants

A total of 54 participants were invited to the study, of which 48 were willing to participate. Two of the six participants who declined to participate explained that they could not look beyond the products and evaluate only the material. The other four participants declined because of their heavy schedule. Two studies were conducted simultaneously. In the first (Study 2a), 12 Dutch and 12 Turkish academic staff and university students from various departments of Dutch and Turkish Universities[1] volunteered to participate. The main motivation to involve Dutch and Turkish participants in this study was one of convenience. Due to our close relation with Turkish universities (as I am originally from Turkey), it was easier to access the academic environment in Turkey.

The second study (Study 2b) was conducted with 12 female and 12 male participants with different nationalities (Dutch, Turkish, Italian, Portuguese, Argentinean, Colombian, Chinese, Tanzanian, German, South Korean, and Brazilian). Gender, as explained before, was expected to create differences in attributing the meaning *sexy* to materials. All of the participants were either academic staff or students from various departments of Dutch universities. The main reason behind conducting this study within an academic environment was that the (dummy) tool is intended to be universal/global in its application, comprehensible by people from different nationalities. For the same reason, English was adopted as the language of the tool. The pool of participants for Study 2 consisted of students and staff with different nationalities and a sufficient level of English. The studies took approximately half an hour per participant.

Procedure

The studies were performed by electronic mail, with the participants asked to perform a total of three tasks: TASK 1 to select a material, TASK 2 to document the selected material with a visual (picture), and TASK 3 to evaluate the selected material (See Chapter 7). In order to prevent bias or unwarranted manipulation in the participants' selections, the tasks were requested iteratively and only once a response from the previous task had been received.

In Study 2a, the participants were asked to select a material that they thought was *elegant*.

The participants were informed that the material they selected could be embodied in an object or in a part of an object. They were further explained that the objects could be made of more than one material and that not all of those materials need have the same expression (meaning). It was particularly emphasized that the focus should be on materials. Thus, if the selected material was a material of an object, the object as a whole need not have the same expression as the material. In addition, the terms 'object' and 'material' were defined and a few material and object examples were included in the definition (see Figure 3 and 4 in Chapter 7).

When the participants informed us that they had found a suitable material, they were sent the second task, in which they were requested to provide visual evidence of the material they selected. They were informed that the visual evidence might be either photographs they took or were taken by others, or illustrations (such as photos, modeling, etc.) that they could find on the Internet, in magazines or similar sources. It was underlined that if the material they selected was a part of an object made of more than one material, an additional picture (a close-up) of that particular part was required.

The third task focused on the evaluation of the materials that the participants had selected. There were two sub-tasks in this task: TASK 3a (verbal explanation) and TASK 3b (evaluation against the sensorial scales). Having received the visuals of the materials from the participants, they were then sent TASK 3a, which asked them to explain in their own words why they thought that the material they selected was *elegant*. Next, the participants were sent the final task (TASK 3b), consisting of five- point bipolar scales attached to 10 sensorial properties. The participants were asked to evaluate the sensorial properties of the material they had selected on the given scales. The procedure for Study 2b was similar to Study 2a, however the participants were asked to select a material that they thought was *sexy*.

Results

Study 2a: elegant materials selected by 12 Dutch and 12 Turkish participants

In total the participants selected 24 elegant materials (Figure 3). The Dutch participants mainly focused on hard materials with natural colours and smooth surfaces, such as ceramics and metal. The Turkish participants selected more glossy and transparent materials such as glass. Two flashy coloured (red and purple) materials appeared in the Turkish participants' selections.

The sensorial scales filled by the participants were analyzed statistically both to see the most significant properties in attributing the meaning elegant to materials in an overall evaluation and also reveal the main differences between the sensorial properties of materials selected by Dutch and Turkish participants. A *One Sample t- test* was executed to compute the importance of the properties. The overall mean score for 10 items (M= 2. 25) was taken as the test value for the One Sample T-test. Bold items in Table 2 show the properties that

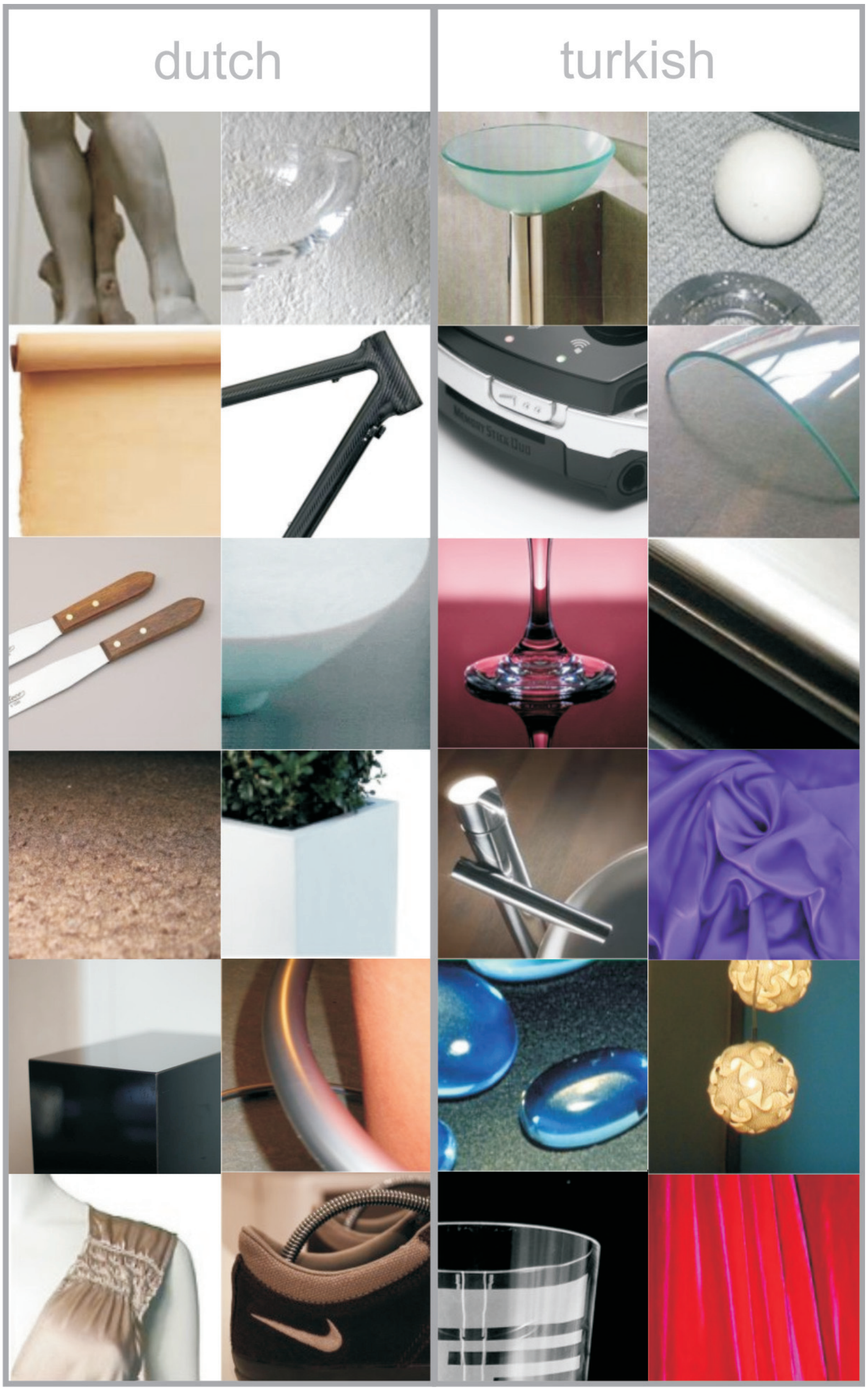

Figure 3. Elegant materials selected by 12 Dutch and 12 Turkish participants.

received scores significantly above or below the overall mean score. The properties that received scores significantly below the overall mean score are presented with a minus sign (-) in Table 2. The implication is that the opposite pole of these poorly scoring properties is significant for the given meaning. For instance, *Roughness* (1. 42) was significantly below (-) the overall mean, therefore *smoothness* of a material would appear to be one of the most important properties in attributing the meaning elegant to materials. *Elasticity* (1. 67) was also rated significantly below the overall mean score, which shows that the selected materials were significantly rated as *not-elastic*. *Glossiness* (3. 46) and *reflectiveness* (2. 88) were rated significantly above the overall mean score (i.e. the selected materials were commonly glossy and reflective).

Table 2. Results of the One Sample T-Test for elegant materials.

Test Value: 2.25	t	df	Sig. (2-tailed)	Mean
soft	-,544	23	,592	2,08
rough (-)	-4,920	23	,000	1,42
glossy	3,607	23	,001	3,46
reflective	2,106	23	,046	2,88
warm	,742	23	,465	2,42
elastic (-)	-2,723	23	,012	1,67
transparent	-,377	23	,709	2,13
ductile	-,119	23	,907	2,21
weak	1,141	23	,266	2,63
heavy	,578	23	,569	2,42

The effect of cultural differences on attributing the meaning *elegant* to materials was analyzed by a multiple analysis of variance (MANOVA) with the ten sensorial properties as dependent variables and culture as the fixed factor. One significant main effect of culture ($p < .05$) was obtained for transparency (Table 3).

Table 3. Results of multiple analysis of variance (MANOVA) for the effect of culture in Study 2a.

	Dependent Variable	df	F	Sig.
CULTURE	soft	1	,071	,792
	rough	1	,234	,633
	glossy	1	,750	,396
	reflective	1	1,641	,214
	warm	1	,540	,470
	elastic	1	,146	,706
	transparent	1	5,453	,029
	ductile	1	,122	,730
	weak	1	,015	,902
	heavy	1	,080	,780

Elegant materials selected by Turkish participants were more transparent than the materials selected by Dutch participants (2.83 vs. 1.42). The full statistical results of this study can be found in Appendix 8.1.

Study 2b: sexy materials selected by 12 female and 12 male participants

For the female participants, particularly the soft and velvet like feelings of a material played an important role in attributing the meaning *sexy*. Three of the female participants mentioned the importance of transparency (or semi-transparency) on sexiness. In contrast, hard and strong materials dominated the male participants' selections. They hardly mentioned the importance of a soft tactual property of a material for conveying the meaning sexy (except for one participant, who selected silk as a sexy material) (Figure 4).

The same methods (One Sample t-test and MANOVA) were used for the statistical analysis of the sensorial scales filled by participants. The results of the One Sample t-test, with bold items depicting those properties receiving scores significantly above or below the overall mean score (M= 2. 56), are presented in Table 4. *Roughness* (1. 50) and *elasticity* (1.79) were rated significantly below the overall mean score, which reveals that the selected materials were commonly rated as *smooth* and *not-elastic*. *Glossiness* (3. 50) was rated significantly above the overall mean score.

Table 4. Results of the One Sample T-Test for sexy materials.

Test Value = 2.56	t	df	Sig. (2-tailed)	Mean
soft	-,052	23	,959	2,54
rough (-)	-6,226	23	,000	1,50
glossy (+)	3,408	23	,002	3,50
reflective	,728	23	,474	2,79
warm	-,922	23	,366	2,33
elastic (-)	-3,098	23	,005	1,79
transparent	-1,125	23	,272	2,21
ductile	-,053	23	,958	2,54
weak	,498	23	,623	2,71
heavy	,072	23	,943	2,58

The results of the multiple analysis of variance (MANOVA), with gender as the fixed factor, revealed one significant main effect of gender ($p< .05$) for *weakness* of materials (Table 5).

Sexy materials selected by the female participants were weaker than the materials selected by the male participants (3.50 vs. 1.92). The full statistical results of this study can be found in Appendix 8.2.

Figure 4. Sexy materials selected by 12 female and 12 male participants.

Table 5. Results of multiple analysis variance for the effect of gender in Study 2b.

	Dependent Variable	df	F	Sig.
GENDER	soft	1	2,543	,125
	rough	1	,232	,635
	glossy	1	,815	,376
	reflective	1	2,178	,154
	warm	1	3,143	,090
	elastic	1	,246	,625
	transparent	1	1,468	,239
	ductile	1	,703	,411
	weak	1	9,757	,005
	heavy	1	2,547	,125

Discussion

In this study, three main questions were addressed: First, are the tasks comprehensible for people with different cultural backgrounds and expertise? Almost all participants (44 out of 48) found the tasks clear and accomplished the tasks without questioning. Four participants found the first task particularly complicated. Two of them replied to the first e-mail expressing their confusion and stated that even though the main assignment (*select a material that you think is elegant/sexy*) was clear, the explanation of the task confused them. They recommended splitting the explanation part and the main assignment, and send them as separate documents. Two participants found the main assignment too broad. They could not understand that they should select a specific material, until they received the second task. Instead, they thought about a material family that they found to be elegant/ sexy, such as *glass is sexy* or *metal is elegant*.

The second question was: are people able to provide pictures of the materials they select? All of the participants were able to do so. Thirteen participants selected materials that were embodied in a part of an object. However, only six of these sent an additional picture showing the selected material in detail. All of the participants emphasized the selected materials by name (such as '*glass in this object*') or by referring to the relevant part of the object (such as '*the material of the handle*') in their verbal explanations (Task 3a). Those participants who did not send the detailed picture mentioned that they found the pictures on the Internet and that it was difficult and time consuming for them to edit the pictures. Instead of taking their own photographs, most of the participants preferred to surf the Internet for sourcing visuals of the materials. Nine participants (out of 48) sent photographs they had taken themselves. Therefore, on the basis of these findings, in a future application of the [MoM] tool the request for an additional photo will be left out. Instead, a more detailed explanation about the selected material (if it is a part of an object) will be required in Task 3a. In general, the quality of pictures (pixel resolution) was sufficient for use in the [MoM] tool. Only four participants sent pictures with low resolution.

The third question was: can people explain their selections in their own words and make an evaluation using the sensorial scales? The participants were able to explain their selections in their own words. They were willing to talk about their selections and their appraisals were comprehensible. Two participants interpreted the sensorial scales incorrectly, using them to evaluate a certain material family rather than the specific material that they had selected. For this reason, instead of filling in the scales by considering the selected material (such as a particular metal type embodied in a vase) they made their ratings based on the material family ('*metal*' in general). These two participants filled out the scales one more time after they were instructed about the purpose of the task.

For both of the meanings *elegant* and *sexy*, certain properties were found more effective than others for attributing the meaning. However, the variety of the selected materials provided an inspiring collage of properties for incorporation into further applications of the [MoM] tool. An increased number of participants would enhance the chance of building an extensive collage, but would reduce the number of common properties amongst the selected materials. In certain cases, both common points and differences in the properties of selected materials by a particular target group can be valuable for the designer. This statement will be tested in the next study.

In general, the results of this study confirm that people with different cultural backgrounds and expertise are able to fulfill the material-meaning related tasks. They can explain their choices and understand the given sensorial scales supported visually by pictograms. Not surprisingly, it was noticed that the participants with design backgrounds (such as industrial designers, architects, graphical designers, etc.) accomplished the tasks without difficulties. All questions arising from confusion about the first task came from four non-designers. The two people who declined to participate in the study and who explained that they could not evaluate materials as 'sexy' or elegant' were also non-designers. This could suggest that the study would yield different results if it was conducted only with designers.

The main goal of the study was to provide sufficient data about the meanings elegant and sexy for creating an example 'outcome' part of the tool. Only one property for each meaning (transparency for elegant and weakness for sexy) appeared to be different for the specified groups (i.e. Dutch vs. Turkish, females vs. males). On the other hand, we could see some patterns (even though they were not that obvious) which evoke the given meanings for the specified groups. The materials that the participants selected, the selected user aspects (gender and culture) and the overall results were satisfactory for creating a dummy application.

4 Creating a dummy application

As explained extensively in the previous chapter, the aim of the Meanings of Materials (MoM) tool is to present an inspiring collage of materials selected by different people and classified by meaning. Designers are encouraged to explore the tool, look at the selected materials and read the explanations given by participants involved in creating the data for the (MoM) tool. A quantitative analysis of the sensorial scales is presented and the significant sensorial properties found effective in the overall evaluation are highlighted. Furthermore, designers can see differences between materials selected by different groups. The MoM model is presented as a guide or support for designers in their analysis of the presented materials. The model draws attention to the key aspects that might play an important role for a particular material's meaning. Taking all these considerations into account, an interactive application (dummy tool) was created with Macromedia Dreamweaver (MX 2004). This application was developed in order to test the efficiency of the outcome of the proposed tool with junior designers. The application was created for the meanings *sexy* and *elegant*. Figure 5 shows the interface of the created application for the meaning *sexy* (see Appendix 8.3 for the meaning *elegant*).

The dummy application's two major aims are to present the findings of the previous study (on sexy and elegant materials) in an inspiring and informative way, and to familiarize

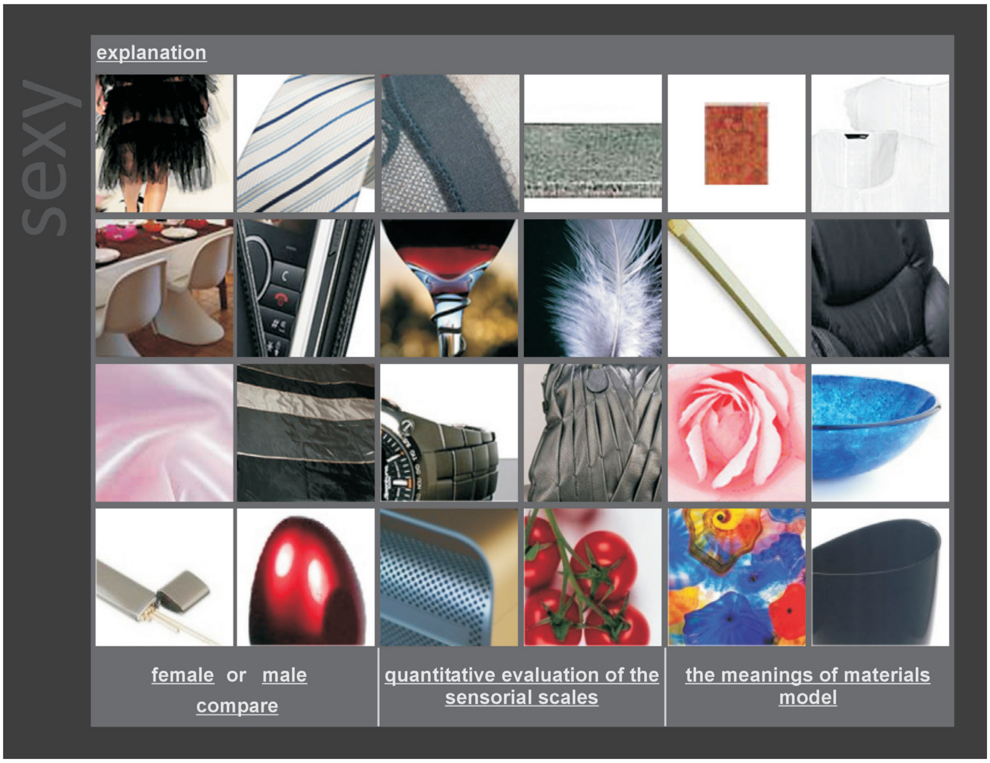

Figure 5. The Meanings of Materials tool, dummy application interface for the meaning *sexy*.

designers with aspects of materials playing an important role in attributing meanings to those materials. The application was designed as an interactive tool enabling designers to navigate through the selected materials (or objects) and examine the 'meaning evoking conditions' for each single case. The main assumption is that designers who browse through the single cases will comprehend the key aspects in attributing meanings to materials and reach the personal interpretation of the patterns that evoke the given meanings (elegant or sexy). The tool aims to support mainly three types of actions: (a) navigating through the collage, (b) focusing on a particular group of participants, and (c) formulating the ideas (of designers) about certain material-meaning relationships. Below, these three actions are explained by referring to Figure 6.

Figure 6. Parts of the interface supporting the three main actions of the tool.

(a) Navigating through the collage

Designers use the mouse in order to navigate through the collage. Each single item (thumbnail) of the collage behaves like a button. When the mouse is hovered over a thumbnail, it becomes framed by an orange line, indicating that a detailed explanation about the item is available. By clicking on the thumbnail, designers can find the details about the single case in question, including a full-view picture of the selected material, the explanation from the individual, and details of the individual (age, gender, nationality and occupation) (Figure 7). It is expected that before *formulating* the ideas with the help of the sensorial scales and the model, even navigating through the collage and focusing on single cases might be sufficient to stimulate ideas (see Appendix 8.4 for all cases). The main navigation action is depicted by numbers 1 and 2 in Figure 6.

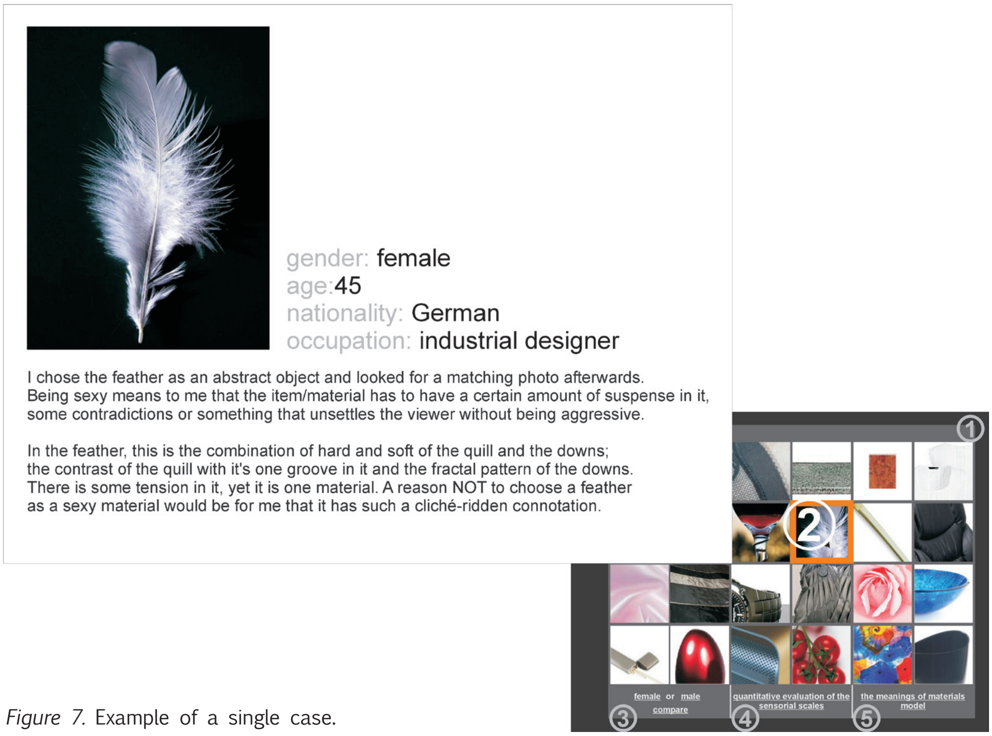

Figure 7. Example of a single case.

(b) Focusing on a particular group of participants

Designers can focus on a certain segment of the group who selected the materials. In this particular application, three buttons mainly serve for this function: *female*, *male* and *compare* (number 3 in Figure 6). A similar division is made for Dutch and Turkish participants in the case of 'elegant' materials. Materials selected by only female participants, for instance, can be seen if the designer clicks on the female button. Once the female button has been clicked on, the males' selection disappears (Figure 8). In this way, designers can focus on the selection made by female participants only. Using the collage of materials selected by a certain group, designers can make their own conclusions regarding colours, shapes, functions, etc. The *compare* button enables designers to focus on the differences and similarities between two groups with reference to the sensorial properties of the selected materials.

The 'compare' page consists of the thumbnails pooled together for the two groups (e.g. females and males separately) alongside a table showing the mean scores for each sensorial property rated by the groups, the verbal explanation of the property (or properties) found *significantly different* between the two groups, and a graph presenting the mean score of this property for each group (Figure 9). It is expected that this part of the tool can be particularly valuable while designing for a particular target group.

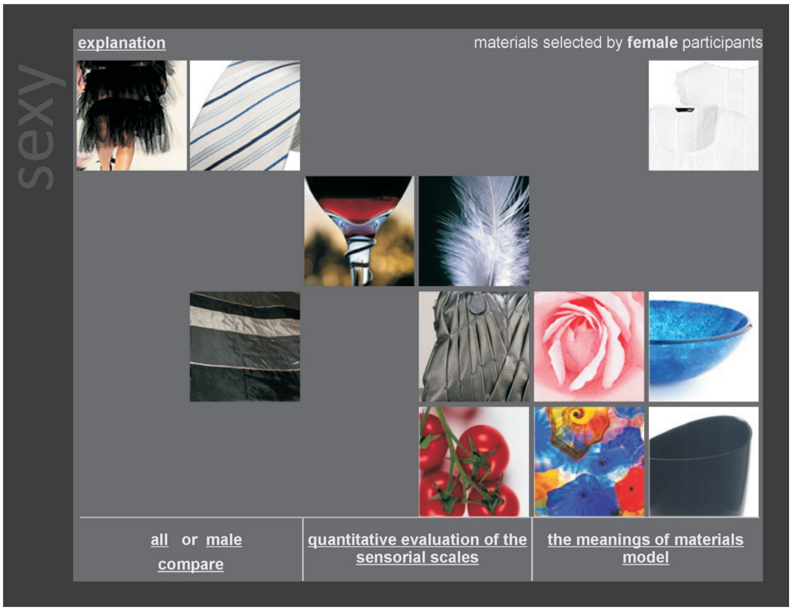

Figure 8. Materials selected by female participants.

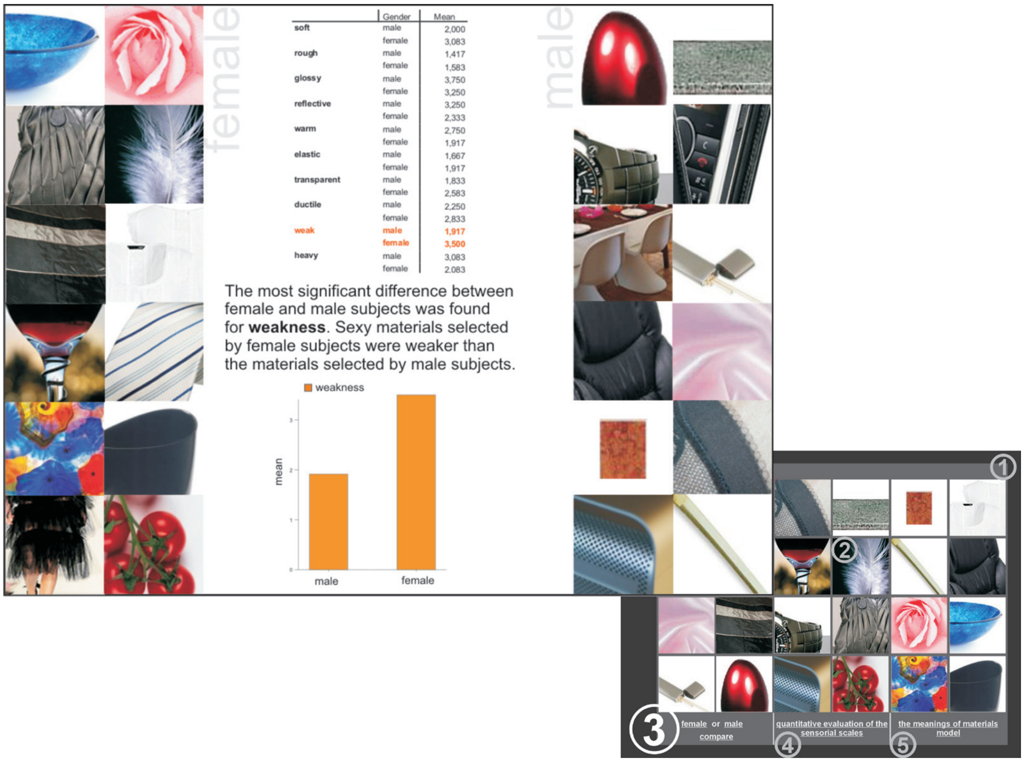

Figure 9. Compare page of the tool.

(c) Formulating the ideas

The tool offers three types of information to support designers in formulating their ideas for how to build a certain meaning through their material choices: quantitative evaluation of the sensorial property scales, a link to a technical website and the meanings of materials model. The quantitative evaluation button (number 4 in figure 6) provides the overall evaluation of the sensorial scales (females and males combined) presented by means of a graph (Figure 10). The sensorial properties that were found significantly effective in attributing the meaning sexy to materials are emphasized in the graph. All ten scales covering the ten evaluated sensorial properties, along with their opposite poles, are presented with pictograms in order to familiarize designers with these properties. Besides this information, the page also offers a link where designers can access technical information about material properties[2].

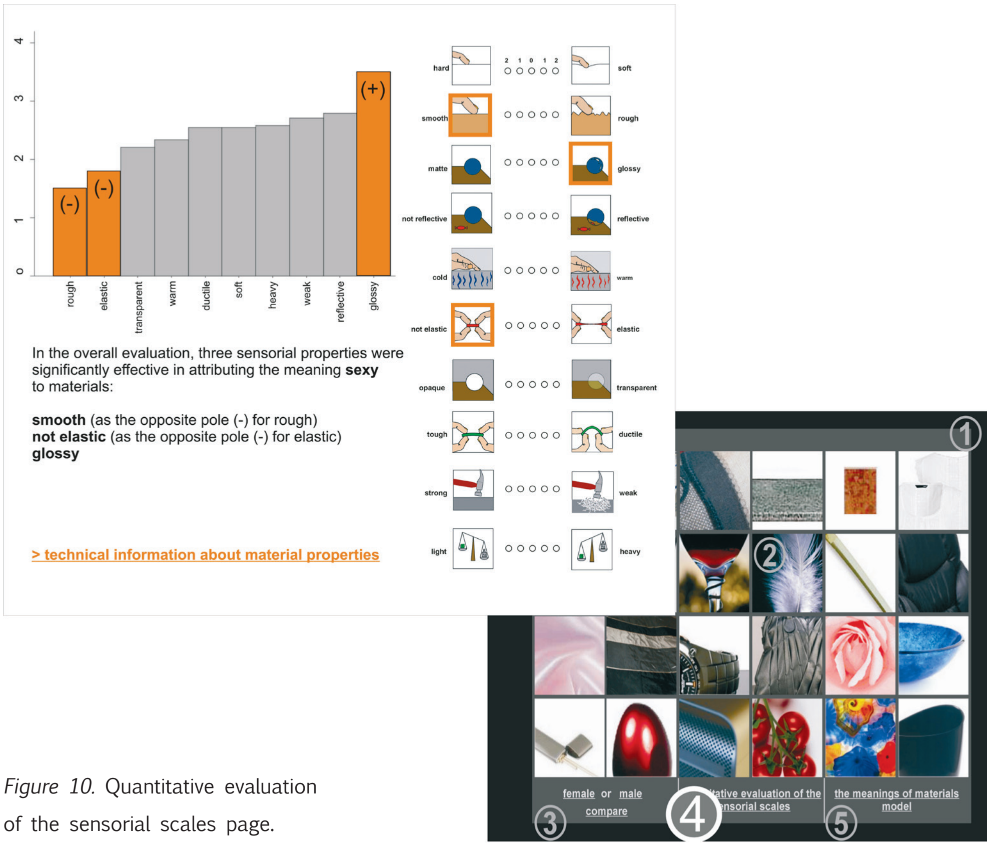

Figure 10. Quantitative evaluation of the sensorial scales page.

Another option to guide designers in formulating their thoughts and analyzing each single case is the Meanings of Materials Model button. By clicking on the model button (number 5), designers find the explanation of the model (Figure 11). The components of the MoM model and the aspects explored in this thesis (i.e. shape, function and manufacturing processes) are presented as individual, clickable buttons. By clicking on these buttons, designers can

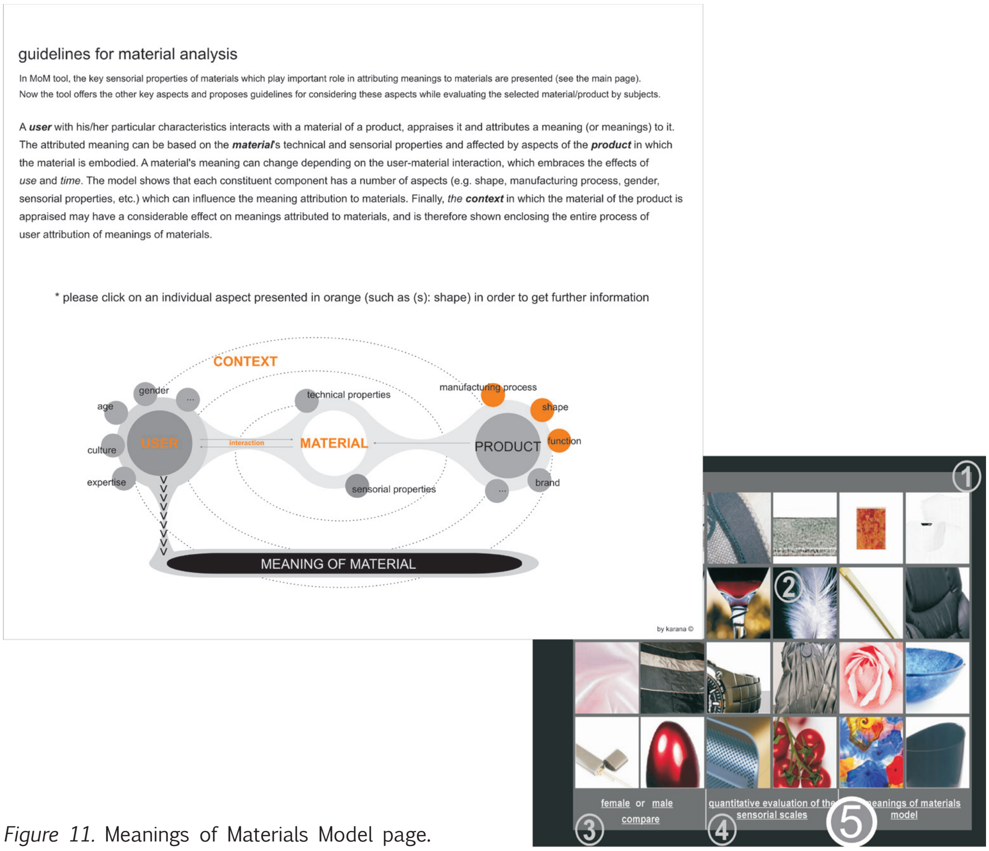

Figure 11. Meanings of Materials Model page.

find more detailed information about the individual components of the Meanings of Materials model (Figure 12). Findings of the studies in Chapter 3, 4 and 5 are used for explaining the role of the components (see Appendix 8.5a for the explanation pages used in the MoM tool). The *explanation* button explains briefly what the tool offers (Appendix 8.5b).

Discussion

The real application is planned to be a web-version of the dummy application, expanded with more cases for each featured meaning (such as 100 cases for each meaning). The dummy of the Meanings of Materials tool aims to assist designers in selecting materials that express the meanings *elegant* and *sexy*. Although the number of cases used for the dummy application is not as high as intended for the real application, it is expected that the dummy application can convey the main principles and practical usage of the tool. In order to determine if the dummy tool fulfills the intended aim of supporting designers in meaning- driven materials selection in an inspirational way, a further study was conducted. This will be discussed in the next section.

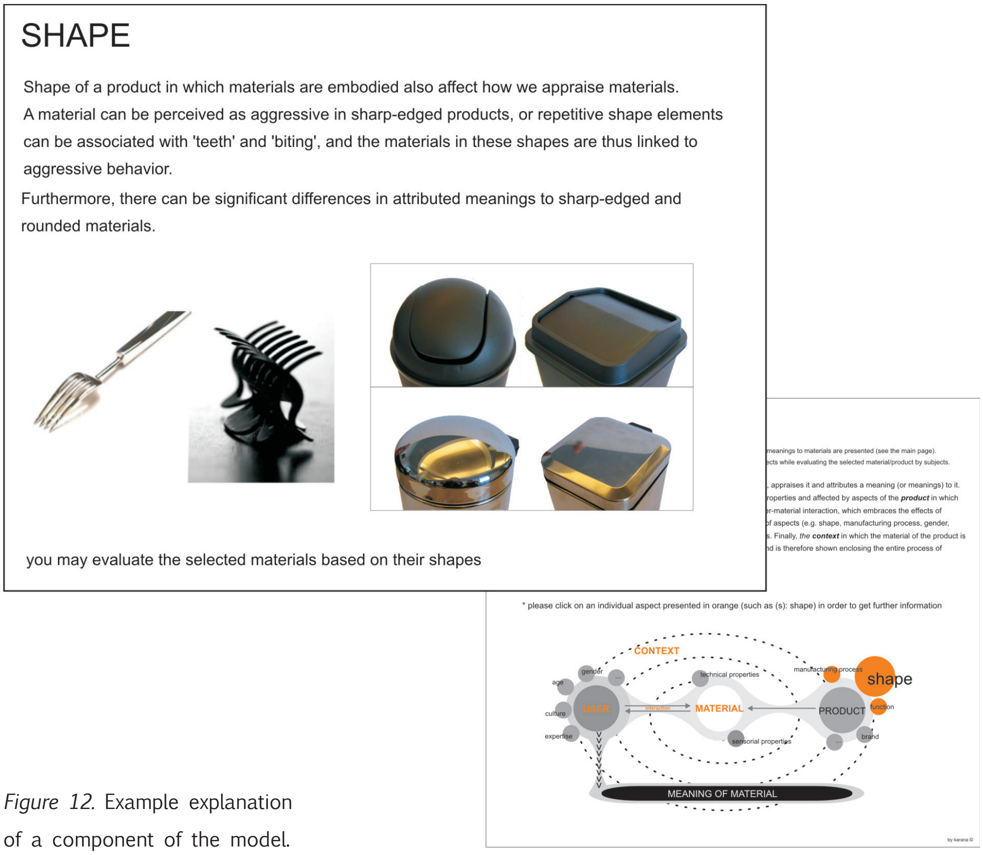

Figure 12. Example explanation of a component of the model.

The aim of the final study of this thesis is to test the usefulness of the dummy tool developed in the previous section. Summarizing, the study aims to answer three major questions: (1) if designers find the tool inspiring, (2) if the tool supports designers to find relationships (or patterns) between certain meanings (sexy and elegant in this case) and materials, and finally (3) whether or not the tool supports designers to select materials expressing certain meanings.

Method

Participants

The participants for the study (N= 24; 12 male, 12 female) were junior designers in their final years of master study within the faculty of Industrial Design Engineering at Delft University of Technology. The study took approximately 1.5 hours per participant. The participants were paid 10 Euro for their contribution.

Procedure

On an individual basis, the participants were invited to a room at the Faculty of Industrial

Design Engineering. They were given a letter describing the task that they were expected to complete in 2 hours. As explained before, the [MoM] tool contained the data derived from the previous study on the meanings elegant and sexy. The task was formed accordingly. Half of the students (12 in total) was asked to design an elegant product, and the other half was asked to design a sexy product. Both groups (elegant and sexy) were also divided into two groups consisting of 6 students. For the elegant product, 6 students were asked to design for the Dutch market, and the other 6 were asked to design for the Turkish market. For the sexy product, 6 students were asked to design for females, and the other 6 for males.

It was assumed that the collage of the materials might be more relevant for a particular product type, and that this would affect the evaluation of the tool. For instance, the textile examples in the tool could be valuable for a task about a sofa, but not that important for an electronic product. Therefore, particular attention was paid to selecting two different products that would allow the participants to be free to choose various kinds of materials. Moreover, in assigning the task of materials selection for certain markets (Dutch- Turkish, female- male), the product types were required to make sense for these market segmentations. For example, it would have been hard to design commonly used domestic products, such as a sitting element, a table, or a telephone specifically for females or males. Finally, the given tasks were required to be easily sketched/ drawn by students. To sum up, three main criteria were followed while deciding on the product types used in this last study: A product, *which can be made of different kinds of materials*, *which makes sense for Dutch- Turkish and female-male market segmentations*, *which can be easily drawn by students*.

Following these criteria, two products were selected for the different meanings being tested through the tool: an elegant fruit bowl for Dutch and Turkish markets, and a sexy spectacle case for males and females. The table below summarizes the given tasks and the number of students (std) who participated in each task.

an elegant fruit bowl	**a sexy spectacle case**
for Dutch market (6 std)	for females (6 std)
for Turkish market (6 std)	for males (6 std)

Before starting the task, it was emphasized that participants were expected to design for the given task and select a material that conveyed the given meaning (sexy or elegant). They were asked to use the MoM tool during their material decisions. The tool was introduced as an inspirational guide that includes the results of a research conducted with the given target groups (Dutch and Turkish, female and male). The participants were informed that they were expected to surf through the examples and cases in the tool and try to use all of the navigation buttons (options). An example of a given task can be seen below.

> Design a sexy spectacle case for females. You are expected to select a material that will contribute to the meaning (sexy) of your design. While deciding on the material(s) of your

design, you are expected to use the (MoM) tool, which presents a new approach to support designers to involve meaning considerations into their materials selection process.

During their search in the tool, they were given guidance about the tool. They were free to surf the tool as much as they wanted. However, they were requested to submit their designs at the end of 2 hours. All of the participants were provided with sufficient equipment (e.g. markers, sketch books, pencils, pastels, etc.) for hand drawings, and they were asked to make their submissions in the form of sketches (hand drawings) (Figure 13).

Figure 13. Two participants from the tool testing study.

They were also asked to specify their material choices using written explanations next to the sketches, as it could be difficult to define a material by hand drawings alone. After their submission, they were given a one page evaluation sheet consisting of nine questions probing different aspects of the tool (Table 6). The evaluation sheet focused on three main aspects: (1) selected materials and individual explanations, (2) quantitative results from the sensorial scales and a link to a technical materials selection website, and (3) the Meanings of Materials Model. After filling in the evaluation sheet, they were asked to explain their designs, their selection process, the material(s) they had selected, whether the selected material(s) is from the tool or not, and if they found a specific example(s) from the tool very inspiring. Finally, they explained their thoughts and recommendations about the tool in general.

Results

All of the participants (N= 24) accomplished the given task and submitted their designs as freehand sketches accompanied by written explanations of the materials they had selected. They all followed the same course of actions: (a) navigation through the whole tool, (b) jotting down the important points in order to make their own definition for the given meaning, (c) focusing on certain examples (mainly the most personally inspiring and appealing), and finally (d) designing their products and selecting materials.

Almost all of the participants (21 out of 24) selected materials that were present in the tool. The other three participants combined the tool's materials with ones not present in

Table 6. Evaluation sheet used for assessing different aspects of the [MoM] tool.

Below you will find the different aspects of the MoM tool. Please evaluate these aspects by the given scales.						
Selected materials						
very helpful						not helpful at all
Individual explanations						
very helpful						not helpful at all
Comparing Dutch and Turkish individuals						
very helpful						not helpful at all
Quantitative results from the sensorial scales						
very helpful						not helpful at all
Link to a technical material selection website						
very helpful						not helpful at all
The Meanings of Materials Model						
very helpful						not helpful at all
Tool in general						
very helpful						not helpful at all
Did you find the MoM tool inspiring for your material choice?						
very much						not at all
Do you want to use the MoM tool in your further design projects?						
very much						not at all

the tool (such as diamond and rubber). These three participants stated that the significant sensorial properties had led them to select these different materials having similar sensorial properties (e.g. diamond was selected for glossiness). Participants, in general, preferred to combine materials instead of selecting only one material. The participants indicated that the materials used in the majority of their designs featuring combined materials were particularly inspirational. Figure 14 and 15 show examples of the submitted designs with the inspirational materials shown adjacent. As this figure shows, a different set of materials (or products) inspired each participant. Two participants, even though they were asked to design for the Dutch market, were inspired by certain examples selected by Turkish people (b and c). A textile example that had been selected by a male was used for designing a sexy product for females (g). Likewise, a participant who designed a sexy product for males (j) made use of a textile selected by a female. Products designed for the Turkish market were specified to have similar materials (metal + glass). In general, the variety of the selected materials for the sexy spectacle case was higher than the variety of the selected materials for the elegant fruit bowl.

Quantitative evaluation of the study

As mentioned earlier, after completion of the design task, the participants were given an evaluation sheet assessing the extent to which they had experienced the tool as inspirational, and whether the components of the tool contributed to their materials selection process. A *One Sample t- test* was executed to analyze the completed evaluation sheets. The mean of

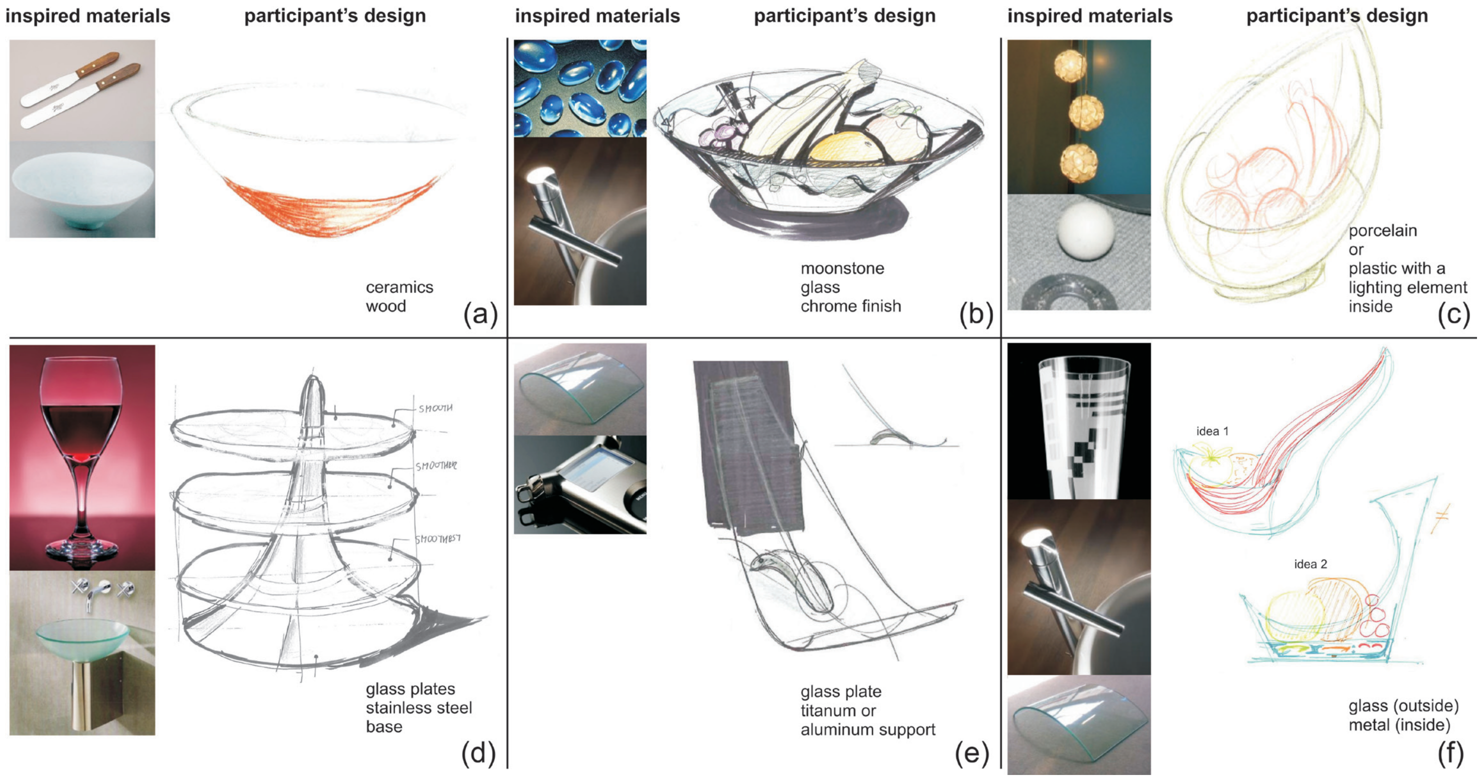

Figure 14. Elegant fruit bowls designed for the Turkish (a, b, c) and Dutch (d, e, f) market.

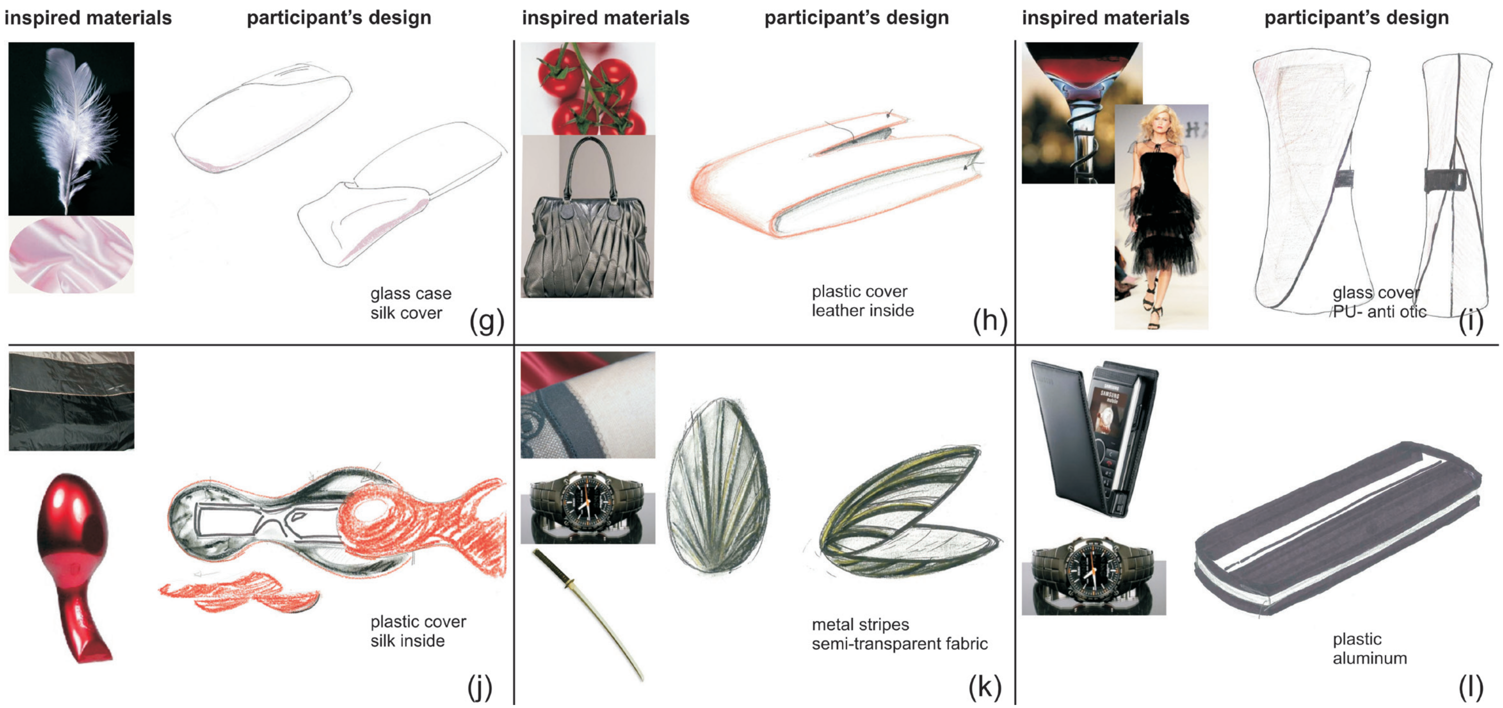

Figure 15. Sexy spectacle cases designed for females (g, h, i) and males (j, k, l).

the five- point scale (M= 3.0) was taken as the test value in order to evaluate the significance of each individual question. Table 7 depicts the results of the quantitative evaluation. The tool was found significantly inspiring by the participants; whereas the contribution of the technical link and the MoM model to the materials selection process was found limited.

Table 7. The results of One Sample T- test.

Test Value = 3.0	t	N	Sig. (2-tailed)	Mean
Material examples	9,167	24	,000	4,29
Individual explanations	4,764	24	,000	3,88
Comparing the groups	3,745	24	,001	3,83
Sensorial scales	2,013	24	,056	3,54
Technical link	-1,570	24	,130	2,50
Model	1,498	24	,148	3,33
Tool in general	11,869	24	,000	4,17
Inspiration	12,460	24	,000	4,50
Willing to use	5,822	24	,000	3,96

Qualitative evaluation of the study

The participants were expected to design products that expressed the two chosen meanings (sexy and elegant) and select materials that contributed to these meanings. They were encouraged to use the Meanings of Materials tool during their materials selection process. The central aim of the study was to assess whether or not the tool was able to support designers to involve meaning considerations into their materials selection processes. Most participants explained that they felt confident that they had succeeded in conveying the given meanings through the materials they had selected. They were willing to use the tool in other design projects. The participants were asked to discuss the tool's positive and negative aspects at the end of the study. They also reported their recommendations for a further application of the tool.

The tool's positive aspects

Most of the participants (21 out of 24) found the tool very inspiring and a general eye-opener for materials selection. Most of them reported that they had started with a few fuzzy ideas on what to do and ended up with a number of material ideas. They specifically mentioned that the tool had encouraged them to start thinking about materials at a very early stage of the design process. The tool was found particularly inspiring for combining different materials into product ideas (e.g. "*I would just think to use one type of material if I hadn't seen that people had various ideas about sexy materials*").

Four participants mentioned that through the tool they had learned about some new materials (such as moon stone). The tool was primarily found contributive in envisaging how a material's final appearance would be when embodied in a product. In addition, most of the participants mentioned that the tool made the *meaning* of the given meaning (elegant and sexy) easy to comprehend and supported them to make their own definition of the meaning (e.g. "*I found the explanation of the individual, who selected the feather as a sexy material, very inspiring and helpful to make my own 'sexy' material definition. She was explaining sexy as … being sexy means to me to that the item/material has to have a certain amount of suspense in it, some contradictions or something that unsettles the viewer without being aggressive.. I think it is a very good definition and exactly conveys what 'sexy' is for me*").

Most of the participants stated that they usually deal with the materials selection at the end of the design process and do not consider systematically materials- meaning relations, sensorial properties, etc. They reported that the major strength of the tool was that *it introduces a new approach for selecting materials, which is normally considered very boring and not touched upon till the last moment of your design process; the tool, in this respect, provides you with a number of inspiring examples, interesting explanations which are really enjoyable to read*. Four participants emphasized that not only the materials of the featured products but also their shapes and uses were inspiring. Figure 16 shows the designs of two participants inspired by the shapes of the featured products as well as the materials.

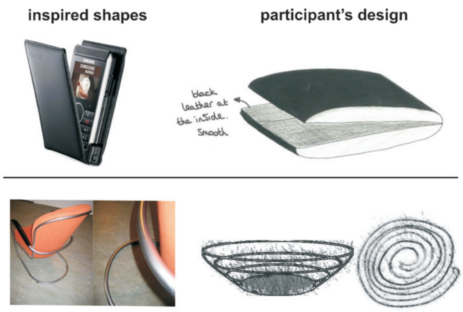

Figure 16. Designs of two participants inspired by the shapes of the products featured in the [MoM] tool.

All 21 participants positive about the tool reported that they had efficiently used the pictures of the selected materials, individual explanations and group division option in order to see a certain group's selections (such as, materials only selected by females). Two participants mentioned that they had completely different material ideas before navigating through the tool. After discovering the taste of the group they aimed to design for, they changed their material decisions accordingly. For ten participants (out of 24), the quantitative results from the sensorial scales and the given significant properties in the 'compare page' were found definitely helpful in focusing their ideas as well as checking if their final decisions covered these properties (Figure 17). The presented mean numbers in the *compare* page were used by one participant efficiently (Figure 17 left bottom circle). It was emphasized by three participants that the tool was also very informative about the manufacturing processes presented in the model. Moreover, the pictograms of the sensorial properties and the

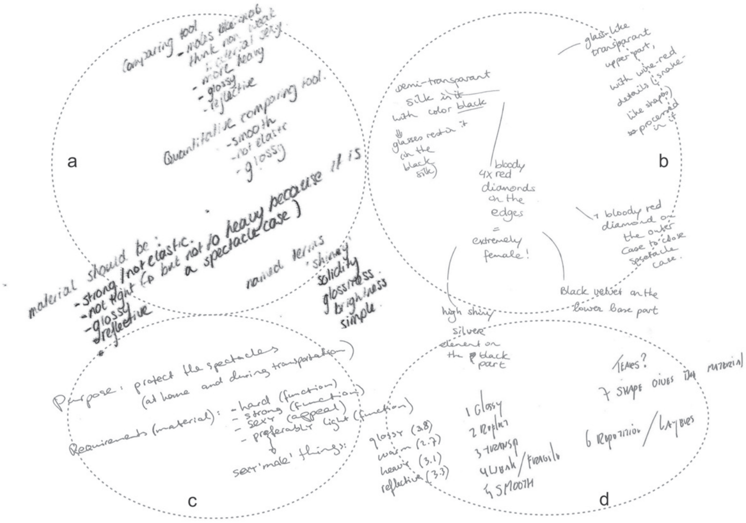

Figure 17. Examples of analyses made by designers by using the sensorial scales.

manufacturing processes were found very useful in familiarizing these participants with these properties. Even though none of the participants used the technical material link, five of them found it necessary for a materials section tool. As indicated by them, *if the concept creation process was carried to a detailed design phase, the need for a technical link would be inevitable.*

The Meanings of Materials model was reported as supportive by twelve participants for gathering and formulating thoughts and ideas. Four of these participants explained that the model was very helpful for checking if a candidate material also fulfilled other significant relations such as shape-materials-meaning, or function- material- meaning. Furthermore, they added that above all, the model was useful for understanding the key aspects that can have an influence in the meanings attributed to materials (e.g. "*the model makes you aware of the realities beyond your concept. You see the importance of other aspects such as shape, function and manufacturing processes*"). Three participants also found the examples given in the model inspiring. Figure 18 (a,b) depicts two examples in which the Meanings of Materials model is implemented into the design processes of participants.

The participant who designed the products in Figure 18a was one of the most enthusiastic participants in the study. She used the tool efficiently to systemize her thoughts and to come up with a confident result. She filled in the components of the model according to the given task:

> "*I wrote down all the important aspects, which I summarized from the pictures under the components of the tool. Finally I had a list of key characteristics for each component and related aspect. For instance, I defined for what kind of user I am designing for, what kind of shape-material combinations are elegant for this user group, what kind of manufacturing*

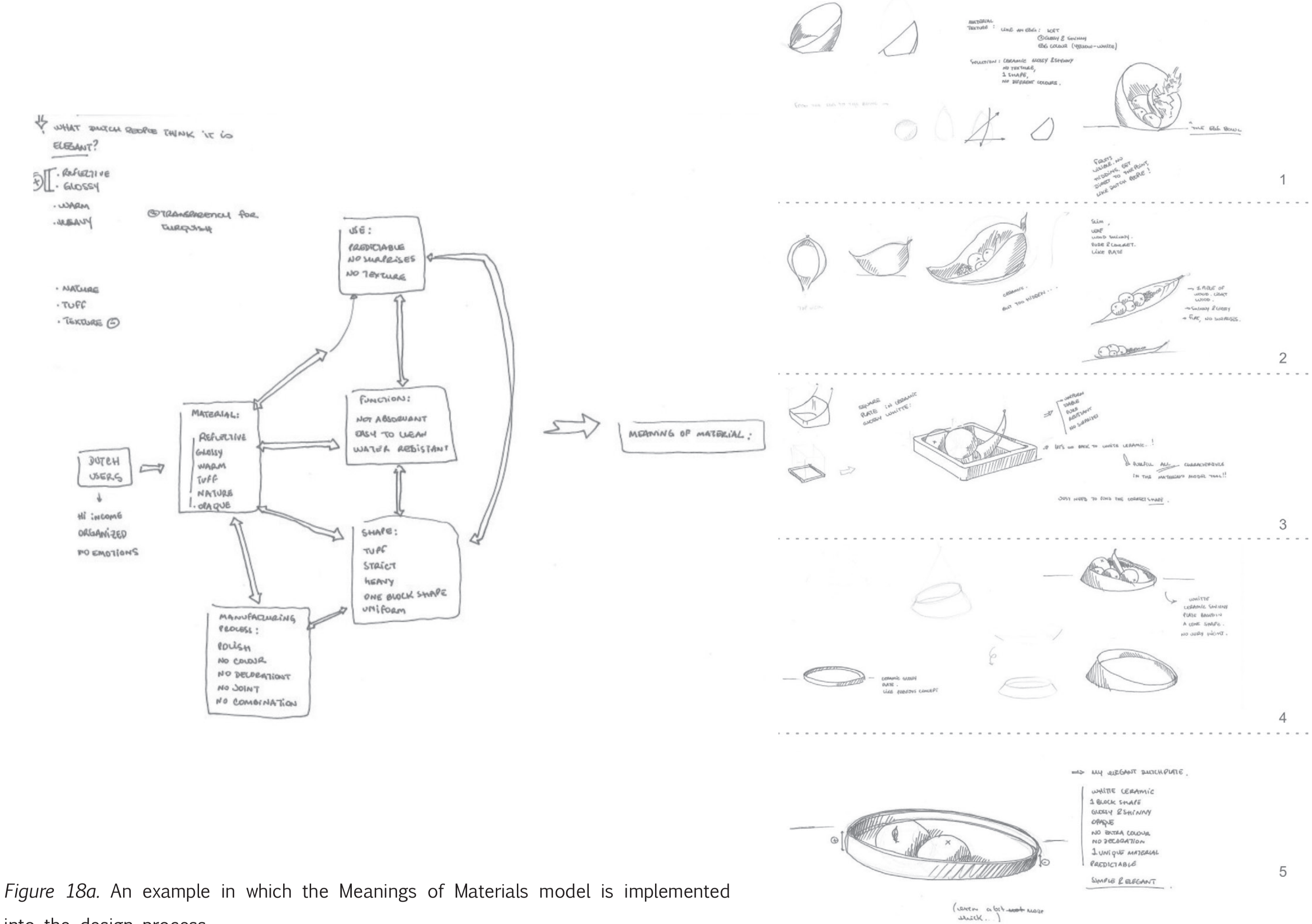

Figure 18a. An example in which the Meanings of Materials model is implemented into the design process.

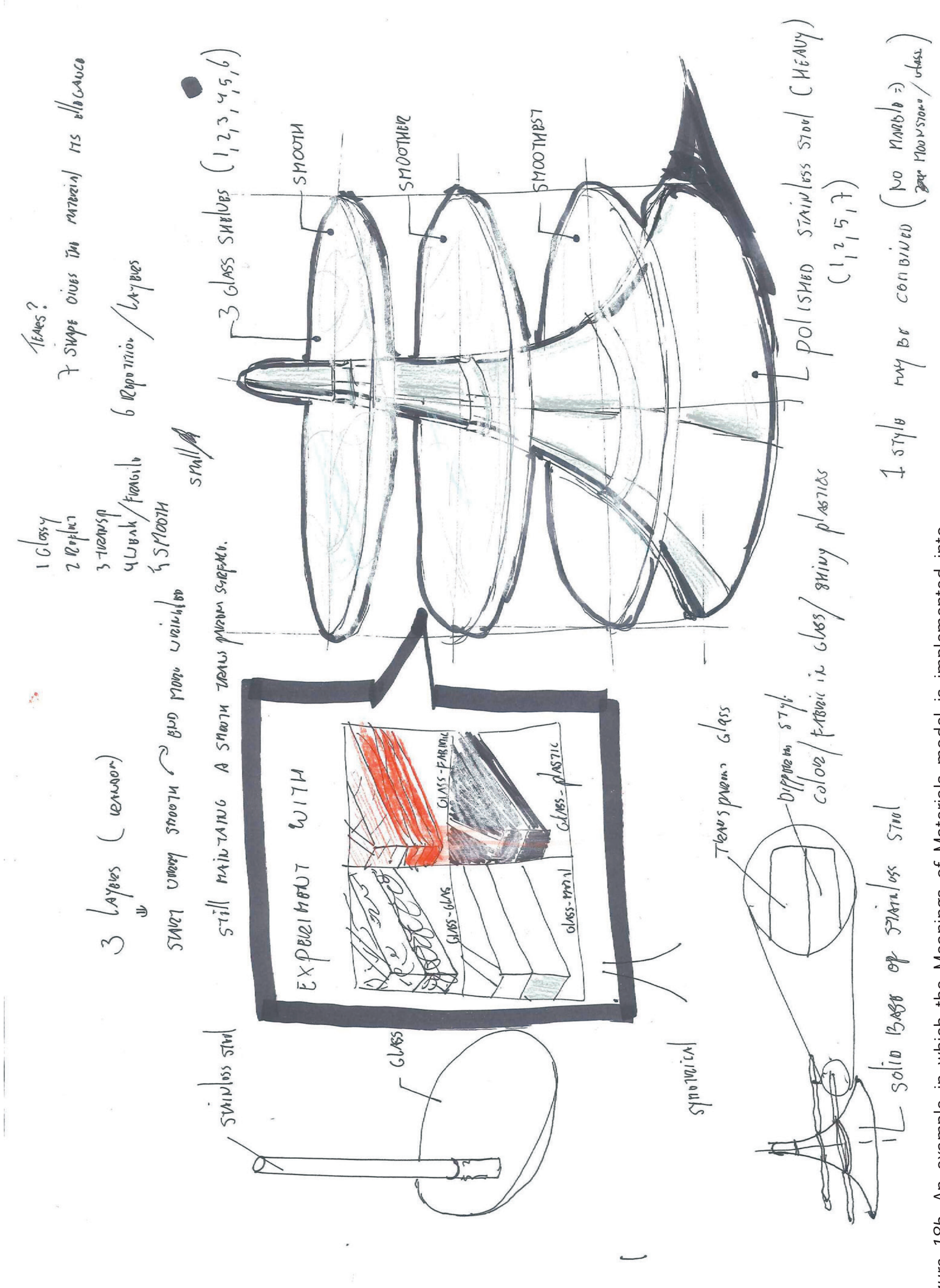

Figure 18b. An example in which the Meanings of Materials model is implemented into the design process.

> *processes can contribute to this meaning. After summarizing all these, I started to come up with my own ideas; and at every step I turned back to the model and checked if I was still following the key characteristics that I listed*".

The second participant in the figure (Figure 18b) also utilized the model to make conclusions on the material examples. He listed the number of significant properties and checked if his final decision fulfilled these properties (see the listed properties from 1 to 7 and the numbers next to selected materials in parenthesis confirming that the material had these properties). He got the idea of *combining materials* from the model. He tried a number of possibilities for material combinations and emphasized that the model was very inspiring in that sense.

The tool's negative aspects

Three participants not enthusiastic with regard to the overall tool stated that the given sensorial properties were not inspiring; on the contrary they were limited and restricted their creativity by leading them to certain materials (e.g. "*designers are encouraged to use these given sensorial properties, which could limit the creative design thinking*"). According to them, seeing 'transparency' as an important sensorial property, for instance, would cause a bias to eliminate particular materials that are not transparent. In addition, they found the given sensorial properties not contributive to (or not different than) the properties that they had concluded themselves having navigated through the material pictures. On the other hand, these three participants emphasized that their appreciation of the tool would be quite different (increased) if the tool incorporated a larger number of examples. Then, they stated that the helpfulness of the sensorial scales would be increased by usefully summarizing the important points that may be hard for a lone designer to detect.

Eight participants (8 out of 24) reported that they had mainly used the pictures and the individual explanations during their materials decisions. The compare page, the sensorial scales, the technical link and the model did not noticeably contribute to their materials selection processes. Furthermore, the 19 participants who found the technical link pointless explained that the aim of the tool was seemingly to support them in selecting materials that expressed certain meanings. Therefore, they did not consider taking technical decisions in performing this task. They added that if they wanted technical information it was easy to access through a number of existing sources. On the other hand, two of the participants mentioned that the transition from the sensorial properties to the technical ones was too abrupt and that they could not understand how to involve technical properties into their materials selection processes.

Some of the participants (10 out of 24) made negative remarks concerning the vagueness of how to implement the Meanings of Materials model into materials selection. They found it difficult to discern the role of the model for the tool. They added that there were too many written explanations, which discouraged them to go through the components of the tool.

Recommendations of the participants
Not surprisingly, the main recommendation about the tool was *to expand it by increasing the number of examples*. Two participants recommended adjoining more results related to some other meanings (e.g. "*seeing the selected materials for other meanings might be also inspiring for designers*"). Three participants suggested adding more options for grouping the selected materials based on other user variables (such as age, occupation, etc.). Three participants proposed collecting user explanations in a more structured way (e.g. "*if you make users answer some specific questions, you can present their answers in a similar format. It might be time efficient to go through a set of organized explanations, rather than random texts*"). Seven participants reported that it would have been very helpful to see the names of the example materials (e.g. "*in some individual explanations, users notify the name of the material, such as titanium, carbon, etc. In some examples it is very hard to get what the material is, unless the user specifies*").

The participants commented that the visual representations of the results such as graphs and pictograms (see the *compare* and *quantitative* results from the sensorial scales pages in Figure 9 and 10) were generally more comprehensible and appealing to them than the numbers and the sentences. Therefore, they suggested presenting the results at the compare page by using graphs (covering all ten scales and not only the most significant scale), so as to see the differences between two groups more clearly. Moreover, two participants recommended offering links between the sensorial properties and certain materials (e.g. "*you present, for instance, the most important sensorial properties for elegant materials as smooth, not elastic, reflective and glossy. I immediately ask: so what? I would like to see some suggestions about particular materials that fulfill these given sensorial properties*"). On the other hand, ten participants mentioned that the usefulness of the given sensorial properties for them was to check if their interpretations of the given examples and the points they concluded were in line with the presented significant properties. For this reason, they recommended to keep the presentation of the sensorial properties unchanged (e.g. "*the result of the sensorial scales was a kind of check list for me. After navigating through the selected products, I made my own list of requirements and constraints. Then I saw the sensorial scales and used the given properties to compare with my own requirements list*").

6 Discussion

Enjoyable, *inspiring* and *informative* are the three adjectives which might be used for summarizing the overall evaluation of the study. The tool, in general, accomplished its purpose to support designers in involving meaning considerations into their materials selection processes. One of the most interesting results of the study was that the tool inspired participants particularly to propose material combinations for their design ideas. The participants were enthusiastic about the collage and very interested in reading individual explanations. Negative remarks concerning the overall tool were also made by the participants. To explain these negative remarks and the results of the questionnaire especially about the low ratings of the technical link and the model, the participants' individual explanations were analyzed. We found three main reasons behind this result: (1) since the given tasks were not too complex and required concept creation rather than embodiment, the participants did not need technical information, (2) functions of the technical link and the model were not clear for participants, thus, for instance, they could not find how to implement the model into their materials selection processes, (3) in general the participants were more interested in the visual information then the texts or numerical values; therefore, the model (containing much written explanation) and the technical link (with numerical values) were discouraging for them. Moreover, certain issues that may have had noteworthy effects on the participants' appraisals were detected as followed:

Sexy spectacle case vs. elegant fruit bowl

It was observed that the participants who designed sexy products were more enthusiastic towards the MoM tool than those who designed elegant products. There might be two possible reasons for this: (1) 'sex' as a subject might elicit more interest in reading the individual definitions of the users and finding out the differences between two genders, and (2) the sexy materials selected by the users might be more appealing, attractive and inconsistent than the elegant materials (such as tomato and feather as sexy materials). The variety of the selected materials and the attractiveness of the given meaning may both have a remarkable influence on the appraisals of the tool.

Negative remarks about the overall tool mentioned in *the tool's negative aspects* came from the three participants who designed a fruit bowl. Three reasons related to this point might be: (1) designing a spectacle case might be found more challenging and this may enhance the participants' willingness to learn from the tool, (2) the type of meaning might affect their interest as explained above (so designing a sexy fruit bowl might be more interesting than designing an elegant fruit bowl), and (3) some elegant materials presented in the collage might be too closely related to the requested design task (such as ceramic plant pot, ceramic bowl, crystal glass, etc.). The direct association of the given task with the tool's materials might cause a decrease in their interest or a lack of inspiration through a lack of diversity of examples. The type of task might also have had an effect on the appraisals of the model and the technical link. The complexity of the given task may enhance the chance for utilizing the model to formulate ideas. Moreover, the technical link might be needed for a task that requires the fulfillment of particular technical functions such as strength, impact resistance, etc.

Duration of the task

The participants completed the given task in approximately 1.5 hours. In this period of time, they mainly focused on concept creation. If the task had been given as a long term project, the appreciation of the tool would have been even higher. The participants would have focused more on the components of the tool (such as the model, the technical link, and the sensorial scales).

Interface of the tool

In this study, a dummy application of the tool was tested in order to assess whether or not the main idea of the tool was working. Therefore, the design of the interface was kept as simple and comprehensible as possible. The components of the tool were simply listed at the bottom of the page, below the thumbnail views of the featured materials. Improving the interface may enhance the general appreciation of the tool. The buttons below the thumbnails, for instance, are listed as *compare*, *quantitative results from the sensorial scales* and *the model*. The participants, instinctively, started their explorations with the leftmost button (compare) and ended with the rightmost button (model). Until discovering the model button, the participants more or less had a good idea what to do with the tool. Their process of discovery through the tool may have had an influence on their evaluation of the usefulness of the model.

Junior designers vs. senior designers

The main reason to conduct this study with junior designers (masters students) was *convenience*. The overall results were satisfying and we did not observe any important drawback due to lack of expertise of the participants. However, we anticipate that the appreciation of senior designers would be higher than junior designers. Because time efficiency is a more critical issue for senior designers who work in design companies, they would appreciate access to the overview of cases presented in the chosen tool format. This very last assumption was explored through a focus group discussion with three senior designers of a Dutch design company.

First, the main aim of the tool and its working principles were introduced on a digital screen. The functions of the tool's buttons were explained and a number of cases were shown to exemplify how people explained the featured materials. After the presentation of the tool, the designers were asked for their comments and recommendations about the tool. All three designers were generally positive about the tool. They stated that they certainly (or inevitably) take meaning considerations into account in their materials decisions, but they usually do not have time to make a detailed market analysis. One of the designers, for instance, mentioned that designers tended to follow 'trends' in their materials selection processes. This can sometimes lead the selection of similar materials and affect their creativity (e.g. "*for instance, glossy materials are very trendy nowadays. We, as designers, focus on glossy materials and try to use them in different applications. However, at a certain point, you realize that you are biased… you ignore (or neglect) other materials, which limits your creativity. In the tool, you see that people think differently. You may not agree with them, but you will certainly find them interesting and inspiring*"). In this respect, the two most attractive and interesting points of the tool for the professional designers were (1) to be able to see a group of people's approach to a certain material- meaning relationship and (2) to read the individual explanations. They mentioned that the tool would be even more attractive for a designer if more people participated in the data generation. In this case, designers might limit the selected materials on the basis of the aspects with which they are interested in (e.g. "*I may want to see the materials selected by middle- aged people, or only by females, etc. These options might be left to the designer, who would definitely enjoy playing with a collage of hundreds of selected materials, and make his own analysis about particular groups*"). In addition, the designers found the idea of presenting the selected materials within their products (or contexts of use) very valuable (e.g. "*You cannot consider a material out of its context; you should think how it will look when it is embodied in a product. In this sense, it is very useful to see such examples in a materials selection tool*"). One of them added that seeing the selected materials and products in the form of a 'collage' was also very useful, as it provided a quick overview. All of the designers mentioned that other types of information given in the tool (such as comparing sensorial ratings of two groups, technical link, and the model) can be valuable at different design phases or for particular design projects.

The designers came up with the idea of enabling designers to explore what people think about a certain material of a product (e.g. "*For instance, a designer tries to convey a meaning but he may not be sure if he achieves to communicate this meaning to a certain target group. Then, he can use the tool in order to ask people to evaluate the material of his design on meaning scales. Thus, instead of sensorial scales, meaning scales can be used in the tool*").

Endnotes

1 My special thanks to Engin Kapkin, research assistant at Anadolu University of Turkey, for his help in conducting the Turkish part of this study in Turkey with Turkish academic staff and students.

2 www.matweb.com is a technical website offering data sheets for over 68.000 metals, plastics, ceramics, and composites.

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General Conclusion :: Part III

In the final part of this thesis, we developed a tool that embraced meaning driven materials selection. The main idea was that a designer who can understand the relationships (or meaning evoking patterns) between materials and meanings can then systematically manipulate meaning creation in materials selection processes. Accordingly, the Meanings of Materials tool was developed (1) to familiarize designers with the main components (or aspects) of the Meanings of Materials model, (2) to show which aspects (under main components) play an important role for certain meanings (such as sensorial properties, gender, culture, shape, etc.), and (3) to stimulate designers to find relationships (or patterns) between these variables for given meanings. The tool was tested by junior designers and discussed with senior designers. The results were confirmative with regards to our three main questions asked at the beginning of this chapter: (1) if designers find the tool inspiring, (2) if the tool supports designers to find relationships (or patterns) between certain meanings and materials, and finally (3) whether the tool is supportive to designers in selecting materials that express certain meanings. The tool was found very inspiring and was considered an eye-opener. In addition, it encouraged designers to make their own definitions about certain material- meaning relationships. Although the model (in general) was not found that practical for expressing the key aspects in meaning attribution to materials, just the presentation of the featured materials in their contexts of use was found sufficiently supportive to designers in being able to detect probable connections between the components of the MoM model (material, products, user and context).

To sum up, the dummy application of the tool was successful in conveying our main ideas about how to support meaning driven materials selection through a specialist materials tool. However, we saw that we need to improve several aspects related to the interface of the tool and the presentation of the data in the real application. Without a doubt, the real application should consist of more examples and should provide designers with various options for limiting the selected materials in terms of user aspects (such as age, gender, culture, etc.).

“Time reversed itself, looped back, collapsed, reordered itself. The world stretched out endlessly- and yet was defined and limited. Sharp images- just the images alone- pass down dark corridors, like jellyfish, like souls adrift. But I steeled myself not to look at them. If I acknowledged them, even a little, they would envelop themselves in meaning. Meaning was fixed to temporal was trying to force me to rise to the surface. I shut my mind tight to it all, waiting for the procession to pass.”

Sputnik Sweetheart
(Murakami, 2002, p. 186)

Findings and Implications

How can designers systematically involve meaning considerations into their materials selection processes? This question was the starting point of this thesis. The question brought a number of further questions with it. *How do people describe materials? How do materials obtain their meanings? Do materials have an intrinsic character?*

What we saw in this thesis was that materials certainly convey meanings: materials look modern or traditional, they convey luxury, they are associated with factories, or they conjure up one's childhood; and in selecting materials, these meanings certainly play a role in designers' final choices. Sources aiming to support designers in their material decisions, however, are dominated by technical (or engineering) information; thus designers primarily use their gut feelings or their common senses for conveying meanings through materials. One of the biggest challenges of this thesis, in this respect, was to bridge this intangible side of the issue with tangible materials selection processes. How would such bridging of two seemingly disparate domains be accomplished?

How do people describe materials?

People share experiences and talk about meanings of artifacts. According to Krippendorff and Butter (2008) we cannot discuss or theorize experience (which refers to meanings in their argument) without using words. In this sense, the first attempt in this thesis was to look for *the aspects playing an important role in experiencing materials* in people's verbalizations. For this aim, we asked people to describe materials (materials as words, material samples and materials in products) (Chapter 2). In addition, we explored several sources (design magazines, materials selection books, etc.) in order to collect items used for describing materials. We came up with 687 descriptive items and classified them into seven descriptive categories: (1) use descriptions, (2) manufacturing process descriptions, (3) technical descriptions, (4) sensorial descriptions, (5) expressive/ semantic descriptions, (6) associative descriptions, and (7) emotional descriptions. We utilized the three experiential categories of product experience in people's material descriptions: aesthetic experience; experience of meaning and emotional experience. On the basis of the these experiential categories, we introduced the term 'materials experience', with which we emphasized that materials- like products- are used for creating certain experiences.

One of the first interesting findings of this study was that people tend to describe materials by their sensorial properties and the meanings they subsequently evoke. Other descriptive categories (such as technical properties, use and emotions) usually come later on in people's evaluations, unless they have a personal bond with the material or the material is unexpected and thereby elicits an emotion such as surprise. On the other hand, it was difficult to draw definite lines between some of the descriptive categories. The ease with which people can employ a material in a context, for instance, leads to preconceived associations of this material with this particular context of use (e.g. "*this material is very useful for slippery environments*", "*this material is associated with slippery environments*"). Thus use and associative descriptions can be very much related to each other. Even though borders between categories are not always lucid, this study has been one of the first attempts (if not the only) at revealing how people describe materials.

The study also showed that *people have ideas about materials even before their embodiment in a product*. It was one of the very first questions raised in Chapter 1: can we talk about an intrinsic character or an inherited meaning of a material? At first sight, yes we can. We came across several examples during the studies conducted across four years. When people are asked to describe 'wood', for instance, they do not only talk about its colour, its smell, or its ease of carving, but also its appropriateness for cozy environments, its association with handcraftsmanship, or nostalgic and antique artifacts. These characteristics behave as if they are wood's intrinsic characteristics, which are primarily constructed by common knowledge, social interaction and prevailing use of a material in certain contexts. Nevertheless, the evolving science of materials and manufacturing technologies has provided designers with an enormous number of possibilities in their material choices. This has led to an increase in the variety of applications for materials in product design over the last decade. A single kind of metal, for instance, may be embodied in a dining plate as well as in an office accessory. The meanings attributed to this particular metal may differ considerably in each case. Therefore, to sustain that a specific material has a definite or an intrinsic character becomes difficult (e.g. "*plastics are cheap surrogate materials*"). Without a doubt, any material can inherit any meaning in a particular context. This thought gave rise to a very important question: how can designers manipulate the creation of meanings in materials selection when working in an era of such a booming number of materials and products? In order to answer this question, we first needed to find the key variables in attributing meanings to materials.

How do materials obtain their meanings?

Key to our understanding of meaning is the recognition that people distinguish materials in everyday experiences not only by technical functions but also according to what the materials mean to them. In other words, we attribute meanings to materials around us: a material may look modern or traditional, feminine or masculine to us. The focus of this dissertation was on exploring how materials obtain their meanings. As emphasized in the introduction of this thesis, in answering this question, our focus was on finding the main aspects that may affect our experiences with materials, but not the cognitive processes that take place in our heads. On the other hand, exploring different approaches in meaning creation was a noteworthy action to strengthen and underpin our own approach. We presented three approaches in Chapter 3. According to the first approach, meaning is *in the object* and it is expressed through formal characteristics of the objects such as shape, lines, size and colour etc., whereas in the second approach, meaning is *in the head of the individual* and constructed in a mental process, in which the individual's memories, associations and emotions play a primary role. Central to the third and last approach was Dewey's notion of experience, which says that meanings are constructed in our interactions with objects, and both an object's formal properties and the individual who perceives the object play a role in the construction of meanings. Following this last notion, in our view the meaning of a material is constructed on the basis of material properties, the product the material is embodied in, how we interact with it, and the context in which the interaction takes place. Without a doubt, an individual's previous experiences, memories, associations, emotions, cultural backgrounds and so forth can also be influential in particular situations. These components of a situational whole (e.g. material, product, context and individual) for a particular meaning- material relation are central in the construction of a *meaning evoking pattern*.

The aim of the work that followed was to show the appropriateness of the interactional approach in attributing meanings to materials. For this aim, we looked for the main factors that play a crucial role in our experiences of materials. We had a couple of tentative ideas about these factors based on the related literature (e.g. on meaning, materials selection, product design, etc.) and the seven descriptive categories presented in the second chapter. For instance, in *materials selection* literature, sensorial properties of materials, shape, function and manufacturing processes are recognized as the most important factors affecting designers' material decisions (Ashby, 2005; Ashby & Johnson, 2002; Van Kesteren, 2008). In *meaning* literature, the role of user, use (interaction) and context is emphasized in the attribution of meanings to artifacts (Johnson, 2007; Krippendorff & Butter, 2008). The seven descriptive categories identified in Chapter 2 also covered the mentioned factors (e.g. sensorial properties, manufacturing process, use, etc.). Keeping them in mind, we conducted a set of qualitative studies in Chapter 3, in order to look for these factors (and for others if they exist) in people's explanations of materials expressing certain meanings. Consequently, we developed the Meanings of Materials Model, which presents the meaning(s) of a material as a relational concept, which is a result of an interaction between the user and the material, in which the *material's properties* (technical and sensorial), the *product* it is embodied in and the *user* jointly play an important role in a particular *context*. In the studies conducted and reported in Chapters 4 and 5, by showing that experimentally a switch can be made from (1) formal aspects (e.g. different material families, sensorial properties, shape and function) that 'behave' as if they have a meaning, to (2) a position in which meaning is entirely in the head of the beholder (user aspects such as gender, expertise and culture), we saw that (3) the proposed duality (interactional approach) between a material and an individual was the most appropriate approach to adopt in any study of the attribution of meanings to materials.

Components of the model, main aspects and variables

Each factor (or component) of the resultant Meanings of Materials Model is wide enough to be treated in a separate thesis. Throughout this research, we saw that a specific aspect of a component (such as culture) can be dominant in the attribution of a meaning within a particular context. A challenge was to identify these aspects and their key variables. For example, certain aspects help us to distinguish one product from another (such as *form, function*, *texture*, *brand*, etc.). These aspects have been explored in a number of studies in the design domain (Chen, 2005; Desmet, 2002; Muller, 2001; Sonneveld, 2007; Van Rompay, 2005). In the study we conducted for the model creation in Chapter 3, from among the above product aspects, geometrical shape and function appeared to be most effective in people's explanations of their experiences of materials. In addition, these aspects were more convenient for exploration and testing than others (e.g. geometrical shape vs. brand, or gender vs. expertise). Figure 1 summarizes the components of the model, and the aspects and variables we focused on in the thesis.

Type of material and sensorial properties

In the study reported in Chapter 4, we saw how two different types of materials (families) - plastics and metal- can affect the overall impression of a product. Metal was perceived as more *elegant*, more *futuristic*, more *frivolous*, *sexier* and less *toy- like* than plastics in the overall evaluation. Interestingly, plastic products were perceived as more masculine than metal ones. This unpredicted result showed that a material can create impressions that differ from its usual or enduring image (which very much supports our main assumption). All other aspects, such as shape, function and culture, can be effective in this unexpected result. What we found in informal discussions with people was that the differences between two materials as noted through their sensorial properties had an important effect on people's evaluations.

We experience objects around us through our senses. In the field of product experience, a number of studies have been conducted to explore how various sensorial modalities shape our experiences (such as Cardello and Wisse (2008) on taste and smell, Sonneveld (2007)

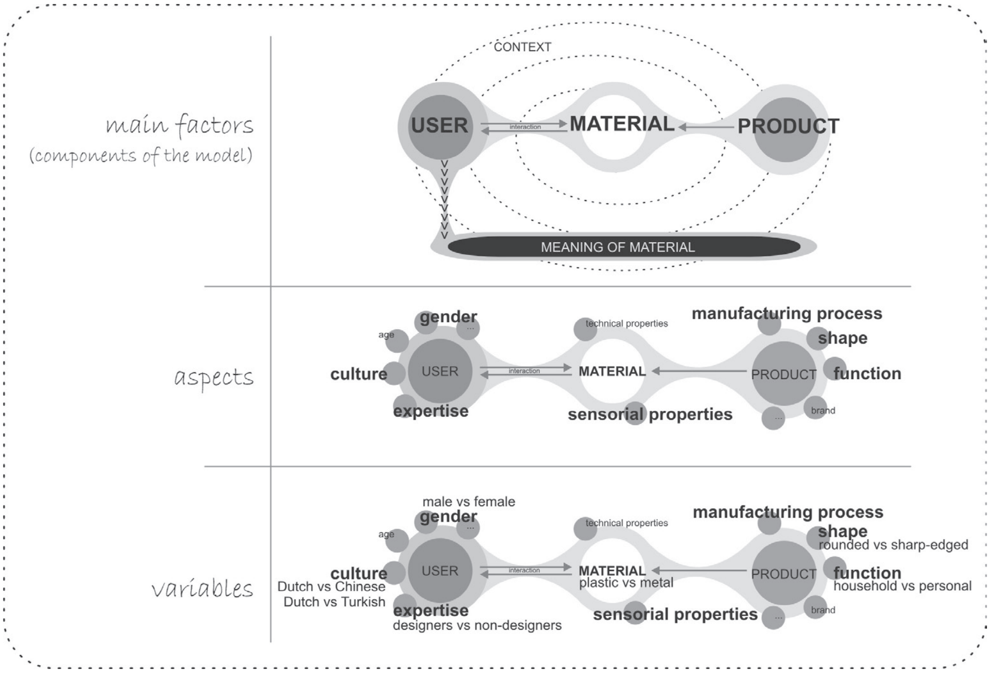

Figure 1. Components of the model, and the aspects and variables focused on in the thesis.

on tactual experience, Van Egmond (2008) on sound). Even though in these studies the focus is mainly on a particular sensory modality, it is emphasized that richer experiences can be achieved by the stimulation of a greater number of sensory modalities at one time (Schifferstein & Spence, 2008). In our research, after conducting a number of studies, a set of sensorial properties grouped under different sensory modalities was listed, and promoted as the properties that are more commonly used for attributing meanings to materials. In literature, it is revealed that visual and tactual information are primarily important in user-product interaction (Nefs, 2008; Schifferstein & Spence, 2008; Sonneveld, 2007). In parallel, our list of sensorial properties showed that materials experience is also dominated by visual and tactual information. In order to provide designers with a manageable list of properties, we needed to select the properties that are relatively common or prevailingly used by designers. For instance, certainly, designers use *smoothness* more often than *odour* to convey meanings through materials. Nevertheless, a particular property that was not present in our final list could still be effective in a specific circumstance (e.g. the odour of a wooden object played an important role in a participant's selection of a *nostalgic* material). Schifferstein (2006, p. 60) emphasizes that "*the role of senses is likely to depend on the specific products used, the frequency with which they are used, and the importance attached to the activities performed*". Thus, how we interact with a material can have an important effect on our appraisal of that material. The importance of a sensorial modality may also be different before and after purchase. While vision is primarily dominant during the acquisition of a product, the importance of other modalities often increases significantly after purchase (Fenko, Schifferstein, & Hekkert, 2007). Even though we assume that knowledge regarding the relative importance of certain sensorial properties is important for designers, future research is recommended with a particular emphasis on the effect of the properties of different sensory modalities on materials experience.

Shape and Function

In shape-material relations, we focused mainly on rounded and sharp- edged geometries. The main reason behind this was the related literature and our findings from previous studies (see Chapter 3 and Karana, Van Weelderen, & Van Woerden, 2007). We found that there is a relationship between geometrical shapes and the meanings people attribute to materials. Exploring the relationship between an *organic* or a *hybrid shape* or different form manipulations such as *height* and *closure* (see Van Rompay, 2005) and *the meanings we attribute to materials* can be an interesting subject for future research.

Generally speaking, all main effects of shape on materials' meanings were as expected in this thesis. For instance, the materials of rounded shape products were evaluated as cozier, sexier, more elegant and less masculine than the materials of sharp- edged products. In function-material relations, we found that *function* had main effects on almost all meanings used in Chapter 4. The materials of lighters were found more *elegant*, more *futuristic*, more *frivolous*, more *aggressive*, *sexier* and less *ordinary* than the materials of wastebaskets. However, these findings did not explain if shape and function affected the materials' meaning (specifically) or the overall impression of the products (generally). Without a doubt, we know from experience that we cannot always easily look beyond a whole product and evaluate its individual aspects such as its shape or material. However, in controlled experiments, we can see how these aspects interact with each other. MATERIAL X SHAPE interaction, for instance, reached significance on attributing the meaning *futuristic*. Rounded shaped plastic, for example, was perceived as more futuristic than sharp-edged plastic, whereas metal was perceived more futuristic when it is shaped into a sharp-edged product. The change in the type of material affected the main effect of FUNCTION on attributing the meaning *toy- like* to materials. Materials both of wastebaskets and lighters were perceived as more toy-like when they are made of plastics rather than metal. This effect, nonetheless, was higher on wastebaskets than on lighters. These findings clearly showed that both shape and function interact with materials when seeking to express certain meanings.

User aspects

Expertise, gender and culture were the three user aspects that we focused on at different stages of this thesis. The effect of *expertise* (which is a special skill or knowledge that is acquired by training, study, or practice) on the meanings we attribute to materials, however, was only evaluated through a qualitative study reported in Chapter 3. In that study, professional designers were different from non-designers in terms of acknowledging new materials and manufacturing technologies. In later stages, we saw that student participants from various departments (industrial design vs. non-design related departments) were not experienced enough to detect significant expertise differences in material evaluations. [1] We could have obtained different results if the study had been conducted with professionals from different domains. Convenience was one of the reasons leading us to focus on *gender* and *culture* as user aspects in Chapter 4, instead of expertise.

Most studies focusing on gender reveal that there are significant differences between men and women in their experiences of the world (Cardello & Wise, 2008; Dalton, Doolittle, & Breslin, 2002; Mojet, Christ-Hazelhof, & Heidema, 2001). Gender differences are, therefore, important to consider in product development and evaluation (Cardello & Wise, 2008). Males and females in our research differed significantly in their attribution of the meanings *futuristic*, *sexy* and *toy-like* to materials. Interestingly, a change in the type of material (metal vs. plastic) was more influential in females' evaluations than males'. Culture, on the other hand, generated the most interesting and strongest results among user aspects. Culture- material interaction was uncovered for the meanings *elegant* and *sexy*. Chinese participants, for instance, found plastic products sexier than metal products, whereas Dutch participants thought that metal products were sexier than plastic products. We made a speculative discussion on the findings of this study in Chapter 4. Understanding *why people differing in culture or gender attribute different meanings to materials*, however, requires a more thorough study which falls beyond the scope of this thesis. On the other hand, these interesting results stimulated us to run another statistical test to explore which of the meanings generated a high *level of agreement* among Chinese and Dutch people, and which of the meanings produced differences between the two cultures.

Type of Meaning

Throughout this research, we saw that when people were asked to select materials that they thought expressed particular meanings (such as aggressive, professional, nostalgic and sexy, etc.), their selections indicated that any material could be attributed any meaning (e.g. metal can be professional and aggressive, as well as nostalgic and sexy). Nevertheless, we also saw that some materials are more easily associated with some meanings than other materials (e.g. people tend to select metal products for the meaning professional). The meanings on which people highly agree with each other are more easily linked to (or associated with) formal properties of materials and products. In other words, as mentioned before, there are user-product relationships which stimulate us to assign meanings to materials in particular situations. In this thesis, we saw that there are situations in which a meaning is attributed to a material primarily on the basis of an individual's own experiences, memories or associations. On the other hand, we also saw patterns expressing a particular material-meaning relationship shared by members of a group. The results of the agreement ratings, in this sense, were interesting.

Agreement among Chinese participants on all meaning scales was very low in general and it was consistently lower than agreement among Dutch participants. This result indicated that the meanings were not recognized and easily associated with materials by Chinese people. Johnson (2007) stresses that meanings are often social and carried out by more than one individual organism. In Krippendorff's words (2006, p. 175) "*the medium in which culture is in a continuous process of being negotiated is language, conversation, and discourse.*" Following these references, we explained the findings of this study with two main rationales: (1) the *meaning* of a particular meaning and the patterns evoking this meaning can be more lucid for a specific culture; (2) certain cultures are more familiar with some materials than others, thus the more the individuals of a culture are familiar with a material, the more they agree on the meanings that the material evokes. Another interesting result of the study was that levels of agreement in the overall evaluation of some meanings were very high, which means that the patterns that evoke these meanings were similar for both cultures. *Ordinary*, *sexy* and *elegant* were three of these meanings. Our attempt was to show that some meanings are more easily associated with material and product features, and on some meanings people of two different cultures can significantly agree with each other. To explore in detail the meanings of materials that are universally accepted (or agreed upon), or those that significantly differ between cultures, can be a valuable contribution to the design domain. As noted at the end of the fourth chapter, in order to create the data for the MoM tool developed in Part III, we found it interesting to explore the patterns that lead people to attribute two of these meanings, elegant and sexy, on which the two cultures significantly agreed with each other.

Interaction, Use and Context in Meaning Attribution

Hekkert, Lloyd and Van Dijk (2009) emphasize that the user-product relationship is part of a larger context which consists of all kinds of factors, e.g. social patterns, technological possibilities, and cultural expressions, that affect the way people perceive, use, experience, respond and relate to products. These actions constitute the nature of the *human-product interaction* (Hekkert, 1997). The effects of these contextual factors on the interaction are mediated by the concerns of the user in terms of goals ('what we want'), standards ('how we believe things ought to be'), or taste ('what we like') (Ortony, Clore, & Collins, 1988). One of the theories of meaning coined by Krippendorff (2006) is concerned with artefacts in use and explains how individuals understand their artefacts and interact with them in their own terms and for their own reasons. The theory is grounded in Ludwig Wittgenstein's (1953) suggestion to locate the meaning of artefacts (for Wittgenstein: words) in their use. It also builds on Gibson's (1979) ecological theory of perception but goes beyond it by focusing on users, interactions and the dynamic nature of use, and not only on what objects essentially afford.

During the studies conducted in this thesis, we observed that how we interact with materials and the meanings we attribute to them could change as a result of previous use. The attribution of meaning is a dynamic and continuous process (Johnson, 2007; Krippendorff, 2006; Osgood, Suci, & Tannenbaum, 1957) and our understanding of artefacts and the emotions that they elicit change through use and over time (Desmet, 2002; Ludden, 2008). Although we did not conduct controlled experiments to test the effects of interaction and use on attributing meanings to materials (as it was difficult to simulate real interaction scenarios that we encounter in daily life), in our studies, the participants evaluated materials of products that they had not used before as well as those they had been using for a long time (their own products). In addition, we provided the participants with real stimuli instead of pictures or computer models. In this way, to a limited extent, we included interaction and use considerations in our studies.

Any theory on meaning reflects the role of context, which refers to a situational whole from which we ground the meanings we attribute to our world. Krippendorf and Butter (2008, p. 362) explain *context* as:

> It denotes the surrounding conditions of something that shed light on its meaning. Regarding texts, most words are ambiguous by themselves – note how many meanings a dictionary typically lists for a single word. In the context of a larger discourse, however, word meanings are usually singular and clear. Similarly, by themselves, artifacts may not mean much unless they are placed in a particular environment in which they play recognizable roles.

We encounter a particular material in different contexts in daily life. Already in the early chapters we touched upon the importance of context in meaning attribution, such that without context things could not makes sense to us. Meanings we attribute to a porcelain tea pot would be different when it is in our own kitchen, in our grandparents' kitchen, on a console in a living room, in an antique shop's window, under a dim lighting of a restaurant, or on a picnic table, etc. Thus, there are a number of contexts in which we experience artefacts. A decent example is given by Krippendorff and Butter (2008) referring to a movie titled *The Gods Must Be Crazy*. They explain the Bushmen's first experience with an empty Coke bottle thrown from a plane. Having never seen a glass bottle before, the Bushmen look for all kinds of contexts of use for it in order to attribute meanings: "*In a place without rocks, the hardness of the bottle encourages its use as that we would call a pestle for smashing roots. Its smoothness is seen to aid the flattening and stretching of snake skins. Its opening finds its use as a stamp for decorating a garment with circles*" (p. 365). The point of the anecdote is that artefacts used in various contexts present us with rich and diverse experiences in real life. In this thesis, we came across several examples in which people explained their meaning-materials relations by referring to their contexts (e.g. materials used in office environment, materials used in factories, etc.). However, it is difficult to estimate in which kinds of context a particular material is used by an individual in his/her daily life. In literature, it is emphasized that context is limitless in size and therefore it is recommended to communicate with people and find out in which context their artefacts are used and what those artefacts mean to those people in their contexts of use (Krippendorff & Butter, 2008; Poole & Folger, 1988; Van Rompay, 2005).

Summarizing, we saw what kinds of aspects may affect the meanings we attribute to materials. The meaning of a material can change in different products; it can be different for different people of different cultures, in different contexts, or at different times. Nevertheless, the effects of certain aspects might be greater in a particular context. How would a materials selection tool convey these findings to designers?

How can product designers involve meaning considerations into their materials selection processes?

In discussing the attribution of meanings to materials, we reflected our understanding of meaning as an *interactional phenomenon* in which both formal qualities (of materials and products) and the beholder equally play an important role. In addition, the conducted studies up to the point of creation of a specialist tool for materials selection also showed that *meaning evoking patterns* in materials experience change depending on the meaning and that these patterns can be interpreted differently by different individuals of different cultures, in different contexts, and in a different period of time. In brief, too many variables are simultaneously effective in attributing meanings to materials. Therefore, designers who wish to select materials that are aimed to contribute to the *meaning* they intend to express should be able to comprehend the dynamic character of the issue and find the meaning evoking patterns for a specific user group, in specific contexts and at a certain time. Consequently, the Meanings of Materials (MoM) tool was created on the basis of (1) the findings presented in the second part of this thesis, (2) an exploration of existing materials selection sources and recently developed tools in the domain of materials selection, and (3) the findings from interviews performed with professional designers reported in Chapter 6. The main characteristics of the tool are as follows:

Systematic selection

As mentioned in Chapter 1, one of the most debated materials topics in the design domain is the necessity of involving intangible characteristics of materials into materials selection processes. Several tools and methods have been developed for materials selection in product design, as discussed in Chapter 6. Most of these tools and methods provide sufficient information about the technical aspects and manufacturability of materials and have an engineering slant. These tools are thus mainly used in the synthesis phase of product design, in which, firstly, objectives and constraints regarding technical properties of materials are identified (Ashby, 2005). Secondly, a number of candidate materials fulfilling the identified constraints and objectives are listed. And finally this list is narrowed down to one or two materials. Thus, a pre-defined order of actions is often followed in materials selection in engineering, which does not satisfy designers whose material decisions are additionally determined by the sensorial properties and the intangible characteristics of materials as we saw in Chapters 6 and 8.

As explained thoroughly in Chapters 7 and 8, the aim of the tool was to present a collection of materials selected by different people who thought that their selection expressed a given meaning. Designers are encouraged to explore the collection, look at the selected materials and read the explanations given by the participants. Sensorial properties were found to play a large role (as indicated by the participants who selected the materials) in the overall evaluation. The tool also incorporates the MoM model, which draws attention to the key aspects that might play an important role for attributing a particular meaning to a material. Testing the usefulness of the MoM tool in Chapter 8, we saw that the tool guides designers to follow certain steps in materials selection, which helps them to identify their objectives and constraints in relation to sensorial properties, product aspects, user, etc. In this respect, the tool aims to stimulate in designers systematic thinking for involving meaning considerations into materials selection, instead of taking decisions with their gut feelings.

Understanding others' understanding

In the introduction to the thesis, it was emphasized that today it is not easy to ensure that the message of a product interpreted by users will be same as the message intended by the designer. Adapting to our discourse, our concept of meaning requires understanding of how other people experience materials in daily life. Krippendorff (2006, p. 66) discusses this issue, which he calls *second- order understanding*, in his book titled *The Semantic Turn*:

Human-centered designers are committed to designing artifacts for use by others who may experience the same designs quite differently. It follows that human-centered designers cannot universalize their own conceptions of what they see and do. They have to understand how those that come in touch with their design understand it in the context of their own world.

Accordingly, understanding what other people think about an artefact requires listening to how they explain their own experiences, and acknowledging their understanding is entirely valid, not inferior or wrong, even when it deviates significantly from our own understandings (Krippendorff, 2006). In short, designers should be aware of the fact that people may see things differently. The MoM tool was conceived to address this concern by providing designers with a number of explanations made by different people on their understanding of a certain material- meaning relationship. In the last chapter, during the discussions on the tool with junior and senior designers, we saw that the designers can be amazed by the differences between their own understanding and others' understanding of meanings. Designers' noted interest in the individual explanations was not surprising for us. However, it was interesting to see that the individuals involved in the generative research were also very much interested in (and "*enjoyed*" in their words) explaining their personal experiences of materials and products.

Communicating others' understanding and designers' own intuitions

In Chapter 6, we listed a set of critical points regarding the expectations of designers from a material selection source. One of these critical points was that several parties (such as clients, other designers and engineers within a design team, material suppliers, etc.) are involved in finalizing the materials selection in a product development process. The designers of a product propose a number of materials and material properties that they think express intended meaning(s). At this point, they find it difficult to defend their ideas because these properties relate to intangible characteristics of materials and are defined based on their own intuitions. After our discussions with professional designers, we saw that one of the main values of the MoM tool is that it not only helps designers to understand what other people (target users) think about a certain meaning-material relationship, but it also supports them in defending their ideas, which are strengthened by other people's explanations on their experiences of materials. The result is that the MoM tool can be inspiring to designers, (by presenting a group of people's explanations) and informative to design teams (by helping support and defend designers' own intuitions).

Material labels or material properties

A wide variety of materials are used in everyday products. At the very beginning of the thesis, on the basis of the existing materials selection sources, five types of materials (families) were selected to be focused on throughout the research: metal, plastic, wood, ceramic and glass. During the studies conducted over four years, we realized that the traditional approach followed in existing materials selection sources, which offers the best material family fulfilling the required technical properties, was not convenient for a [meaning driven] materials selection. We found that it is difficult (if not impossible) to detect whether a material family (or a particular material of a main family, such as aluminium), or a sensorial property of a material, evokes a specific meaning (or indeed whether it is necessary to make such divisions?). In the first case, people primarily talk about a general (or common) social image of a material (e.g. "*This watch is futuristic because it is made of titanium*"), which is what we defined as meanings that behave like the intrinsic qualities of materials. In the latter case, however, a material may convey a certain meaning mainly owing to its glossiness and smoothness. In this case, both titanium and ceramics, for instance, can be evaluated as futuristic. Accepting that any material can inherit any meaning in a particular context, the second case was more relevant to our argument. Realizing this, we departed from our implicit thought (which we did not mention before) of providing designers with labels for materials (such as aluminium, rubber, polypropylene, etc.) that convey a specific meaning in a certain context. Instead of giving explicit names, therefore, in the MoM tool we support designers with the material properties and the qualities of a *meaning evoking pattern* for a certain group of people or the qualities of individual cases. We provide pictures of materials and products in which certain meanings are stated to be embodied, along with explanations of the chosen materials and products from the research participants who made the selections.

Tool for a complete materials selection or concept creation

Since we do not offer material labels in the MoM tool and do not link meanings to certain technical properties, some of the designers who participated in the tool testing in Chapter

8 found the tool suitably convenient for concept creation. They did not see this standpoint as a drawback of the tool; rather it was considered a strong point. Indeed, it is not entirely wrong to say that the tool is particularly useful for creating concepts. As we mentioned in Chapter 6, materials selection can be considered as a design process in itself spanning concept creation, detailed design and embodiment. Decisions regarding an image of a product, how it is perceived by a specific target segment, and what kinds of associations it evokes are mainly taken in the concept creation phase in the design process. Focusing on the creation of meanings in materials selection, the MoM tool, in this respect, supports designers primarily in creating concepts and ideas. Providing an inspiring collage of materials and products, the tool was successful in supporting designers in their concept creation with a particular focus on materials. On the other hand, the projects undertaken by designers in testing the tool showed that some designers could finalize their material decision with explicit material labels. What we noticed was that the role of the tool for designers can vary depending on the type of project (that is, the product that they aim to design).

Future research

Manufacturing processes

Schifferstein and Hekkert (2008) explain that people are biologically equipped with a number of systems (e.g. motor system, sensory system, cognitive system) to interact with their environment; and products, analogously, have a number of formal properties, such as shape, size, weight, and materials that are embodied in products by particular processes. However, they emphasize that products obtain their meanings on the basis of what is perceived sensorially (e.g. smoothness, glossiness, darkness). In early discussions, we assumed that we could provide a list of manufacturing processes that affect the sensorial properties of materials and, as a result, the meanings attributed to materials. A joining process used to combine two materials, for instance, may provide invisible connection lines, which may stimulate people to evaluate these materials as more valuable than when they are crudely joined. However, we saw that it was rather difficult for people to assess a manufacturing process and its effect on a material meaning. Therefore, in the MoM tool, instead of asking people to evaluate the manufacturing processes of the products and materials they selected, we decided to provide designers with a list of processes from which they should recognize the impact of meaning creation through materialization. More detailed studies focusing on product details created by certain processes (such as specific joining details), technical properties of materials, and how these support other product and material properties in meaning creation, can be interesting for future research.

Material combinations

We encounter everyday products made of more than one material such as sitting elements made of wood and metal or electronic products made of metal and plastics. In Chapter 5, the importance of material combinations in the attribution of meanings to materials was emphasized and a pictogram for material combinations was created. In the application of the MoM tool in Chapter 8, the material combinations pictogram was implemented into the design process by one of the participants (see Figure 18b in Chapter 8). In addition, presenting a material collection consisting of different materials, the MoM tool was found particularly inspiring for combining different materials into product ideas. However, understanding how meanings people attribute to a particular material change when the same material is combined with another material can be a very interesting and valuable topic for further exploration.

Colour and texture

There are certainly more aspects that we recommend to be explored in future studies. Two of these aspects are *colour* and *texture*. The choice of both materials and manufacturing processes has consequences for the *colour* and *texture* of a product surface. In other words, colour and texture can be material properties, but, more frequently, they are applied to a material with an additional process. Investigating *how people's evaluations change when materials are kept in their original colours* and *why designers prefer to keep the original colour and texture of a material in some circumstances* can be valuable for future research.

Brands and materials

Some materials (and material properties) are associated with particular brands (e.g. *Bang & Olufsen* with dark coloured plastics and metal, *Koziol* with colorful semi-transparent or transparent plastics, *BUILT NY* with neoprene). Somebody who is familiar with these brands can more or less picture the range of materials under each brand. What happens if one of these brands introduces a product made of a material that is outside of the brand's established material range? One can investigate the attribution of meaning to the materials presented under a well-known brand and the possible strategies a company should follow when introducing new materials to a market.[2]

Emotional experiences with materials

In the first chapter, we saw that designers can deliberately use materials for eliciting certain emotions such as surprise. In Chapter 2, we found emotional items in people's material evaluations (such as hate, disgust, love, etc.). The focus of the thesis was on meanings evoked by materials. It would be interesting to explore the emotional responses of people towards different materials. A study with a particular focus on emotions elicited by materials can support designers in defining strategies for developing products that elicit curiosity, love, surprise and so forth, and thereby provide long- lasting or sustained user- product attachments (Mugge, Schoormans, & Schifferstein, 2008). However, it should be recognized that the emotional impact of a product is not determined just by its formal aspects (or appearance) such as materials, shape, colour, etc. as emphasized by Desmet (2002, p. 185) "*the emotion is elicited by meanings derived from the in-store- display, brand, previous experiences, etcetera. It is the combination of all these emotional stimuli that determines what emotions a person experiences towards products*".

Conceptually similar meanings
In Chapter 3, a set of material relevant meanings was developed and grouped based on conceptual similarities between the meanings. The conceptually different meanings were subsequently used in the studies conducted throughout the thesis. Focusing on conceptually different meanings (items) was valuable for exploring how different sets of items can generate different experiences. We saw that it was sensible to follow this approach in that, for instance, the relative importance of the components of the MoM model differs considerably when a meaning is related to age (e.g. a user's personal experience for the meaning *nostalgic*) or to quality (e.g. sensorial properties and geometrical shape for the meaning *elegant*). It would be interesting to focus on some other items from the same conceptual groups in order to see if items from the same group can be evoked by similar patterns and whether it is possible to model these patterns for conceptually similar meanings. For instance, in the attribution of the meaning *sophisticated* to materials, do people use the same or similar patterns as they use for the meaning *elegant* (sophisticated and elegant were grouped under the 'quality' factor in Chapter 3)?

'Cradle to cradle' as a meaning
Cradle to Cradle was a phrase coined by Walter R. Stahel in the 1970's. The phrase was popularized by William McDonough and Michael Braungart (2002) in their book Cradle to Cradle: Remaking the Way We Make Things. The production framework to which the phrase alludes seeks to create manufacturing techniques that are not only efficient but also essentially waste free. In cradle to cradle production, all material inputs and outputs are seen either as technical or biological nutrients. Technical nutrients can be recycled or reused with no loss of quality and biological nutrients composted or consumed. Nowadays, several important companies with large production facilities are looking for collaborations with researchers from universities in order to devise new solutions (e.g. new production facilities, new materials, etc.) for new products following a cradle to cradle approach. A problem is that materials that can be used in the cradle to cradle design, such as *biobased materials*, are not easily distinguished by users through their daily experiences. Companies, therefore, often prefer to attach 'labels' to emphasize their cradle to cradle approach. In this respect, it can be very interesting and valuable to explore the question of how designers can express 'cradle to cradle' thinking through the formal qualities of their materials.

Teaching Materials in Design Education
In informal discussions with design students across four years, we saw that students find it difficult to integrate their technical material knowledge in design practice. This may be because materials are still taught as a separate (and technical) domain for design activity and because material knowledge is usually transferred without considering user experiences and user contexts. The principle of '[meaning driven] materials selection' can be adapted within design education and can complement the teaching of technical based selection. We expect that the proposed method of meaning driven materials selection would not only

enhance the abilities for quick and appropriate materials decisions but also increase the creativity of students.

Considering the value of the intangible side of materials selection, the Industrial Design Engineering Department of TEI in Greece invited me to give a workshop to 140 third year bachelor students as part of a 'Materials and Design' course. The idea was to stimulate students to involve meaning considerations into their material decisions as well as to inspire them by showing different ways of creating experiences through materials (e.g. focusing on different sensorial domains, creating different 'uses' through different materials, etc.). This invitation was a good opportunity to test the usefulness of meaning driven materials selection in design education (see the results of this workshop in Appendix Z).

Theory of meaning

In the thesis, our main concern was to provide practical knowledge for the reader who is primarily interested in materials in design. While doing so, we summarized some basic concepts in meaning creation, but did not elaborate on the cognitive processes involved in meaning attribution or engage in philosophical discussions on meaning theories. Future exploration with more emphasis on *meaning theories* and the *cognitive processes* in materials experience can give an important extension to all material related studies, as well as to the work reported in this thesis. One can, for example, explore if there exists any recurring structure of (or within) our cognitive processes in our experiences of materials. As explained in Chapter 3, these recurring structures of our cognitive processes are referred to as image schemas by Lakoff and Johnson (1980). The *verticality schema*, for instance, emerges from our tendency to employ an up-down orientation in picking out meaningful structures of our experience. Can we find these kinds of schemas in materials experience? Or what kinds of recurring structures of (or within) our cognitive processes can we find in the attribution of meanings to materials?

About the real application of the tool

The dummy application of the MoM tool was developed for testing the usefulness of the tool. In the real application, the purpose is to create an online database that stores the data collected from people by online queries, and subsequently organizes the data according to a specific request. A number of details need to be discussed and explored before the creation and application of the real tool can be pursued. For instance, *how can we stimulate designers to contribute to the development of the database through new research on new meanings, instead of confining designers to only the existing data?* Emphasizing the dynamic nature of a meaning (i.e. that the meaning of a material can change over time and that it depends on the target user group), by giving verbal explanations and examples in the introduction to the tool, or by conducting workshops in design companies, can enhance the requirements and necessity for commencing a new query, instead of relying on existing data.

Furthermore, the interface of the real tool should be designed considering user- interface interaction. We should also reconsider how to present the collected data to designers. *How can we reorganize the items of the tool?* As we saw in the last chapter of the thesis, one of the most attractive points of the tool was its visual presentation of materials. The written information (such as the explanations of the MoM model components) and numerical values can be presented visually so as to be more appealing to designers. The findings of the tool testing also gave us the idea of integrating the MoM tool into a technical materials selection tool (e.g. Cambridge Engineering Selector). In this way, we can provide designers with seamless links between sensorial properties (MoM tool), technical properties (CES) and manufacturing processes (CES), which might lead to a single materials selection tool appropriate for use from concept design through to detailed design phases of product design. *Can this kind of integration be possible?*

These are just a few of the questions one can ask in preparing to create a real application of the MoM tool. Certainly, the creation of the real application can be another four years of research.

Last words: A critical point

I find it appropriate to emphasize that the findings of this thesis should not be interpreted as an endeavour on my part to encourage designers to imitate materials and material properties instead of using authentic materials. It should be recognized that a substitute material can fulfill the same utility function as an authentic material (or even be a better option), yet it cannot take the place of the authentic material in its quality of interaction or its evocation of meanings and emotions. The quote from Ayn Rand’s famous character, architect Howard Roark (in *the Fountainhead*, (2004, p. 12)), can thereby be the last words of this thesis:

> …Here are my rules: what can be done with one substance never be done with another. No two materials are alike. No two sites on earth are alike. No two buildings have the same purpose…

Endnotes

1 On the basis of the results obtained in this study, one can conclude that expertise is not a key aspect in the attribution of meanings to materials. For the meanings we focused on in Chapter 4, gender and culture played a more important role than expertise. On the other hand, in a workshop conducted with 140 Greek students (see Appendix Z) we observed a noteworthy effect of expertise on the attribution of the meaning 'futuristic' to materials. The Greek design engineering students were familiar with new technologies and materials and the materials they selected expressed the effect of their expertise level.

2 Recently, a PhD student in 2009 has started a research on 'branding and materials'

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Summary

Meanings of Materials

> How do we experience materials around us? When do we think that a certain material is modern, elegant, sexy, feminine, or professional? Across four years, we explored these kinds of questions with the aim of illuminating the intangible face of the material domain.

Product designers are expected to create products transferring certain *meanings*. Materials of products are used for supporting the intended meanings in product design; one material may convey luxury, another material can be associated with a particular culture. It is to be expected that materials are attributed different meanings in different products and contexts, affected by certain key variables such as form, function, manufacturing processes, use, and user characteristics. Designers, to be capable of selecting appropriate materials for the intended meanings, should be *familiar with all these key variables*, which may be very complex and time consuming in the context of an entire design project. Moreover, meanings and values attributed to materials may *change in time*, thus designers should be alert to the probable changes in taste and product appreciation by target users.

Exploring *how materials obtain their meanings* and *how materials cooperate with other elements of product design (such as form, function and users) for expressing certain meanings* was the main focus of this research. The thesis was structured in three parts: (1) materials experience, (2) attributing meanings to materials, and (3) [meaning driven] materials selection in product design.

PART I: materials experience

In the first chapter, the role of materials in the domain of product design was briefly discussed. The chapter presented a number of examples in which materials are selected not only for technical benefits but also for gratifying senses, conveying particular meanings and eliciting emotions. The chapter concluded that materials, like products, are used for creating experiences. This statement was further explored in Chapter 2, in which descriptive items on materials were collected in a set of studies. These items (N=687) were classified into seven descriptive categories, each of which was comprehensively clarified in the chapter. We saw that people tend to describe materials not only with reference to technical and sensorial properties, but also according to the meanings they attribute to materials, and the kinds of associations and emotions that materials evoke. On the basis of the found experiential categories (aesthetic experience, experience of meaning, and emotional experience), Chapter 2 and the end of Part I arrived at the introduction of a new term for the design domain: *materials experience* defined as *the whole series of effects elicited by the interactions between people and materials in a particular context.*

PART II: attributing meanings to materials

In the second part of the thesis, the objective was to find the key variables in the attribution of meanings to materials. The first attempt was to explore different theories in meaning creation in order to explain the approach that we followed throughout this research. Three perspectives were discussed: object-centred, individual-centred and interaction-centred. In line with the interaction-centred perspective, we concluded that the meaning of a material is based on the interactions between an individual and his/her environment, shaped by the qualities of the entire context, and open to change over time. In materials experience, in addition to expressive meanings (e.g. modern, sexy, sober, etc.) certain associative descriptions, which require retrieval from memory and past experiences, can also express particular qualities of materials, such as *toy- like, business- like* and *associated with factories.* These material descriptions are commonly used in material appraisals and behave like expressive characteristics. Accordingly, in Chapter 3, *meanings of materials* were defined as what we think about materials, that is, what kinds of values we attribute after the initial sensorial input in a particular context.

Chapter 3 also reported on a study that had the aim of revealing what kinds of factors play a crucial role in people's attribution of meanings to materials. The study consisted of three focus group studies, each with different types of participants, who were asked to select five products expressing given meanings predominantly through their materials. Throughout the focus group sessions, various aspects that play a role in the attribution of meanings to materials were intensively discussed. The results were supported with a thorough literature survey to build the Meanings of Materials Model (MoM). The model concluded with the principle that *materials obtain their meanings not only based on their technical and sensorial properties, but also through the products they are embodied in, through the users who* *contact with these products, and how or in which contexts these products are interacted and used*. In Chapter 3, the results of the studies also showed that there are some patterns (characteristics of entire situations) that affect the meanings we attribute to materials. To be capable of finding these patterns within particular situations, designers should be familiar with the key factors in attributing meanings to materials.

Chapter 4 and 5 focused on the exploration of the effects of some of these factors (which were also identified as components of the MoM model). The role of the *product* and the *user* in attributing meanings to materials was tested and verified through a study in Chapter 4. First, a set of pre-studies were conducted to list a number of conceptually different material-relevant meanings. Then, the main study investigated the effects of shape and function as product aspects, and gender and culture as user aspects, on attributing certain meanings to two material types: plastics and metal. The study supported our main assumption that our understanding of a material's meaning is grounded in certain aspects mainly related to the product the material is embodied in, the material itself with its descriptive physical and sensorial properties, and us as a user of the material and the product. Chapter 4 also included a measurement of agreement levels on the meanings of materials amongst Dutch and Chinese participants. The results of the measurement determined that while people may agree highly with each other on one meaning, on another meaning their agreement level might be low. Sensorial properties of materials were revealed as the most crucial aspects of meaning evoking patterns for those meanings that had a high level of agreement. On the basis of this finding, focus was directed in Chapter 5 towards more detailed exploration of sensorial properties of materials.

After conducting a number of studies, Chapter 5 revealed a certain set of sensorial properties, linked to different sensory modalities, to be most commonly used for attributing meanings to materials. Furthermore, the chapter showed that manufacturing processes create certain sensorial experiences in particular contexts, which in turn might affect how we appraise materials and products. Part II of the thesis concluded that people are primarily impressed by formal qualities of products and materials, and certainly for many product areas, their appraisals of products and purchasing decisions are visually and tactually dominated. However, it is impossible to determine a one-to-one relationship between a certain property and a certain materials experience.

PART III: [meaning driven] materials selection in design

In the last part of the thesis, a tool for supporting designers to involve meaning considerations in their *materials selection* was developed. In Chapter 6, first a set of critical factors in materials selection for product designers were identified, on the basis of a comprehensive literature review and interviews conducted with professional designers. Furthermore, various sources used by product designers to assist their materials selection were listed and three recently established tools for material selection were briefly explained. Tools and sources were evaluated in terms of their suitability for product designers' material selection processes. Chapter 7 introduced a new approach defined as [meaning driven] materials selection. On the basis of this approach, the [Meanings of Materials] tool was developed as an inspiring *interactive* alternative that appeals to designers. The purpose of the tool was summarized as a support to designers in (1) *their understanding of the key variables in meaning attribution to materials* and (2) *their identification of the patterns behind a particular material-meaning relationship*. The tool offers various types of products and materials (as a compendium of intended meanings) for inspiration. The process of conceiving and developing the [Meanings of Materials] tool is presented intensively in the chapter.

In the last chapter of the thesis (Chapter 8), a dummy application of the [Meanings of Materials] tool was created and tested by junior designers and discussed with senior designers. Three main questions were explored in the evaluation of the tool: (1) if designers find the tool inspiring, (2) if the tool helps designers find the relationships (or patterns) between certain meanings and materials, and finally (3) whether or not the tool supports designers to select materials expressing certain meanings. The results were extensively discussed at the end of Chapter 8. The positive and negative aspects of the tool were revealed and recommendations were made for further developments and applications.

In conclusion, this thesis presents the concept of *meanings of materials* and has made a start in making this concept more actionable in design thinking. In order to accomplish this, we first showed that materials are unequivocally used for creating meanings in products. Then, we showed how particular formal qualities of materials (e.g. glossiness, softness, brightness) and products (e.g. rounded shaped products) may give rise to a particular meaning of a material. We also showed how these meanings were inevitably influenced by the expertise, gender and culture of the individual who appraises the material. In addition, this thesis showed that certain sensorial properties are more commonly used than others by designers for conveying intended meanings through the materials of their products. The developed [Meanings of Materials] tool aimed to reflect these findings and facilitate [meaning driven] materials selection. Developing a real application of the tool requires additional explorations and studies. Frequent use of the tool in real applications is intended to lead to an increase in the tool's database, which in return can be valuable for extending our knowledge of meaning-material relationships.

Samenvatting

Betekenissen van Materialen

> Hoe beleven we de materialen om ons heen? Wanneer denken we dat een bepaald materiaal modern, elegant, sexy, vrouwelijk of professioneel is? Vier jaar lang hebben we dit soort vragen onderzocht, met als doel het materialenveld van zijn ontastbare kant te laten zien.

Van productontwerpers wordt verwacht dat ze producten creëren die bepaalde betekenissen overbrengen. De materialen in producten worden gebruikt om de beoogde betekenissen te ondersteunen: het ene materiaal straalt bijvoorbeeld luxe uit terwijl het andere materiaal geassocieerd wordt met een bepaalde cultuur. Verwacht mag worden dat er aan materialen verschillende betekenissen worden toegekend in verschillende producten en in verschillende contexten, onder invloed van bepaalde sleutelvariabelen zoals vorm, functie, fabricageproces, gebruik en gebruikerseigenschappen. Om materialen te kunnen kiezen voor de beoogde betekenissen moeten ontwerpers *vertrouwd raken met al deze sleutelvariabelen,* wat in de context van een heel ontwerptraject gecompliceerd en tijdrovend kan zijn. Bovendien kunnen betekenissen en waarden toegekend aan materialen nog *veranderen in de tijd,* zodat ontwerpers op hun hoede moeten zijn voor veranderingen in smaak en productwaardering bij de doelgroep.

Centraal in dit onderzoek stond het verkennen *hoe materialen hun betekenissen verkrijgen en hoe materialen samenhangen met andere elementen van het productontwerp (zoals vorm,* *functie en gebruikers) bij het uitdrukken van bepaalde betekenissen*. Het proefschrift bestaat uit drie delen: (1) materiaalbeleving, (2) toekenning van betekenissen aan materialen en (3) [betekenisgestuurde] materiaalkeuze in het productontwerpen.

DEEL I: materiaalbeleving

In het eerste hoofdstuk werd de rol van materialen in het vakgebied productontwerpen kort behandeld. Het hoofdstuk presenteerde een aantal voorbeelden waarin materialen niet alleen vanwege technische voordelen waren geselecteerd, maar ook om de zinnen te strelen, om bepaalde betekenissen over te brengen en om emoties los te maken. Geconcludeerd werd dat materialen net als producten worden gebruikt om belevingen op te wekken. Deze bewering werd verder onderzocht in hoofdstuk 2, waar beschrijvende termen werden verzameld in een aantal studies. Deze termen (N=687) werden gerubriceerd in zeven omschrijvende categorieën die elk uitgebreid toegelicht werden in het hoofdstuk.

We zagen dat mensen ertoe neigen om materialen niet alleen te beschrijven onder verwijzing naar technische en zintuiglijke eigenschappen, maar ook volgens de betekenissen die ze aan materialen toekennen en de soorten associaties en emoties die materialen oproepen. Op basis van de gevonden belevingscategorieën (esthetische beleving, beleving van betekenis en emotionele beleving), resulteerden hoofdstuk 2 en het eind van deel I in de invoering van een nieuwe term voor het ontwerpdomein: *materiaalbeleving* gedefinieerd als *de opeenvolging van effecten die worden opgewekt door interacties tussen mensen en materialen in een bepaalde context*.

DEEL II: het toekennen van betekenissen aan materialen

Het doel van het tweede deel van het proefschrift was het vinden van de sleutelvariabelen bij de toekenning van betekenissen aan materialen. Als eerste poging werden verschillende betekenisvormingtheorieën verkend om de aanpak te verklaren die we voor het gehele onderzoek gehanteerd hebben. Drie invalshoeken werden besproken: een objectgerichte, een individugerichte en een interactiegerichte. In overeenstemming met de interactiegerichte invalshoek constateerden we dat de betekenis van een materiaal gebaseerd is op interacties tussen een individu en zijn/haar omgeving, gevormd wordt door de kwaliteiten van de gehele context, en openstaat voor verandering in de tijd. Behalve expressieve betekenissen (zoals modern, sexy, sober etc.) kunnen in de beleving van materialen ook specifieke associatieve beschrijvingen, die moeten worden opgediept uit de herinnering en uit vroegere ervaringen, bepaalde kwaliteiten van materialen uitdrukken, zoals *speelgoedachtig, zakelijk* en *fabrieksmatig*. Zulke materiaalbeschrijvingen zijn ook gebruikelijk bij het oordelen over materialen, en ze gedragen zich als expressieve kenmerken. In overeenstemming daarmee werden *betekenissen van materialen* in hoofdstuk 3 gedefinieerd als wat we denken over materialen, d.w.z. wat voor soort waarden we toekennen na de eerste zintuiglijke blootstelling in een bepaalde context.

Hoofdstuk 3 beschreef ook een studie naar het soort factoren dat een cruciale rol speelt bij het toekennen van betekenissen aan materialen door mensen. De studie bestond uit drie focusgroep studies, elk met verschillende soorten deelnemers, aan wie gevraagd werd vijf producten te selecteren die gegeven betekenissen vooral door hun materialen uitdrukken. Gedurende de gehele focusgroep sessies werden verschillende aspecten die een rol spelen in de toekenning van betekenissen aan materialen diepgaand besproken. De resultaten werden onderbouwd met een grondig literatuuronderzoek, om zo het *Meanings of Materials*-model (MoM, 'betekenissen van materialen') te vormen. Het model komt neer op het principe dat *materialen hun betekenissen niet alleen verkrijgen op basis van hun technische en sensorische eigenschappen, maar ook door de producten die ze belichamen, door de gebruikers die ermee in contact komen, en hoe en in welke contexten er interactie met, en gebruik van, deze producten plaatsvindt.* In Hoofdstuk 3 toonden de resultaten van de studies ook aan dat er bepaalde patronen (karakteristieken of gehele situaties) zijn, die de betekenissen die we aan producten toekennen beïnvloeden.

Hoofdstuk 4 en 5 richtten zich op het onderzoeken van de effecten van enkele van deze factoren (die ook werden onderscheiden als componenten van het MoM-model). De rol van het *product* en de *gebruiker* in het toekennen van betekenissen aan materialen werden getoetst en geverifieerd door middel van een studie in hoofdstuk 4. Eerst werd een serie voorstudies verricht om tot een lijst met een aantal conceptueel verschillende materiaalrelevante betekenissen te komen. Daarna werden in de hoofdstudie de effecten van vorm en functie als productaspecten, en geslacht en cultuur als gebruikersaspecten onderzocht op de toekenning van bepaalde betekenissen aan twee materiaalsoorten: kunststof en metaal. De studie staafde onze hoofdaanname dat ons begrip van de betekenis van een materiaal verankerd is in bepaalde aspecten, die hoofdzakelijk gerelateerd zijn aan het product dat het materiaal belichaamt, het materiaal zelf met zijn beschrijvende fysische en sensorische eigenschappen en onszelf als gebruiker van materiaal en product. Hoofdstuk 4 bevatte ook een studie om de overeenstemmingsniveaus tussen Nederlandse en Chinese proefpersonen te bepalen op het gebied van materiaalbetekenissen. De studie toonde aan dat mensen die het zeer eens zijn over de ene betekenis toch een laag overeenstemmingsniveau kunnen hebben met betrekking tot de andere betekenis. Van sensorische eigenschappen van producten werd aangetoond dat ze voor betekenissen met een hoog overeenstemmingsniveau doorslaggevende aspecten vormen bij gedragspatronen die betekenissen oproepen. Op basis van deze bevinding werd in hoofdstuk 5 de aandacht gericht op een gedetailleerdere verkenning naar sensorische eigenschappen van materialen.

Na een aantal studies ontvouwde zich in hoofdstuk 5 een bepaalde groep met verschillende sensorische modaliteiten verbonden sensorische eigenschappen die konden worden gebruikt voor het toekennen van betekenissen aan materialen. Verder werd in het hoofdstuk aangetoond dat fabricageprocessen bepaalde sensorische belevingen veroorzaken in specifieke contexten, die op hun beurt kunnen beïnvloeden hoe we over materialen en producten oordelen. Deel II van het proefschrift besluit ermee dat mensen in de eerste plaats onder de indruk raken van formele eigenschappen van producten en materialen, en dat hun oordeel over producten en hun aankoopbeslissingen met name voor bepaalde soorten producten visueel en tactiel gedomineerd worden. Het is echter niet mogelijk om een één op één-verband vast te stellen tussen een bepaalde eigenschap en een bepaalde materiaalbeleving.

DEEL III: [betekenisgestuurde] materiaalkeuze in het ontwerpen

Het laatste deel van het proefschrift behandelt de ontwikkeling van een tool die ontwerpers ondersteunt in het rekening houden met betekenis bij de *materiaalkeuze*. In hoofdstuk 6 werd op basis van een uitgebreide literatuurstudie en interviews met ontwerpprofessionals eerst een reeks kritieke factoren in het selecteren van materialen door ontwerpers aangeduid. Verder werden diverse bronnen die productontwerpers gebruiken ter ondersteuning van de materiaalkeuze geïnventariseerd en drie recente, algemeen bekende tools voor materiaalkeuze werden kort toegelicht. Tools en bronnen werden geëvalueerd op basis van hun geschiktheid voor materiaalkeuzeprocessen uit te voeren door productontwerpers.

Hoofdstuk 7 introduceerde een nieuwe aanpak die wordt omschreven als [betekenisgestuurde] materiaalkeuze. Op basis van deze aanpak werd de [Meanings of materials]-tool ontwikkeld als een inspirerend *interactief* alternatief dat ontwerpers moet aanspreken. Het doel van de tool werd samengevat als ondersteuning voor ontwerpers bij (1) *hun begrip van de sleutelvariabelen bij de betekenistoekenning aan materialen* en (2) *het herkennen van de patronen achter een bepaalde materiaal-betekenis relatie.* Ter inspiratie biedt de tool verscheidene soorten producten en materialen (als compendium van beoogde betekenissen). Het proces van concipiëren en ontwikkelen van de [Meanings of materials]-tool werd in dit hoofdstuk uitvoerig behandeld.

In het laatste hoofdstuk van het proefschrift, hoofdstuk 8, werd een dummytoepassing van de [Meanings of materials]-tool opgezet. Deze werd getoetst door juniorontwerpers en besproken met seniorontwerpers. Bij het evalueren van de tool werden drie hoofdvragen onderzocht: (1) of ontwerpers de tool inspirerend vinden, (2) of de tool ontwerpers helpt de verbanden (of patronen) te vinden tussen bepaalde betekenissen en materialen, en tenslotte (3) of de tool ontwerpers al dan niet ondersteunt bij het selecteren van materialen die bepaalde betekenissen moeten uitdrukken. De resultaten werden uitgebreid besproken aan het eind van hoofdstuk 8. De plus- en minpunten van de tool werden uiteengezet, en aanbevelingen voor verdere ontwikkelingen en toepassingen werden gedaan.

Ter conclusie: dit proefschrift presenteert *betekenissen van materialen* als begrip, en het heeft een start gemaakt met het beter hanteerbaar maken van dit begrip in het ontwerpgerelateerde denken. Om dit te realiseren toonden we eerst aan dat materialen ondubbelzinnig gebruikt worden om betekenissen in producten te verwezenlijken. Daarna toonden we aan hoe bepaalde formele kwaliteiten van materialen (zoals glans, zachtheid, helderheid) en producten (zoals producten met ronde vormen) aanleiding kunnen zijn voor een bepaalde betekenis van een materiaal. We toonden ook aan hoe deze betekenissen onvermijdelijk beïnvloed worden door expertise, geslacht en cultuur van het individu dat over het materiaal oordeelt. Bovendien toonde dit proefschrift aan dat bepaalde sensorische eigenschappen vaker door ontwerpers gebruikt worden om door middel van de materialen in hun producten beoogde betekenissen uit te dragen dan andere. De ontwikkelde [Meanings of Materials]-tool beoogde deze bevindingen uit te drukken en [betekenisgestuurde] materiaalkeuze te vergemakkelijken. Het ontwikkelen van een echte applicatie gebaseerd op de tool vereist aanvullende verkenningen en studies. Intensief gebruik in echte toepassingen moet leiden tot een groei van de database van de tool, die in ruil daarvoor waardevol kan zijn bij het uitbreiden van onze kennis over de verbanden tussen betekenissen en materialen.

Appendix Z is based on:

Karana, E (2009), *Meaning Driven Materials Selection in Design Education,* International Conference of Engineering Design (ICED) 2009, San Diago, USA, accepted.

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Appendix Z: Meaning Driven Materials Selection in Design Education: A workshop in Greece.

Appendix 2.1

687 collected material descriptions.

abrasion resistance	associated with fast-food-restaurants	breathes
absorbs heat	associated with food	bright
absorbs impact forces	associated with grandparents	brightly colored
absorbs light	associated with gypsies	brilliant
absorbs moisture	associated with high quality	brittle
absorbs noise	associated with high- technology	bronze
absorbs UV rays	associated with hygiene	brushed
absorbs vibration	associated with Ikea	brutality
absorbs water	associated with kitchens	bumpy
accessible	associated with living rooms	buoyant
acoustic	associated with mountains	burns
acoustic insulation	associated with old cultures	bursts
acoustic isolation	associated with Philip Starck	business like
active	associated with pop art	calm
admirable	associated with pots	can be dry-cleaned
advanced	associated with pottery	can be glued
aesthetic	associated with round forms	can be injection molded
affordable	associated with small presents	can be painted
against vandalism	associated with summer	can be printed on
ages	associated with tabletops	can be produced at low costs
aggressive	associated with teapots	can be sterilized
airy	associated with weapons	can be washed
allows ultra thin layers	attractive	can have a small wall thickness
aloof	authentic	canary
amazing	authority	captivating
ancient	awful smell	carpenter
annealed	badly finished	carved
anti stress	base	cast
antique	basic	castable
approachable	beautiful	chalky
aromatic	bendable	change colour in time
arrogant	bestial	charismatic
art object material	biodegradable	charming
artificial	biscuit texture	cheap
artistic	biscuit-rough	cheap production possibilities
asshole-proof	blank	cheerful
associated with a nice perfume	blow molded	chemical
associated with bathrooms	bluish tinted	chemical resistance
associated with big machinery	board material	chic
associated with camping	boasts	child friendly
associated with children	boiled-sweet transparency	chilly
associated with churches	bold	chunky
associated with construction profiles	boring	civilized
associated with design	bounces	classic
associated with factories	breakable	classy

clean	craft-like	dull
clear	creamy	durable
clinical	creative	dusty
closed	crockery	dynamic
clumsy	crystalline	earthly
coarse	cuddleable	easy
coated	curved	easy to clean
coefficient of expansion	cute	easy to dent
cold	cuttable	easy to fabricate
cold colors	dances	easy to handle
color ability	dandy	easy to mould
color combinations	dangerous	easy to print
color freedom	dark	easy to process
color saturation	deadly	easy to shape
colored	decadent	easy to work
colorful	decorative	ecological
colorless	deformable	economical
combined	degradable	effective
comfortable	degrade in UV light	elastic
comic	delicate	elastomeric
commercial	dense	electric conductivity
commodity	dentable	electrical insulation
common	deodorizing	elegant
compact	depressing	embroidered
compressed	depth	empty
compression molded	descent	enameled
compression resistance	design like	endless potential
concentric	different	engineering
condensable	different forms are possible	enthusiast
conductive	difficult	environmental friendly
conducts heat	diffused	eradicator
confidence	dimensional stability	even
confrontating	dirty	excellent
consistent	disapproved	exciting
construction material	discerning	exclusive
constructive	disposable	exotic
contemporary	dissolvable	expands with temperature changes
contradicts	distant	expensive
cool	distinctive	expression
corrosion resistance	distorted	external
cosmetic	doesn't make a nice sound when you scratch	extruded
cost-effective	domestic	fairness
cozy	drilled	fake
cracks	dry	familiar
cracks	ductile	fantastic

fascinating	graceful	inflatable
fashionable	granular	Inhuman
fatty	greasy	injection-molded
feels great	gritty	innovative
feminine	grubby	inorganic
fine	handcraft	inspirational
fingerprint is visible	handy	insulator
fire resistant	happy	intelligent
firm	hard	interesting
flame resistant	harmful	internal
flammable	harsh	intrigues
flashy	has an intrinsic character	intrinsic
flat	heavy	inviting
flexible	high impact resistance	isolating
flimsy	high perceived value	itchy
floatable	high quality	jelly (like)
fluffy	high sound	jewel-like
fluidity	high-tech	joyful
fluorescent	hip	kitsch
foamy	historical	klinking sound
for eating from	hollow	labor-intensive
for everyday products	home-like	laminated
for model making	homey	layered
formable	homogeneous	lets microwave-radiation through
fragile	honest	light
frail	horrible	light colored
fresh	hot colors	like a pasta waiting for its sauce
friendly	hygienic	like a sponge cake
frosty	hype	like a steamy shower
functional	I don’t like the material	like Edam cheese
funny	I feel young with it	like skin
futuristic	I like it	like Tupperware
fuzzy	I love it	liquid
galvanized	ideal	lively
ghostly translucency	imitation	living
gives feedback	impact resistance	living room material
gives me a camping feeling	impact strength	local
gives me a party feeling	important	long lasting
glamour	inaccurate	loutish
glazed	incredible	low cost
glittery	Indestructible	luminous
glossy	indigenous	luxurious
glowing	indispensable	magical
glued	industrial	magnetic
gooey	inert	makes me feel comfortable

makes me feel depressive	odorless	refined
makes me feel peaceful	oil resistance	reflective
makes me feel relaxed	old	refractive index
makes me happy	old fashioned	reliable
makes me pleasant	one-dimensional	renewable
makes sound (crunches/squeaks)	opaque	replace material
makes you wanna play with it	open	reshapeable
malleable	optical clarity	resilient
marble-like	optical effects	resistance to chemical corrosion
masculine	ordinary	resistance to corrosion
mass produced	organic	resistance to environmental impacts
massive	organically formed	resistance to high temperatures
material for a take away lunch box	painful	resistance to tearing
matte	paintable	resistance to weather conditions
mature	pale	responsive to touch
mechanical	peaceful	retaining its form
melting	peeps	retro
meshy	people like it	reusable
milky translucency	perfect	reversible
mirror effects	personal	revolutionary
mirror like	plasticized	rhythmic
modern	playful	ribbed
moisture resistance	pleasant	rich
molded	pleasurable	rigid
muffled sound	poisonous gasses when burned	robust
multi textured	polished	romantic
multi-colored	polluting	rots fast
multi-functional	poor	rough
musical	popular	rude
mysterious	porous	rural
nasty	powdery	rusty
natural	powerful	safe
neat	practical	satisfying
neutral	precious	scary
new	pretty	scratch resistant
nice	primeval	scratchable
nice to hold	primitive	scratchy
nice to touch	professional	seamed
nicely finished	pure	secure
nonsense	ratio between weight and volume	seductive
nostalgic	raw	self-cleaning
obedient	reactive	self-lubricating
obtainable	real	semi-transparent
obtrusive	recognizable	sensitive
obvious	recyclable	serious

service temperature
severe
sewed
sexy
shallow
sharp
shiny
silent
silky
simple
sleek
slippery
sludgy
smart
smell foul
smells funny
smells good
smooth
sober
soft
solid
solvent resistance
sophisticated
sound absorption
sound insulation
sounds like a rainstorm (when scratched)
sounds nice
sounds sharp
sounds tinny
special
specialist
specific
spongy
springy
squeezable
squidgy
stabile
standard
status symbol
stays damp for a long time
sterile
sticky
stiff
stodgy
stone-like
straight
strategic
strength
stretches
striped
strokable
strong
structure material
sturdy
stylish
subtle
surprising
surrogate
sustainable
sweaty
sweet
syntactical
tacky
tactile
tangible
tarnishing
tasteless
technical
tempered
tensile strength
textured
thermal conductivity
thermal expansion
thermal insulator
thermoformed
thick
thin
tight
time consuming
timeless
tinted
tiny
tough
toxic
toy-like
traditional
transformable
translucent
transparent
transportable
trendy
trustworthy
twists
ugly
ultrasonically welded
unexpected
unique
universal
unpredictable
unusual
unwanted
urban
used for toys
used in almost all small products
used in art objects
used in bathrooms
used in bottles
used in factories
used in kitchens
used in living rooms
used in museums
used in offices
used in windows
useful
utilitarian
UV stable
vacuum-formed
valuable
versatile
virgin
viscosity
visible marks of usage
vulgar
vulnerable
waggish
warm
warm colors
washable
water resistance
waterproof
waxy
weak
wear resistance
weather-resistant
weight
weird
welded
well known
widely used
wild
wonder material
wooden sound
workable
worn
wow factor
you can look through
you want to fiddle with it

Appendix 4.1

Translated scales for Dutch and Chinese participants.

To what extend the **material** of the product expresses the given **meaning**?
*In welke mate drukt het **materiaal** van het product de gegeven **betekenis** uit?*

	3	2	1	0	1	2	3	
Cozy *Knus*								Aloof *Afstandelijk*
Elegant *Elegant*								Vulgar *Vulgair*
Futuristic *Futuristisch*								Nostalgic *Nostalgisch*
Toy-like *Als speelgoed*								Professional *Professioneel*
Frivolous *Losbandig*								Sober *Ingetogen*
Agressive *Agressief*								Calm *Kalm*
Ordinary *Gewoon*								Strange *Vreemd*
Sexy *Sexy*								Not sexy *Niet sexy*
Masculine *Mannelijk*								Feminine *Vrouwelijk*

To what extend the **material** of the product expresses the given **meaning**?
产品的材料多大程度上表达了给出的意义呢？

	3	2	1	0	1	2	3	
Toy-like 玩具								Professional 专业
Ordinary 常规								Strange 奇怪
Sexy 性感								Not sexy 不性感
Frivolous 轻浮								Sober 严肃
Cozy 安								Aloof 避开
Agressive 侵略								Calm 冷静
Masculine 男性化								Feminine 女性化
Futuristic 现代								Nostalgic 怀旧
Elegant 优雅								Vulgar 庸俗

Appendix 4.2

Multiple analysis of variance table showing the effects of expertise.

	dependent variable	F	Sig.
Gender	Futuristic	4,018	,046
	Ordinary*	16,202	,000
	Sexy*	11,824	,001
Expertise	Cozy	,480	**,489**
	Elegant	1,001	**,318**
	Futuristic	1,264	**,262**
	Toylike	1,519	**,219**
	Frivolous	2,736	**,099**
	Aggressive	,029	**,864**
	Ordinary	,158	**,691**
	Sexy	3,118	**,079**
	Masculine	2,238	**,136**
Shape	Cozy*	28,230	,000
	Elegant	7,848	,006
	Futuristic	4,018	,046
	Toylike	5,238	,023
	Ordinary	7,766	,006
	Sexy*	21,592	,000
	Masculine*	52,182	,000
Material	Elegant*	43,605	,000
	Futuristic*	50,255	,000
	Toylike*	60,008	,000
	Frivolous*	27,441	,000
	Sexy*	65,372	,000
	Masculine	8,202	,005
Function	Cozy	4,715	,031
	Elegant*	27,068	,000
	Futuristic*	58,917	,000
	Toylike*	16,397	,000
	Frivolous	5,279	,022
	Aggressive*	11,697	,001
	Ordinary*	115,533	,000
	Sexy*	98,883	,000
Gender X Shape	Cozy	7,943	,005
	Sexy	6,296	,013
Gender X Material	Toylike*	11,189	,001

p< .05 (Note: (*) efects with p≤ .01)

Appendix 5.1

An example page from the online questionnaire

masculine

As a designer, you want to express through its **material** that your product is **masculine**. Which sensorial properties of the material would affect this meaning? Please tick each property that you think is effective.

Als ontwerper, wilt u door middel van **materiaal** uitdrukken dat uw product **mannelijk** is. Welke zintuiglijke eigenschappen van het materiaal beïnvloeden deze betekenis? Gelieve aan te kruisen welke eigenschappen hiervoor effectief lijken.

- [x] **massiveness** (massive/ airy /hollow)
  massiefheid (massief / luchtig / hol)
- [ ] **dampened / resonant sound of the material**
  bedompt / resonerend geluid van materiaal
- [ ] **low / high pitch sound of the material**
  laagtonig / hoogtonig geluid van materiaal
- [ ] **intenseness of colour** (intense / mild)
  intensiteit van de kleur (intens / zwak)
- [ ] **colourfulness** (colorful / colorless)
  kleurrijkdom (kleurrijk / kleurloos)
- [ ] **scratchiness** (scratchy / not scratchy)
  krasbaarheid (krasbaar / krasvast)
- [ ] **reflectiveness** (reflective / non-reflective)
  spiegeling (spiegelend / niet spiegelend)
- [ ] **brittleness** (brittle / unbreakable)
  broosheid (broos / onbreekbaar)
- [ ] **weight** (light / heavy)
  gewicht (licht / zwaar)
- [x] **softness** (soft / hard)
  zachtheid (zacht / hard)
- [ ] **roughness** (rough / smooth)
  ruwheid (ruw / glad)
- [ ] **ductility** (ductile / rough)
  vervormbaar (kneedbaar / taai)
- [ ] **glossiness** (glossy / matte)
  glans (glanzend / mat)
- [ ] **odorous** (natural/ fragrant / odourless)
  geurigheid (natuurlijk/ geurig / geurloos)
- [ ] **elasticity** (low/ high)
  elasticiteit (laag/ hoog)
- [ ] **stickiness** (sticky / not sticky)
  kleverigheid (kleverig / niet kleverig)
- [x] **stiffness** (stiff / flexible)
  stijfheid (stijf / flexibel)
- [x] **warmth** (warm / cold)
  warmte (warm / koud)
- [ ] **darkness** (dark / light)
  donkerte (donker / licht)
- [x] **strength** (low/ high)
  sterkte (laag/ hoog)
- [ ] **transparency** (transparent / translucent / opaque)
  transparantie (transparant / melkachtig / ondoorzichtig)

Appendix 6.1

Review of different sources defining the effective material aspects for materials selection processes

Materials (1967)	Patton (1968)	Esin (1980)	Ashby (1992)	Lindbeck (1995)	Budinski (1996)	Mangonon (1999)	Ashby & Johnson (2002)	Ashby (2005)
- Mechanical properties	- Service requirements	- Production requirements	- General properties	- Mechanical properties	- Chemical properties	- Physical factors	- General attributes	- General properties
- Cost	- Fabrication requirements	- Economic requirements	- Mechanical properties	- Physical properties	- Physical properties	- Mechanical factors	- Technical attributes	- Mechanical properties
	- Economic requirements	- Maintenance	- Thermal properties	- Chemical properties	- Mechanical properties	- Processing and fabricability	- Eco attributes	- Thermal properties
			- Wear	- Thermal properties	- Dimensional properties	- Life of component factors	- Aesthetic attributes	- Electrical properties
			- Corrosion/ oxidation	- Electrical properties	- Business issues	- Cost and availability		- Optical properties
				- Acoustical properties		- Codes, statutory and other		- Eco properties
				- Optical properties		- Property profile		- Environmental resistance
						- Processing profile		
						- Environmental profile		

Appendix 6.2

Sources used by designers in selecting materials.

Material Suppliers

Several material firms offer a number of engineering design tools that can aid the engineers and designers. These tools provide access to valuable engineering data, and the ability to perform material searches and online calculations to help determine design feasibility. Four of these suppliers are GE Plastics, 3M, Dupont and Bayer.

Fairs and Conferences

The growing excitement and exploration in materials and manufacturing in the design community encouraged new organizations to present the advances in technology and materials world to the market and at the same time to product designers. Today, most of the practicing designers believe that these kinds of organizations, consisting of fairs and conferences, are enhancing their creativity and they are offering a good way of experiencing materials by observing them in embodied products (Karana, 2004).

For the aim of using different materials, designers mostly prefer *design fairs* more than *materials fairs*. They would like to see manufactured products rather than raw materials (Karana, 2004). Material ConneXion holds one of the most famous worldwide material exhibitions. Founded in 1997*, Material ConneXion,* is the largest global resource of new materials. The significance of the firm is that, it has the biggest material samples library which houses over 1,400 new and innovative materials representing eight categories: polymers, glass, ceramics, carbon-based materials, cement-based materials, metals, natural materials and natural material derivatives. The complete library information of the organization is accessible via the Internet, using Material ConneXion's database. They have numbers of material experts offering market research, exhibit services and other business tools to help address a variety of material challenges.

Published Sources

The traditional sources of materials data are handbooks. One of the most frequently used handbooks for materials selection is the *Elsevier Materials Selector* (1991). ASM, which was published by American Society of Testing Material (ASTM), is also one of the most widely used sources. ASM has issued methods of testing materials for over 2000 widely used specifications (ASTM, 1958). The *International Plastics Selector* (1987) is another well- known handbook in the field of material selection. There are equivalent publications for ceramics and glasses; for composites; for foams; rocks and minerals; wood and wood products (Ashby, 1992).

A book series by Lefteri (2001- 2008) provides designers with a myriad of material possibilities. Each book introduces the properties of a certain material family: wood, metal, glass, ceramics and plastic. It covers a wide range of information its inclusion of both everyday, familiar products and those that are new, exciting and unexpected. The books covers a wide range of areas, exploring the application of materials in architecture, interior design, product design, furniture design, fashion and applied arts, all combined with solid technical information. Likewise, *Design Magazines* are used by designers for following improvements and novelties in material technologies.

Software Programs and Online Data Sources

Increasingly, materials data are packaged as software: computerized databases[1]. One of the most important software databases is **Cambridge Engineering Selector** (CES). It is a remarkable tool centered on methods developed by Mike Ashby and colleagues at Cambridge University and Granta Design. It combines three principal functions: (1) straightforward search for information, material properties, process methods, suppliers, and so on; (2) a systematic approach for analysis of material and process information and optimal selection; and (3) modeling of complex properties such as creep or fatigue, or of process cost. CES consist of all material types.

Another one is **PLASCAMS 220**, which is the Plastics Materials Selector (1990) including Polymers only. The user can find the mechanical and processing properties of polymers, thermoplastics and thermosets. According to Ashby (1992), the PLASCAMS 220 is easy to use for data retrieval, with much useful information. However, the selection procedure cumbersome and not design related.

Apart from those databases, there are several online databases (websites) which mostly provides free access for user. A well-known example for a website providing materials properties data particularly for industrial designers is **Design InSite**. Design InSite is a Danish website, founded in 1997, aiming to be a guide to manufacturing for especially industrial designers. Various manufacturing processes and materials are described as well as the products where they are used. They define their purpose as to inspire designers in their design work to consider materials and processes, which are new or unknown to them. The web site includes descriptions of about 190 products, 120 materials and 100 processes. Both traditional and newer materials and processes like smart materials, rapid prototyping techniques, powder metallurgy and surface treatment processes are covered in the site. **MatWeb** is another well-known online database used by designers. There are convenient drop-down lists of polymer trade names and polymer manufacturers in the site. MatWeb is used as a source for materials selection by certain software programs such as CES.

Footnote

1 A database is a collection of information organized and presented to serve a specific purpose -usually is that of retrieving selected items of data. A telephone directory is a database. So is a dictionary (Ashby, 1992).

Appendix 8.1

Sensorial properties of the elegant materials selected by Turkish and Dutch participants.

Dependent Variable	Culture	Mean
soft	Dutch	2,00
	Turkish	2,17
rough	Dutch	1,50
	Turkish	1,33
glossy	Dutch	3,17
	Turkish	3,75
reflective	Dutch	2,50
	Turkish	3,25
warm	Dutch	2,58
	Turkish	2,25
elastic	Dutch	1,75
	Turkish	1,58
transparent	**Dutch**	**1,42**
	Turkish	**2,83**
ductile	Dutch	2,33
	Turkish	2,08
weak	Dutch	2,67
	Turkish	2,58
heavy	Dutch	2,50
	Turkish	2,33

Appendix 8.2

Sensorial properties of the sexy materials selected by males and females.

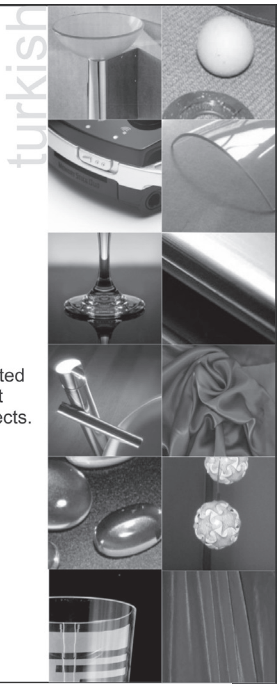
Dependent Variable	Gender	Mean
soft	male	2,00
	female	3,08
rough	male	1,42
	female	1,58
glossy	male	3,75
	female	3,25
reflective	male	3,25
	female	2,33
warm	male	2,75
	female	1,92
elastic	male	1,67
	female	1,92
transparent	male	1,83
	female	2,58
ductile	male	2,25
	female	2,83
weak	**male**	**1,92**
	female	**3,50**
heavy	male	3,08
	female	2,08

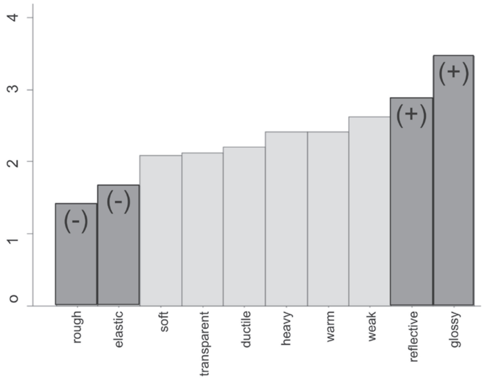
Appendix 8.3

Created application for the meaning elegant.

	Culture	Mean
soft	Dutch	1,750
	Turkish	2,167
rough	Dutch	1,667
	Turkish	1,333
glossy	Dutch	2,833
	Turkish	3,750
reflective	Dutch	2,417
	Turkish	3,250
warm	Dutch	2,750
	Turkish	2,250
elastic	Dutch	1,667
	Turkish	1,583
transparent	Dutch	1,417
	Turkish	2,833
ductile	Dutch	2,000
	Turkish	2,083
weak	Dutch	2,750
	Turkish	2,583
heavy	Dutch	2,583
	Turkish	2,333

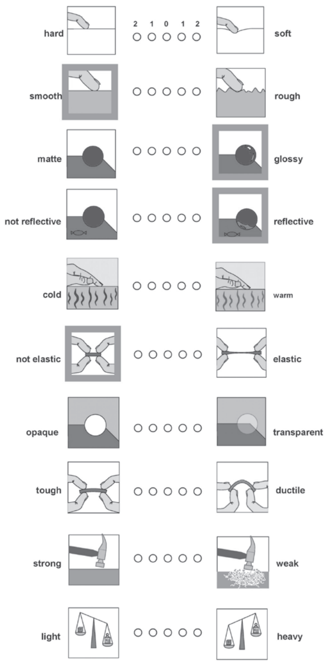
The most significant difference between Turkish and Dutch subjects was found for **transparency**. Elegant materials selected by Turkish subjects were more transparent than the materials selected by Dutch subjects.





In the overall evaluation, four sensorial properties were significantly effective in attributing the meaning **elegant** to materials:

smooth (as the opposite pole (-) for rough)
not elastic (as the opposite pole (-) for elastic)
reflective
glossy



Appendix 8.4

Individual explanations for sexy materials.

gender: female
age: 30
nationality: Turkish
occupation: researcher in architecture department

I just think that tulle is a very classical one in terms of sexy materials. It's transparent, it's feminine. It has a lot of associations to very sexy objects; such as dresses, underwear, soks, hats. It can also be describe as mysterious, because it is hiding what's behind.

gender: female
age: 30
nationality: Italian
occupation: researcher in a pharmaceutical company

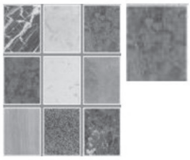
I think that silk is sexy because of its brightness and softness.
It's a symbol of charm. In that way I chose a tie to represent this material: a silk tie makes a man so fascinating!

gender: male
age: 37
nationality: Colombian
occupation: Assistant Professor

1. The main materiales that I think are sexy are:
Leather
Silk
Aluminum or chromed surfaces
Silicone or soft plastics (TPE, PU)
2. Picture: silla panton
3. In this case, the material (the last material for the panton chair was PP + FV) is sexy for the shape and color, but in my opinion all materials can be sexy if you use sensual shapes or if you use in a special context. (you can use metal fabric in a dress, metals are no so sexy, but inmediatly you wear it, its become sexy)

gender: female
age: 21
nationality: Dutch
occupation: educational sciences student

I chose very thin cotton, because it has something mysterious. It's a natural product. You can wear it everywere. But you need to wear something underneath it. Like a thin cotton blouse with a shirt under it.



gender: male
age: 27
nationality: Chinese
occupation: PhD student at info and com technology

I like it because its color is bright and its surface is very smooth, you will be confident in a building with this kind of materials.

gender: male
age: 39
nationality: Tanzanian
occupation: researcher

There are many reasons, here are the main three.
·Natural colors – e.g. granites can be pink to dark gray or even black, depending on their chemistry and mineralogy.
·Texture - Granite has a medium to coarse texture, occasionally with some individual nice-looking crystals .
·Application/uses – wide spread usage as antiquity (from historical times – e.g. in pyramids & hindu temples - to date), as a material for sexy consumer products (e.g. kitchen tops, flower pots, etc.) and as sexy construction material (used in building walls, as flooring tiles and monuments).

gender: male
age: 34
nationality: South Korean
occupation: researcher at design engineering

It's difficult to say why I think it sexy. It's just a kind of visceral feeling. Maybe I would say that I might be influenced by sexy naked porno models on sex magazines who always wore stockings. The semi-transparent fabric of stockings also evokes me sexy feeling. On the other hand, the stocking itself looks like a packaging material to make things look fabulous and sleek. I like the feeling of touching stockings: it is of course artificial fabric but gives a soft feeling to me. If I add the last remark, I feel sexy when I hear a lady slip off her stocking.

gender: male
age: 25
nationality: Turkish
occupation: architect

I selected metal in this telephone as a sexy material. First of all, the product is black but Metal part is metalic color, which attracts attention. Because metal is hard, strong and durable, it is used there as a protective cover. it is shiny and like a mirror, so it may be the reason why I select this material as sexy.

gender: male
age: 24
nationality: Portuguese
occupation: management student

It is the material that, by touch, resembles the most with human skin.

gender: male
age: 28
nationality: Turkish
occupation: PhD at computer science

The Samurai swords, namely Katana, are sexy to me for the following two reasons. First, it subconsciously symbolizes the power and resistance, which I attribute to the movies that I have seen, and the Katana related documentaries I have watched on TV. Second, the shiny steel-made body is so glamorous, which makes me feel as if I am looking at a very attractive woman :)

gender: female
age: 45
nationality: German
occupation: industrial designer

I chose the feather as an abstract object and looked for a matching photo afterwards. Being sexy means to me that the item/material has to have a certain amount of suspense in it, some contradictions or something that unsettles the viewer without being aggressive. In the feather, this is the combination of hard and soft of the quill and the downs; the contrast of the quill with it's one groove in it and the fractal pattern of the downs. There is some tension in it, yet it is one material.
A reason NOT to choose a feather as a sexy material would be for me that it has such a cliché-ridden connotation.

gender: female
age: 27
nationality: Turkish
occupation: architect

I think the transparency and purity of glass is very effective for me. Furthermore, glass is feminine for me. Because the character of the material allows shaping easily, it has an additional value for me. I think, as an object, wine glass also emphasizes the femininity. It is tiny, curved..it is sexy but very elegant at the same time.

gender: female
age: 24
nationality: Portuguese
occupation: researcher at chemistry

Although the leather is visually not very appealing to me, it has the right texture. It is not too smooth (like silk) but not very rough. So you really feel it when you touch it. Also it has the right temperature (not cold nor hot), kindly like you give it your on temperature, contrary to metal which temperature depends on room temperature.

gender: male
age: 27
nationality: Turkish
occupation: researcher on wireless and mobile communication

That is rather difficult to explain. Itjust looks sexy but probably the elegant and harmonious combination of black andsteel on the strap of this man watch makes it that sexy for me.
If it was pinkor yellow for example, I would definitely not find it sexy but girly orchildish.
If it was original steel color but not black then I would think it isvery common and ordinary among watch straps on the market so that might kill it's sexy image in my mind.
If it was not steel but black plastic then I wouldprobably think it is not strong and classy enough for a good quality man watch.I think the solidity of steel contributes its sexiness as well.

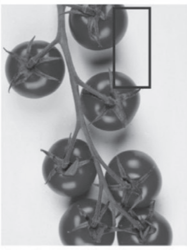
gender: female
age: 28
nationality: Hungarian
occupation: researcher at industrial design

It is soft and smooth, it is a nice feeling when it touches your skin, you have the feeling that you want to touch it. It is also pleasant to look at it, it is elegant, cool and shiny, looks very attractive.

gender: male
age: 29
nationality: Argentinean
occupation: engineer

I think silk is sexy because can be smooth and warm. Some other materials can be smooth but many of them are cold in general (e.g.: glass).

I probably feel this material is a sexy one, because I associate it with women, for instance, a pretty woman wearing a dress made from silk can be very attractive and sexy, but is not the same feeling if it is a men who is wearing the dress.



gender: female
age: 28
nationality: Turkish
occupation: architect/ PhD

Actually I know that this is neither a material itself nor an object.
But what I saw it first on the website was the black rectangle part more or less, and it was impossible to get that it was tomatoes. The black rectangle I saw was sexy image in my head. Therefore I'm just showing the great picture but actually I will explain for the black rectangle.

**I guess it was the red colour first and green parts also complemented.
Second is about the shiny skin and rounded contours.
And when I saw it first I thought it is something plastic.**

gender: male
age: 23
nationality: Chinese- American
occupation: architect

I think thick aluminum plate is sexy. perforated sheets are pretty hot as well. by thick, i mean sturdy enough to resist bending - solidity is important.
i've attached 2 pics of the object this material is found on: apple mac pro.

gender: male
age: 54
nationality: Dutch
occupation: researcher, educator

-warm and deep main color,
-some mystery about its appearance (what's below it?),
-glossiness, brightness, and even color change depending on the direction of looking,
-unique looks of its own (not comparable to anything else, there is not even a common word for it in daily language)

gender: male
age: 33
nationality: Brazilian
occupation: geologist

I choose metal (silver)
I think it is sex is because it is simple, but at the same time functional and sofisticated.

gender: female
age: 28
nationality: Turkish
occupation: architect/ researcher

-it is transparent
-But not too much, the color creates that the transferred light is limited. The material has control on the object (even it is pure glass)
-When the material is refined, (as in the example, it has wrinkled irregularly, the wrinkles on a smooth surface create difficulties to understand its pattern -the objects' way of thinking- . Somehow the material can be called mysterious.
-When the material colored, it becomes catchy (which is also created by the pattern mentioned above)

gender: female
age: 19
nationality: Dutch
occupation: medical student

It is soft, has a sexy color and a beautiful shape (round and full).You get it when someone thinks that you are sexy.

gender: female
age: 29
nationality: South Korean
occupation: student at a music school

It looks sexy to me because of its glossy and hard feeling. The hard feeling gives me a feeling of being protected and gently treated. For instance, if I make love on this glossy acrylic material, a man is supposed to treat me softer and gentler because of the hard feeling which the material gives. So I feel sexy about the material.

gender: female
age: 23
nationality: Portugese
occupation: PhD
at applied science

The material that I selected is glass.
The reason why I think that glass can be considered a sexy material is related with its versatility: glass can be easily shaped in different forms and have different colors, but also it can be either transparent or frosted. Even though it is not a very strong material, it is, in my opinion, one of the best materials to combine with more resistant ones to give more personality to the material used as backbone.

Individual explanations for elegant materials.

gender: male
age: 24
nationality: Turkish
occupation: industrial design student

I choiced this material because it is shiny, smooth and hard.

gender: male
age: 23
nationality: Turkish
occupation: industrial design student

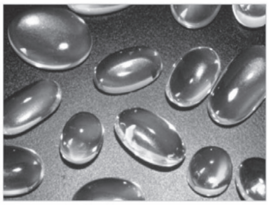
The most effective reasons that I qualify the glass as an elegant material are that it makes you feel pleasant when you touch it because of its smoothness. In addition, it has a surface which can reflect the surround like mirror and at the same time, it can show inside, and being light weight and giving opportunity to form aesthetic designs are the minor reasons, when I think about glass as an elegant material.

gender: male
age: 19
nationality: Dutch
occupation: psychology student

White marble has a very soft appearance; together with the sophisticated sculpture by Michelangelo. This leads to an elegant whole. Well, of course it is an emotion the material evokes, and emotions are often hard to explain by words...
beautiful statue and it is elegant ...

gender: female
age: 25
nationality: Turkish
occupation: industrial design student

Firstly, I think that the material is elegant because the design which the material used on has plain, pure lines.
Also, shiny and smooth surface of the material caused to think that it is elegant.



gender: male
age: 25
nationality: Turkish
occupation: industrial design student

It is transparency and deepness of the blue color make me think that the moonstone is an elegant material. It shows its from in an unreal way by the effect of the light of enviroment. In addition, it is as innocent as tears which is also elegant.

gender: male
age: 26
nationality: Turkish
occupation: research assist. in industrial design

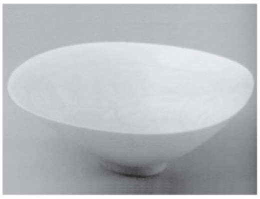
Before choosing an elegant material, I imagined an elegant character in my mind. Of course the character was female. She is very fragile person; even though, she looks strong. She is slim and honest. She is tall and cute. I think that material which I chose has to have the same properties that my character has. Immediately I find the glass which resembles to the properties. It has strong but breakable structure which we might say that it is equal with being fragile. It must be really transparent glass to serve itself honestly.
I think the form of the vase I chosed is also effected me that glass is elegant material.

gender: male
age: 44
nationality: Dutch
occupation: Assis. Prof. at the design engineering

All of the following reasons:
-Because of the colour, which is off-white and somehow conveys that it's from a natural source, but also conveys that it needed careful processing to arrive to its final state. The slight variations in colour and also texture enhance that expression
-Because of how it feels between your fingers. Usually thinner than paper, and also compliant in a way.
-Because of how it feels when you rub over it – soft and somewhat silky
-Because it's vulnerable

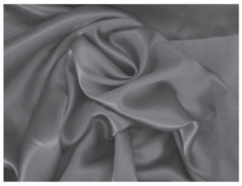
gender: female
age: 21
nationality: Dutch
occupation: medicine student

I didn't find and exact picture of what I meant but in fact it is wooden cutlery. I think it is elegant for several reasons:
-wood is a natural material wich is never the same; the color, the design is always slightly different
-the elegance is also present in it's use: wood has a low variability in temperature so it always is nice to have in your hand, unlike metal.
-The combination of the wood and the metal gives an elegant contrast which gives the cutlery an authentic look and a taste of handcraft.



gender: male
age: 20
nationality: Dutch
occupation: architecture student

I picked porcelain for several reasons. Firstly, porcelain is a very fragile material. I think this is elegant because very strong materials like steel or concrete tend to come across as "crude". Secondly, porcelain can be molded into almost every imaginable shape. Lastly, porcelain is very suitable for painting in beautiful colours although I have to add that I find it most elegant when left white.



gender: female
age: 26
nationality: Turkish
occupation: industrial designer

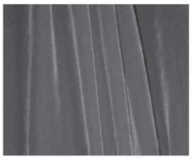
The material I choiced is the material of fashionable times and spaces. It gives you a sense of fluidity, smoothness and the sensibility of the fabric.

gender: female
age: 24
nationality: Dutch
occupation: master student at architecture

I think ceramic (porcelain) is a very elegant material. This pot, especially because of its white color, hard rigid body looks very strong and confident, which make it very elegant.

gender: female
age: 21
nationality: Turkish
occupation: industrial design master student

In this example that I chosed, the most interesting thing is that designer of the lighting has used epoxy as a major material. Although epoxy is not a strong material, designer has formed it to look strong and elegant. This is why I think that epoxy might be an elegant material.

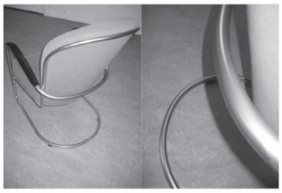


gender: male
age: 22
nationality: Turkish
occupation: graphical design student

Velvet. Its texture has an elegant effect which is given by itself, when you look at it or when you touch it.

gender: male
age: 24
nationality: Turkish
occupation: industrial design student

The color, texture, glossiness, and reflections and refractions that we can see on the surface of the material make me think that the material is elegant.



gender: female
age: 20
nationality: Dutch
occupation: applied earth sciences student

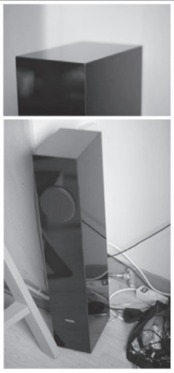
It is shiny, smooth and tight. The tubes are rounded. In the chair these tubes are bended in nice elegant rounded curves. This matches. Rounded tubes fit with rounded shapes. Rounded shapes are often elegant.

gender: male
age: 21
nationality: Dutch
occupation: industrial design student

it's flexibility, that makes it easy to transform into different positions. the curved shape, following the shoe but also coming back in the little fragments of the spring.
the shiny metal, that makes it look a bit cold and because of that makes you keep distance as not allowed to touch, like a fragile flamenco dancer. when you look closer, you see that the spring is made of a wire, which is nicely curved following a spiral.

gender: male
age: 27
nationality: Dutch
occupation: teacher- design engineering

I choose the material Silk. Because the material does not force itself on the user, it is somewhat reserved.
It follows the users movements in a smooth and fluent way
Although it looks fragile, it is very strong,
but in a feminine way.

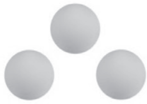


gender: male
age: 20
nationality: Dutch
occupation: mechanical engineering student

Because the glossy look of the material makes it looks modern and somewhat luxurious/expensive and therefore (imo) elegant.
Furthermore also the shape of the chosen object might have influenced my opinion.

gender: male
age: 25
nationality: Dutch
occupation: industrial design student

·It is made out of soft material. (reason for selecting my carpet)
After a bit more thinking I thought of the next 'distinguishing characteristics':
·It adjusts to the shape of an external object, like my feet or the legs of my chair.
·After moving my chair I can still see the 'footprints' of the legs of my chair.
These footprints become vaguer in time and after a few minutes (± 1.5) my carpet is fully 'recovered' for the eye. This because the position and strength of the different fibers in that place of the carpet most probably did change.



gender: male
age: 25
nationality: Turkish
occupation: industrial designer

I think that this material is elegant because even though, it seems smooth, it is relatively hard and unexpectedly heavy. It is amazing combination of smooth surface and intensive structure.

gender: male
age: 25
nationality: Turkish
occupation: industrial designer

To compare with other materials, glass seems more elegant to me because it allows flexibility to form. In addition, it is natural in both visual and physical aspects.

gender: male
age: 26
nationality: Turkish
occupation: mechanical engineer

I think that titanium is an elegant material because of it is color, apperiance and being lightweight. I think that using this material effected product designs in a positive way.

gender: female
age: 22
nationality: Dutch
occupation: management student

I selected 'crystal' as an elegant material, because I think crystal is a synoniem for richness, style, luxury and welfare. Not only as a part of a necklace, bracelet or ring (as in an elegant ornament) but also in a piece of tableware (as I selected). Drinking your liquor in a crystal glass feels much more elegant than drinking this in a regular glass.

gender: male
age: 25
nationality: Dutch
occupation: industrial design master student

Carbon as a material is lightweight and has thin thickness rather than other materials. In addition, it is strong and durable. In the example that I sent there is a bicycle frame which is a common usage area of carbon. Generally, we might say that bicycle frames have thin structure if it is considered that they always face with harmful impacts. Although carbon gives a sense of weakness, it is extremely strong. This function feel you that carbon is elegant material. Also, it is surface quality is extremely high.

Appendix 8.5

a. Explanation pages for the components and the aspects of the MoM Model.

USER

The assessment of products and their materials and attributing meanings to them is related to past experiences and personal tastes of users. In addition, demographic differences such as age, gender, education, income, etc. and cultural backgrounds may affect how people appraise materials and what kind of meanings they attribute to them.

any material in any product can be nostalgic for a particular individual

MATERIAL PROPERTIES

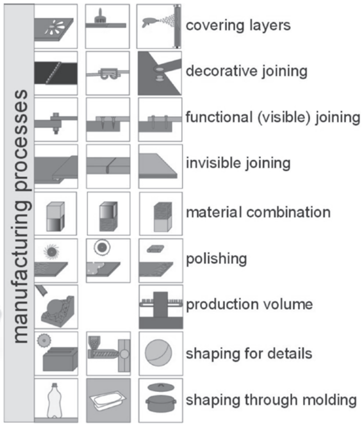
'Material properties' cover the characteristics that distinguish a material from other materials.
A material can be different from another material through its unique technical properties like strength, elasticity, heat conductivity, etc. Technical properties of materials are experienced through sensorial properties by users. In other words, sensorial properties of materials appear as moderators in material-user interaction, and they help us to appraise a material and attribute meanings to it.

Smoothness and semi-transparency in two product examples these two different materials can connote similar meanings with their similar sensorial properties

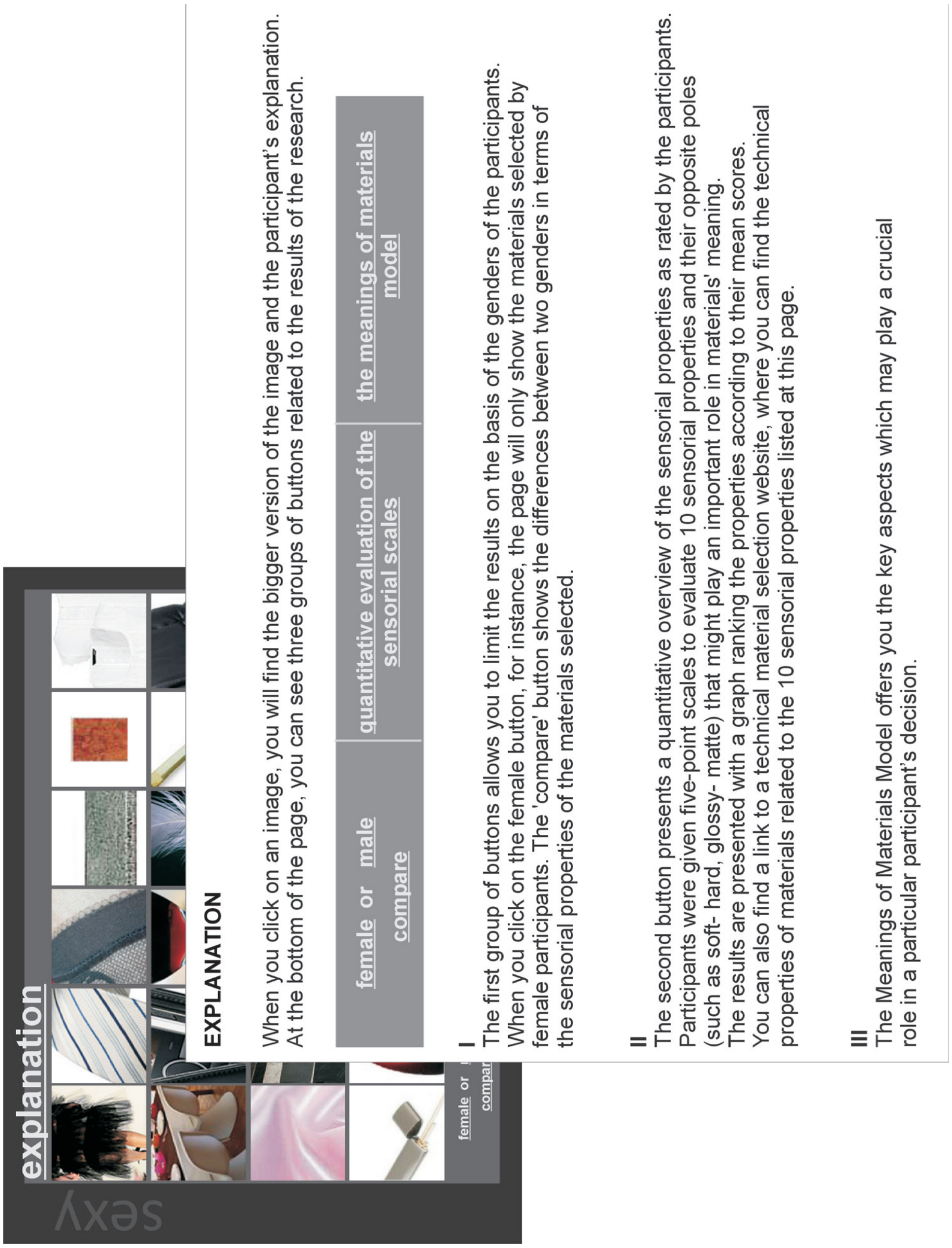
you may evaluate the selected materials based on their technical and sensorial properties

MANUFACTURING PROCESSES

How a material is processed may have an important effect on the attribution of meanings to materials. This effect is not a direct one, but it is through shape or sensorial properties. For instance, a polishing process (which is a surface treatment process) affects the surface quality of a material, and its consequence may be a change in material's meaning. Coloring (painting) should be recognize as an important factor here.



b. Explanation page of the tool.



Appendix Z

Meaning Driven Materials Selection in Design Education: A workshop in Greece
Industrial Design Engineering Department of TEI

Considering the requirements of the tutors of the course Materials and Design, I defined three main aims to be achieved in this workshop: (1) to inform students about what kind of variables play an important role in the attribution of meanings to materials, (2) to show them the importance of understanding their target users (introducing the MoM tool), and (3) to inspire them for new ideas about materials. In order to achieve these aims, the first step was to generate data for the MoM tool by making students select materials expressing certain meanings and evaluate their selections with their own words as well as with the sensorial scales. Four meanings were selected for this step: cozy, feminine, futuristic and strange. These meanings were used in the study reported in Chapter 4. The main motivation in selecting these meanings for the workshop was to attract the students' attention and consequently provide a high participation in the study. In addition, we assumed that (as we saw in Chapter 4) the attribution of the meanings strange and feminine to materials, for instance, is affected more by shape and function than by the material properties alone. On the other hand, the attribution of futuristic or cozy can be dominated more by the material properties. These meanings could be good examples to show the effects of other key variables (such as shape and function) in the attribution of meanings to materials.

A week before the workshop: Task 1

Procedure

140 students were divided into four groups. The individuals of each group were asked to select a material which expresses the given meaning (cozy, feminine, futuristic or strange), and explain their selection. The task was given by the assistant of the course in Greece. The students sent their selections with their explanations to an e-mail address particularly created for the workshop (meaningsofmaterials@gmail.com). Once they sent their selections, they received an automatic reply consisting of a pdf version of the sensorial scales. The pdf version was developed to collect the results of the scales automatically as xml. files. The students were informed that their submission would not be completed, unless they sent their evaluations on the sensorial scales.

Results

29 cozy, 33 feminine, 35 futuristic and 33 strange materials were collected at the end the study (so in total 130 students sent their selections and explanations). However, students had difficulties in sending the results of the sensorial scales. Some of them could not save their results as *xml.* file. This action had been planned to be done automatically (with the 'submit by e-mail' button at the end of the pdf document). However, some PCs in the student labs did not have the program required for the automatic sending function. Some of these students sent their results as word document by writing the numbers they marked in the scales; and some of them just copied the page by 'print scrn' button of their keyboards, and sent it as jpeg. Despite the mentioned difficulties, there were 90 valid submissions (23 for cozy, 22 for feminine, 20 for futuristic and 25 for strange).

Cozy materials selected by 29 Greek students

The Greek students mainly focused on soft and warm materials such as plumage, polyurethane foam and cotton (Figure 1). Some students explained their cozy materials with the overall context in which the selected materials are used. For instance, a student explained how the soft and light material of an earphone provides comfort and pleasure in use (Figure 1_1E). Likewise, another student explained how the material of a bathtub expresses coziness because it offers relaxation, comfort and pleasure (Figure1_5B)

Figure 1. Cozy materials selected by Greek students.

Following the method used for generating the data for the MoM Tool in Chapter 8, the sensorial scales filled by the students were analyzed statistically to see the most significant properties in attributing the meaning cozy to materials. A *One Sample t- test* was executed to compute the importance of the properties. The overall mean score for 10 items (M= 2. 8) was taken as the test value for the One Sample t-test. Bold items in Table 1 show the properties that received scores significantly above or below the overall mean score. As recognized from Chapter 8, the properties that received scores significantly below the overall mean score are presented with a minus sign (-) in the table. According to the findings, *Transparency* (1. 78) was significantly below (-) the overall mean, therefore *opaqueness* of a material would appear to be one of the most important properties in attributing the meaning cozy to materials. *Roughness* (2. 09), *glossiness* (2. 13) and *reflectiveness* (2. 13) were also rated significantly below the overall mean score, which shows that the cozy materials were significantly rated as *smooth, matte* and *non-reflective*. *Softness* (3. 91) and *warmness* (3. 48) and *ductility* (4. 04) were rated significantly above the overall mean score (i.e. the selected materials were commonly soft, warm and ductile). The results of the study for cozy materials are presented in Figure 2.

Table 1. Results of the One Sample T-Test for cozy materials.

COZY:: Test Value = 2.8	t	df	Sig. (2-tailed)	Mean
soft-hard	3,237	22	,004	3,91
rough-smooth	-2,843	22	,009	2,09
glossy-matte	-2,560	22	,018	2,13
reflective-nonreflective	-2,560	22	,018	2,13
warm-cold	2,627	22	,015	3,48
elastic-not elastic	1,356	22	,189	3,22
transparent-opaque	-4,184	22	,000	1,78
ductile-tough	3,918	22	,001	4,04
weak-strong	1,050	22	,305	3,09
heavy-light	-1,855	22	,077	2,22

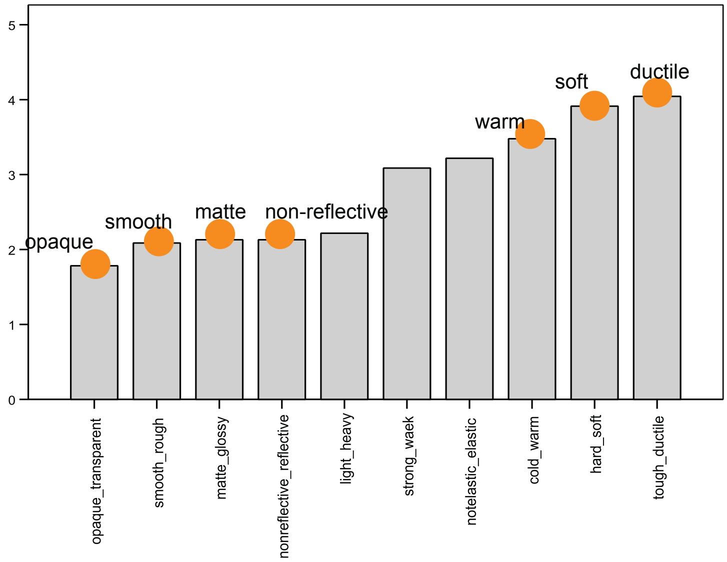


Figure 2. Results of the study for cozy materials

Feminine materials selected by 33 Greek students

Glossy and smooth materials dominated the Greek students' selections for the meaning feminine (Figure 3). Interestingly, eleven students selected 'diamond' as a feminine material. Two other students selected crystal and glass, and associated their selections with diamond (Figure 3_ 6B and 6E). Three students selected silk due to its soft, warm and smooth feeling.

The overall mean score for 10 sensorial scales (M= 2. 5) was taken as the test value for the One Sample t-test (Table 2). Table 2 shows that *elasticity* (1. 77), *ductility* (1. 86) and *roughness* (1. 95) were significantly below (-) the overall mean (i.e. the selected materials were commonly not-elastic, tough and smooth). *Glossiness* (3. 68) and *reflectiveness* (3.50) of a material would appear to be two of the most important properties in attributing the meaning feminine to materials in this study. The overall results are presented in Figure 4.

Table 2. Results of the One Sample T-Test for feminine materials.

FEMININE:: Test Value = 2.5	t	df	Sig. (2-tailed)	Mean
soft-hard	-1,490	21	,151	2,00
rough-smooth	-2,179	21	,041	1,95
glossy-matte	3,371	21	,003	3,68
reflective-nonreflective	3,420	21	,003	3,50
warm-cold	-1,264	21	,220	2,18
elastic-not elastic	-2,861	21	,009	1,77
transparent-opaque	,136	21	,893	2,55
ductile-tough	-2,096	21	,048	1,86
weak-strong	-,571	21	,574	2,32
heavy-light	,000	21	1,000	2,50

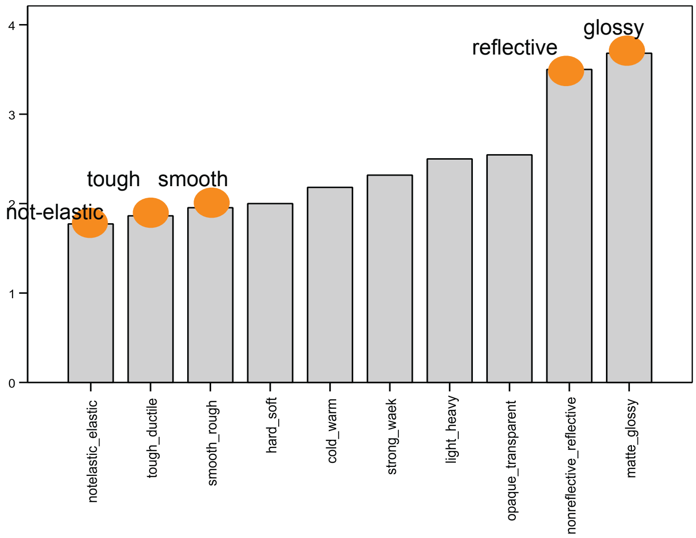


Figure 4. Results of the study for feminine materials

feminine

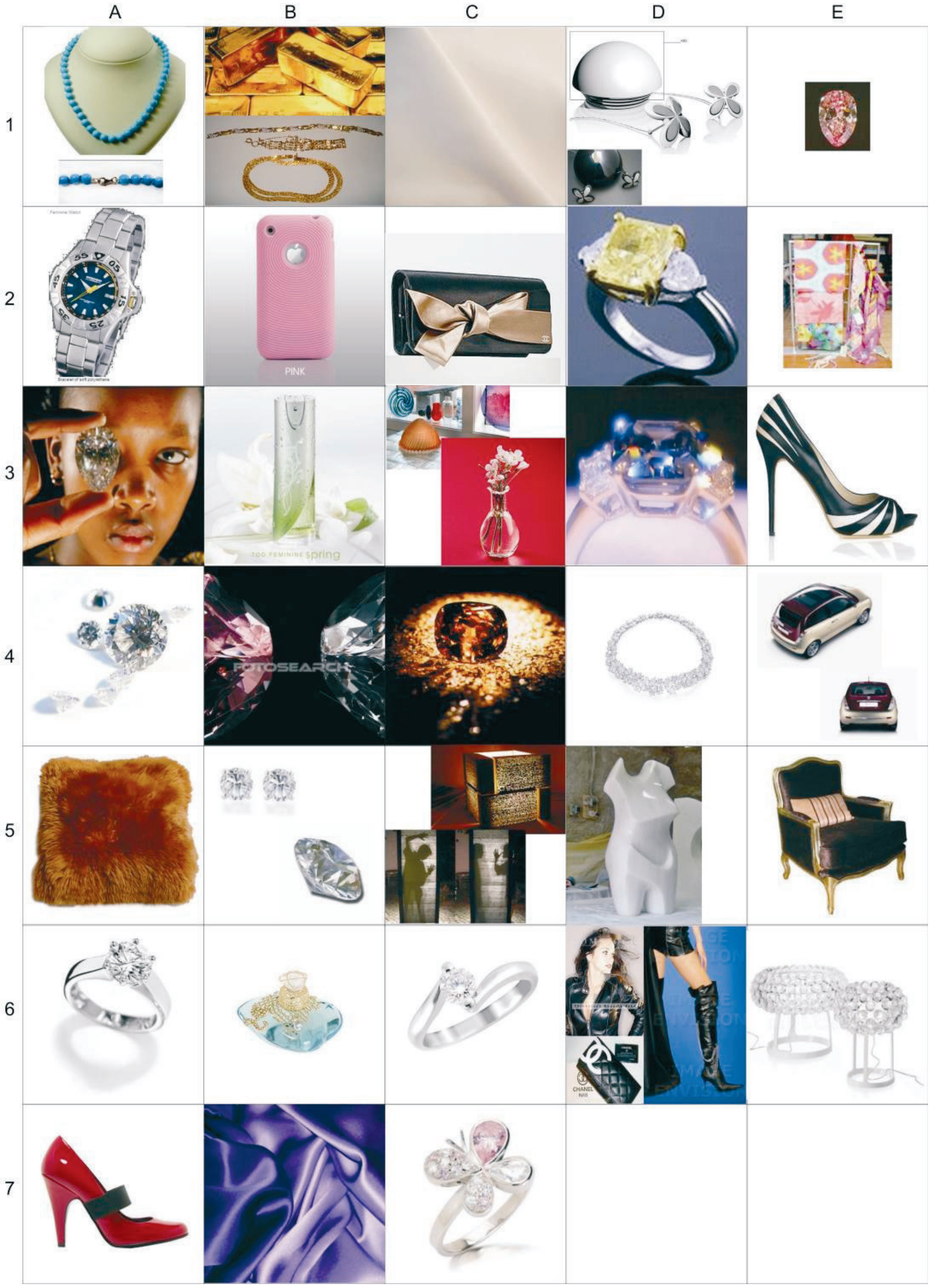


Figure 3. Feminine materials selected by Greek students.

Futuristic materials selected by 35 Greek students

The Greek students mainly selected smooth, glossy and hard materials for the meaning futuristic (Figure 5). They often associated the properties strength, hardness and lightness with the futuristic design. Aerogel, which is a material with a very low density and weight and made by the drying of liquid gels of alumina, chromia, tin oxide or carbon, were selected by seven students as a futuristic material. Amorphous metals, Plexiglas (PMMA), inox, carbon fibers, carbon nanotubes, e-textiles were some other materials considered as futuristic by the Greek students.

Table 3 shows the overall evaluation of the sensorial scales (the overall mean score M= 2. 4). As followed in the table, *softness* (1. 70) and *roughness* (1. 70) were significantly below (-) the overall mean (i.e. the selected materials were commonly hard and smooth). *Glossiness* (3. 40) and *reflectiveness* (3.30) were significantly above the overall mean (i.e. the selected materials were commonly glossy and reflective). The overall results are presented in Figure 6.

Table 3. Results of the One Sample T-Test for futuristic materials.

FUTURISTIC:: Test Value = 2.4	t	df	Sig. (2-tailed)	Mean
soft-hard	-3,621	19	,002	1,70
rough-smooth	-2,570	19	,019	1,70
glossy-matte	2,735	19	,013	3,40
reflective-nonreflective	3,000	19	,007	3,30
warm-cold	-,355	19	,727	2,30
elastic-not elastic	-,489	19	,630	2,25
transparent-opaque	,000	19	1,000	2,40
ductile-tough	-1,831	19	,083	1,95
weak-strong	-,882	19	,389	2,15
heavy-light	1,675	19	,110	2,95

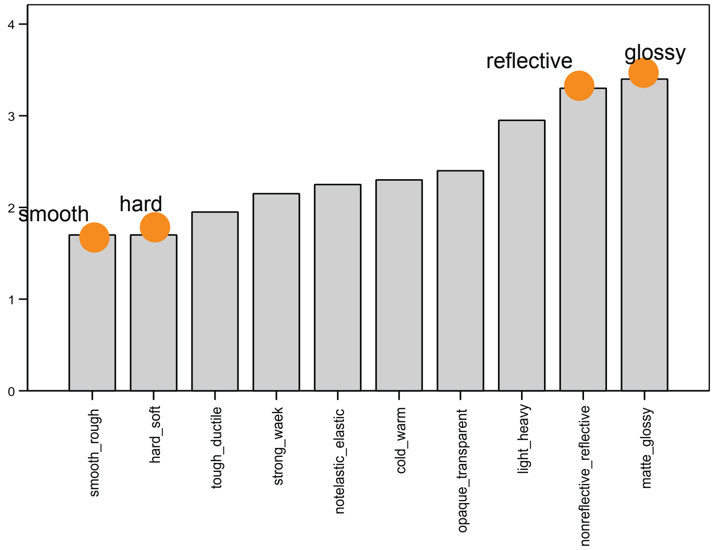


Figure 6. Results of the study for futuristic materials

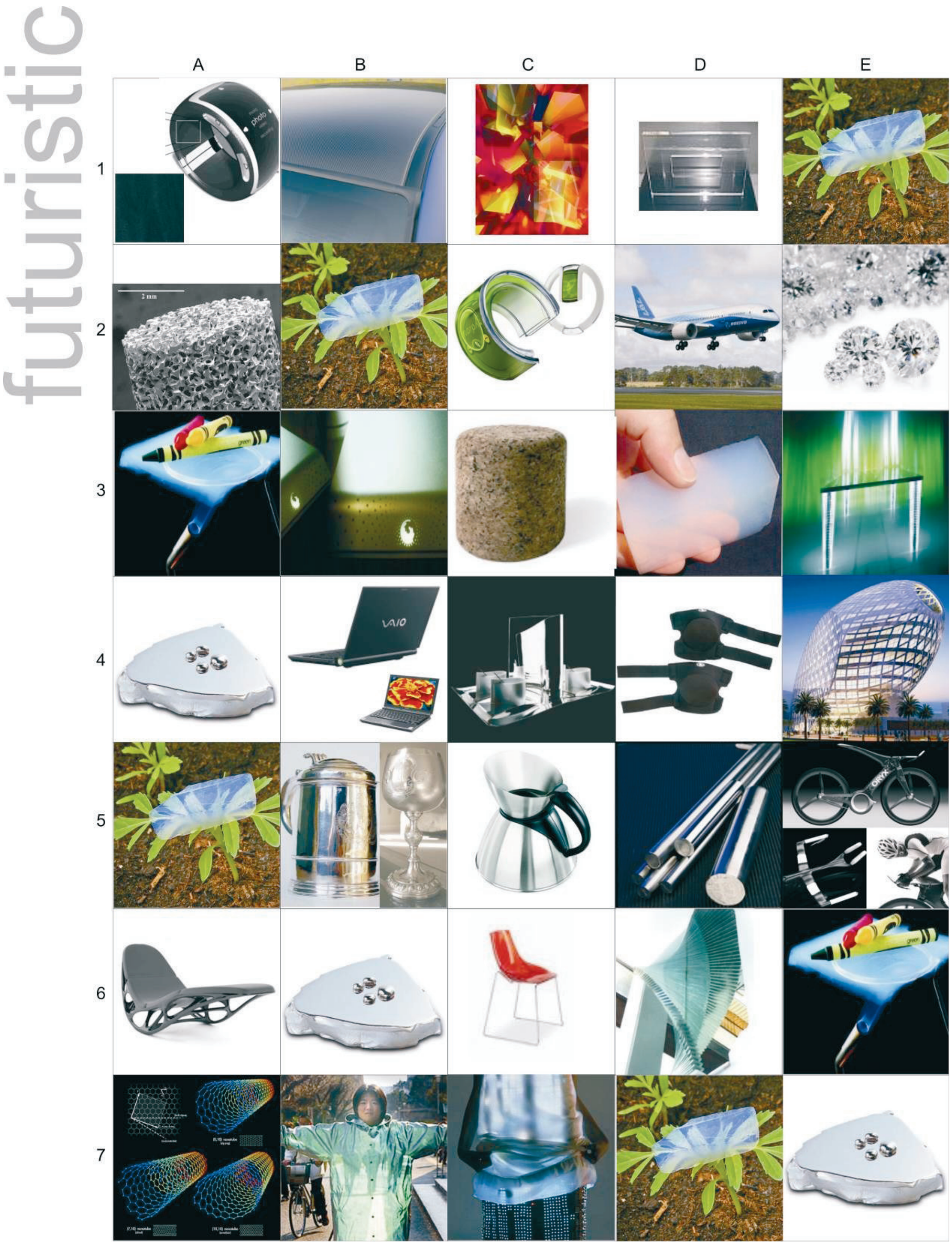


Figure 5. Futuristic materials selected by Greek students.

Strange materials selected by 33 Greek students

The biggest variety of materials was obtained in this category (Figure 7). Stainless steel, polypropylene, ferrofluid, PMMA, aerogel, latex, bubinga (a type of wood), carbon fiber reinforced polymers, fiber glass, hardened leather and bones were some of the strange materials selected by the students.

Table 4 shows the overall evaluation of the sensorial scales (the overall mean score M= 2. 6). As followed in the table, there were only two scales which obtained significantly high (or low) scores in the overall evaluation of the strange materials: *glossiness* (3. 24) was significantly above the overall mean (i.e. the selected materials were commonly glossy) and *heaviness* (2. 00) was significantly below (-) the overall mean (i.e. the selected materials were commonly light). The overall results are presented in Figure 8.

Table 4. Results of the One Sample T-Test for strange materials.

STRANGE:: Test Value = 2.6	t	df	Sig. (2-tailed)	Mean
soft-hard	-,241	24	,812	2,52
rough-smooth	-1,866	24	,074	2,16
glossy-matte	2,122	24	,044	3,24
reflective-nonreflective	-,679	24	,503	2,40
warm-cold	-1,095	24	,284	2,40
elastic-not elastic	,816	24	,423	2,88
transparent-opaque	,344	24	,734	2,72
ductile-tough	,603	24	,552	2,80
weak-strong	,136	24	,893	2,64
heavy-light	-2,384	24	,025	2,00

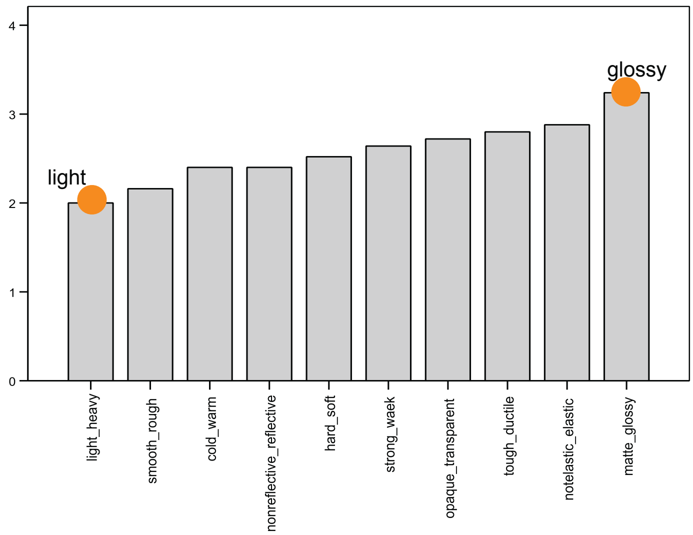


Figure 8. Results of the study for strange materials

Figure 7. Strange materials selected by Greek students.

Overall Discussion: Task 1

In general, the students were able to select materials expressing the given meanings and explained their selections clearly. However, a few students (particularly for the category strange) focused on products more than materials and explained their selections accordingly (see the guitar and the car in Figure 7). It was surprising to see a number of similar materials selected for a particular category (such as aerogel for futuristic, or diamond for feminine). In informal discussions with the students, I understood that the main reason to select diamond as a feminine material was a recent TV commercial which had become popular with the motto 'diamonds are the best friends of women'. Almost all students who selected diamond as a feminine material had explained their selections by mentioning the same motto. Indeed, this finding is a very good example how the cultural and social contexts affect a meaning-material relationship. If we conducted the same study with Dutch students and asked them to select feminine materials, the selected materials would probably be different. Similar to the diamond example, I found out that the tutor of the materials and design course had mentioned aerogel very briefly in one of his lectures a few months ago. In this case, the students' background and expertise was effective in the selection of futuristic materials.

It was also interesting to find that seven properties were significantly effective in the attribution of the meaning cozy to materials. This result shows that the meaning evoking patterns for the coziness of a material is very apparent for the Greek students and it is very much related to certain sensorial properties of materials. On the other hand, in the selection of futuristic materials the main motive was the technical (or functional) superiority of a material. For the feminine materials, shape (such as the material of a flower like home audio), function (such as the material of a high-heeled shoe) and the certain sensorial properties of materials (such as glossiness and reflectiveness) played an important role. The strange materials had some unexpected properties which conflicted with the students' expectations from a particular material regarding its strength, weight, etc. (e.g. a material which looks very fragile but very durable and strong, or a material which looks very heavy, but very light in reality). Ludden (2008), in her PhD thesis, explains this phenomenon with 'sensory incongruity' which occurs when, for example, an individual sees a product and forms an expectation about how it will feel, hear and smell on the basis of its visual properties and on his/her previous experiences. If this expectation is disconfirmed upon perception through a second sense (such as touch), the information from the two senses is incongruent. As a result, people experience surprise.

A handout and a poster consisting of the results obtained from Task 1 were prepared to be used in Task 3.

1st Day of the Workshop

Task 2

The first day of the workshop started with the introduction lecture mainly focusing on the effects of materials on the design domain and on different societies (based on Chapter 1). 130 students attended to the first day. We discussed the values of different materials in Greek culture and their differences from other cultures. Then the focus was converted to the materials selection in industrial design. We evaluated the existing materials selection sources with a number of examples from these sources. The students talked about their own selection processes, their needs and expectations from a materials selection source. The conclusion of this preliminary session was that the existing materials selection sources were very adequate for the technical materials selection. However, in order to be able to use these technical sources efficiently, the students first need to identify their objectives and constraints regarding technical and sensorial properties of materials. The question was 'how do we decide to use, for instance, a 'transparent, hard and smooth material' for our design?

Task 2 was 'to design a sitting element' (e.g. a chair, a stool, a sofa, an armchair, etc.) for Greek university students. The students were divided into four groups. Each group was given one of the meanings used in the first task. They were informed that their sitting element should express the given meaning. However, a particular emphasis should be put on the material decisions. The chair in Figure 8 was shown to students and explained that the chair looks strange mainly because of its structure. The legs of the chair look as if they are not able to carry a load. Therefore, the chair looks strange as it is meant to be a chair but cannot fulfill its utility function. In that sense, the chair was not a good example for the given task, because the material was not really contributing to the main idea/ meaning tried to be achieved.

The students were told that they could make their own groups (max 3 students) for this task. They were asked to make sketches and select a final concept out of them. They were also asked to write the profile (the sensorial and technical properties) of the material(s) they selected and explain their selections. They were recommended to focus on these two questions during the brainstorming session:
- what kinds of materials (or material properties) can evoke the given meaning for the target group (Greek university students)?
- what are the other product aspects which can be effective in the creation of the given meaning?
They were allowed to make mock-ups to present the selected material(s) more efficiently. They were given two hours to complete the task.

Results: Task 2
After submitting their designs (mostly in sketches, only 1 mockup), the students were asked to explain the process. They mentioned that they had difficulties to find where to start, and how to integrate the materials selection into the whole design process. They had difficulty to find the relationships between the given meanings and the material properties (particularly for the meaning strange) as they were not to use to select materials in this way. In addition, they said that they hardly think about a target group's approach about a particular material. Some of the students were not confident with their final material decisions.

Figure 8. Example of a strange product.

Task 3
After discussing the difficulties the students faced in the first task, the second part of the lectures started. This time the focus was on 'how do materials obtain their meanings?' (based on Chapter 2 and 3). The students were introduced with the MoM Model and the main idea behind the MoM Tool (Meaning Driven Materials Selection). Before given the last task (Task 3) the results of the first task were presented to the students (Figure 1,3,5,7). They were very excited to see the overall evaluation of the task and what kinds of materials had been selected by the other students. The handouts consisting of the selected materials, individual explanations and the overall evaluations of the sensorial scales were delivered to the students; and the last task was given.

Task 3 was to go through the selected materials and try to understand the given meaning-material relationships for their target group (that is, for Greek university students). The main question of this task was: *when does this target group think that a material is cozy/feminine/futuristic/strange*? They were asked to focus on the MoM Model and try to find the links between different aspects of products and materials (i.e. finding out the meaning evoking patterns). On the basis of the identified patterns, they were asked to improve (or redesign) their sitting element which they submitted in the second task. The students were allowed to use 3D modeling/rendering programs in this task. They were asked to complete their submissions until the next morning (Second Day of the Workshop).

2nd Day of the Workshop: Results of Task 3

On the second day of the workshop, we made an exhibition with the submitted projects. The groups presented their designs and explained the materials they selected. In total, 37 projects were submitted. The most important observations of **Task 3** were as follows:

(1) In general, the reactions of the students to the process were very positive. They enjoyed the meaning driven materials selection and found it very inspiring and useful to consider the materials experience in a very early phase of a design process. The selected materials and explanations helped them to identify their main constraints and objectives in terms of material properties as well as shape and use. They found the process particularly valuable to create ideas for combining different materials.

(2) Some students were very surprised to see that their own thoughts about a certain material-meaning relationship were completely different from the rest of the students. In this sense, they realized the value of understanding their target group's approach about materials and their values.

(3) Five groups found that their material decisions in Task 2 were comparable to the results obtained from Task 1. They mentioned that they felt more confident with their selections in Task 3, after seeing the results of Task 1.

(4) Task 3 encouraged many students to explore the most appropriate materials fulfilling the sensorial and technical requirements identified based on the result of Task 1. They used CES (Cambridge Engineering Selector) and some other online databases to find the materials with the identified properties. In addition, some materials selected in Task 1 were not very well-known for some students. A student, for instance, explained that "*I saw carbon fiber reinforced polymers selected by one of my friends in the first task. I liked the appearance of the material in the picture, but most importantly, according to the student's explanation, this material was very strong. I wanted to use it in my design. But I realized that I first need to know how strong and durable it was for making a sitting element.*" Therefore, the student made a further search about carbon fiber reinforced polymers and their applications. Likewise, another student read more about aerogel material in order to understand if she could use it to make a chair. Thus, the meaning driven materials selection stimulated students to explore other materials selection sources for detailed material information.

(5) One of the most important observations from the workshop was that the students were able to see the patterns for evoking the given meanings. They could see how certain aspects play a more crucial role than the others for each meaning. For the meaning feminine, for example, the students emphasized the value of shape-material combination. A group of students, who designed a feminine chair, tried several material combinations in order to find the best shape-material match expressing femininity. They mentioned that the results of the sensorial scales were very helpful to find the points to focus on. The students who designed for the meaning strange were able to detect what makes a material/product strange for Greek students. One of the students explained that "*if a material is very light but still can carry you very efficiently, you think that it is strange. Therefore, in my design, I looked for a very light but at the same time a very strong material which carries high load. Moreover, if the form also emphasizes its lightness, I guess you achieve to create a strange sitting element*". The student explained that she had been inspired by aerogel, which had been found strange by most of the students as it was very light but very strong, and by the form and structure of the polyurethane chair (Figure 7_4C). Similar to this example, another group designed a chair made of polypropylene but formed it in a way that the material looks very soft, like a cushion.

(6) The workshop encouraged students to think about multi-sensory design in their material

decisions. They mentioned how their designs gratify senses in different ways. One group, for instance, designed a feminine armchair which was made of metal legs and polyurethane body covered with velvet. At first glance only the color of the chair (which was light purple) was connoting femininity, but not the form. However, the main idea of the armchair was that it was releasing a female perfume when someone sits on it. The group emphasized the importance of 'touch' and 'smell' in products for creating the meaning feminine (velvet was stimulating the sense of touch and odorous of the armchair was stimulating the sense of smell). In other words, the group was successful to convert the main idea by particularly focusing on the sensorial properties of materials. The group explained that they were inspired by the selected perfume bottles and the velvet armchair in Task 1.

(7) It was noticeable that every group was inspired by a different case(s) (results of Task 1). Albeit there were a number of diamonds selected in Task 1, only one group designed a feminine sitting element using diamond. Instead, some groups tried to create associations through glossy and transparent materials; and some of them focused on completely different cases. This showed that even though a particular material dominates the 'material collection', designers still find other cases to inspire, they weight up the consequences of their selection and think about other selected materials instead of sticking to the most dominant selection (e.g. the students used sateen, velvet, leather, Plexiglas, marble, silk and metal in their feminine sitting elements). One group who designed a strange armchair used paraffin wax (used for making candles). The material was not one of the collected strange materials. However, the group explained that "*we saw in some of the examples that using a well-known material in a completely different context can be found very strange, such as an armchair made of cork (Figure 7_3D) or a coffee table made of leather (Figure 7_6A)*".

(8) A negative point was observed during the workshop. Two groups (in total 6 students) tended to stick very strictly to the results of the sensorial scales. They felt obliged to focus on these results in their material decisions. After discussing the projects exhibited on the second day, they realized that they did not have to use the results of the scales. The main idea aimed to be conveyed through the scales was to help students (designers) to identify the meaning evoking patterns regarding their target group. They understood that the intention was not to offer them 'definite' solutions for a particular material-meaning relationship, but to help them in identifying their constraints and objectives by taking their target groups' approach into account.

General Discussion: Workshop in Greece

This workshop was an important attempt to test the usefulness of *meaning driven materials selection* in design education. We saw that the principle of 'meaning driven materials selection' can be adapted within design education and can complement the teaching of technical based selection. We also saw that the proposed method of meaning driven materials selection did not only enhance the abilities for quick and appropriate materials decisions but also increase the creativity of students. It was a pleasant surprise to see that the students were also more encouraged to search about the technical properties of materials and find new materials or new application techniques for their designs. This result has strengthened the idea of integrating the MoM Tool to a technical materials selection tool (such as CES).

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Finally, my love, askim, liefje, Jaap;
Reason is powerless in the expression of Love * … I love you.

* Mevlana Celaleddin Rumi (1207-1273)

About the Author

Elvin Karana was born on the 20th April 1979 in Ankara, Turkey. She commenced her bachelor degree in 1998 at the Industrial Design Department, of the Middle East Technical University (METU). In 2002, Elvin completed her studies with a 'high' honours degree, coming top in her year. During her studies she won two design awards*. She progressed onto her masters studies as a research assistant and assisted in a 'materials and design' course within the same department. Next to her academic activities, she worked as a consultant designer for an architecture company and designed an interior and corporate identity of a café in Ankara. In January 2005, she commenced her doctoral research at the Design Engineering Department at TU Delft. During her PhD, she presented her research at a number of international conferences and gave workshops on 'meanings of materials'. She got the best paper award in the 1st Kansei Engineering and Emotional Research Conference held in Japan in 2006. She took place in the organizing committee of 4th International Design and Emotion Conference (Ankara, 2004), Meeting Materials (Gent, 2006) and the International Conference on Tools and Methods for Competitive Engineering (TMCE) (Izmir, Turkey 2007). She currently works as a lecturer and researcher in the Design Engineering Department at TU Delft.

After becoming a part-time student in a conservatorium for a year at high school, she joined the Classical Turkish Music Club at university and was a chorist and soloist for seven years. She actively took place in the club management, and lead the design team of the 'communication' board for five years. In her last year at METU, she gave solo concerts and represented the METU chorus as a soloist on national TV (TRT). Now living in the Netherlands, she sings for select audiences, only for friends.

* The highest award in the YKK Fasteners Competition, the 4th award in Cimsa Cement Street Furniture Competition.

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