Express your material self:
Experiential material characterization in product design

Doctoral Dissertation by Lore Veelaert

Universiteit Antwerpen

Faculty of Design Sciences
Department of Product Development

Express your material self:
Experiential material characterization in product design

Proefschrift voorgelegd tot het behalen van de graad van Doctor in de Productontwikkeling aan de Universiteit Antwerpen te verdedigen door Lore Veelaert

Promotor(en):
Ingrid Moons
Els Du Bois

Antwerpen, 2022

Doctoral Jury

Prof. dr. Patrick De Pelsmacker – University of Antwerp (Belgium) – Chair
Prof. dr. Ingrid Moons – University of Antwerp (Belgium) – Supervisor
Prof. dr. Els Du Bois – University of Antwerp (Belgium) – Supervisor
Prof. dr. Elvin Karana – Delft University of Technology (the Netherlands) – Committee member
Prof. dr. Kim Ragaert – Maastricht University (the Netherlands) – Jury member
Prof. dr. Cees de Bont – Loughborough University (United Kingdom) – Jury member

About the cover
'De klimmers.'
Cover art by Greet Simons
Cover photograph & Graphical design by Lore Veelaert

ISBN **97890-5728-735-0**
Depotnummer: **D/2022/12.293/07**

Disclaimer

"We don't see things as they are,

we see them as we are."

Anais Nin (1961)

GLOSSARY

Aesthetic Experience	The appreciation of beauty by the consumer; refers to the pleasure that the appearance or look of a product can evoke independent of its utility.
Attribute	This term is used to refer to the *sensorial attributes* of materials, as part of a material's experiential qualities.
Characteristic	This term is used to refer to the *interpretive and affective characteristics* of materials, as part of a material's experiential qualities.
Consumer innate innovativeness	The importance people attach to buying new products at an early stage rather than remaining with previous choices and consumption patterns.
Designerly	'*Designerly ways of knowing'* was first posited by Nigel Cross (Cross, 1982). It links both design education and design research. It "traces the development of a research interest in articulating and understanding the nature of design cognition, and the concept that designers (whether architects, engineers, product designers, etc.) have and use particular 'designerly' ways of knowing and thinking" (Cross, 2006, pp. 15–27).
Environmental concern	Reflections of a single, broad environmental attitude (one's attitudes toward specific environmental topics).
Experiential characterization	Refers to the process by which we reveal the experiential material qualities; it concerns investigating how a material is received, what it makes people think, feel and do.
Experiential quality	Refers to the distinct nature of materials as received, described, and acted-upon by people (e.g. sensorial attributes, interpretive characteristics, affective characteristics, and performative actions).
Green self-identity	An individual's overall self-perception based on his/her mental identification with the typical green consumer.
Individual self-expressive values	Psychographic consumer characteristics that relate to the way people tend to express themselves.
Material perception	This term refers to the process of representing appearance changes rather than the estimation of internal parameters. When we look at an object and experience a vivid subjective impression of its material properties, we are not actually perceiving its physical properties at all. Instead, it is a set of appearance characteristics - i.e., properties of the way the material tends to appear in the image - that capture its distinctive 'look' (Fleming, 2014, p. 73).

Materialism	The importance a consumer attaches to worldly possessions; the importance ascribed to the ownership and acquisition of material goods in achieving major life goals or desired states.
Materials experience	The experiences that people have with, and through, the materials of a product (Karana et al., 2008b).
Meanings of materials	Expressive/semantic and specific associative characteristics, both of which are used for defining the qualities of materials. It are what we think about materials, what kind of values we attribute after the initial sensorial input in a particular context (Karana, 2010, p. 275).
Multisensory	This term refers to the integration of information that is obtained through different sensory modalities, such as vision and touch.
Personal values	Beliefs that lead to end states or behaviour that are desirable, and that vary in importance or priority; motivational goals that transcend specific situations (cfr. *Schwartz end values*, *human values*).
Personality traits	Describe what people are like, they reflect people's patterns of thoughts, feelings, and behaviours (cfr. *Big Five, Five-Factor model*).
Product attachment	The strength of the emotional bond that a consumer experiences with a durable object (Schifferstein & Zwartkruis-Pelgrim, 2008).
Product experience	This term is used to refer to "the entire set of affects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning) and the feelings and emotions that are elicited (emotional experience)" (Hekkert, 2006, p. 160).
Property	The mechanical and physical properties of materials are determined by their chemical composition and their internal structure, and the forces applied; these properties are measurable or observable (e.g. *technical properties*).
Self-identity	How one sees him/herself as occupant of specific roles.
User-centred design (UCD)	In user-centred design processes, designers involve users throughout their iterative design process by means of various research and design techniques, in order to focus on the needs of these users.

TABLE OF CONTENTS

GENERAL INTRODUCTION

0. General Introduction

This Section introduces the background and topic of this doctoral dissertation. It is situated in the field of experiential material characterization within product design, and approaches this subject from two perspectives. On the one hand, it involves the perspective of consumers as performers of the experiential characterization. On the other hand, it involves the perspective of designers as decision makers on materials and products, and as the creators of intended product and materials experiences. Therefore, this introduction covers topics such as experientialism, product experience, materials experience, sensory science, experiential material characterization, and materials experience within a circular economy. In addition, it explicates the research aims, the research questions, and the outline of the thesis.

0.1 Materialism versus Experientialism

The importance of experiences in the daily lives of people is widely acknowledged (Schmitt et al., 2015), and both experiential aspects (Hirschman & Holbrook, 1982; Holbrook & Hirschman, 1982) and material aspects (Belk, 1985; Richins & Dawson, 1992) of purchase and consumption have been studied in consumer psychology for the past decades. Schmitt et al. (2015) state that there is a false dichotomy between the two constructs of material and experiential purchases: "Instead of viewing material possessions and experiences at two opposite ends of a continuum, we propose that any purchase that results in consumption may be viewed and judged by the consumer along two value-creating dimensions. The two dimensions are (a) materialism—the value created for the consumer based on the perceived material and monetary aspects of the purchase and consumption—and (b) experientialism—the value created based on the perceived experiential aspects of the purchase. In other words, consumer experiences have both materialistic and experiential components". Moreover, happiness and accompanying psychological value can be derived from both these components. Two distinct happiness outcomes can be distinguished, namely the hedonic path or pleasure-based happiness, and the eudaimonic path or meaning-based happiness. The first path is suspected to be more predicted by the materialism dimension and the eudaimonic path by the experientialism dimension (Schmitt et al., 2015).

0.2 Product Experience

Nowadays, we are living in a world with an abundance of products available. Moreover, for each product, an excessive number of options is at our disposal to choose from. Each of these options has similar technical specifications. Think of smartphones, televisions, cars, food processors, irons, and so on. Thus, how do consumers choose one model of a product to actually buy? Karana et al. (2014, p. xvii) articulate that the answer concerns value: "A product has a cost – the outlay in manufacturing and marketing it. It has a price – the sum at which it is offered to the consumer. And it has a value – a measure of what the consumer thinks it is worth. Consumers buy products that they perceive as having a value (to them) that most exceeds their price." There are three aspects that determine value, that lead to successful product design, and that can be seen as forming a product's character: **functionality, usability, and satisfaction**. First of all, a product should function properly and safely. Second, a product should be easily understood and handled. Third, a product should augment the user's life, and give satisfaction and pleasure. Certainly, in order to please demanding consumers, products need to fulfil both functional and hedonic user needs (Bloch, 1995; Hassenzahl, 2003, 2010; Hekkert, 2006; Krippendorff & Butter, 2007; Norman, 2004).

With regard to user experience and product experience, multiple publications can be found that report similar characteristics of experiences (Desmet & Hekkert, 2007; Hassenzahl, 2013; Schifferstein & Hekkert, 2008): (i) experiences are inherently subjective, (ii) product experience arise in interaction with a product, (iii) experiences are affected by personal and situational factors, and (iv) experiences develop or change over time (Karana et al., 2014, p. 5). In their affective **product experience framework**, Desmet & Hekkert (2007) and Schifferstein & Hekkert (2008) distinguish three types of experience: **aesthetic experience, experience of meaning, and emotional experience**. First, the aesthetic experience reflects to what extent an artefact delights our senses. Second, the experience of meaning concerns the attribution of characteristics to artefacts. Third, the emotional experience appears when goals are attained or violated. Principally, these emerge as three components of a single experience, and may be difficult to separate from each other as they relate to and affect each other. Nonetheless, in regard to their underlying process, these three components can be disconnected from a conceptual perspective.

0.3 Pathway Towards Materials Experience

Sensing a product is fundamental in the user-product interaction, and is empowered by the appearance of the product, namely its form and materials (van Kesteren, 2008). Materials are "the substance through which designers' intentions are embodied"(Hodgson & Harper, 2004), they form "the visual and tactile interface with the world around us" (Pedgley et al., 2021, p. 94), "we interact with materials through products, and it is through the senses that we experience materials" (Karana et al., 2014, p. xix).

The work of Manzini – "The Material of Invention" – (1986) is considered as the first milestone that emphasized the important role of materials – and its aesthetics – in design to create positive and meaningful experiences, and the necessary designerly competences to select materials.

Only decades later, in 2002, Ashby & Johnson (2002) published the first textbook with an interdisciplinary and "**designerly**" view of the materials world, that highlighted both technical properties from an engineering perspective and aesthetic attributes (originating from sensorial properties), perceptions, and intentions from a product design perspective. Moreover, they underlined the two overlapping roles of materials that should be considered in the materials selection process; that of "providing technical functionality while creating product personality" (Karana et al., 2014, p. xxvi).

Around the same time, Doordan (2003, p. 3) issued "how the material employed affects the form, function, and perception of the final design" and disclosed a three-fold **framework on fabrication, application, and appreciation** of materials, of which the latter term started to expand and gain more attention in the domain of materials and design.

From that moment, a significant rise of design research began, concerning (sub)topics such as materials selection, material sensory qualities, meanings, emotions, user experience, design education, etc. For example, the dissertations of Desmet (2002) on Designing Emotions, of Zuo (2003) on Sensory Interaction with Materials in Product Design, of Rognoli (2004) on the Expressive-Sensorial dimension of materials, of van Kesteren (2008) on Selecting Materials in Product Design, of Karana (2009) on Meaning of Materials, of Wastiels (2010) on Material Experience in Architecture, of Hasling (2015) on Learning through Materials, of Asbjørn (2018) on a Material Framework for Product Design, and further contributions of Zuo et al. (2001) on sensory properties of materials, of Miodownik (2007) on sensoaesthetic materials, of Karana et al. (2015) on material driven design, of Wilkes et al. (2016) on interdisciplinary translation of materials experiences, of Pedgley et al. (2016)

on materials experience in design education, and many more (Arabe, 2004; Crilly et al., 2004; Fisher, 2004; Ljungberg & Edwards, 2003; Sonneveld, 2007).

The actual introduction and definition of the term "materials experience" occurred in 2008 when Karana et al. (2008b) described it as "the experiences that people have with, and through, the materials of a product". Thus, "materials experience acknowledges and emphasizes that – by shaping what we feel, think, and do – materials have the power to foster meaningful experiences" (Karana, Pedgley, et al., 2015, p. 19).

Finally, over the years, two comprehensive books have been published on materials experience, gathering all insights on this subject and several subtopics: Materials Experience – Fundamentals of Materials and Design (Karana et al., 2014), and more recently, Materials Experience 2 – Expanding Territories of Materials and Design (Pedgley et al., 2021).

0.4 Materials Experience Framework

Being inherently physical, materials are the substance that allows user-product interaction, as a product cannot even exist without materials. Therefore, the foundational model of product experience (Desmet & Hekkert, 2007) was translated to materials experience (Karana & Hekkert, 2010). This understanding merges aesthetic experiences granted by materials with meanings evoked by materials as well as with emotions elicited by materials (Karana, Pedgley, et al., 2015).

First, **aesthetic (sensorial) experience** refers to the "pleasure attained from sensory perception" (Hekkert, 2006, p. 159; Hekkert & Leder, 2008), and can involve multiple sensory modalities at once (Schifferstein & Wastiels, 2014). For example, a material can be perceived as glossy, cold, and hard. Second, **experience of meaning** refers to what a material represents to us, what we think of it, and the values attributed to it following the sensorial intake. Meanings are rooted in our sensory perception. Karana et al. (2015, p. 21) state that "this attribution happens as a result of a dynamic action between the user and the material embodied in an artifact". For example, a material feels cosy or looks professional. Third, **emotional experience** refers to how a material makes us feel (Desmet, 2010). It are the qualities of a material (Crippa et al., 2012) that determine the visceral level of emotions and reactions (Norman, 2004). For example, a material can surprise (Ludden et al., 2008) or disgust us.

Originally, materials experience was constituted of these three experiential levels. However, in 2015, another level was added, leading to a **four-level framework for materials experience** (Giaccardi & Karana, 2015). In addition to the experiential material qualities of **sensorial** attributes, **interpretive** characteristics (meanings), and **affective** characteristics (emotions), the level of **performative** actions was included. This framework "emphasizes that a comprehensive definition of materials experience should acknowledge the active role of materials not only shaping our internal dialogs with artifacts, but also in shaping our ways of doing" (Pedgley et al., 2021, p. 3). Indeed, it allows to interpret materials through a dynamic interactional lens, and explores what actions materials make us perform. For example, a material can invite us to stroke or fold it.

Obviously, these four experiential levels of material qualities are "highly intertwined, subjective, time- and context-dependent" (Karana, Pedgley, et al., 2015, p. 21), and as such are difficult to be seen apart from each other, to study them, to make them measurable. Moreover, aspects such as time, use contexts, cultures, and individuals, modulate these interactions between users and materials.

0.5 Sensory Sciences

The study of sensorial experience (i.e. sensory science) has its roots in food and consumer science (Varela & Ares, 2012), where sensory profiling was developed to evaluate drinks and food. These experiences are the drivers behind the behavioural response of consumers and are linked to other experiences such as feel, think, and act (H. T. Chen & Lin, 2017), in line with the four experiential levels of materials experiences. With regard to its evaluation, it comprises methods to measure both the sensory product perception of consumers, and the emerging affective and behavioural responses. In non-food industries, this is also defined as "sensory metrology" (D'Olivo et al., 2013; Pense-Lheritier et al., 2021).

> *"First and foremost, it is important to realize that the sensory properties we aim to measure result from the interaction between the object and the perceiver of that object (the consumer). Thus, any sensory measurement depends on both the product to be evaluated and the person that evaluates the product. In this regard, the very term "sensory property" is somewhat misleading as it implies that it is a property of the product solely and that it could be accessed independently from human assessment. In other words, sensory measurements are literally subjective: they depend on the subjects who perform the measurement. However, it does not mean that sensory measurements are unreliable. Au contraire!"* (Pense-Lheritier et al., 2021, p. 18)

0.6 Experiential Material Characterization

> *"There is a character hidden in a material even before it has been made into a recognizable form – a sort of embedded personality, a shy one, not always visible, easily concealed or disguised, but one that, when appropriately manipulated, can contribute to good design."* (Karana et al., 2014, p. xx)

> *"The materials moderate the product judgement. We are not suggesting that the materials themselves, when isolated, do not evoke meanings. (They certainly can and do). Rather, we are saying that in the context of an application, the material appraisals are made with regard to how that application is enhanced or undermined through the choice of materials."* (Karana, Pedgley, et al., 2015, p. 22)

When a material is considered as an "actor" that can adopt particular personalities and play different roles that are assigned to it when applied in a product, designers need expertise on how to predict and define not only the performance qualities, but also the experiential qualities of materials. This way, they can gain insight in the patterns of material-meaning relationships (Karana & Hekkert, 2010).

To that end, Camere & Karana (2018) developed the **Ma2E4 toolkit** (Materials-to-Experiences at four levels) to facilitate experiential characterization of materials through user studies. As a foundational structure, the toolkit builds upon the four experiential levels: **sensorial**, **interpretive** (meanings), **affective** (emotions), and **performative** (actions, performances) (Giaccardi & Karana, 2015). The tool is intended to be specific – reflecting on the individual levels – as well as holistic – reflecting on the links between the four levels. Concerning the vocabulary for the toolkit, sensorial scales by (Karana, 2009), validated by (Karana, 2009), and adapted by (Sauerwein et al., 2017), were included, as well as 22 meanings for the interpretive characteristics (Karana, 2009). For the affective level, 20 positive (Desmet, 2012) and negative (Fokkinga, 2015) emotions were validated and selected to be evaluated over two dimensions, that of arousal (i.e. level of intensity) and valence (i.e. pleasant versus unpleasant) (Russell, 2003). The novelty of the Ma2E4 toolkit is in the inclusion of 22 performative material qualities in terms of moving, touching and holding the material (Angelini et al., 2015; Karana et al., 2016).

However, with regard to a holistic experiential characterization of materials in product design, which takes all four experiential levels into consideration, the tools and methods are still limited. Moreover, they do not elaborate on the physical means or material representations to study materials experience. Thus, a large gap is detected concerning how "to translate subjective experiences of materials into data" (Wilkes et al., 2016, p. 1229). This way, equivalent support and inspiration for experiential material qualities can be made available, as there is for technical material properties that are correlated with standard, established procedures (Piselli et al., 2018).

0.7 Importance of Materials Experiences in a Circular Economy

As designers, we have the responsibility to reflect on environmental concern and to transition towards a more sustainable and circular economy (Pedgley et al., 2021). Building further upon the importance of materials as an interaction medium, they have a significant impact on product attachment and as such on its longevity of usage. With regard to materials experience in design for sustainability, literature refers to terms such as "aesthetics of sustainability" (Karana, Pedgley, et al., 2015), "aesthetics of environmentally sensitive products" (Walker, 1995), "total beauty" (Datschefski, 2001), "green aesthetics" (Saito, 2007), and "sustainable beauty" (Hosey, 2012). Several material expressions are found that can be emphasized for this matter: naturalness (Overvliet & Soto-Faraco, 2011) and high-quality (Overvliet et al., 2016), imperfection (Ostuzzi et al., 2011; Salvia et al., 2011) and graceful ageing (Rognoli & Karana, 2014). All in all, several strategies can be employed to design longer-lasting products by accentuating different experiential material qualities (Chapman, 2021; Karana et al., 2017), such as the encouragement of appropriate behaviours (e.g. to keep for longer and to care for) (Karana, Pedgley, et al., 2015).

Well-known and traditional materials often carry meanings that are grounded in sensorimotor experience and can be considered universal – such as wood that is warm to touch and is accordingly perceived as cosy or inviting – or materials that are predominantly used in a specific context can be associated with learned meanings (Karana et al., 2014). However, new or alternative materials encounter difficulties in their adoption and acceptance as their meanings still need to be discovered and learned, before they become intrinsic over time (Pedgley et al., 2021).

A particular example that will be referred to throughout this thesis, is the case of plastic materials. In the 20th century, plastics were introduced as new materials, and many new types have emerged over the last decades – and are still emerging now – including recycled plastics and bio-based plastics. Their image has been changing over time, from cheap, inauthentic, toxic and low-quality materials, to materials being widely used in products (e.g. medical) that require high quality and hygiene, and to materials that are the cause of multiple environmental problems and waste (European Commission, 2017; Karana et al., 2014), and consequently, to being perceived as unsustainable and sometimes even reprehensible.

0.8 Research Questions

Overall, a technical-experiential imbalance and knowledge gap is detected with regard to material knowledge and experiential material data available. In addition, Pedgley (2014) emphasizes that product design is a user-centred discipline, putting the focus on the study of people and their relationship with materials, as opposed to the study of merely materials on their own. Therefore, the foundations of this thesis lie in the integration of people (**consumers**) and experiential material characterization, with a focus on the **physical representation** of materials and on the specific case of **plastics**. Hence, the overall research question is *how to capture the way consumers and end-users experience materials*, and the four main research questions that will be addressed in the four parts of this thesis are:

- *What is the state of the art of experiential material characterization in product design?*
- *How can research on experiential material characterization be improved by means of an appropriate demonstrator form?*
- *How can user/consumer aspects be involved more extensively in experiential characterization of materials?*
- *What does an integrated framework for future experiential material characterization look like?*

In addition, plastics were chosen as focus material because (i) a great percentage of daily consumer goods contain plastic materials, (ii) Flanders is home to the largest integrated chemical cluster of Europe (Essenscia, 2020), and (iii) plastics are very versatile, chameleon-like materials that can be easily moulded, can have many different properties in terms of colour, transparency, flexibility versus stiffness, etc., and can take on many characters.

0.9 Thesis Outline and Research Aims

This thesis presents my research into experiential characterization of materials in product design. The main theoretical contribution of this thesis lies in the integration of physical representations of (plastic) materials with consumer segmentation in characterizing the experiential qualities of materials. The specific aims of this doctoral thesis are:

- To conduct a **systematic literature review** on experiential characterization studies in the materials and design domain, in order to summarize the current state of the art, to formulate an overview to facilitate systematic studies to explore experiential qualities of materials, and to identify gaps or opportunities for further research.
- To develop a standardized physical **material demonstrator form** for experiential material characterization by consumers, with plastic materials as a starting point.
- To get insight into meaningful **consumer segments** that differ in terms of material perception preference, based on various traits and values related to self-expression.
- To formulate **guidelines** to systematically set up experiential material characterization experiments (i) with plastic demonstrator forms and (ii) by consumers.

The thesis consists of four major parts. The first part offers insight in the world of experiential characterization studies in the materials and design domain, and the methodological challenges involved in studying materials experience. It reveals learnings on six needs for future research. The second part focusses on one of these needs, and explores the appropriate physical representation of materials for experiential characterization studies. The third part focusses on the need of including extensive user aspects, and examines how consumers can be clustered in meaningful segments that prefer different material qualities. The fourth part includes a conclusion on how to set up experiential material characterization experiments based on the previous findings, as well as a reflection on the research done, theoretical and designerly conclusions, and suggestions for future research.

This thesis contributes to the way design researchers can continue materials experience studies and systematically gather experiential material data. They can build upon a segmentation survey and four clusters to integrate user aspects, and they can employ a dedicated demonstrator form as a standard representation of plastic materials. In addition, the integration of material demonstrator forms in a material library, can help designers in physically exploring and comparing materials for their designs, and in experiencing the potential materials experiences first hand.

Figure 0.1 visualizes the structure of these four parts, their chapters, and the research questions involved.

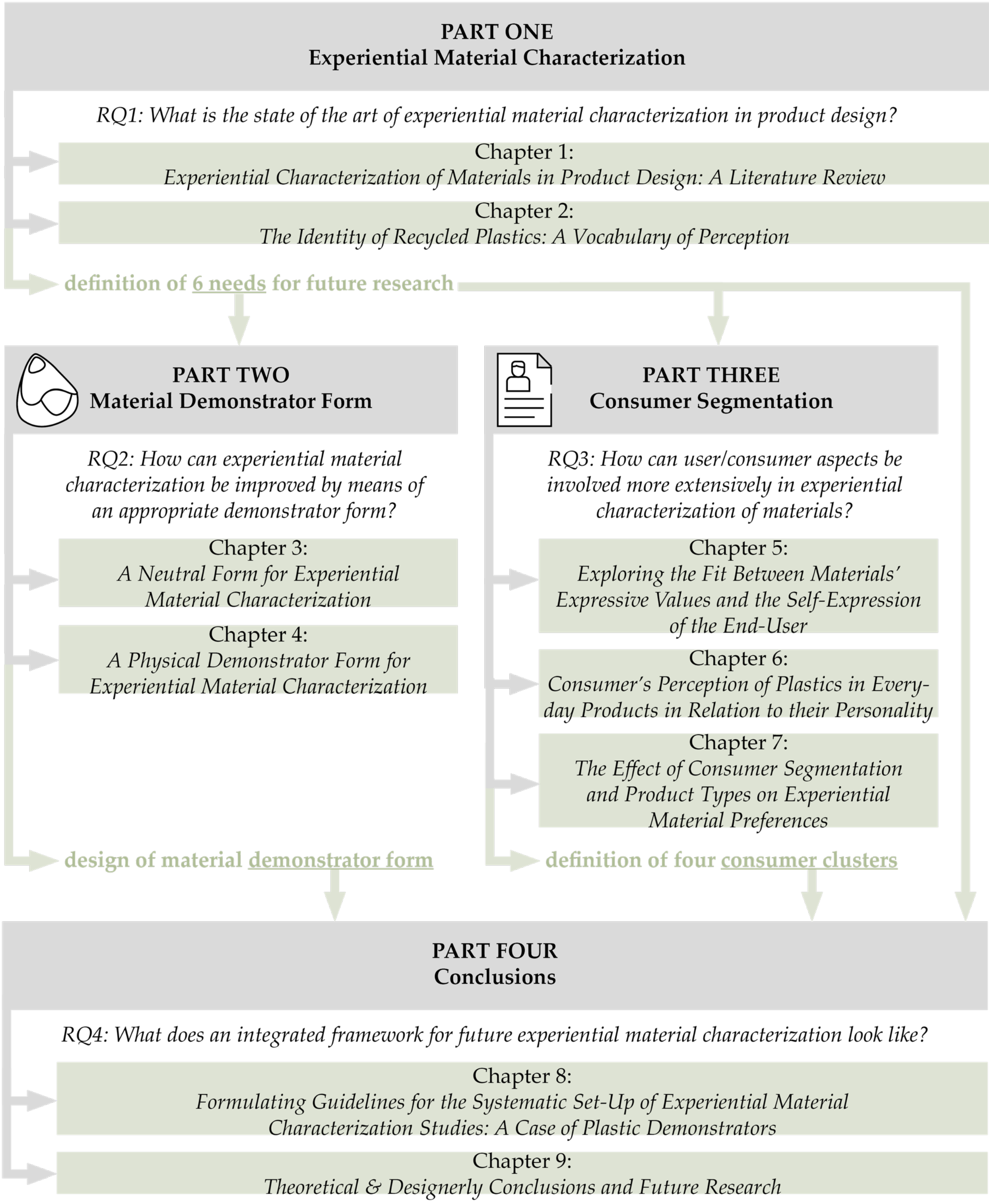


Figure 0.1. Visualization of the overview and structure of the doctoral dissertation.

PART ONE deals with the state of the art concerning experiential material characterization. In **Chapter 1,** an extensive *literature review* is presented of 64 cases of experiential characterization studies in the materials and design domain. This overview aims to facilitate systematic studies to explore experiential qualities of materials and to identify gaps or opportunities for further research. The learnings within this chapter involve several methodological aspects of materials experience studies, such as the variables, stimuli, interaction modalities, experimental set-up, methods, and respondents. Two main gaps are identified which serve as the basis for the next parts of this thesis: physical material representations in an abstract form for multimodal material characterization experiments (see PART TWO), and integration of extensive user aspects to facilitate consumer segmentation (see PART THREE). This review is published in the article "Experiential Characterization of Materials in Product Design: A Literature Review" in Materials and Design.

Chapter 2 discusses a specific case of a *semi-quantitative, experiential material characterization study*, namely of three exemplary and high-quality post-consumer recycled plastics that are materialized in standard stimuli forms, i.e. flat plates. This case links with the domain of emerging sustainable materials, and aims to understand how recycled plastics are perceived and appraised by stakeholders involved in the front-end of the design process, i.e. material engineers and designers (n=60), as an essential condition for successful adoption and application in practice and within a circular economy. Building upon semantic experiential scales as discussed in Chapter 1, this study underpins the potential of this evaluation method, as well as the analysis and challenges involved when characterizing materials by different users, especially plastics. These results are published in the article "The Identity of Recycled Plastics: A Vocabulary of Perception" in Sustainability, and as an abstract in the proceedings of the European Marketing Academy (EMAC): "Front-End Marketing for Recycled Plastics: The Role of Experiential Material Evaluation".

PART TWO focusses on the need for a standardized physical material demonstrator form that triggers consumers in holistic multimodal interactions, while minimizing the interference with product (function) and context associations, as discussed in Chapter 1.

First, **Chapter 3** explores the conception of neutrality to create meaning-less or "neutral" demonstrator forms to objectively compare materials. In a *pre-study* with designers (n=20), six pairs of interpretative characteristics are selected as neutrality criteria, and shaped in 240 forms by designers and non-designers (n=20) in the *main study*, and finally reworked to four averaged neutral forms, following a framing methodology of *Research By Design*. It concludes, however, that more complexity and interactivity is needed to trigger consumers in interacting with material demonstrators for more extensive material exploration. The paper "A Neutral Form for Experiential Material Characterization" is published in the proceedings of the Design Society: International Conference on Engineering Design (ICED 2019).

Therefore, **Chapter 4** resumes the search for an appropriate demonstrator form by means of a stepwise and *mixed method methodology* consisting of six *qualitative and quantitative studies* with form experts (n=5), designers (n=18), and consumers (n=302, n=61, n=57). This chapter aims to develop a standard, complex form or material demonstrator that is suitable for experiential material characterization by consumers through enabling tangible and rich interaction with materials. Therefore, differences are tested in effectiveness of consumers assessing (sensorial and interpretive) experiential material qualities by means of a specific 3D form compared to a conventional flat plate sample. Conclusively, the proposed demonstrator form is found more appropriate for experiential material characterization than a standard flat plate. As a result, designers or design researchers can benefit from this demonstrator when they conduct consumer research. Moreover, it offers potential for generalizability within the field of materials experience. The article "A Physical Demonstrator

Form for Experiential Material Characterization" is in press in the International Journal of Designed Objects. The demonstrator form and mould are registered as Non-Written-Output at the University of Antwerp's library.

PART THREE deals with the need of Chapter 1 of including more user aspects in experiential material characterization. It investigates how consumers can be clustered in meaningful segments that prefer the same material qualities and differ in this preference with other segments. Leading up to a large-scale survey, two explorations are carried out from the perspective of individual self-expressive values based on personal values as well as on personality traits.

First, **Chapter 5** aims to explore possible relationships between materials, their expressive value, and their link with individual self-expressive values. Two *pre-studies* with designers (n=20, n=16) and a *main study* with consumers (n=70) are set up to (i) select a set of visually clear and recognizable 'abstract' materials, that can be rendered on (ii) a set of distinctive 3D forms, and to (iii) question consumers (in)directly about the relationship between materials and individual self-expressive values through an *online survey*. This chapter reveals insight in the expressive values that twelve pre-selected materials evoke in itself and in interaction with different pre-selected forms, and indicates the potential of classifying respondents in meaningful self-expressive categories, based on their self-expressive value orientation. It concludes that there is a reasonable fit between the materials' expressive values and the individual self-expressive values. The paper "Exploring the Fit between Materials' Expressive Values and the Self-Expression of the End-User" is published in the proceedings of the 20th Congress of the International Ergonomics Association (IEA2018).

Second, **Chapter 6** aims to explore consumers' perception of plastic materials in everyday products and their link with consumers' own personality, defined in terms of five personality traits. This *qualitative study* involves everyday products as moderator of the perception of a plastic material, which mediates the perceived fit of the plastic with the consumer's personality. In a *"mobile application" survey*, respondents of a consumer panel (n=195) are asked to upload a picture of their most and least favourite plastic product that they use in everyday life, to describe the material(s) it is made of, and explain why it (does not) fit with their personality. By means of *content analysis*, a categorization is made of the posted products, the describing experiential material qualities, and the attributed personality fit descriptions. Moreover, a *cluster analysis* is performed on the personality traits of respondents revealing four personality clusters of consumers. The way they differ in perceived materials experience is described along these clusters. The paper "Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality" is published in the proceedings of Sustainable Production, Life Cycle Engineering and Management (EcoDesign conference).

Based on the insights of the previous two chapters, **Chapter 7** is based on a large-scale *quantitative* study, and discusses individual self-expressive values (personal values, personality traits, environmental concern, green self-identity, innovativeness, aesthetic experience, and materialism) that are considered relevant to reflect on consumer segments that are expected to differentiate in the way they prefer experiential material qualities (a set of sensorial attributes and interpretive characteristics). In a *pre-study*, four product conditions are defined by means of an *online survey* with design and marketing researchers (n=16). The *main study* concerns a large-scaled *online survey* with Flemish consumers (n=1309) in collaboration with a market research agency. First, a *factor analysis* reduces the number of segmentation items. Second, a *manipulation check* shows that the product conditions are perceived as foreseen. Third, a *cluster analysis* is done on the factors of all cluster variables in order to identify four meaningful and homogeneous segments of consumers. Fourth, a validation is done to check the *internal cluster consistency* of the chosen cluster solution. Fifth, a *regression analysis* is done to predict the probability of a respondent belonging to each cluster.

Sixth, *main effects* (clusters) and *interaction effects* (product type) on experiential material preferences are calculated, in order to verify if clustering consumers on various psychographic characteristics is meaningful in the context of experiential material preference. Conclusively, four segments are detected that significantly differ in terms of preferences of experiential (sensorial and interpretive) material qualities. They create a suitable foundation for the inclusion of extensive user aspects (through consumer segmentation) in future research and data generation through experiential material characterization. The article "The Effect of Consumer Segmentation and Product Types on Experiential Material Preferences" is submitted for publication in the Journal of Design Research.

PART FOUR concludes this thesis, and provides a theoretical conclusion based on the insights of all previous parts that are translated to guidelines for future experiential material characterization, and an answer to the four main research questions. In addition, it provides a designerly conclusion that describes the implications, practical recommendations, and future visions in the context of experiential material characterization.

Chapter 8 summarizes the reasoning process and argumentation regarding the experimental set-up and its parameters of a concrete case of plastic material demonstrator forms that are assessed by consumers. It aims to identify a set of appropriate methodological choices as a first step towards streamlined future material characterizations to build up an experiential 'database' of various plastic materials. These *guidelines* discuss several elements, such as stimuli, interaction modalities, dependent variables, assessors, method, and practical considerations. The paper "Formulating Guidelines for The Systematic Set-Up of Experiential Material Characterization Studies: A Case of Plastic Demonstrators" is published in the proceedings of the Design Society: International Conference on Engineering Design (ICED 2021).

Finally, **Chapter 9** reflects on the research that is done and the limitations of the dissertation. Next, a *theoretical conclusion* is formulated as well as propositions for each research question and in general. Building upon the reflections, this chapter also defines what the opportunities are for future research. Finally, this thesis ends with *designerly conclusions* from both a consumer and designer perspective, and elaborates on a future vision of a materials experience library and other opportunities.

PART ONE

PART ONE deals with the state of the art concerning experiential material characterization. In Chapter 1, an extensive literature review is presented of 64 cases of experiential characterization studies in the materials and design domain. This overview aims to facilitate systematic studies to explore experiential qualities of materials and to identify gaps or opportunities for further research.

Chapter 2 discusses a specific case of experiential material characterization, namely of three exemplary recycled plastics that are materialized in standard stimuli forms, i.e. flat plates. This case links with the domain of emerging sustainable materials, and aims to understand how recycled plastics are perceived and appraised by stakeholders involved in the front-end of the design process (material engineers and designers), as an essential condition for successful adoption and application in practice and within a circular economy.

Chapter 1 is based on:

Veelaert, L., Du Bois, E., Moons, I., & Karana, E. (2020). Experiential characterization of materials in product design: A literature review. *Materials and Design*, 190. https://doi.org/10.1016/j.matdes.2020.108543

1. Experiential Characterization of Materials in Product Design: A Literature Review

Lore Veelaert, Els Du Bois, Ingrid Moons, Elvin Karana

Abstract: Driven by the competitive market that product designers face today, a growing interest emerges in exploring experiential material qualities to enhance product experience. The maturing of the research area calls for standardization to evolve to more streamlined and systematic approaches to conduct characterization experiments. To this aim, we conducted a literature review on 64 cases of experiential characterization studies in the materials and design domain. In this paper, we summarize the current state of the art, formulate an overview to facilitate systematic studies to explore experiential qualities of materials, and identify gaps or opportunities for further research. The presented learnings shed light on the following aspects used in materials experience studies: (i) variables, (ii) stimuli, (iii) interaction modalities, (iv) experimental set-up, (v) methods employed in the conducted studies, and (vi) respondents. Two important gaps were identified with regard to the physical material representations in an abstract form as a critical element for multimodal material characterization experiments, and to an integration of extensive user aspects beyond demographic variables to facilitate consumer segmentation. Additional future research suggestions were formulated, concerning within-material-class comparisons, complementary methods and experimental set-up, and the temporality of materials experience.

Keywords: *materials and design, experiential characterization, materials experience, product design*

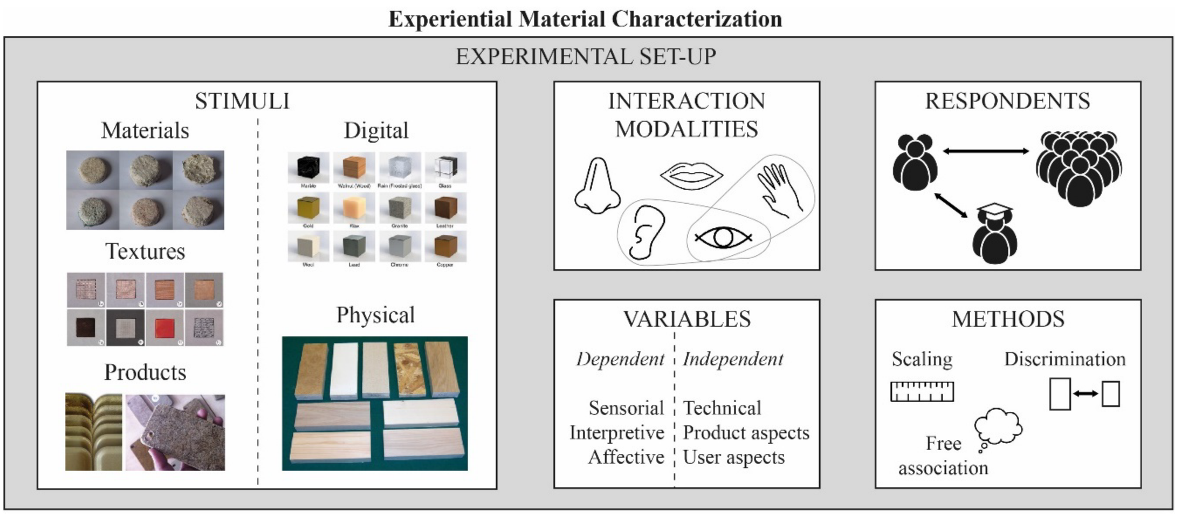


Figure 1.1. Graphical abstract of Chapter 1.

1.1 Introduction

In product design, materials are considered as the building blocks of physical products and contribute to the product's functionality and meaning. Technical material properties which relate to a materials' physical function can be objectively measured by means of standardized tests (Ashby & Johnson, 2002; Jahan et al., 2010). This has led to an extensive amount of material data in datasheets and textbooks. However, over the last decade, an increased interest established in materials experience, which brings to the attention the role of materials in affecting our ways of thinking, feeling and doing (Giaccardi & Karana, 2015; Karana, 2009; Karana et al., 2014). In a relatively recent study, Giaccardi and Karana (2015) defined four experiential levels which constitute our material experiences, namely *sensorial* (e.g., it is soft or rough), *interpretive* (e.g., it is modern or nostalgic), *affective* (e.g., it is surprising, disgusting), and *performative* (e.g., invites me to touch). These four levels interrelate with each other, and collectively constitute our ultimate experiences. For example, a material with a high gloss quality (sensorial) can be associated with professionalism or office environment (interpretive); or a material can look hard but feel soft to touch (sensorial), which can elicit surprise (affective), and calls to be caressed (performative).

From the perspective of a product designer, materials should be incorporated early in the design process and should involve both experiential and technical aspects (Ashby & Johnson, 2002; van Kesteren et al., 2007a). However, no equivalent data support is available for the former characteristics, as the approaches are not correlated with standard, established procedures (Piselli et al., 2018). This is partly because materials experience is a complex phenomenon with many influential contextual and temporal factors related to the product which embodies materials, context of use, and socio-cultural aspects. By contrast, experiential studies in other domains, for example within the food industry, have been well developed since the 1950s, involving very defined tests and well-founded procedures to statistically discriminate or describe food product experiences (Reinbach et al., 2014; Sidel & Stone, 1993; Varela & Ares, 2012). Recently, these insights have been applied to materials science to measure visual and tactile material properties (D'Olivo et al., 2013; Faucheu et al., 2015; Piselli et al., 2018). In addition, within architecture, warmth and roughness perception of interior and building materials has been studied as well in relation to technical properties (Wastiels et al., 2012a, 2012b).

When it comes to a holistic experiential characterization of materials in product design, which takes all four experiential levels into consideration, the tools and methods are limited. There is still a large gap in the domain "to translate subjective experiences of materials into data" (Wilkes et al., 2016, p. 1229). We particularly identified a gap in a straight-forward set-up of such materials experience experiments that study the different experiential qualities. Accordingly, this research aims to review previously conducted experiential characterization studies to date, in order to map the critical elements with particular attention to the variables, stimuli, interaction modalities, experimental set-up, employed methods, and respondents. Based on an analysis of their advantages and disadvantages, our aim is to support a better understanding of the phenomenon to facilitate the transition to more streamlined and standardized approaches to conduct experiential material characterization studies in product design. We end with a discussion Section addressing gaps and opportunities for further studies within this field.

1.2 Method

First, a general literature search was conducted in three steps: (i) initial keyword search, (ii) backward and forward search (Levy & Ellis, 2006), and (iii) an additional keyword search. We used four online libraries: ScienceDirect, Scopus, ACM Digital Library, and Web of Knowledge, containing publications of various scientific domains. The native search engines of these databases were used to proceed with initial keyword search. Finally, the full text articles were analysed to extract information about different aspects of the experiments.

1.2.1 Constructing a List of Keywords for Initial Search

In order to construct a list of search keywords, we have built upon existing frameworks to encompass the foundations of Materials Experience. This subject can be traced back to the work of Manzini (1986), The Material of Invention, in which he reported on the **aesthetics of materials** and their role in creating **user experience**. Only later, Ashby and Johnson (Ashby & Johnson, 2002) referred to the **aesthetic experience** and aesthetic **attributes** of materials as well. They assigned a dual role to materials, that is to provide both technical functionality and **product personality**. In this context, they mentioned **sensorial properties** and other **personal** dimensions of materials.

Doordan (2003) suggested a triad framework involving the fabrication, application, and **appreciation** of materials, whereas the latter referred to the **consumer's** or **user's reception** of a material embodied in an **artefact**. Zuo et al. (2001) deepened this understanding in their **material representation** framework with a focus on **texture perception** in design, and described **perceived characteristics** of materials such as **sensory** properties, **emotional/affective** and **associative/interpretive** dimensions (**meanings, values**). Rognoli and Levi (2004) introduced the expressive-sensorial qualities of materials. Finally, we build upon the work within the Materials Experience Lab (Karana & Rognoli, n.d.) who extended the **product experience** frameworks or models (Desmet, 2002; Govers, 2004; Hassenzahl, 2013; Hekkert, 2006; Schifferstein & Hekkert, 2008) – that include reflective dimensions such as product personality, self-concept and expression (Govers, 2004) – to the context of **Materials Experience**, defined by Karana et al. (2008b) as "the experiences that people have with, and through, the materials of a product", with the physical reality of an artefact as one of its prominent sources (Karana, Pedgley, et al., 2015). In their work, Karana et al. (2015) concluded that: "…designing **meaning**ful materials experiences requires competence in materials that is tied not only to three **experiential** components (i.e., **aesthetics, meanings**, and **emotions**), but also to understanding the possible effects of various design aspects (e.g., **form**, process, finishing), **user** characteristics (e.g., gender, culture, age), and context of use on the resulting materials **experience**."

Overall, experiential **characterization** is a cross-disciplinary subject, including design domains such as material-oriented textile or fashion design, product design, interaction design (both material and immaterial), and architecture, as well as social sciences, psychology, materials science and engineering. For example, Faucheu et al. (2015) reported on the **tactile evaluation** of materials and products, while Masson et al. (2016) studied **sensory** and **subjective** characteristics of coffee cups. Although many studies could also be found on sensory **analysis** and related methods from the perspective of Food (Dehlholm et al., 2012; Sidel & Stone, 1993), 'food' was excluded in this particular review as we focussed on the context of product design. Thus, based on the above-mentioned frameworks and a first backward and forward search, additional synonymic keywords (*) were found to complete the list of subtopics and combinable keywords for the literature search, such as multi-modal, haptic, semantics, sample, stimuli, etc.:

- Materials experience, product experience
- Perception, perceived, perceptive*
- Experiential, expression, expressive
- Aesthetic(s), appearance, visual
- Sensorial, sensory, multi-sensory*, multi-modal*, touch, haptic*, tactile
- Meaning(s), associative, associations, interpretive, subjective, semantic(s)*
- Consumer, (end)* user
- Personality, personal, self-expression
- Artefact, form, sample*, stimuli*
- Properties, attributes, characteristics, values, variables*, qualities
- Analysis, evaluation, characterization

For clarity, in this paper we use 'qualities' to refer to the distinct nature of materials as received, described and acted-upon by people, and we use the 'characterization' to refer to the process by which we reveal these qualities (Ingold, 2012). Thus, besides 'technical properties' of materials, we refer to 'experiential qualities' such as 'sensorial attributes' and 'interpretive characteristics'.

1.2.2 Publication Pool

We used the above-mentioned keywords and combinations thereof (e.g. "design" and "materials" and "sensory*" and not "food") to search the libraries of ScienceDirect, Scopus, ACM Digital Library, and Web of Knowledge for relevant publications. For our analysis, we selected only those papers in the initial results, that described or defined user-centred characterizations in any form, if they did address: experiential or (multi)sensory evaluation of material samples or products (see list of Keywords). In addition, the results of the keyword search were limited by publication time between January 2000 and March 2019, based on the dates of the frameworks in the previous Section. Initial inclusion resulted in 68 articles, from which 42 were selected as relevant based upon abstract that involved characterization experiments. A backward and forward search of these articles led to 24 new articles. Finally, all articles were screened based on their full texts with a focus on method and results, leading to the discarding of 16 papers. In total, 80 articles were screened whereof 50 of them were included for this review.

The following descriptive data were collected: title of the article, authors' names, year of publication, type of publication (e.g. journal), publication name (e.g. Materials and Design), five-year impact factor of journal articles or CORE rank of conference proceedings, author's affiliation, number of citations, and finally the article's keywords that facilitated the refinement of the described search. Impact factor or conference rank, and number of citations expressed the scientific relevance, indicating the validity and scientific interest in the topic. Year of publication and authors affiliation showed how the interest was distributed timewise and geographically.

The herein presented literature review builds on 50 articles that were found in both journals (40) and conference proceedings (10). Based on an initial screening of the articles, three different focusses within the conducted experiments could be detected, depending on their main focus. First of all, 11 articles focused on the evaluation of Products as a whole (e.g. hairdryers (Zuo et al., 2016) and hammers (Vergara et al., 2011)), while 30 articles were directed to Materials in particular (e.g. isolated material samples (Overvliet & Soto-Faraco, 2011) or materialized in existing products (Karana et al., 2009a)), and 9 articles even investigated Textures specifically (regardless the material on which it is applied (Picard et al., 2003)). Table 1.1 sums up the titles, number of individual findings, and impact or rank of the journals and conferences respectively, including the references of the 50 articles, subdivided over the three focusses, and chronologically ordered within each category.

Next, the 50 full text articles were analysed in-depth to extract information about different aspects of the described methods in the context of Experiential Material Characterization. However, as several articles discuss multiple studies, we could actually include 64 conducted studies in total. After coding, the following subjects were found in the literature and selected as relevant encryption categories for organizing and providing a framework for the literature review: (i) experiential and independent variables, (ii) stimuli used in experiential characterization studies, (iii) interaction modalities with stimuli, (iv) experimental set-up, (v) methods employed in the conducted studies, and (vi) respondents, complemented with Experiment duration, Data analysis, Study limitations, and Conclusions. All information was collected in an Excel spreadsheet. In the following Sections, the results are discussed according to the six main themes above, as building blocks of the total experimental set-up.

Table 1.1. Distribution of articles (and studies) over the three focusses, with Thomson Reuters 5-Year impact factor/CORE rank.

Sources					
Journals (N=40)	**#**	***IF***	***Conferences (N=10)***	**#**	***rank***
Materials & Design	9	4,75	ICED: International Conference on Engineering Design	3	B
International Journal of Design	6	1,94	IDETC/CIE ASME: International Design Engineering Technical Conferences & Computers and Information in Engineering	2	N/A
International Journal of Industrial Ergonomics	6	1,61	International Academic MindTrek Conference	1	N/A
Acta Psychologica	3	2,22	ACM SIGGRAPH: Symposium on Applied Perception	1	C
Applied Ergonomics	2	2,66	IEA: Congress of the International Ergonomics Association	1	B
Food Quality and Preference	2	4,19	D&E: International Conference on Design & Emotion	1	A
Journal of Cleaner Production	1	6,35	NordDesign Conference	1	B
Design Journal	1	N/A			
International Journal of Designed Objects	1	N/A			
Vision Research	1	2,0			
Building and Environment	1	5,22			
Color Research & Application	1	1,03			
Intern. Journal on Interactive Design and Manufacturing	1	N/A			
Sustainability	1	2,18			
Wear	1	3,27			
Journal of Wood Science	1	1,30			
Consciousness and Cognition	1	2,52			
Design Studies	1	2,64			

Articles		
Within material focus	***Within texture focus***	***Within product focus***
(Giboreau et al., 2001) 2 studies	(Picard et al., 2003) 2 studies	(Hsu et al., 2000)
(Karana et al., 2007) 3 studies	(X. Chen, Shao, et al., 2009)	(Petiot & Yannou, 2004)
(Bergmann Tiest & Kappers, 2007)	(Hope et al., 2012)	(W. Chang & Wu, 2007)
(X. Chen, Barnes, et al., 2009) 2 studies	(D'Olivo et al., 2013)	(Artacho-Ramírez et al., 2008)
(Karana et al., 2009a)	(Y. T. Chen & Chuang, 2014)	(Mugge et al., 2009)
(Karana & Hekkert, 2010)	(Etzi et al., 2014) 2 studies)	(C.-C. Chang & Wu, 2009)
(Høibø & Nyrud, 2010) 2 studies	(Faucheu et al., 2015)	(Vergara et al., 2011)
(Fenko et al., 2010)	(Yanagisawa & Takatsuji, 2015)	(Mugge, 2011) 2 studies
(Georgiev & Nagai, 2011)	(Zuo et al., 2016)	(Agost & Vergara, 2014)
(Overvliet & Soto-Faraco, 2011)		(Masson et al., 2016)
(Wastiels et al., 2012a)		(Kapkın & Joines, 2018)
(Crippa et al., 2012)		

(Wastiels et al., 2012b) 2 studies (Lindberg et al., 2013) (Wastiels et al., 2013) (Karana & Nijkamp, 2014) (Martín et al., 2015) 2 studies (Fujisaki et al., 2015) (Silvennoinen et al., 2015) (Wilkes et al., 2016) 4 studies (Overvliet et al., 2016) (Lilley et al., 2016) (Sauerwein et al., 2017) 2 studies (Piselli et al., 2017) (Dacleu Ndengue et al., 2017) (Ulusoy & Nilgün, 2017) (Choi, 2017) (Piselli et al., 2018) (Bahrudin & Aurisicchio, 2018) (Veelaert et al., 2018)		
30 articles – 41 studies	**9 articles – 11 studies**	**11 articles – 12 studies**

1.3 Results

1.3.1 Variables

1.3.1.1 Dependent Experiential Variables

As discussed in the introduction on materials experience, experiential characterization of materials can manifest on different levels, and both from a holistic and a detailed perspective. We build upon the Materials Experience Framework (Karana et al., 2014) for analysing the dependent variables, as this is considered the most relevant framework in literature that provides an extensive understanding of material-people relationships in design. Other works in literature either elaborate on understanding one experiential level, or focus on only sensory perception of materials. Furthermore, substantiated by many other papers and used as a reference within the field, Camere and Karana (2018) recently incorporated this framework and four experiential levels in their Ma2E4 toolkit, : (i) *sensorial* level, (ii) *interpretive* level (i.e. associations or meanings), (iii) *affective* level (i.e. emotions), and (iv) *performative* level (i.e. actions) (Giaccardi & Karana, 2015). However, the latter has not yet been studied in found articles and was therefore discarded from cross Table 1.2 below. Moreover, within the affective level, seven studies specifically mention material preference (like-dislike) that incorporates emotional justification and cognitive reasoning, e.g. (X. Chen, Shao, et al., 2009; Fujisaki et al., 2015; Høibø & Nyrud, 2010; Hope et al., 2012; Hsu et al., 2000; Lilley et al., 2016; Piselli et al., 2018).

Overall, Table 1.2 shows that sensorial attributes (42%) and interpretive characteristics (37%) were most often involved as dependent variables in the studied experiments. However, sensorial attributes (47%) were most common within a material (and texture) focus, while within a product focus mostly interpretive characteristics (65%) were adopted. When looking at combinations of multiple experiential levels in one assessment, within a material focus, 68% of the studies stayed within one level, while 16% involved two levels and 16% three levels. Within a texture focus, 36% involved merely one level, 45% two levels and 18% three levels. Finally, within a product focus, 45% focused on one level and 55% on two levels.

Table 1.2. Frequencies of experiential levels within Material, Texture and Product focus.

	Sensorial	Interpretive	Affective	**Total**
Material	27	19	11	**57**
Texture	11	5	5	**21**
Product	2	11	4	**17**
Total	**40**	**35**	**20**	**95**

Next to the twelve sensorial attributes that are incorporated in the Ma2E4 toolkit (Hard-Soft, Smooth-Rough, Matte-Glossy, Not Reflective-Reflective, Cold-Warm, Not Elastic-Elastic, Opaque-Transparent, Tough-Ductile, Strong-Weak, Light-Heavy, Regular Texture-Irregular Texture, Fibred-Not fibred), various other properties were mentioned in the articles, such as Scratchability, Acoustics, Stiffness, etc. All in all, Smooth-Rough was mentioned most (28x), followed by Hard-Soft (24x) and Cold-Warm (22x). Also, Matte-Glossy (9x), Sticky-Non-Sticky (9x), Moist-Dry (7x) were common.

Furthermore, the list of interpretive characteristics is even longer, as compared to the eleven meanings in the vocabulary of the Ma2E4 toolkit (Aggressive-Calm, Cosy-Aloof, Elegant-Vulgar, Frivolous-Sober, Futuristic-Nostalgic, Masculine-Feminine, Ordinary-Strange, Sexy-Not Sexy, Toylike-Professional, Natural-Unnatural, Handcrafted-Manufactured). Cheap-Expensive/ Luxurious and Playful/Cheerful-Dull were each counted seven times, while Masculine-Feminine, Natural-Unnatural, Modern-Traditional were all counted six times. Other common meanings are Beautiful-Ugly (5x), Ordinary-Strange (5x), Elegant-Vulgar (4x), Futuristic-Nostalgic (4x), High Quality-Low Quality (4x), Old-New (4x), Aggressive-Calm (3x), Cosy-Aloof (3x), Sexy-Not sexy (3x), Toy like-Professional (3x), Lasting-Disposal (3x), and Safe-Unsafe (3x).

Finally, Pleasant-Unpleasant (8x) is mostly mentioned within the emotional attributes, compared to the other emotions used within the PrEmo tool of Desmet (2002). Crippa et al. (2012) state that in general, emotions evoked by materials are rather weak, however, Ludden, Schifferstein and Hekkert (2008) showed that materials are one of the most effective tools for eliciting ‘surprise’, and Karana and van Kesteren (2006) reported that also for ‘love’ and ‘hate’ materials play a substantial role.

1.3.1.2 Independent Variables

In addition to the previously mentioned dependent variables that are frequently studied, different independent variables were involved as well, mainly within material focus (63%), as shown in Table 1.3. Although this review focused on experiential qualities of materials, twelve studies also included *technical* material properties – that can be objectively measured – and searched for a correlation with subjective perceptions of these properties, as was first attempted by Rognoli (2010) in the Expressive-Sensorial Atlas. In this regard, material roughness was often incorporated (Bergmann Tiest & Kappers, 2007; Lindberg et al., 2013; Piselli et al., 2017, 2018), as well as warmth (Wastiels et al., 2012a) or even both (X. Chen, Barnes, et al., 2009; X. Chen, Shao, et al., 2009; Wastiels et al., 2012b). Moreover, Wilkes et al. (2016) used different developed tools and physical property data to predict acoustics, taste and touch perception.

Since Karana's Meanings of Materials Model presents "the meaning of a material as a relational concept in which material, product and user are jointly effective" (Karana et al., 2010, p. 2932), independent variables can be included from both a *product* or *user* perspective. Within the former, product's function and shape or form can affect the materials experience, while within the latter, a user's age, gender, culture or personal values can be included. Overall, the effect of form was considered eight times, mainly focusing on form curvature that influences the material's expression.

Table 1.3. Frequencies of various technical, product and user aspects within the three focusses.

	Technical	Function	Shape/form	Culture	Gender	Age	Personal values	**Total**
		Product aspects		**User aspects**				
Material	12	1	4	2	1	0	1	**22**
Texture	1	0	0	1	0	0	0	**2**
Product	0	1	4	0	1	1	1	**11**
Total	**13**	**2**	**8**	**3**	**2**	**1**	**2**	**35**

Although recognized as an important factor in literature, and repeatedly mentioned in the discussion or future research (Y. T. Chen & Chuang, 2014; Hope et al., 2012; Hsu et al., 2000; Kapkın & Joines, 2018; Karana & Nijkamp, 2014; Ulusoy & Nilgün, 2017), few studies actually investigated in depth the effect of user aspects as moderating aspects of the materials experience, but remained rather limited to the demographic variables. Ulusoy and Nilgün (2017) stated that meanings are related to society and cultural background, making them more sensitive than sensorial attributes for that matter. Currently, only two studies were found that involved personal or expressive values of consumers, i.e. in the form of Schwartz personal values (Veelaert et al., 2018) and reference personality values (Agost & Vergara, 2014, p. 1076). The former concluded that relationships can be found between someone's self-expression, their material preference and the expressive values that are seen in a material. The latter stated that "not only target customers' demographic data but specifically their values and criteria must be taken into account from the beginning of the development process". In addition, in her work on product personality, Mugge (2011) reported that specific personality of the respondents was not considered. However, building on the self-congruity theory (Sirgy, 1982), she adduced that a person's personality is a potential moderator and should thus be investigated in future studies.

1.3.2 Stimuli Used in Product and Materials Experience Studies

1.3.2.1 Materials (Type and Class)

The studied stimuli concerned different materials in different material classes, such as textile (natural or synthetic fabrics), metal, plastic, composite (compositions of plastics with other materials), elastomer, wood, ceramic, glass, and other (e.g. natural materials). Within one study, the number of material classes went up to eight different classes, however with a median of only two classes for both material and texture focus.

Table 1.4 summarizes the material stimuli used in experiments within each material class. Overall, metals were used 24 times, followed by both plastics and wood with 21 times, and textile 18 times. Within texture focus, 28% of the stimuli were textiles, representing the great interest in texture and touch within textile research (Giboreau et al., 2001). Within material focus, metals, woods and plastics appeared the most, representing the most common materials in industrial design. However, when looking at the studies focusing on comparing one specific material to another one of the same class, clearly textiles (n=6), wood (n=5) and other materials (n=6) are most often examined. Studies concerning only plastics, glass or rubber materials have not been found.

Table 1.4. Frequencies of different material classes studied in articles within Material and Texture focus.

	Textile/leather	Metal	Plastic	composite	Elastomer/ rubber	Wood	Ceramic/stone	Glass	Other	**Total**
Material	11	21	17	2	6	19	10	10	16	**112**
Texture	7	3	4	2	2	2	0	1	4	**25**
Total	**18**	**24**	**21**	**4**	**8**	**21**	**10**	**11**	**20**	**137**

Two main reasons could be detected for the studies' material choice. Firstly, materials were often selected as being familiar, most typical or commonly used in everyday products (Bergmann Tiest & Kappers, 2007; Georgiev & Nagai, 2011; Karana & Hekkert, 2010; Lilley et al., 2016; Yanagisawa & Takatsuji, 2015), in construction/architecture or interior design (Lindberg et al., 2013; Ulusoy & Nilgün, 2017; Wastiels et al., 2012a, 2013), in other specific sectors (X. Chen, Shao, et al., 2009; Etzi et al., 2014) such as automotive fabrics (Giboreau et al., 2001; Picard et al., 2003), or distributed along several material classes (Martín et al., 2015; Veelaert et al., 2018). Secondly, materials were often selected to cover relative heterogeneity, assuring observable differences, and providing a wide and diverse range of tactile/physical properties, such as roughness, and aesthetic properties, such as colour and appearance (Bergmann Tiest & Kappers, 2007; X. Chen, Barnes, et al., 2009; X. Chen, Shao, et al., 2009; D'Olivo et al., 2013; Fujisaki et al., 2015; Lilley et al., 2016; Martín et al., 2015; Wastiels et al., 2012a, 2013; Wilkes et al., 2016). When investigating free impressions, Georgiev and Nagai (2011) made a distinction based on frequently touched and sometimes touched materials.

Moreover, five studies conducted a pre-study to reduce and select the final material stimuli set. Hereby, duplication could be reduced while maintaining a range of variable values (X. Chen, Barnes, et al., 2009), or the strongest ratings on particular attributes were selected (Martín et al., 2015), such as the ugliest and most beautiful samples (Sauerwein et al., 2017) or the most pleasant and unpleasant ratings (Etzi et al., 2014).

1.3.2.2 Material Representations

Several material representations were used in the studies (frequencies shown in Table 1.5), going from abstract words (e.g. "plastic", "metal" and "wood), to digital renders or photographs of the stimuli, and finally to physical samples. Martín et al. (2015) state that "physical samples are still the standard". Whether digital or physical, materials could also be used in different forms. Among the various studies, often multiple samples are evaluated and compared, going from a flat material sample (decontextualized), to an abstract form, or to an actual product (contextualized). Figure 1.2 shows several examples of used material representations such as text-digital models, flat samples, blocked samples, and products.

Figure 1.2. Overview of selection of used material stimuli in reviewed papers: **word-digital models** (a) Reprinted from (Veelaert et al., 2018), Copyright (2019), with permission of Springer Nature

Switzerland AG, (b) Reprinted from (Karana et al., 2007), Copyright (2009), with permission from ASME, **flat samples** (c) Reprinted from (Wastiels et al., 2012b), Copyright (2012), with permission from Elsevier, (d) Reprinted from (D'Olivo et al., 2013), with permission of D'Olivo, (e) (Hope et al., 2012); **blocked samples** (f) Reprinted from (Sauerwein et al., 2017), in accordance with Creative Commons regulations, (g) Reprinted from (Lindberg et al., 2013), Copyright (2013), with permission from Elsevier, (h) Reprinted from (Fujisaki et al., 2015), in accordance with Creative Commons regulations; and **products** (i) Reprinted from (Dacleu Ndengue et al., 2017) with permission of Dacleu Ndengue, (j) Reprinted from (Crippa et al., 2012), in accordance with Creative Commons regulations, (k) Reprinted from (Karana & Nijkamp, 2014), Copyright (2014), with permission from Elsevier, (l) Reprinted from (Lilley et al., 2016), in accordance with Creative Commons regulations, (m) Reprinted from (Wilkes et al., 2016), Copyright (2016), with permission from Elsevier, (n) (Karana et al., 2009a) (p) Reprinted from (Karana & Hekkert, 2010), in accordance with Creative Commons regulations**.**

Table 1.5. Frequencies of material representations within Material, Texture, and Product focus.

	Words	Render	Photo	Physical	**Total**		Flat sample	Abstract form	Product	**Total**
Material	2	2	4	35	**43**		28	2	10	**40**
Texture	0	0	0	11	**11**		10	0	1	**11**
Product	0	2	6	7	**15**		0	0	12	**12**
Total	**2**	**4**	**10**	**53**	**70**		**38**	**2**	**23**	**64**

Representing materials by means of words was only done twice, reflecting only on general material classes (Choi, 2017), and rather pre-studying the effect of material form on meaning (Karana et al., 2007). The use of *photographs* or *rendered images* was mostly used in the context of a multimodal comparison (Artacho-Ramírez et al., 2008; Etzi et al., 2014; Martín et al., 2015; Vergara et al., 2011), in the case of materials applied in products (Bahrudin & Aurisicchio, 2018), or when adapting curvature of specific products in an online survey (Mugge, 2011). Practical advantages are time-saving surveys online and a wider range of materials while obtaining a controlled and equal presentation or context (Agost & Vergara, 2014; Veelaert et al., 2018). The disadvantage is the limitation to one modality, in contrast to a multimodal materials experience. Nevertheless, it could show resemblance with a realistic (pre) purchase situation (Artacho-Ramírez et al., 2008), such as a catalogue or web shop, where products can be compared with each other as well (Mugge, 2011).

By contrast, the vast majority of the reviewed studies utilized tangible *physical samples*, either decontextualized material samples or contextualized product samples. Within the material and texture focus, 75% of the cases used small and *flat material samples* devoid of context, differing in terms of shape, size, and preparation. 50% was found rectangular, 46% square and 4% round, with a surface area between 15 cm2 (Dacleu Ndengue et al., 2017) and 1600 cm2 (Md=98 cm2) so that the surface could be touched by the whole hand (Wastiels et al., 2012a, 2013). Samples were usually provided as free-standing pieces or cut-outs, but could also be mounted on foam (Giboreau et al., 2001) or MDF board for an equal background (Bergmann Tiest & Kappers, 2007; Hope et al., 2012), or even mounted in standard sample holders with a specific window to display the top surface, isolated from the background (D'Olivo et al., 2013; Faucheu et al., 2015; Fujisaki et al., 2015; Overvliet et al., 2016; Overvliet & Soto-Faraco, 2011; Piselli et al., 2018; Sauerwein et al., 2017). In one case, the holders were weighted to overwrite the material's weight perception (Wilkes et al., 2016). In their discussion, Piselli et al. (2018) recommended to conduct sensory tests with *abstract shaped specimens*.

Following the MOM model (Karana, 2010), the appraisal of materials also depends on the application context (Bahrudin & Aurisicchio, 2018). Crippa et al. (2012, p. 5) stated that "materials are experienced mainly through the product they are embodied in". Consequently, besides product related studies, also within material or texture related studies, *products were used as material representations* (22%), going from imaginary products to isomorphic material-object sets and product applications. Referring to (Laughlin et al., 2011), Wilkes et al. (2016, p. 1229) in particular investigated sound and taste perception by means of isomorphic tuning forks and spoons. In other studies, products were used for various reasons, including (i) product type or value, (ii) shape/appearance, (iii) function/context, (iv) familiarity, and (v) practical considerations.

First, products were chosen from different categories (kitchen products, hi-tech products, household appliances, personal or fashion products, and interior products) that are mentioned most frequently as cherished household possessions, and most involved in creating the owner's identity (W. Chang & Wu, 2007). For example, both car and vacuum cleaner (Mugge et al., 2009) and ceramic flooring tiles (Agost & Vergara, 2014) were chosen to represent products with high or low symbolic value, while waste basket and lighter (Karana & Hekkert, 2010) and breakfast tray and smartphone case (Karana & Nijkamp, 2014) were selected for high or low personal value.

Second, most studies aimed at a great variety of appearances both in colour (Dacleu Ndengue et al., 2017; Masson et al., 2016), size and shape going from very angular or sharp-edged to very curved or rounded (Karana & Hekkert, 2010; Mugge, 2011), as sufficient variation was stated to be essential for a reliable scale (Mugge et al., 2009). In contrast, some studies consciously kept the form constant, as was the case with smartphone cases (Dacleu Ndengue et al., 2017) and bowls with both concave and convex surfaces (Crippa et al., 2012). In the latter study, nine bowls were used, however, with no uniformity or equal wall thicknesses, and their perception could be associated with food because of the product's function. In addition, several studies mentioned an appropriate level of complexity, choosing simple forms with a minimum of production details or additional elements such as buttons and screens (Artacho-Ramírez et al., 2008; Kapkın & Joines, 2018; Karana et al., 2009a; Karana & Hekkert, 2010). Only one study deliberately varied CD players with both low and high complexity by means of shape and buttons (Mugge, 2011).

Third, products were chosen as stimuli for being objects with an identified function (Dacleu Ndengue et al., 2017), e.g. smartphone covers, that provide contextual information (Kapkın & Joines, 2018), e.g. soap dispensers, leading to studies with the same products having the same function (Crippa et al., 2012; Masson et al., 2016), e.g. bowls or coffee cups, as opposed to studies with a set of products that was chosen to vary the functionalities in different contexts (Karana & Nijkamp, 2014; Mugge, 2011), e.g. smartphone cases and trays.

Fourth, products such as a bowl (Crippa et al., 2012), razor, wallet, backpack, sunglasses, toothbrush, cool box, plate (Bahrudin & Aurisicchio, 2018), hammer (Vergara et al., 2011), CD player (Mugge, 2011), hard disk drive, soap dispenser (Kapkın & Joines, 2018) were selected because they represent concrete and familiar, daily consumer products that are commercially available and mature with a high market penetration degree.

Fifth, products had to be able to be purchased in a great variety (Mugge et al., 2009), be simple enough to reproduce without difficulties, or be easily manipulated experimentally in a lab (Artacho-Ramírez et al., 2008; Fenko et al., 2010). Karana and Nijkamp (2014) and Lilley et al. (2016) chose to employ mobile phone cases (both) and trays (only Karana and Nijkamp) as a rapid and cost-effective method to interact with different materials in the same object.

Finally, when examining the number of stimuli – whether they are material samples or product stimuli – the number of stimuli in one study varied between 3 and 96 (Md = 10) within the material focus, 5 and 51 (Md = 13) within texture focus, and 4 and 120 (Md = 16) within product focus.

1.3.3 Interaction Modalities with Stimuli (Material Representations)

Based on the studied articles, seven different levels of modalities were detected referring to the senses that were involved in the interaction and manipulation of material (or product) stimuli. Within a material focus, a few specific cases investigated (i) *auditory*, (ii) *audio-visual*, or (iii) *oral* (taste) perception of materials. However, Sauerwein et al. (Sauerwein et al., 2017) state that “in material appraisals, touch and vision are the most dominant sensorial modalities (Karana, 2009; Schifferstein & Wastiels, 2014)”.

The unimodal (iv) *visual* condition implies that participants are merely allowed to look at stimuli, whether it is presented in a photo, render, or physically present. Despite such static evaluation, our mental process could create an integrated representation of both visual and tactile content. Indeed, “in apperception process, information from different sensory modalities as well as already existing mental information contents are integrated into a meaningful mental representation. Apperception can be described as ‘seeing something as something’” (Silvennoinen et al., 2015, p. 3).

By contrast, a solely tactile condition or (v) *blind touch* only involves haptic sense, which avoids focus towards sight as the primary sense, and “reduces potential bias attributable to preconceptions about certain materials” (Lilley et al., 2016, p. 8). This could explain its frequent occurrence within texture-focused research. Moreover, a distinction could be made between passive and active stimulation, wherein the latter implies that “the stimulus is stationary and the subject actively explores [the] object or surface” (Zuo et al., 2013, p. 30), and the former means that the experimenter applies and moves the stimuli on the participant’s cheek, hand, or arm. Lindberg et al. (2013) were able to control unimodal tactility by blocking vision and hearing with black painted goggles, noise-cancelling headphones, and soft pads between samples and table. Next, (vi) *visual touch* integrates a tactile sensation that could either complement or contradict the visual perception, which is defined as visual-tactile (in)congruity (D’Olivo et al., 2013). Yet, this dual modality entails a rather static touch, e.g. index finger touches sample surface. Finally, when vision is again included as well, we reach ultimate multimodality by means of (vii) *free exploration* or dynamic touch (Hope et al., 2012) in which the sample is grabbed, picked up, rubbed and fully assessed by rubbing it between thumb and index finger, manipulated, and “played with” (Y. T. Chen & Chuang, 2014). Chen and Chuang (2014) suggested that further researches should investigate the opportunities of such extensive contact when exploring material expressions. Giboreau et al. (Giboreau et al., 2001) observed four most common one-hand gestures that were performed to describe tactile properties of fabrics, as shown in Figure 1.3.

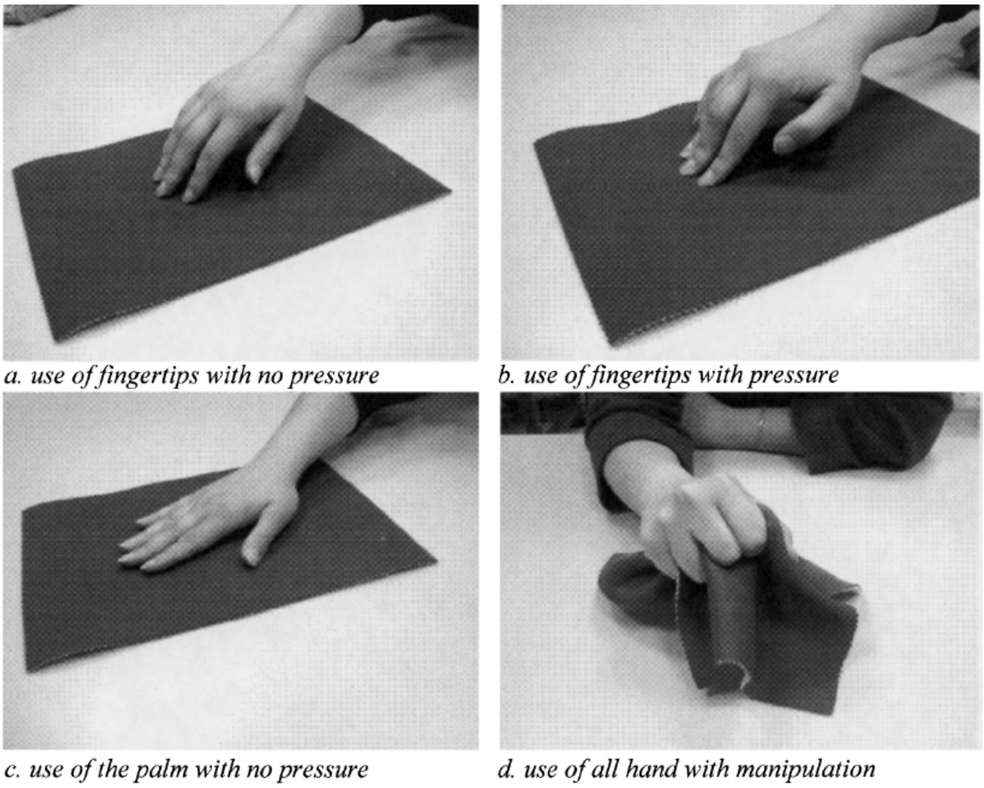


Figure 1.3. Photos showing most common gestures with fabrics. Reprinted from (Giboreau et al., 2001), Copyright (2001), with permission of Elsevier.

Table 1.6 summarizes the frequencies of these modalities within material, texture and product focused studies. Overall, the singular modalities of visual and blind touch perception were the most common in past research, and 27% of the studies mentioned to compare results of multiple modalities. Within a product focus, either visual (57%) or free exploration (36%) were preferred, while within texture focus, blind touch (50%), visual touch (22%) and visual perception (17%) were found to be. Finally, within a material focus, sample interaction was more evenly distributed over visual (27%), blind touch (23%), visual touch (19%), and free exploration (19%), apart from a few specific cases that included other senses.

Table 1.6. Frequencies of included modalities within Material, Texture, and Product focus.

	Auditory	Audio-visual	Oral	Visual	Blind touch	Visual touch	Free exploration	**Total**
Material	4	1	2	17	14	12	12	**62**
Texture	0	0	0	3	9	4	2	**18**
Product	0	0	0	8	0	1	5	**14**
Total	**4**	**1**	**2**	**28**	**23**	**17**	**19**	**94**

Conclusively, visual stimulation is most prominent in existing research, which makes sense as visual appearance is a "critical determinant of consumer response and product success" (Bloch, 1995;

W. Chang & Wu, 2007; Crilly et al., 2004). Indeed, Artacho-Ramírez et al. (2008) state that: "…in the actual marketplace there is a wide range of similar products in terms of functionality, price and quality. In this kind of markets, attention is increasingly focused on the visual characteristics of products, as their functionality and performance are often taken for granted (Crilly et al., 2004)".

However, while the visual sense clearly has a key influence only in the consumer's (pre) purchase decision process (or in web shop situations), the majority of product uses are operated through physical contact with products, increasing the importance of the tactile sense in product design nowadays (Y. T. Chen & Chuang, 2014). Moreover, human perception is inherently multisensory (Schifferstein, 2010), thus the senses cannot be isolated when human behaviour is analysed, but a holistic, multimodal approach is needed in sensory material evaluation (D'Olivo et al., 2013). Ndengue et al. (2017, p. 431) argue that integration across senses can lead to several advantages: "Combining complementary sources of information is advantageous because it extends the range and variety of what can be perceived from one sense in isolation and can reduce perceptual ambiguity. Furthermore, integrating multiple sensory sources usually leads to improved perceptual performance, more precise judgements and enhances detection of stimuli."

Additionally, different sensorial attributes require different or even multiple modalities for perception, e.g. a material's colour is perceived by vision and its hardness by touch, while the roughness of a material can be assessed by both looking at it and touching it (Yanagisawa & Takatsuji, 2015).

1.3.4 Experimental Set-up

Most papers reported the conditions of their experimental set-ups, only some of which include full laboratory environment. First of all, in the context of (visual) material characterization, twenty studies indicated to control the light conditions, and eight studies also mentioned constant room temperature (between 20 and 27°C). Concerning the former, Høibø and Nyrud (2010) specifically mentioned the ISO 1988 standard, while Overvliet et al. (2016; 2011) used a photographic daylight tent, illuminated by 6x50W white daylight 5000K light bulbs that provided constant lighting conditions with scattered light, and others blind windows and doors to control diffuse, artificial lighting (Bergmann Tiest & Kappers, 2007; Faucheu et al., 2015; Martín et al., 2015; Wastiels et al., 2012b; Yanagisawa & Takatsuji, 2015) or maintain natural lighting. In addition, other senses can be controlled or restricted as well, for example using noise cancelling headphones (Fujisaki et al., 2015; Lindberg et al., 2013; Overvliet & Soto-Faraco, 2011), blocking vision by means of black painted goggles (Y. T. Chen & Chuang, 2014; Lindberg et al., 2013) or blindfolds, and using ear plugs to dampen any sounds (Etzi et al., 2014). By contrast, Wastiels et al. (2013) stated that auditory, smell and taste stimuli were constant for all test conditions and could thus be ignored.

Clearly, most studies took place in isolated test rooms, where tables were set-up that displayed the various samples, representing a physical scale or ranking, and participants were seated in front (C.-C. Chang & Wu, 2009; Giboreau et al., 2001; Hsu et al., 2000). Hope et al. (2012) used a benchmark material as a reference for assessing texture by positioning it in the middle of the scale. This way, equal interpretation of attributes in between participants was increased. Furthermore, in the case of Napping procedures (D'Olivo et al., 2013; Faucheu et al., 2015), a table cloth or area of 75x75 cm was delimited, representing a physical, two-dimensional scale. Piselli et al. (2017) displayed their samples on a stand at 45° to guarantee the same incident lighting angle on a material's surface, while Wastiels et al. (2013) positioned them vertically at eye-height.

Overall, several studies involved a custom-made experiment box with one open side – with or without curtain to hide the sample in blind conditions (X. Chen, Barnes, et al., 2009; X. Chen, Shao, et al., 2009; Fenko et al., 2010; Picard et al., 2003; Silvennoinen et al., 2015). For example, Ulusoy and Nilgün (2017) employed a box of 40x50x50 cm and a floor-fixed chair to maintain a 50 cm viewing distance. Furthermore, three studies described a very precise and practical experimental set-up (see Figure 1.4).

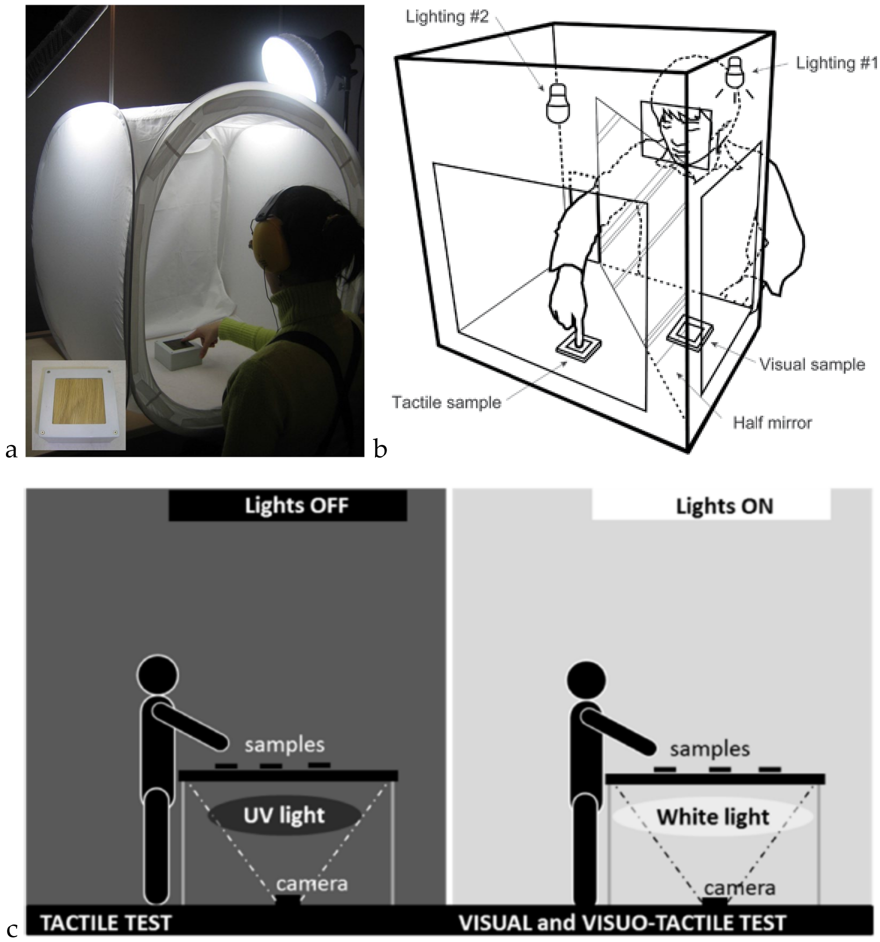


Figure 1.4. Three experimental set-ups used in studies by (a) Reprinted from (Overvliet et al., 2016), Copyright (2016), with permission of Elsevier; (b) Reprinted from (Yanagisawa & Takatsuji, 2015), in accordance with Creative Commons regulations; (c) Reprinted from (Faucheu et al., 2015), with permission of Faucheu.

First, Overvliet et al. (2016; 2011) repeatedly used a 80x80x80 cm photographic tent, covered with white cloth for tactile exploration, and with an opening in the middle of the back so the experimenter can change the sample. The samples were placed on a 50 cm viewing distance with an angle of 45°. Participants needed to maintain a stable head posture while exploring each sample for exactly three seconds in each modality, making circular movements with the index finger's pad of their dominant hand. Second, Faucheu et al. (2015) employed a translucent table top as a napping area, with (UV) light and a camera underneath that recognizes QR codes on the bottom of the material samples in order to automatically log the napping results of a participant. Third, Yanagisawa and Takatsuji (2015) operated a half-mirror apparatus that allowed them to virtually synthesize differing combinations of visual and tactile stimuli. At 45 degrees in the box, a half-mirror plate was placed to separate it in two spaces, one for the visual sample and one for the tactile sample, each placed horizontally. Both halves had a window, either to look or to touch the sample, and a modulated light allowed to adjust luminance accordingly. The participant was seated on a chair in front of the table with the box and could touch the sample using his/her right index finger.

Finally, 58 percent of the studies mention a random order in which the material stimuli are presented, and 14 percent mention a random order in which the variables or scale items are assessed.

1.3.4.1 Duration of Test

44 percent of the studies specifically mentioned the average duration of their experiments, leading to an average time of 37,1 minutes per participant. However, if we excluded the three cases that involve notable time-consuming interview techniques, the average would drop to 30,3 minutes. Nevertheless, in general experiments in the context of experiential characterization could be considered time inefficient, and near a typical concentration limit of forty minutes (X. Chen, Barnes, et al., 2009). Duration measurements of Faucheu et al. (2015) and Wastiels et al. (2012a) showed contradictory results between different modalities. The former reported that the tactile condition took twice the time of the visual or visuo-tactile condition, while the latter noted a clearly shorter time for the tactile condition compared to visual or visuo-tactile. Also, in the study concerning roughness perception of Bergmann Tiest and Kappers (2007), the visual condition (38 minutes) was significantly faster that the tactile condition (69.5 minutes).

All in all, some researchers countered the time disadvantage by distributing respondents over specific conditions. For example, Wastiels et al. (2012a) used a between-subjects design where participants were randomly assigned to a condition (visual, tactile or visuo-tactile), as did Silvennoinen et al. (2015). Karana and Nijkamp (2014) eased the judgment process and reduced a single session time by dividing their sample set of twelve versions of two products to two respondent groups, with each group evaluating the different material versions of the same product, as did (Artacho-Ramírez et al., 2008; Mugge, 2011; Ulusoy & Nilgün, 2017) with one model per participant, and (Piselli et al., 2017) who provided fifteen out of thirty combinations for each participant.

1.3.5 Methods Employed in the Conducted Studies

In the context of marketing research and sensory evaluations, various methods can be proposed to study the perception of consumers and create perceptual maps (Kaul & Rao, 1995; Petiot & Yannou, 2004). Although this has been primarily developed for the food industry, explorations into the application on non-food products or even materials can be found as well (O'Sullivan, 2017; Piselli et al., 2018). Overall, such sensory tests are subdivided in three categories: (i) *descriptive* analysis to characterize sensory attributes, (ii) *discrimination* tests to examine similarities or differences, and (iii) more subjective *hedonic* tests to assess consumers' preferences (Piselli et al., 2018), albeit the latter can be considered as a specific descriptive method. In addition, (iv) open interviews or *free impressions* can also be recorded to evaluate a stimulus. Table 1.7 shows the usage of different tests within the three main categories, that will be further described below, and within a material, texture or product focus.

Table 1.7. Frequencies of measure methods within Material, Texture, and Product focus.

	SDM	Unipolar	Binary decision	Ranking	MDS (sorted Napping)	Pairwise comparison	Hierarchical grouping	Free associations	**Total**
	Scaling			**Discrimination**				**Free**	
Material	17	13	3	4	2	1	1	5	**46**
Texture	6	1	0	0	3	0	0	2	**12**
Product	8	4	0	0	2	1	1	3	**19**
Total	**31**	**18**	**3**	**4**	**7**	**2**	**2**	**10**	**77**

1.3.5.1 Descriptive Testing

Descriptive testing is usually done by means of scaling methods, elaborating on perceived experiential qualities, their intensity and direction. In this regard, the *semantic differential method* (SDM) developed by Osgood et al. (1957) was probably the most frequently used (Hsu et al., 2000; Petiot & Yannou, 2004), as is shown in Table 1.7 with 40% of the observations. It consists of *unstructured* scales with verbal anchors at beginning and end by various semantic attributes, that are defined by pairs of antonymous or *bipolar* adjectives. Figure 1.5 shows an example of a semantic differential scale used in (Lilley et al., 2016). Often, factor analysis or principal component analysis was applied to reduce the number of items and to find underlying correlations (Petiot & Yannou, 2004). In the context of materials experience, the SDM method was applied in the sensorial scales of (Karana et al., 2010), and also used by others (Karana et al., 2009a; Sauerwein et al., 2017), where the items were reinforced and clarified by the use of pictograms. They stated that in this way, even untrained respondents can reliably assess sensorial attributes, leading to a higher agreement and lower ambiguity of personal interpretations.

However, Kapkın and Joines (2018) argued that such bipolar scales presume that two experiential qualities are antonyms, whereas contradictory meanings can co-exist and thus be independent. Consequently, also *structured, unipolar scales* can be applied to evaluate to what extent a certain characteristic is present or absent. This scale is labelled with numbers and/or descriptive terms going for example from ‘not at all …’ to ‘completely …’.

Choi (2017, p. 969) stated that untrained respondents “are not always able to clearly specify their perceptions of materials and it is very difficult for participants to differentiate material perceptions semantically through a seven point scale”. Consequently, a simple *binary decision* or digital-logic approach can be employed as well, which allows to indicate whether a characteristic is present or not, but not to what extent.

When looking at the 49 experiments with scales in the reviewed papers, the scales consisted of at least five points and maximum hundred points, with an average of ten points (Md=7). Lilley et al. (2016) preferred an odd number of scale points, as this provides a midpoint for neutrality. Similarly, 85 percent of the scaling experiments employed an odd number as well. Moreover, each experiment evaluated one to 34 different items, with an average of ten items.

1.3.5.2 Discrimination Testing

While scaling methods usually involve a single stimulus to evaluate in an absolute manner and without the presence of a reference framework or reference stimuli, discrimination tests are used to determine relative differences among two or more samples. Indeed, Cleaver (2018, p. 447) pointed out that human beings "perform better when assessing products in relation to another rather than in absolute terms", as perception is inherently more comparative. Hence, holistic approaches or multi-attribute issues are becoming increasingly popular, especially in sensory analysis (Pagès et al., 2010).

First, a *ranking test* is an easy and fast method where the participant has order a set of samples according to a specific attribute from least to most, however combining the limited data from multiple rankings is rather difficult (Cleaver, 2018; Piselli et al., 2018).

Second, *multidimensional scaling* (MDS) is used for visualizing the distances between stimuli, and thus the degree of similarity as well, within a perceptual space that is not limited to two dimensions (Petiot & Yannou, 2004). A specific method within sensorial analysis, derived from a food focus, is the *napping* test that has also been applied to sensory evaluation of materials, and is easy and fast to set up, taking about fifteen minutes and ten assessors to evaluate a large sample set of minimum ten stimuli (Dacleu Ndengue et al., 2017; Faucheu et al., 2015; Pagès et al., 2010; Piselli et al., 2018). Pagès et al. (2010) define this procedure as follows: "…The set of I products is presented to the panellists who are asked to position the products on a large sheet of paper (tablecloth) according to their similarity, i.e., two products are all the more close (on the tablecloth) as they look alike and all the more distant as they differ. For a given panellist, the data can be assimilated to the two coordinates of the products on the tablecloth. For each of these procedures, panellists are informed of the overall character of the evaluation (hence, the term "holistic approach") and of the fact that they must use their own criteria, i.e., those which are the most important to them."

This process can also be enhanced by asking assessors to characterize the groups or the samples with associated descriptions and attributes. In addition, two variants of Napping exist: Sorted Napping and Mapping. *Sorted napping* is a combination of Napping and a categorization task where samples are grouped according to their resemblances (Pagès et al., 2010), while *Mapping* is a combination of Napping and a ranking task where two descriptors are used as dimensions of a sensory space or map, and their correlation can be studied (Piselli et al., 2018), as shown in Figure 1.6.

Third, a *paired comparison* (PC) test is a fast way to examine whether relative differences can be detected with regard to a specific attribute between two samples out of a set of many, however, it does not indicate the extent of the difference, making it rather hard to interpret the outcome of the test (Piselli et al., 2017, 2018). Nevertheless, it can be used to provide a measure of judgement inconsistency (Petiot & Yannou, 2004).

Fourth, in a *hierarchical grouping* task, participants are asked to divide a group of stimuli in two or more (unequal) subgroups based on similarities, and to substantiate their categorization choice (C.-C. Chang & Wu, 2009; Giboreau et al., 2001). Depending on the number of stimuli, this can be done in intermediate steps, facilitating the articulation of the freely selectable attributes that define the similarity.

Figure 1.5. Materials samples physically placed on semantic scale. Reprinted from (Lilley et al., 2016), in accordance with Creative Commons regulations.

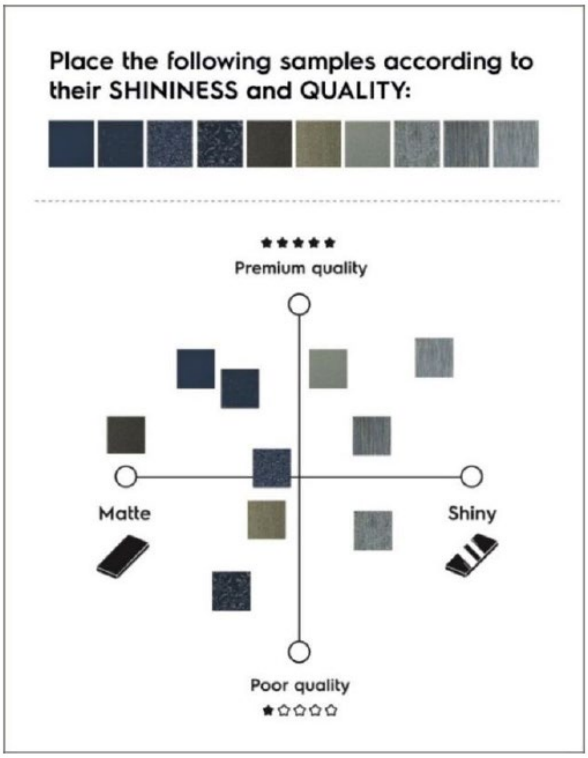


Figure 1.6. Test example of Mapping. Reprinted from (Piselli et al., 2018), Copyright (2018), with permission from Elsevier.

1.3.5.3 Free Impressions

Finally, 13 percent of the studies use an open interview technique to discover *free associations or impressions* of the subjects, whether or not in combination with additional methods that can reinforce each other (eight percent). By means of in-depth interviews (often semi-structured) not only the stimuli's characteristics can be collected, but also the underlying reasons why a sample is perceived in that way can be explored and elaborated on. However, this qualitative method is rather time-consuming, both to conduct and to process, as it requires software for coding and qualitative data analysis (content analysis) (Bahrudin & Aurisicchio, 2018; Ulusoy & Nilgün, 2017).

1.3.6 Respondents

1.3.6.1 Number of Respondents

Considering the time-consuming experiments within experiential characterization of materials or products, along with the practical feasibility of conducting such test, the number of respondents was in general quite low for statistical operations. Indeed, Kapkıin and Joines (2018) indicated insufficient or unbalanced number of participants in certain groups to reliably investigate possible effects, and in the discussion Section of reviewed articles, eleven studies specifically mentioned that future work should cover a larger sample size in order to generalize findings (Bahrudin & Aurisicchio, 2018; Y. T. Chen & Chuang, 2014; Choi, 2017; Georgiev & Nagai, 2011; Hope et al., 2012; Hsu et al., 2000; Lilley et al., 2016; Lindberg et al., 2013; Masson et al., 2016; Veelaert et al., 2018; Vergara et al., 2011). The overall average was 51 respondents, with a median of 30 respondents, and going from 10 to 474 respondents.

However, when these results were viewed from the three focuses, clear differences could be detected. Within the texture focus, 10 to 25 people participated in the experiments, which gave an average of 16 respondents (Md = 17). Within the material focus, 10 to 221 people took part, leading to an average of 42 participants (Md = 30). Yet, it must be noted that in the case of the largest sample group, the 221 respondents only scored one semantic scale on preference, while a sensory panel of eleven expert assessors ranked the material samples on additional attributes (Høibø & Nyrud, 2010), as did 10 untrained subjects in a Napping procedure (Faucheu et al., 2015). Within the product focus, 11 to 474 people responded, leading to the highest average with 119 respondents (Md = 73). The high numbers such as 474 (Mugge, 2011) or 283 (Agost & Vergara, 2014) occurred in the case of large scale online surveys using digital renders or photographs as stimuli.

1.3.6.2 Experience and Discipline

Apart from the number of respondents, also the experience background and discipline of the respondents distinguished between the different studies (see Table 1.8). In 43 percent of the studies, *students or academics* were involved (with μ=37 respondents), whereas *consumers* participated in 30 percent (μ=85), and *professionals* (μ=20) or others (μ=21) in 13 or 14 percent of the experiments. However, Chang and Wu (2007) noted that college students may not represent a broader consumer population.

Building on the cases in which the respondents' discipline was specified, 56 percent of the cases involved *non-design* background, whereas 29 percent of the respondents had a *design* background, 9 percent an *architecture* background, and 7 percent an *engineering* background.

Table 1.8. Frequencies of experience and discipline levels within Material, Texture, and Product focus.

	Students/ academics	Professionals	Unspecified	Consumers	**Total**	Design	Non-design	Architecture	Engineering	**Total**
	Experience					**Discipline**				
Material	20	5	5	14	**44**	8	20	4	1	**33**
Texture	5	1	4	2	**12**	1	2	0	1	**4**
Product	5	3	1	5	**14**	4	3	0	1	**8**
Total	**30**	**9**	**10**	**21**	**70**	**13**	**25**	**4**	**3**	**45**

Nine papers included respondents within different experience levels and/or disciplines (C.-C. Chang & Wu, 2009; Crippa et al., 2012; Giboreau et al., 2001; Høibø & Nyrud, 2010; Hsu et al., 2000; Kapkın & Joines, 2018; Piselli et al., 2018; Vergara et al., 2011; Zuo et al., 2016). On the one hand, this was done to have a broad distribution of respondent types (C.-C. Chang & Wu, 2009; Crippa et al., 2012; Zuo et al., 2016). On the other hand, comparisons could be made mostly between professionals and consumers (four times), or between all three disciplines (one time), and between designers versus non-designers (two times).

For example, Vergara et al. (2011) compared three user groups in their study on hammers; professionals, DIY enthusiasts, and trainees. They reported several factors that were affected by the users' level of experience, wherein trainees specifically led to significant differences as they seemed more negative and critical. Moreover, they stated that experts described more usability problems and provided stronger considerations for future usage scenarios. Similarly, Høibø and Nyrud (2010) reported that consumers without experience in wood evaluation, had greater difficulties to detect small differences in wood quality than professionals. Hsu et al. (2000) showed some significant differences between professional designers and users in the context of product form perception. Also in the study of Kapkin and Joines (2018), occupation (designers versus non-designer) appeared to have a main effect on several meanings such as seriousness, and had an interaction effect with gender. Piselli et al. (2018) used a two-by-two design, including respondents with (no) experience in an industrial product context, and (no) experience in materials, and concluded that all participants recognized certain sensory differences and similarities. All in all, their results supported the claim that sensory analysis could allow the consumer's involvement early in the design process, however a specific training of the panel members – whether they consist of designer and/or consumers – could lead to a higher level of consensus, as this would align their perception or interpretation of the sensorial attributes. Finally, Giboreau et al. (2001) suggested that a complementary approach, involving different levels of expertise, could be a powerful methodology for sensory profiling and categorization. This perspective might offer interesting opportunities concerning time and feasibility aspects.

Based upon the reviewed studies, we could conclude that the advantage of including designers or professionals is that they might have more feeling with materials and the application thereof, and that they might be more capable of abstract thinking, increasing feasibility of experiments with merely flat material samples. By contrast, addressing end-users or consumers in experiential characterization might be more challenging, as their interest and empathy need to be captured. In that regard, for example, Choi (2017) employed a digital-logic approach (yes/no) to ensure an easier user evaluation of attributes. A closer look on the studies involving consumers, revealed that physical but flat samples were used eleven times, a material rendered on an abstract form two times, a picture of a flat material sample once, and both a physical product and a photo/render of product each three times. Using a physical, yet abstract material form to trigger consumers, did not occur.

1.4 Discussion

In this Section, we aim to reveal learnings to systematically address experiential material characterization, with increased attention to the physicality of stimuli and to user aspects. The reviewed articles showed different attempts to respond to the methodological challenges within the field of experiential material characterization. For example, several studies tried to cope with the influence or interaction of different senses when assessing materials by experimenting with blind conditions, such as (X. Chen, Barnes, et al., 2009; Fenko et al., 2010; Lilley et al., 2016, p. 8; Lindberg et al., 2013; Piselli et al., 2017). Notwithstanding, an additional challenge can be seen on the choice of material stimuli or representation as this experimental aspect has a great influence on the overall perception of a material. The interaction between product (or form) meaning and materials meaning proved rather difficult to bridge, and researchers are challenged to find abstract forms or products that do not carry too many meanings in itself so that material meaning can be projected more independently.

1.4.1 Need for Within-material-class Comparisons

Most of the reviewed experiments involved familiar material classes such as metal, wood and plastic that are commonly used in mass produced everyday products. However, little experiments were done on comparisons within material classes instead of between classes. In the context of texture focus (e.g. textiles) and building materials (e.g. woods), efforts have been made already, yet a lack can be detected within-class concerning other materials and contexts. For example, plastics (Rognoli, Salvia, et al., 2011) were first introduced as "identity-less" imitation materials, were later boosted by Tupperware, but are now facing issues concerning sustainable perception in relation to bioplastics, recycled plastics and many more. Consequently, this material class could serve as an interesting and valuable path to pursuit in further research, and a valuable contribution for designers. One of the consequences of studying materials within the same class, is that they are more difficult to compare than metal to wood for example, and that materials such as plastics are nearly impossible to experience by means of photos or renders (Veelaert et al., 2018). Therefore, physical tests with material samples must be the standard (Martín et al., 2015).

1.4.2 Need for Physical Material Representations

When physical material stimuli are intended, several considerations and challenges arise. In the reviewed studies, mostly decontextualized samples (flat cut-outs) or contextualized materials applied in products were employed. Piselli et al. (2018) suggested shaped specimens in further research, however, since Karana et al. (2007) showed the effect of form on material meaning, we propose an abstract "in-between"; a form that allows an equal and thus constant presentation of various materials, but is varied in itself, similar to the bowls of Crippa et al. (2012) that were both convex and concave, but not associated with food or other specific product functions. The shaped specimen means should evoke interaction and allow or facilitate free exploration. Moreover, it does require an appropriate level of complexity of the form to trigger the respondent to empathize with a material sample multimodally.

In addition, we suggest that a digital layer could be explored as well, as we see potential in Virtual Reality techniques to complement the experiential understanding of materials (Barati, 2019). All in all, by means of a physical in-between sample form, controlled experimental conditions would be possible and additional product or contextual factors can be included by asking participants to envision the studied material in particular situations (envisioning factors), in order to create more flexibility despite standardization, as done by (Fujisaki et al., 2015; Ulusoy & Nilgün, 2017), which can increase the time-efficiency and can overcome practical issues in the production of samples (i.e. form must be simple enough to reproduce without difficulties).

1.4.3 Need for Multimodal Interaction with Stimuli

In the case of physical material samples and within-class comparisons, the interaction context is an important aspect to be considered. In material appraisals, the most dominant sensory modality is that of vision. In addition, blind touch and visual touch are also often studied. However, human perception is inherently a multisensory experience (Dacleu Ndengue et al., 2017), thus the senses cannot be isolated when human behaviour is analysed, but a holistic, multimodal approach is needed in sensory material evaluation (D'Olivo et al., 2013), reducing perceptual ambiguity. This could decrease the difficulty of comparing e.g. various plastics (such as ABS versus PP) when using only touch or only vision, as occurred in (Veelaert et al., 2018).

Therefore, we argue that free exploration (or dynamic touch) deserves more attention in experiential characterizations as this is most consistent with the use phase of a material/product. In this way, participants can "play with" a sample and fully explore all experiential quality levels. Hence, future research can also anticipate to the performative level that is currently understudied. Camere and Karana (2018) emphasized the need for understanding of the 'performative' level of experience. Grounding on the study presented in "The Tuning of Materials: A Designer's Journey" (Karana et al., 2016), they attempted to create an initial vocabulary of actions which can be used in experiential characterization. Yet, the vocabulary is suggested to be further developed and tested in future studies. All in all, we see opportunities in involving multiple experiential levels (for full materials experience), and in exploring the links between these levels as well.

1.4.4 Need for Complementary Experimental Set-up and Methods

The experimental set-up should be adjusted to the context of physical material representations and multimodal exploration. As we suggested free exploration, higher flexibility instead of control is needed in order to lower the threshold. A table set-up might be convenient to display the physical material sample(s). We suggest a custom-made experiment table, in line with the sample box holders as often found in the reviewed articles. This table could include a benchmark with a reference material so that equal interpretation between participants is increased as well, and should facilitate the chosen measure method such as scaling, ranking, etc. Finally, both scale items and samples should be supplied in a random order, and their number should balance between exhaustion and time efficiency.

In order to measure experiential qualities, various methods were analysed. Although in-depth interviews (also 'elicitation interviews) are time-consuming to conduct and process, they can be employed as a complementary approach to empirical studies, as less people are required; e.g. depending on the context, minimal three up to ten people in case of elicitation (Hogan et al., 2016). Within descriptive measures, scaling (e.g. the semantic differential method, SDM) was most frequently used, with five or seven scale points, an average of ten items per test, and without or with pictograms to increase reliability and agreement and decrease ambiguity among untrained subjects.

However, as perception is inherently more comparative, we acclaim the increasing popularity of holistic approaches or multi-attribute issues in sensory analysis, that allow to assess relative distances between samples (creating a reference framework). Thus, we see potential in MDS methods such as structured Napping (Mapping) that employs a pre-defined couple of descriptor items to accommodate untrained consumers and to overcome the limitations of SDM that lacks a comparative reference framework and is more analytical instead of spontaneous. Moreover, multiple experiential levels can be combined, and a rather large group of stimuli can be assessed (minimum ten to fifteen).

1.4.5 Need for Studying Temporality of Materials Experience

In addition, we detect a gap in longitudinal studies to understand materials experience over time. In the context of user's product experience and product adoption, Karapanos et al. (2009, p. 729) concluded that "while early experiences seemed to relate mostly to hedonic aspects of product use, prolonged experiences became increasingly more tied to aspects reflecting how the product becomes meaningful in one's life", which can be related to the expression of the self through materialised objects that we own. In order to study the temporality of materials experience as well, ethnographic studies are required which can be complemented again with empirical in-lab experiments.

1.4.6 Need for Integration of Extensive User Aspects for Consumer Segmentation

The effect of user aspects has been already demonstrated, albeit insufficiently studied in depth beyond demographic aspects despite the fact that in the end it is the consumer's opinion that is important for market success. Specially meanings of materials are sensitive to such user aspects that can act as important moderators in the creation of material expression. Firstly, several authors (Y. T. Chen & Chuang, 2014; Hope et al., 2012; Kapkın & Joines, 2018) mentioned insufficient or unbalanced number of participants in certain groups to reliably investigate possible user effects, which made them reluctant to generalize findings. As large-scaled studies might be required for marketing database purposes (Hsu et al., 2000), we argue that this can also offer segmentation opportunities to thoroughly include extensive user aspects beyond demography – such as personal values, personality traits, or the self-identity of consumers – that will offer more valuable insights to designers in their materials selection, as well as to marketeers.

Secondly, in contrast to designers or professionals that might have more feeling with materials, the application thereof, and abstract thinking (increasing the feasibility using merely flat samples), we argue that consumers must be addressed in experiential characterization to properly include user aspects, which might be more challenging as their interest and empathy need to be captured. Although this combination did not occur in the reviewed studies, we propose that the use of a physical, yet abstract material sample form can trigger consumers in a dynamic, multimodal characterization, while minimizing the interference with product context associations, and should be the first step in future research.

1.5 Conclusion

In this paper, we presented a literature review study on experiential characterization in product design, in which we described the current state of the art and identified gaps or opportunities for further research. As a directive for optimal future research, we suggest to respond to the specific scope of the intended study, and make use of the proposed needs as learnings or points of attention that can be translated into an appropriate experimental set-up. For example, a scope can start from a specific material and its material characteristics, that can be conducted with abstracted stimuli, or rather from a material application and the underlying dynamics of materials experience. Moreover, the scope can focus on one specific experiential level, or on the interaction between multiple levels, or can also manifest within a material, texture or product focus. In addition, a future scope can include more quantitative studies to involve experiential preferences of users and to segment people (self-experience and material experience can be congruent with each other), extensive inclusion of user aspects, compared to other combinations of more experimental studies. Although the scope of an intended study will have a major influence, the main conclusions can be made with regard to [i] Material representations; we suggest that a physical representation of a material in an abstract form (next to more defined forms, such as flat samples) can be a critical element for multimodal material characterization experiments that allow a certain flexibility (by means of envisioning factors) despite standardization of experimental conditions, as well as they can show form possibilities of materials in a broader sense; [ii] attention to User aspects; we suggest that the user aspects included in experiential characterization studies should go beyond demographic aspects (e.g. values, personality, etc.) so that more detailed segmentation profiles can be included when assessing the expression of materials by consumers, not only designers. Additionally, future research is suggested on within-material-class comparisons (e.g. virgin versus recycled polypropylene), complementary methods and experimental set-up that facilitates free exploration of materials and multi-attribute comparison of different samples, and the temporality of materials experience (e.g. longitudinal ethnographic studies that complements empirical in-lab experiments).

Chapter 2 is based on:

Veelaert, L., Du Bois, E., Moons, I., De Pelsmacker, P., Hubo, S., & Ragaert, K. (2020). The Identity of Recycled Plastics: A Vocabulary of Perception. *Sustainability*, 12(5), 1953. https://doi.org/10.3390/su12051953

2. The Identity of Recycled Plastics: a Vocabulary of Perception

Lore Veelaert, Els Du Bois, Ingrid Moons, Patrick De Pelsmacker, Sara Hubo and Kim Ragaert

Abstract: As designing with recycled materials is becoming indispensable in the context of a circular economy, we argue that understanding how recycled plastics are perceived by stakeholders involved in the front-end of the design process, is essential to achieve successful application in practice, beyond the current concept of surrogates according to industry. Based on existing frameworks, 34 experiential scales with semantic opposites were used to evaluate samples of three exemplary recycled plastics by two main industrial stakeholders: 30 material engineers and 30 designers. We describe four analyses: (i) defining experiential material characteristics, (ii) significant differences between the materials, (iii) level of agreement of respondents, and (iv) similarities and differences between designers and engineers. We conclude that the three materials have different perceptual profiles or identities that can initiate future idea generation for high-quality applications. The study illustrates the potential of this evaluation method. We propose that designers can facilitate the valorisation and adoption of these undervalued recycled materials, first by industry and ultimately by consumers as well.

Keywords: *design from recycling, plastic waste, materials experience, aesthetic perception, circular economy*

2.1 Introduction

The growing number of (new) materials (Roth et al., 1994) leads to a complex and time-consuming materials selection process in industrial design engineering (Rao & Davim, 2008). Additionally, in the context of our expanding consumer society, the role of plastics within product design has been essential (Ashby & Johnson, 2012) since they offer designers great freedom in shaping and manufacturing their products. Consequently, plastics are widely used for consumer goods such as toys, housings, packaging, etc. Inevitably, an increasing amount of products leads to an increasing amount of (plastic) waste as well (Geyer et al., 2017). Considering the future scarcity of raw materials, there is a clear need for sustainable product development in a circular economy (Ellen MacArthur Foundation & McKinsey & Company, 2012; Singh & Ordoñez, 2016). Hence, engineers and product designers are addressed to rethink the product's life cycle and to retain its plastic materials in closed loops (Ordoñez & Rahe, 2013). The increasing attention to sustainable and circular product design requires industry to substitute traditional materials with alternatives such as bio-plastics or materials derived from waste (e.g. recycled plastics) (Freinkel, 2013; Geiser & Gros, 2001; Karana, 2012). Consequently, within Europe, the industrial interest in the field of polymer recycling is ever-growing (European Commission, 2015).

The research presented in this study is part of the project 'Design from Recycling', supported by industry in Flanders, one of the Belgian regions, that examines how to design with recycled plastics. More particularly, it focusses on the challenge of using these recyclates in high-quality products for industrial mass production, instead of low-grade applications and downcycling practices (Veelaert, Du Bois, et al., 2017). While Design 'for' Recycling emphasizes the recyclability at the end of a product's life, Design 'from' Recycling actually closes the intended loop through the design and manufacture of products made from existing recycled (plastic) flows. Put differently, it initiates a new product life cycle for the plastic waste that would otherwise be landfilled or incinerated, without extracting new resources (Sauerwein et al., 2017; Singh & Ordoñez, 2016; Vezzoli, 2014).

Generally, two types of incoming plastic waste material can be distinguished: post-industrial waste versus post-consumer waste. Post-industrial waste consists of plastic scrap that arises in the production plant itself, and that can rather easily be collected and reused as long as it is not contaminated, leading to minimal quality loss or change in appearance. In contrast, our focus lies on post-consumer waste that consists of multiple and/or contaminated polymers (e.g. polypropylene, acrylonitrile-butadiene-styrene) that have already endured a full life cycle (Ignatyev et al., 2014), making it more difficult to control quality and appearance. As chemical recycling is not yet fully developed on an industrial scale, nowadays, mixed plastic waste is mechanically recycled through a process of sorting, washing, shredding and reprocessing as flakes, allowing industrial processing such as extrusion and injection moulding as a final step to new product applications (Ragaert, Delva, et al., 2017), or even high-quality products. The result of this recycling process allows to technically characterize recycled material samples through standardized lab tests, leading to material properties that can be easily integrated into material databases (e.g. CES Material Selector). From an engineering perspective, such databases are the start for materials selection and currently, mainly technical and objectively measurable data is taken into consideration.

However, in terms of material knowledge considerations in product design, literature indicates that a balance is required between technical properties on the one hand, and experiential qualities on the other (Bang et al., 2015; Hasling, 2016; Karana et al., 2008a). Van Kesteren (2008) states that "for high-quality products, product designers should select materials that comprise in both aspects". To accomplish this, collaboration is needed between engineering and user-centred design (Veelaert et al., 2016). Although post-consumer plastic waste offers a twofold environmental benefit as no new resources are required and less material is discarded (Halada & Yamamoto, 2001; Vezzoli, 2014), the origin of these materials does have an impact on the perceived aesthetics and material experience, compared to their virgin (or even post-industrial) counterparts (Karana, 2012; Schifferstein & Wastiels, 2014). The usual strategy to simply substitute and mimic traditional materials in existing products and moulds, without considering the design consequences, has become insufficient for implementing post-consumer recycled plastics (Hubo & Ragaert, 2014; Huysman et al., 2017; Ragaert, 2016; Ragaert, Delva, et al., 2017; Veelaert, Du Bois, et al., 2017). Due to the lack of technical excellence, from the industry's point of view, the current perception of recyclates is limited to the concept of surrogates (Veelaert, Du Bois, et al., 2017), which deters the industry from implementing recycled plastics in high-quality products in the broad market. Instead, post-consumer recyclates are applied in low grade, bulky outdoor products, such as flowerpots.

"Surrogate" (Rognoli, Salvia, et al., 2011) products made of recycled plastics often fail on both the functional and the symbolic level when introduced to the market (Karana, Barati, et al., 2015; Maine et al., 2005; Manzini, 1986). Despite life cycle advantages, recycled materials are not necessarily received in a positive way by either its industrial users (e.g. material engineers and designers) or by consumers when embodied in daily products (Dehn, 2014; Karana, 2012). Rognoli et al. (2011) state that: "The term 'surrogate' not only evokes the idea of substitute, but it also usually adds a negative value: the surrogate is a product of lower value, used in place of a genuine one. Being a 'surrogate' means not having its own identity". Consequently, such new materials often experience a struggle for adoption in high-quality applications due to their lack of identity (Karana, 2012; Vezzoli, 2014), similar to other emerging materials (Salvia et al., 2011) such as bioplastics.

A material's identity is partly created by the experience(s) the material evokes with people. Therefore, to approach recycled plastics from a user-centred perspective, we build upon the

Materials Experience Framework (Karana et al., 2014). A material is experienced on four levels that interact with each other and with external aspects such as context, product, and user (Karana et al., 2010). A material can be glossy and smooth (***sensorial level***), expressing an elegant or professional character (***interpretive leve***l; meanings or associations), eliciting confidence and respect (***emotional level***), and can trigger users to enfold the material or product (***performative level***) (Karana, Barati, et al., 2015). Karana et al. (Karana, Barati, et al., 2015, p. 37) state that "this requires qualifying the material not only for what it is, but also for what it does (Manzini, 1986), what it expresses to us, what it elicits from us (Karana et al., 2014), and what it makes us do (Giaccardi & Karana, 2015)". Literature indicates that 'meaning-evoking patterns' or relationships can be identified between the different experiential levels of materials (Karana, 2009). In this research, we focus on the two main levels, i.e. sensorial and interpretive level, as these are most elaborated in practice (Camere & Karana, 2018). Thus, when considering these expressive patterns in the design of new products, one can respond to and influence how people experience and appreciate the sensorial and interpretive characteristics of recycled plastics, and ultimately improve the introduction and commercial success of recycled plastics (Karana et al., 2014; Sauerwein et al., 2017).

The environmental performance (Huysman et al., 2017) and technical functionalities (Hubo & Ragaert, 2014; Ragaert, Delva, et al., 2017; Ragaert, Hubo, et al., 2017) have been examined to great extent by industry and academia. In contrast, additional research is needed on the user-centred or experiential perspective of plastic recyclates. As designing with recycled materials is becoming indispensable in the context of a circular economy, we argue that understanding how post-consumer recycled plastics are perceived is essential to achieve successful application in practice. Thus, a gap remains concerning experiential insights and descriptive data on materials, that would facilitate ***designers*** to develop effective strategies to manipulate meaning-creation and to formulate meaningful material identities. This way, and in collaboration with ***material engineers***, such new and undervalued materials can be successfully positioned on the market, which is needed to increase the valorisation of recycled plastics in the design of new and high-quality products (Sauerwein et al., 2017). With respect to experiential material characterization, previous work (Veelaert, Du Bois, et al., 2020) showed that most studies are conducted on small sample sizes (e.g. 10 to 15 participants in (Bahrudin & Aurisicchio, 2018; Lilley et al., 2016)), with craft or DIY (do-it-yourself) materials instead of mass recycled plastics (e.g. (Rognoli et al., 2015; Sauerwein et al., 2017)), and/or without standardized stimuli produced with high-quality on an industrial scale (e.g. (Karana et al., 2009a; Lindberg et al., 2013)). Therefore, the first aim and contribution of this research is to study the experiential qualities of three types of exemplary recycled plastics, on a relatively larger scale than previous studies, with representative materials, and with standardized stimuli and measure scales, which contributes to material knowledge from a user-centred perspective.

Perception is a subjective matter and depends on context and users. As we aim to measure users' perceptions of recycled materials, we focus on two main dimensions of experiential material qualities: the perception of sensorial attributes (which includes aesthetic appearance, touch, etc.) and the interpretive characteristics (that include meanings and associations regarding quality, sustainability, etc.). The (potential) perceptions of these experiential material qualities by multiple users are summarized and contained in the 'material identity' which can be the starting point to market a recycled material. In this study, we focus on two important stakeholder groups that encounter new recycled materials early in the life cycle, i.e. material engineers and designers who will embody recycled materials in new consumer products. Furthermore, at this stage, designers still have the ability to enhance and/or adapt the inherent sensorial and experiential material qualities, in collaboration with material engineers, i.e. through computation of the material by processing techniques, colour additives, more/extra sorting steps, etc. This is essential as designers have to optimize the whole product perception and interaction with its user, and must therefore communicate with material engineers. Consequently, the second aim and contribution of this study is to understand how high-quality post-consumer recycled plastics are perceived by these two industrial stakeholders, with a focus on sensorial attributes and interpretive characteristics, and to detect the potential difficulties in their communication (e.g. one stakeholder group might perceive more and/or other characteristics). The following sub research questions can be formulated:

- (RQ1) Which experiential qualities best describe three types of recycled materials (i.e. what are the prominent sensorial and interpretive characteristics)?
- (RQ2) What are the significant differences in material perception between recycled materials?
- (RQ3) What are the similarities (RQ3.1) and differences (RQ3.2) between the material perception of designers and engineers (i.e. level of agreement on experiential qualities versus significant differences)?

2.2 Conceptual Framework for Experiential Characterization of Materials

In order to study material perception, we build upon the frameworks of **sensorial** scales (Karana et al., 2009b) that are commonly used for attributing meanings to materials. Previous research (Veelaert, Du Bois, et al., 2017) shows that these scales are a valuable tool to facilitate the sensorial evaluation of materials – also for non-designers – and to initiate a more in-depth exploration of a material's perceptions. This approach represents various sensorial attributes by means of both verbal and visual opposites on a five-point semantic differential scale. Three existing frameworks or methods are explored and compared to measure sensorial attributes as proposed by Karana and van Kesteren (Karana, 2009; Karana et al., 2009b; van Kesteren et al., 2007b). They are shown in Appendix 2A. The sensorial attributes (semantic opposites) that are mentioned in at least two lists are selected: Glossiness, Transparency, Colourfulness, Colour intensity, Softness, Ductility, Weight, Strength, Elasticity, Texture, Odour and Temperature. However, reflectiveness is excluded as it is considered irrelevant in the specific context of recycled plastics. The same goes for the attribute of 'transparency' (since all mixed recyclates are opaque). However, this item is retained as a control item to evaluate whether participants were attentive. In addition, in line with previous research (Karana et al., 2009b), the list is extended with more attributes related to strength as this property can be interpreted in different ways from a technical material perspective, depending on the applied force (compressive, tensile, impact, shear, etc.): Stiffness, Brittleness, Scratchability, Greasiness, and Acoustics.

Similar to the procedure for sensorial attributes, an experiential scale with semantic opposites is also compiled to evaluate the **interpretive** characteristics of recycled materials, and thus the associations (meanings) they evoke. First of all, Karana's nine meaning sets are selected (Karana, 2009), which are proven to be clear, understandable, and relevant for material appraisals: Aggressive-Calm, Cosy-Aloof, Elegant-Vulgar, Frivolous-Sober, Futuristic-Nostalgic, Masculine-Feminine, Ordinary-Strange, Sexy-Not sexy, Toy-like-Professional. Furthermore, this list is extended with eight adjective pairs based on Ashby and Johnson's (2012) list of 'perceived attributes' and used meanings by van Kesteren et al. (2007b): Delicate-Rugged, Disposable-Lasting, Formal-Informal, Cheap-Expensive, Classic-Trendy, Honest-Deceptive, Mature-Youthful, Traditional-Modern.

Conclusively, seventeen sensorial attributes and seventeen interpretive characteristics are used for the experiential characterization of recycled plastics by designers and engineers.

2.3 Materials and Methods

2.3.1 Stimuli

For the purpose of this study, three particular recyclates are considered that can be easily differentiated and that serve as exemplary post-consumer recycled plastics as they are currently collected in large quantities. We focus on post-consumer plastic waste materials that are processed and recycled 'as is', which means that no additives nor compatibilizers are added to improve processing or technical properties. Together with the industrial partners, it was agreed to focus on two material streams that are very common, both in virgin and in recycled version, since good use of these large-quantity waste streams has the greatest potential impact on aiming for a more circular production. For this study, two different material sources are selected: mixed polyolefins (MPO: the 'floating' fraction in the recycling process) versus recycled Acrylonitrile-butadiene-styrene (rABS) from specific collection fractions. From a technical perspective, these two material groups are very different, e.g. mixed polyolefins (MPO) are flexible and rABS is brittle. From a sensorial perspective, MPO has a grey colour with visual contaminations or 'speckles' while rABS is black and smooth. To address the potential effect of colour in meaning creation, black colour is added to the MPO material to generate a third material stimulus set:

- Material 1: post-consumer recycled mixed polyolefins (**MPOgrey**) mainly containing Polyethylene (PE) and Polypropylene (PP).
- Material 2: post-consumer recycled mixed polyolefins (**MPOblack**) mainly containing Polyethylene (PE) and Polypropylene (PP), darkened with black colour additives.
- Material 3: post-consumer recycled Acrylonitrile-butadiene-styrene (**rABS**) originating from end-of-life vehicles (ELV) and Waste Electrical and Electronic Equipment (WEEE).

Karana (2009) states that "materials have a history, which helps us to assign meanings to them even when they are not embodied in products". Therefore, a standardized and equal stimulus set is created for three types of recycled plastics, through injection moulding, in an attempt to minimize function or context-bound effects, and to generalize meaning creation. Similar material stimuli are also used in various experiential studies found in literature (D'Olivo et al., 2013; Hope et al., 2012; Karana, 2012; Wastiels et al., 2012b). This stimulus set of each material consists of a bar, a doggy bone, and a flat square, as visualized in Figure 2.1. Each material stimulus is labelled with the numbers shown above (with three forms within each material stimulus set). Consequently, participants are not able to associate the materials to their virgin origins, neither does the form suggest any specific (past) usage or functionality. Since the used injection moulding technique delivers very consistent samples, an individual stimulus set is provided for each participant, allowing them to bend or break their samples first-hand.

(**a**) (**b**) (**c**)

Figure 2.1. Stimulus sets of the materials used in the study: (**a**) MPO grey; (**b**) MPO black; (**c**) rABS.

2.3.2 Participants

In this study, the targeted stakeholder groups (material engineers and designers) are represented by master students to aim for as little prejudices as possible concerning the technical application of the materials. In total, 60 students aged 21 to 29 participated in the study (average age 23 years). The participants (N=6*0*, 43 males, 17 females) were recruited among master students during material related courses from both an engineering and a product development department at two universities in Flanders, one of the Belgian regions: material engineers from the Department of Materials, Textiles and Chemical Engineering at Ghent University (n=30, 25 males, 5 females) and designers from the Department of Product Development at Antwerp University (n=30, 18 males, 12 females). Using master students as participants increases the comparability in background as they already had the same training during their three bachelor years. Moreover, as they lack professional experience, they are not yet 'biased' by prejudices in industry that might limit the translation to real-life applications. Given the male majority among the engineering students, no equal gender distribution was achieved, however, this might also be a correct reflection of an industrial context.

2.3.3 Procedure

We conducted two sessions, one at the engineering department and one at the design department, during the same week. Both groups of participants (engineers and designers) followed the same procedure. The study took approximately 15-20 minutes for each participant and was conducted individually in a classroom. Each participant was given three stimulus sets (i.e. three forms for each of the three recycled materials), as described in the '2.3.1 Stimuli' Section and shown in Figure 2.1. The three stimulus sets were provided simultaneously, in order to facilitate the evaluation by comparing the three materials. Participants were instructed to evaluate the stimuli using all their senses (sight, touch, smell, hearing), except for taste since the recycled plastics are not food grade. Each material was assessed overall by means of its three forms together.

2.3.4 Measures

We utilized the lists of seventeen sensorial attributes and seventeen interpretive characteristics, based on the frameworks discussed in the '2.2 Framework' Section. Drawing upon the principles of recent similar research (Karana et al., 2009b), participants had to complete an evaluation sheet comprising a list of five-point bipolar semantic differential scales (-2, -1, 0, 1, 2) linked to the thirty-four characteristics, and shown in Appendix 2B. Only the participant's perception of these experiential qualities (sensorial attributes and interpretive characteristics) was studied, independent from application. Thus, in total, 102 scores were collected per participant (34 scores x 3 materials). In addition, their age, gender, and study background were requested.

First, for each material, the **prominent material characteristics** (experiential qualities) are determined by means of One-Sample T tests (*RQ1*). Second, the **significant differences between the three materials** are determined by means of Paired-Samples T tests (*RQ2*). Third, the **level of agreement** among designers, among engineers and among the total respondent group, is assessed by means of calculating the standard deviations for each of the material characteristics per material (*RQ3.1*), while the **significant differences between designers and engineers** on the scores of the material characteristics of each material are calculated by means of Independent-Samples T tests (*RQ3.2*).

2.4 Results

The mean scores and standard deviations for each material on each of the criteria, for the two stakeholder groups and for the entire group of 60 respondents are given in Appendix 2C. The analyses are discussed below.

2.4.1 Prominent Characteristics of Each Material

This Section explores which sensorial attributes and interpretive characteristics are most defining for each material (RQ1). Therefore, the sensorial and interpretive scales are analysed statistically by means of *One-Samples T Tests* for each material in order to identify which of the scores are significantly different from the 'neutral point' (Test Value=0). For each material, this test is calculated overall, and for designers and engineers individually.

2.4.1.1 Prominent Characteristics of the rABS material

The results for rABS are shown in Table 2.1 and ordered according to the total significance levels (designers and engineers combined). As mentioned before, the attribute of Transparency serves as our control variable, assuming all respondents would score all materials as very opaque. Logically, this attribute is located on top of the list. Moreover, of the 21 significant characteristics, sensorial attributes (13 counts) are found as more prominent characteristics than interpretive characteristics (8 counts). When focusing only on designers or on engineers, 20 significant characteristics were found within each group.

According to the total group of respondents, rABS is considered a material with the following most 'defining' sensorial attributes ($\boldsymbol{p < 0.05}$): Opaque, Colourless, Hard, Low elasticity, Stiff, Intense colour, Tough, Odourless, Shrill acoustics, Smooth texture, Brittle, Scratch resistant, Light and with the following interpretive characteristics: Aloof, Formal, Mature, Elegant, Ordinary, Honest, Aggressive, and Futuristic.

2.4.1.2 Prominent Characteristics of the grey MPO material

The results for MPO grey are shown in Table 2.2 and again ordered according to the total significance levels, with again Transparency on top. Of the 21 significant characteristics, sensorial attributes (13 counts) are found more prominent than interpretive characteristics (8 counts). However, for this material more significantly prominent characteristics are found for designers (20 counts) than for engineers (16 counts). According to the total group of respondents, MPO grey is considered a material with the following sensorial attributes ($\boldsymbol{p < 0.05}$): Opaque, Matte, Ductile, Weak colour, Unbreakable, Soft acoustics, Light, Scratchable, Dry, Strong, Rough, Fragrant, Warm and with the following interpretive characteristics: Cheap, Not sexy, Toy-like, Vulgar, Informal, Disposable, Rugged, and Calm.

2.4.1.3 Prominent Characteristics of the black MPO material

The results for MPO black are shown in Table 2.3 and ordered according to the total significance levels, with again Transparency on top. For this material, only fifteen significant characteristics are found, with more prominent sensorial attributes (11 counts) than interpretive characteristics (4 counts). MPO black is considered a material with the following sensorial attributes ($\boldsymbol{p < 0,05}$): Opaque, Smooth, Ductile, Light, Soft acoustics, Unbreakable, Greasy, Scratchable, Colour intense, Glossy, Colourless and with the following interpretive characteristics: Cheap, Not sexy, Toy-like, and Disposable.

Table 2.1. Mean differences and Significance levels for One-Samples T Tests of rABS material.

Material characteristic	**Level**	**Designers**	**Engineers**	**Total**
	Sensorial vs Interpretive	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*
Transparency (opaque – transparent)	S	**-1.90 (<0.000)**	**-1.96 (<0.000)**	**-1.93 (<0.000)**
Colourfulness[1] (colourless – colourful)	S	**-1.20 (<0.000)**	**-1.71 (<0.000)**	**-1.45 (<0.000)**
Softness (hard – soft)	S	**-1.45 (<0.000)**	**-1.18 (<0.000)**	**-1.32 (<0.000)**
Elasticity[1] (low – high)	S	**-1.50 (<0.000)**	**-0.89 (<0.000)**	**-1.21 (<0.000)**
Stiffness (stiff – flexible)	S	**-1.40 (<0.000)**	**-0.96 (<0.000)**	**-1.19 (<0.000)**
Colour intensity (weak – intense)	S	**1.00 (<0.000)**	**1.04 (<0.000)**	**1.02 (<0.000)**
Ductility[1] (tough – ductile)	S	**-1.20 (<0.000)**	**-0.63 (0.014)**	**-0.93 (<0.000)**
Odour (odourless – fragrant)	S	**-1.20 (<0.000)**	**-0.68 (0.009)**	**-0.95 (<0.000)**
Cosy – aloof[1]	I	**1.23 (<0.000)**	0.36 (0.057)	**0.81 (<0.000)**
Formal – informal	I	**-0.9 0(<0.000)**	**-0.61 (0.009)**	**-0.76 (<0.000)**
Acoustics[1] (soft – shrill)	S	**1.28 (<0.000)**	0.25 (0.229)	**0.77 (<0.000)**
Mature – youthful[1]	I	**-0.90 (<0.000)**	**-0.36 (0.022)**	**-0.64 (<0.000)**
Texture (smooth – rough)	S	**-0.53 (0.007)**	**-0.79 (0.001)**	**-0.66 (<0.000)**
Brittleness (brittle – unbreakable)	S	**-0.70 (0.001)**	-0.39 (0.102)	**-0.55 (0.001)**
Scratchability[1] (scratchable – scratch resistant)	S	**0.90 (<0.000)**	0.11 (0.621)	**0.51 (0.002)**
Elegant – vulgar	I	-0.43 (0.062)	**-0.36 (0.015)**	**-0.40 (0.004)**
Weight[1] (light – heavy)	S	-0.13 (0.580)	**-0.79 (<0.000)**	**-0.45 (0.007)**
Ordinary – strange[1]	I	**-0.77 (<0.000)**	-0.07 (0.779)	**-0.43 (0.01)**
Honest – deceptive	I	-0.27 (0.174)	**-0.41 (0.019)**	**-0.33 (0.011)**
Aggressive – calm	I	-0.27 (0.293)	**-0.58 (0.005)**	**-0.41 (0.012)**
Futuristic – nostalgic	I	-0.27 (0.211)	**-0.46 (0.025)**	**-0.36 (0.014)**
Frivolous – sober	I	**0.50 (0.019)**	0.07 (0.738)	0.29 (0.052)
Strength (weak – strong)	S	**0.55 (0.030)**	0.04 (0.866)	0.30 (0.071)
Greasiness (dry – oily)	S	-0.24 (0.316)	-0.36 (0.143)	-0.30 (0.078)
Sexy - not sexy	I	0.00 (1.000)	**-0.61 (0.017)**	-0.29 (0.078)
Toy-like – professional	I	**0.48 (0.041)**	0.04 (0.889)	0.26 (0.129)
Temperature (cold – warm)	S	-0.10 (0.586)	**0.39 (0.025)**	0.14 (0.280)
Disposable – lasting[1]	I	**0.53 (0.024)**	-0.21 (0.326)	0.17 (0.290)
Traditional – modern	I	0.00 (1.000)	**0.32 (0.047)**	0.16 (0.303)
Glossiness (matte – glossy)	S	0.07 (0.738)	-0.36 (0.067)	-0.14 (0.322)
Cheap – expensive	I	0.30 (0.130)	-0.07 (0.745)	0.12 (0.411)
Delicate – rugged	I	0.17 (0.510)	0.04 (0.887)	0.11 (0.557)
Classic – trendy[1]	I	-0.27 (0.265)	**0.44 (0.031)**	0.07 (0.663)
Masculine – feminine[1]	I	-0.37 (0.078)	0.29 (0.200)	-0.05 (0.736)

[1] Significant difference between designers and engineers (according to Appendix 2D).

Table 2.2. Mean differences and Significance levels for One-Samples T Tests of MPO grey material.

Material characteristic	**Level**	**Designers**	**Engineers**	**Total**
	Sensorial vs Interpretive	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*
Transparency (opaque – transparent)	S	**-1.93 (<0.000)**	**-1.97 (<0.000)**	**-1.95 (<0.000)**
Glossiness (matte – glossy)	S	**-1.43 (<0.000)**	**-1.1 (<0.000)**	**-1.27 (<0.000)**
Ductility (tough – ductile)	S	**0.97 (<0.000)**	**1.29 (<0.000)**	**1.12 (<0.000)**
Cheap – expensive	I	**-1.10 (<0.000)**	**-1.03 (<0.000)**	**-1.07 (<0.000)**
Colour intensity[1] (weak – intense)	S	**-1.17 (<0.000)**	**-0.55 (0.011)**	**-0.86 (<0.000)**
Brittleness (stiff – flexible)	S	**1.00 (<0.000)**	**1.07 (<0.000)**	**1.03 (<0.000)**
Acoustics (soft – shrill)	S	**-1.07 (<0.000)**	**-0.79 (<0.000)**	**-0.93 (<0.000)**
Sexy – not sexy	I	**0.87 (<0.000)**	**0.83 (<0.000)**	**0.85 (<0.000)**
Weight[1] (light – heavy)	S	**-0.53 (0.027)**	**-1.24 (<0.000)**	**-0.88 (<0.000)**
Toy-like – professional	I	**-0.67 (0.004)**	**-0.66 (0.001)**	**-0.66 (<0.000)**
Scratchability (scratchable – scratch resistant)	S	**-0.66 (0.004)**	**-0.76 (0.003)**	**-0.71 (<0.000)**
Greasiness (dry – oily)	S	**-0.80 (<0.000)**	**-0.59 (0.021)**	**-0.69 (<0.000)**
Elegant – vulgar	I	**0.67 (0.002)**	**0.41 (0.026)**	**0.54 (<0.000)**
Formal – informal	I	**0.80 (0.002)**	0.39 (0.118)	**0.60 (0.001)**
Disposable – lasting	I	**-0.63 (0.011)**	**-0.55 (0.040)**	**-0.59 (0.001)**
Delicate – rugged	I	**0.63 (0.002)**	0.24 (0.182)	**0.44 (0.001)**
Strength (weak – strong)	S	**0.71 (<0.000)**	0.21 (0.352)	**0.46 (0.002)**
Aggressive – calm	I	**0.47 (0.032)**	0.31 (0.071)	**0.39 (0.005)**
Texture[1] (smooth – rough)	S	**0.77 (<0.000)**	-0.17 (0.326)	**0.31 (0.017)**
Odour (odourless – fragrant)	S	0.17 (0.444)	**0.55 (0.013)**	**0.36 (0.021)**
Temperature (cold – warm)	S	0.37 (0.078)	0.21 (0.326)	**0.29 (0.049)**
Softness (hard – soft)	S	0.23 (0.282)	0.31 (0.142)	0.27 (0.070)
Stiffness (stiff – flexible)	S	0.17 (0.484)	0.41 (0.076)	0.29 (0.081)
Futuristic – nostalgic	I	0.43 (0.062)	0.00 (1.000)	0.22 (0.102)
Masculine – feminine	I	-0.23 (0.269)	-0.21 (0.227)	-0.22 (0.102)
Mature – youthful	I	0.40 (0.090)	0.03 (0.846)	0.22 (0.135)
Colorfulness[1] (colourless – colourful)	S	0.13 (0.601)	**-0.66 (0.008)**	-0.25 (0.156)
Traditional – modern[1]	I	**0.47 (0.032)**	-0.17 (0.232)	0.15 (0.253)
Honest – deceptive	I	-0.23 (0.387)	-0.07 (0.730)	-0.15 (0.360)
Classic – trendy	I	0.34 (0.086)	-0.14 (0.355)	0.10 (0.410)
Ordinary – strange	I	0.43 (0.085)	-0.21 (0.352)	0.12 (0.482)
Frivolous – sober	I	-0.10 (0.688)	0.24 (0.199)	0.07 (0.663)
Cosy – aloof	I	-0.17 (0.531)	0.24 (0.326)	0.03 (0.851)
Elasticity (low – high)	S	-0.23 (0.452)	0.28 (0.293)	0.02 (0.933)

[1] Significant difference between designers and engineers (according to Appendix 2D).

Table 2.3. Mean differences and Significance levels for One-Samples T Tests of MPO black material.

Material characteristic	**Level**	**Designers**	**Engineers**	**Total**
	Sensorial vs Interpretive	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*	*Mean diff. (Sign.)*
Transparency (opaque – transparent)	S	**-1.86 (<0.000)**	**-1.96 (<0.000)**	**-1.91 (<0.000)**
Texture (smooth – rough)	S	**-1.43 (<0.000)**	**-1.39 (<0.000)**	**-1.41 (<0.000)**
Ductility (low – high)	S	**1.00 (<0.000)**	**1.07 (<0.000)**	**1.03 (<0.000)**
Weight[1] (light – heavy)	S	**-0.53 (0.011)**	**-1.11 (<0.000)**	**-0.81 (<0.000)**
Acoustics (soft – shrill)	S	**-0.80 (0.001)**	**-1.00 (<0.000)**	**-0.90 (<0.000)**
Cheap – expensive	I	-0.43 (0.068)	**-0.81 (<0.000)**	**-0.61 (<0.000)**
Brittleness[1] (brittle – unbreakable)	S	**0.87 (<0.000)**	0.22 (0.364)	**0.56 (0.001)**
Greasiness[1] (dry – oily)	S	**1.20 (<0.000)**	-0.25 (0.257)	**0.50 (0.002)**
Scratchability (scratchable – scratch resistant)	S	**-0.62 (0.013)**	-0.39 (0.141)	**-0.51 (0.005)**
Sexy – not sexy	I	0.33 (0.143)	**0.48 (0.025)**	**0.40 (0.009)**
Toy-like – professional	I	-0.47 (0.065)	-0.41 (0.086)	**-0.44 (0.011)**
Colour intensity (weak – intense)	S	**0.50 (0.009)**	0.29 (0.293)	**0.40 (0.015)**
Disposable – lasting	I	-0.17 (0.493)	**-0.67 (0.003)**	**-0.40 (0.016)**
Glossiness (matte – glossy)	S	0.48 (0.050)	0.29 (0.212)	**0.39 (0.020)**
Colourfulness (colourless – colourful)	S	-0.17 (0.509)	**-0.71 (0.010)**	**-0.43 (0.021)**
Delicate – rugged	I	0.40 (0.090)	0.19 (0.345)	0.30 (0.052)
Stiffness (stiff – flexible)	S	0.23 (0.326)	0.43 (0.083)	0.33 (0.053)
Formal – informal	I	**0.53 (0.027)**	-0.04 (0.839)	0.26 (0.087)
Honest – deceptive	I	-0.33 (0.134)	-0.11 (0.574)	-0.23 (0.124)
Mature – youthful[1]	I	**0.43 (0.035)**	-0.11 (0.502)	0.18 (0.192)
Frivolous – sober	I	-0.27 (0.211)	-0.04 (0.846)	-0.16 (0.268)
Masculine – feminine	I	0.00 (1.000)	-0.30 (0.187)	-0.14 (0.343)
Elegant – vulgar	I	0.07 (0.778)	0.22 (0.282)	0.14 (0.370)
Odor[1] (odourless – fragrant)	S	**-0.70 (0.004)**	0.43 (0.090)	-0.16 (0.389)
Aggressive – calm[1]	I	0.17 (0.421)	**-0.44 (0.031)**	-0.12 (0.404)
Temperature (cold – warm)	S	-0.03 (0.839)	-0.18 (0.363)	-0.10 (0.410)
Traditional – modern	I	-0.07 (0.769)	**0.30 (0.043)**	0.11 (0.443)
Strength[1] (weak – strong)	S	0.46 (0.062)	-0.22 (0.352)	0.13 (0.463)
Elasticity (low – high)	S	-0.33 (0.134)	0.18 (0.502)	-0.09 (0.616)
Cosy – aloof	I	0.00 (1.000)	0.15 (0.476)	0.07 (0.627)
Softness (hard – soft)	S	-0.13 (0.588)	0.00 (1.000)	-0.07 (0.687)
Classic – trendy	I	0.00 (1.000)	0.04 (0.839)	0.02 (0.896)
Ordinary – strange	I	-0.03 (0.884)	0.00 (1.000)	-0.02 (0.909)
Futuristic – nostalgic[1]	I	0.27 (0.147)	-0.30 (0.058)	0.00 (1.000)

[1] Significant difference between designers and engineers (according to Appendix 2D).

2.4.2 *Significant Differences Between Materials*

This analysis investigates the significant differences between the three materials from the perspective of the total respondent group first, and from the perspective of the separate stakeholder groups (RQ2).

2.4.2.1 Significant Differences Between Materials according to the total group

A *Paired-Samples T test* is performed on each characteristic item. The *Exact Significances (2-tailed)* for each combination of two materials are shown in Table 2.4, with the bold results indicating differences between two material groups (**$p < 0.05$**).

As expected, most similarities appear between the grey and black version of MPO, since the only objective difference between these two materials is the addition of black pigment. Obviously, this makes the black MPO more colour intense than the grey edition. In addition, the pigment increases the experienced glossiness and smoothness of the surface, and appears to have an effect on odour, temperature, greasiness, and oddly on the perceived strength of the material. Regarding the interpretive characteristics, an effect of the black colour addition is found for the perception of Elegant-Vulgar, Aggressive-Calm, Sexy-Not sexy, and Cheap-Expensive, i.e. the black MPO version is perceived less vulgar, less cheap, less unsexy, and rather aggressive instead of calm.

When comparing the rABS material to both MPO variants on a sensorial level, rABS is scored as less colourful but with an intense colour (no contamination speckles such as the MPOs), harder, tougher, stiffer, shriller acoustics, more scratch resistant, more brittle, odourless, heavier, and less elastic. On an interpretive level, rABS is more aloof, elegant, professional, sexy, lasting, formal, expensive, and mature. Against expectations, rABS is not found glossier nor smoother than the black MPO, but is experienced aggressive, ordinary, and futuristic in contrast to the calm grey MPO, and sober in contrast to the black MPO.

Overall, most significant differences are found between rABS and the MPO variants (25 and 23 counts), compared to within the MPO materials (11 counts). In addition, in all comparisons, more differences are found on the sensorial level than on the interpretive level.

2.4.2.2 Significant Differences Between Materials according to designers

Table 2.5 shows the Exact Significances (2-tailed) of a Paired-Samples T for each item and for each combination of two materials, according to designers. The bold results indicate differences between two material groups (**$p < 0.05$**).

Designers detect significant differences between rABS and MPO grey (MPO grey Warmer) and between rABS and MPO black (rABS more Ordinary), but do not experience significant differences on certain characteristics between rABS and MPO grey (Weight, Aggressive-Calm), between rABS and MPO black (Glossiness, Odour, Elegant-Vulgar, Sexy-Not sexy, Disposable-Lasting), and between MPO grey and MPO black (Temperature, Strength, Aggressive-Calm).

Table 2.4. Means and exact Sig. (2-tailed) for Paired-Samples T test comparing three materials by the total group.

Test Statistics	**rABS ⇔ MPO grey** *Exact. Sig. (2-tailed)*	**rABS ⇔ MPO black** *Exact. Sig. (2-tailed)*	**MPO grey ⇔ MPO black** *Exact. Sig. (2-tailed)*	**rABS** *Mean*	**MPO grey** *Mean*	**MPO black** *Mean*
Colour intensity (weak - intense)	**<.001**	**0.001**	**<.001**	1.02	-0.86	0.40
Colourfulness (colourless - colourful)	**<.001**	**<.001**	0.269	-1.45	-0.25	-0.43
Glossiness (matte - glossy)	**<.001**	**0.011**	**<.001**	-0.14	-1.27	0.39
Transparency (opaque - transparent)	0.568	0.261	0.159	-1.93	-1.95	-1.91
Softness (hard - soft)	**<.001**	**<.001**	0.081	-1.32	0.27	-0.07
Texture (smooth - rough)	**<.001**	**<.001**	**<.001**	-0.66	0.31	-1.41
Temperature (cold – warm)	0.541	0.171	**0.043**	0.14	0.29	-0.10
Odour (odourless - fragrant)	**<.001**	**<.001**	**0.004**	-0.95	0.36	-0.16
Weight (light – heavy)	**0.024**	**0.048**	0.655	-0.45	-0.88	-0.81
Greasiness (dry - oily)	**0.043**	**<.001**	**<.001**	-0.30	-0.69	0.50
Acoustics (soft - shrill)	**<.001**	**<.001**	0.748	0.77	-0.93	-0.90
Scratchability (scratchable - scratch resistant)	**<.001**	**<.001**	0.233	0.51	-0.71	-0.51
Ductility (tough - ductile)	**<.001**	**<.001**	0.917	-0.93	1.12	1.03
Elasticity (low - high)	**<.001**	**<.001**	0.536	-1.21	0.02	-0.09
Strength (weak - strong)	0.406	0.444	**0.025**	0.30	0.46	0.13
Stiffness (stiff - flexible)	**<.001**	**<.001**	0.478	-1.19	0.29	0.33
Brittleness (brittle - unbreakable)	**<.001**	**<.001**	0.051	-0.55	1.03	0.56
Cosy – aloof	**0.002**	**<.001**	0.790	0.81	0.03	0.07
Elegant – vulgar	**<.001**	**0.019**	**0.023**	-0.40	0.54	0.14
Futuristic – nostalgic	**0.007**	0.154	0.224	-0.36	0.22	0.00
Toy-like – professional	**<.001**	**0.004**	0.311	0.26	-0.66	-0.44
Frivolous – sober	0.421	**0.042**	0.123	0.29	0.07	-0.16
Aggressive – calm	**0.002**	0.255	**0.009**	-0.41	0.39	-0.12
Ordinary – strange	**0.036**	0.087	0.557	-0.43	0.12	-0.02
Sexy – not sexy	**<.001**	**0.005**	**0.002**	-0.29	0.85	0.40
Masculine – feminine	0.458	0.637	0.499	-0.05	-0.22	-0.14
Delicate – rugged	0.151	0.304	0.301	0.11	0.44	0.30
Disposable – lasting	**0.009**	**0.021**	0.382	0.17	-0.59	-0.40
Formal – informal	**<.001**	**<.001**	0.146	-0.76	0.60	0.26
Cheap – expensive	**<.001**	**0.001**	**0.009**	0.12	-1.07	-0.61
Classic – trendy	0.813	0.938	0.583	0.07	0.10	0.02
Traditional – modern	0.935	0.880	0.553	0.16	0.15	0.11
Honest – deceptive	0.399	0.552	0.858	-0.33	-0.15	-0.23
Mature – youthful	**<.001**	**<.001**	0.922	-0.64	0.22	0.18
Total sign. Sensorial differences	14	14	7			
Total sign. Interpretive differences	11	9	4			
Total number of sign. differences	**25**	**23**	**11**			

Table 2.5. Means and exact Sig. (2-tailed) for Paired-Samples T test comparing three materials by designers.

Test Statistics	**rABS ⇔ MPO grey** *Exact. Sig. (2-tailed)*	**rABS ⇔ MPO black** *Exact. Sig. (2-tailed)*	**MPO grey ⇔ MPO black** *Exact. Sig. (2-tailed)*	**rABS** *Mean*	**MPO grey** *Mean*	**MPO black** *Mean*
Colour intensity (weak - intense)	**<.001**	**0.019**	**<.001**	1.00	-1.17	0.50
Colourfulness (colourless - colourful)	**<.001**	**0.002**	0.343	-1.20	0.13	-0.17
Glossiness (matte - glossy)	**<.001**	0.231	**<.001**	0.07	-1.43	0.48
Transparency (opaque - transparent)	0.573	0.424	0.161	-1.90	-1.93	-1.86
Softness (hard - soft)	**<.001**	**<.001**	0.239	-1.45	0.23	-0.13
Texture (smooth - rough)	**<.001**	**<.001**	**<.001**	-0.53	0.77	-1.43
Temperature (cold – warm)	**<.001**	**<.001**	**<.001**	-0.10	0.37	-0.03
Odour (odourless - fragrant)	**<.001**	0.110	**<.001**	-1.20	0.17	-0.70
Weight (light – heavy)	0.195	0.050	1.000	-0.13	-0.53	-0.53
Greasiness (dry - oily)	0.074	**<.001**	**<.001**	-0.24	-0.80	1.20
Acoustics (soft - shrill)	**<.001**	**<.001**	0.174	1.28	-1.07	-0.80
Scratchability (scratchable - scratch resistant)	**<.001**	**<.001**	0.909	0.90	-0.66	-0.62
Ductility (tough - ductile)	**<.001**	**<.001**	0.895	-1.20	0.97	1.00
Elasticity (low - high)	**<.001**	**<.001**	0.662	-1.50	-0.23	-0.33
Strength (weak - strong)	0.713	0.841	0.148	0.55	0.71	0.46
Stiffness (stiff - flexible)	**<.001**	**<.001**	0.769	-1.40	0.17	0.23
Brittleness (brittle - unbreakable)	**<.001**	**<.001**	0.573	-0.70	1.00	0.87
Cosy – aloof	**<.001**	**<.001**	0.565	1.23	-0.17	0.00
Elegant – vulgar	**0.001**	0.173	**0.042**	-0.43	0.67	0.07
Futuristic – nostalgic	**0.038**	0.115	0.573	-0.27	0.43	0.27
Toy-like – professional	**0.001**	**0.016**	0.527	0.48	-0.67	-0.47
Frivolous – sober	0.129	**0.019**	0.545	0.50	-0.10	-0.27
Aggressive – calm	0.056	0.222	0.300	-0.27	0.47	0.17
Ordinary – strange	**0.001**	**0.033**	0.156	-0.77	0.43	-0.03
Sexy – not sexy	**0.005**	0.316	0.027	0.00	0.87	0.33
Masculine – feminine	0.717	0.250	0.315	-0.37	-0.23	0.00
Delicate – rugged	0.223	0.487	0.394	0.17	0.63	0.40
Disposable – lasting	**0.005**	0.063	0.124	0.53	-0.63	-0.17
Formal – informal	**<.001**	**<.001**	0.499	-0.90	0.80	0.53
Cheap – expensive	**<.001**	**0.018**	**0.023**	0.30	-1.10	-0.43
Classic – trendy	0.091	0.459	0.459	-0.27	0.34	0.00
Traditional – modern	0.178	0.178	0.868	0.00	0.47	-0.07
Honest – deceptive	0.073	0.926	0.842	-0.27	-0.23	-0.33
Mature – youthful	0.766	**0.001**	**<.001**	-0.90	0.40	0.43
Total sign. Sensorial differences	13	12	6			
Total sign. Interpretive differences	9	7	4			
Total number of sign. differences	**22**	**19**	**10**			

2.4.2.3 Significant Differences Between Materials according to engineers

Table 2.6 shows the *Exact Significances (2-tailed)* of a *Paired-Samples T* for each item and for each combination of two materials, according to engineers. The bold results indicate differences between two material groups ($\boldsymbol{p < 0.05}$).

Engineers detect significant differences between rABS and MPO grey (Traditional MPO grey versus Modern rABS), between rABS and MPO black (Warm rABS versus Cold MPO black, Masculine MPO black versus Feminine rABS) and between MPO grey and MPO black (more Unbreakable MPO grey, Frivolous MPO grey versus Sober MPO black, Traditional MPO grey versus Modern MPO black), but no longer experience significant differences on certain characteristics between rABS and MPO grey (Cosy-Aloof, Futuristic-Nostalgic, Ordinary-Strange, Disposable-Lasting, Mature-Youthful), between rABS and MPO black (Texture, Weight, Greasiness, Scratchability, Brittleness, Cosy-Aloof, Toy-like-Professional, Frivolous-Sober, Disposable-Lasting, Mature-Youthful) and between MPO grey and MPO black (Temperature, Odour, Greasiness, Strength, Elegant-Vulgar, Cheap-Expensive).

When comparing the significant differences detected by designers and by engineers, nine disagreements are found between rABS and MPO grey (Temperature, Weight, Cosy-Aloof, Futuristic-Nostalgic, Aggressive-Calm, Ordinary-Strange, Disposable-Lasting, Traditional-Modern, Mature-Youthful), sixteen between rABS and MPO black (Glossiness, Texture, Temperature, Odour, Weight, Greasiness, Scratchability, Brittleness, Cosy-Aloof, Elegant-Vulgar, Toy-like-Professional, Frivolous-Sober, Ordinary-Strange, Sexy-Not sexy, Masculine-Feminine, Mature-Youthful) and eight between MPO grey and MPO black (Odour, Greasiness, Brittleness, Elegant-Vulgar, Frivolous-Sober, Aggressive-Calm, Cheap-Expensive, Traditional-Modern). These results indicate that most dissimilarities occur when comparing rABS to MPO black.

2.4.3 Level of Agreement

Next, we aim to answer RQ3.1 to find out which attributes and meanings our participants agree upon; both within the group of material engineers (n=30) and within the group of designers (n=30) separately, as well as the agreement within the total group (N=60). This is done by descriptively assessing the standard deviations for each material characteristic, as a high standard deviation might indicate a lack of agreement within a group of respondents. Table 2.7 shows the average standard deviations per material characteristic across the three materials, ordered by high to low level of agreement according to the total respondent group, and based on the standard deviations for each criterion across materials (last column).

Our control attribute 'Transparency' has the lowest standard deviation: almost everyone scored the materials as very opaque, which in fact they are. This is an indication that participants evaluated the materials attentively. The other lowest standard deviations, and thus highest levels of agreement, are obtained for Ductility, Texture, Temperature, and Futuristic-Nostalgic. By contrast, the highest standard deviations are found for Elasticity, Disposable-Lasting, Ordinary-Strange, Colourfulness, and Scratchability.

The average of the standard deviations for all material characteristics is lower for engineers than for designers, indicating that engineers show a higher overall level of agreement. However, designers show a slightly higher level of agreement on the sensorial attributes than on the interpretive ones.

Table 2.6. Means and exact Sig. (2-tailed) for Paired-Samples T test comparing three materials by engineers.

Test Statistics	**rABS ⇔ MPO grey** *Exact. Sig. (2-tailed)*	**rABS ⇔ MPO black** *Exact. Sig. (2-tailed)*	**MPO grey ⇔ MPO black** *Exact. Sig. (2-tailed)*	**rABS** *Mean*	**MPO grey** *Mean*	**MPO black** *Mean*
Colour intensity (weak - intense)	**0.000**	**0.031**	**0.005**	1.04	-0.55	0.29
Colourfulness (colourless - colourful)	**0.000**	**0.003**	0.587	-1.71	-0.66	-0.71
Glossiness (matte - glossy)	**0.003**	**0.019**	**0.000**	-0.36	-1.10	0.29
Transparency (opaque - transparent)	- [1]	0.327	- [1]	-1.96	-1.97	-1.96
Softness (hard - soft)	**0.000**	**0.000**	0.202	-1.18	0.31	0.00
Texture (smooth - rough)	**0.026**	0.074	**0.000**	-0.79	-0.17	-1.39
Temperature (cold – warm)	0.200	**0.000**	**0.000**	0.39	0.21	-0.18
Odour (odourless - fragrant)	**0.000**	**0.001**	0.752	-0.68	0.55	0.43
Weight (light – heavy)	**0.031**	0.461	0.490	-0.79	-1.24	-1.11
Greasiness (dry - oily)	0.294	0.892	0.056	-0.36	-0.59	-0.25
Acoustics (soft - shrill)	**0.001**	**0.000**	0.364	0.25	-0.79	-1.00
Scratchability (scratchable - scratch resistant)	**0.016**	0.131	0.102	0.11	-0.76	-0.39
Ductility (tough - ductile)	**0.000**	**0.000**	0.739	-0.63	1.29	1.07
Elasticity (low - high)	**0.000**	**0.001**	0.670	-0.89	0.28	0.18
Strength (weak - strong)	0.416	0.284	0.094	0.04	0.21	-0.22
Stiffness (stiff - flexible)	**0.000**	**0.000**	0.443	-0.96	0.41	0.43
Brittleness (brittle - unbreakable)	**0.000**	0.173	**0.042**	-0.39	1.07	0.22
Cosy – aloof	0.733	0.435	0.285	0.36	0.24	0.15
Elegant – vulgar	**0.003**	**0.029**	0.313	-0.36	0.41	0.22
Futuristic – nostalgic	0.086	0.877	0.129	-0.46	0.00	-0.30
Toy-like – professional	**0.026**	0.130	0.416	0.04	-0.66	-0.41
Frivolous – sober	0.568	0.718	**0.031**	0.07	0.24	-0.04
Aggressive – calm	**0.007**	0.883	**0.003**	-0.58	0.31	-0.44
Ordinary – strange	0.789	0.908	0.295	-0.07	-0.21	0.00
Sexy – not sexy	**0.000**	**0.002**	**0.025**	-0.61	0.83	0.48
Masculine – feminine	0.075	**0.038**	1.000	0.29	-0.21	-0.30
Delicate – rugged	0.447	0.459	0.566	0.04	0.24	0.19
Disposable – lasting	0.483	0.183	0.733	-0.21	-0.55	-0.67
Formal – informal	**0.040**	**0.033**	0.131	-0.61	0.39	-0.04
Cheap – expensive	**0.008**	**0.012**	0.215	-0.07	-1.03	-0.81
Classic – trendy	0.060	0.205	0.205	0.44	-0.14	0.04
Traditional – modern	0.040	0.040	1.000	0.32	-0.17	0.30
Honest – deceptive	**0.022**	0.095	0.153	-0.41	-0.07	-0.11
Mature – youthful	0.846	0.106	0.170	-0.36	0.03	-0.11
Total sign. Sensorial differences	13	10	5			
Total sign. Interpretive differences	8	6	3			
Total number of sign. differences	**21**	**16**	**8**			

[1] Standard error of difference was zero.

Table 2.7. Standard Deviation of material characteristics for designers, engineers and total.

Material characteristic	**Level**	**Designers**	**Engineers**	**Total**
	Sensorial vs Interpretive	*Average Std. Dev.*	*Average Std. Dev.*	*Average Std. Dev.*
Transparency (opaque - transparent)	S	0,333	0,189	0,274
Ductility (tough - ductile)	S	0,862	0,973	0,950
Texture (smooth – rough)	S	0,821	1,019	0,960
Temperature (cold – warm)	S	0,994	1,003	1,004
Futuristic – nostalgic	I	1,115	0,839	1,010
Color intensity (weak – intense)	S	0,838	1,166	1,027
Mature – youthful	I	1,128	0,857	1,028
Glossiness (matte – glossy)	S	1,076	0,996	1,043
Classic – trendy	I	1,138	0,914	1,055
Cheap – expensive	I	1,089	1,004	1,056
Traditional – modern	I	1,244	0,767	1,060
Elegant – vulgar	I	1,190	0,909	1,062
Acoustics (soft – shrill)	S	0,990	1,104	1,086
Masculine – feminine	I	1,105	1,063	1,096
Aggressive – calm	I	1,212	0,950	1,106
Honest – deceptive	I	1,229	0,975	1,108
Weight (light – heavy)	S	1,211	0,926	1,121
Frivolous – sober	I	1,207	1,029	1,129
Sexy - not sexy	I	1,132	1,115	1,130
Softness (hard – soft)	S	1,184	1,082	1,130
Formal – informal	I	1,122	1,120	1,141
Cosy – aloof	I	1,137	1,105	1,153
Delicate – rugged	I	1,213	1,090	1,155
Brittleness (brittle – unbreakable	S	1,070	1,234	1,160
Stiffness (stiff – flexible)	S	1,223	1,144	1,186
Strength (weak – strong)	S	1,165	1,174	1,200
Greasiness (dry – oily)	S	1,006	1,231	1,201
Toy-like – professional	I	1,243	1,169	1,207
Odour (odourless – fragrant)	S	1,091	1,229	1,211
Scratchability (scratchable – scratch resistant)	S	1,141	1,249	1,211
Colourfulness (colourless – colourful)	S	1,260	1,083	1,213
Ordinary – strange	I	1,205	1,194	1,225
Disposable – lasting	I	1,271	1,195	1,256
Elasticity (low – high)	S	1,197	1,280	1,267
Average of sensorial attributes		1,027	1,064	1,073
Average of interpretive characteristics		1,175	1,017	1,116
Total average		**1,101**	**1,041**	**1,095**

Additionally, sensorial attributes have a lower average standard deviation (i.e. higher level of agreement). This might reflect the greater difficulty or ambiguity in recognizing and associating meanings to (unknown) materials. In contrast, engineers show a higher agreement on interpretive characteristics. More specifically, the items of Colour intensity, Weight, and Traditional-Modern have the largest differences between the standard deviations for designers and engineers, while Temperature, Strength, and Formal-Informal have the smallest differences in level of agreement.

2.4.4 Differences between Designers and Engineers

Finally, to explore which material characteristics evoked significant differences between designers and engineers (RQ3.2), an *Independent Samples T-Test* is performed for each material separately. Table 2.8 depicts the means of each material characteristic of each material according to designers and engineers, while the footnote indicates whether the (2-tailed) *T-Test for Equality of Means* was significant (see also Appendix 2D for all actual significant levels). Significance levels lower than 0.05 indicate significant differences in the characteristic's score between designers and engineers. A Levene's Test for Equality of Variances preceded this analysis in order to determine whether equal variances can be assumed or not ($\boldsymbol{p < 0.05}$) to interpret the correct significance levels.

The results show that the rABS material induces the most significant differences ($\boldsymbol{p < 0.05}$) between designers and engineers (12 counts), followed by MPO black (8 counts) and MPO grey (5 counts). rABS shows significant differences between the two groups on the characteristics of Colourfulness, Weight, Acoustics, Scratchability, Ductility, Elasticity, Cosy-Aloof, Ordinary-Strange, Masculine-Feminine, Disposable-Lasting, Classic-Trendy and Mature-Youthful. In other words, engineers find rABS more colourless, lighter, feminine, disposable and trendy, while designers find the material softer sounding, more scratch resistant, tougher, less elastic, cosier, more ordinary, masculine, lasting, classic and more mature. MPO grey is perceived significantly different concerning Colour intensity, Colourfulness, Texture, Weight and Traditional-Modern, meaning engineers find it colourless, smooth, lighter and traditional in contrast to designers who perceive the material with weaker colour intensity, rough and modern. Finally, MPO black is scored significantly different regarding Odour, Weight, Greasiness, Strength, Futuristic-Nostalgic, Aggressive-Calm and Mature-Youthful. Engineers find it fragrant, lighter, dry, weak, futuristic, aggressive and mature, while designers score it odourless, greasy, strong, nostalgic, calm and youthful. The other characteristics do not show significant difference ($\boldsymbol{p > 0{,}05}$).

Table 2.8. Means of material characteristics for each material according to designers and engineers.

	rABS		MPO grey		MPO black	
	Designers	*Engineers*	*Designers*	*Engineers*	*Designers*	*Engineers*
Colour intensity (weak – intense)	1.00	1.04	-1.17[1, 2]	-0.55[1, 2]	0.50[2]	0.29[2]
Colourfulness (colourless – colourful)	-1.20[1, 2]	-1.71[1, 2]	0.13[1]	-0.66[1]	-0.17	-0.71
Glossiness (matte – glossy)	0.07	-0.36	-1.43	-1.10	0.48	0.29
Transparency (opaque – transparent)	-1.90	-1.96	-1.93	-1.97	-1.86	-1.96
Softness (hard – soft)	-1.45	-1.18	0.23	0.31	-0.13	0.00
Texture (smooth – rough)	-0.53	-0.79	0.77[1]	-0.17[1]	-1.43	-1.39
Temperature (cold – warm)	-0.10	0.39	0.37	0.21	-0.03	-0.18
Odour (odourless – fragrant)	-1.20[2]	-0.68[2]	0.17	0.55	-0.70[1]	0.43[1]
Weight (light – heavy)	-0.13[1, 2]	-0.79[1, 2]	-0.53[1]	-1.24[1]	-0.53[1]	-1.11[1]
Greasiness (dry – greasy)	-0.24[2]	-0.36[2]	-0.80	-0.59	1.20[1, 2]	-0.25[1, 2]
Acoustics (soft – shrill)	1.28[1]	0.25[1]	-1.07	-0.79	-0.8	-1.00
Scratchability (scratchable – scratch resistant)	0.90[1]	0.11[1]	-0.66	-0.76	-0.62	-0.39
Ductility (tough – ductile)	-1.20[1, 2]	-0.63[1, 2]	0.97	1.29	1.00	1.07
Elasticity (low – high)	-1.5[1]	-0.89[1]	-0.23[2]	0.28[2]	-0.33	0.18
Strength (weak – strong)	0.55	0.04	0.71	0.21	0.46[1]	-0.22[1]
Stiffness (stiff – flexible)	-1.40	-0.96	0.17	0.41	0.23	0.43
Brittleness (brittle – unbreakable)	-0.70	-0.39	1.00	1.07	0.87[1]	0.22[1]
Cosy – aloof	1.23[1]	0.36[1]	-0.17	0.24	0.00	0.15
Elegant – vulgar	-0.43[2]	-0.36[2]	0.67	0.41	0.07	0.22
Futuristic – nostalgic	-0.27	-0.46	0.43[2]	0.00[2]	0.27[1]	-0.3[1]
Toy-like – professional	0.48	0.04	-0.67	-0.66	-0.47	-0.41
Frivolous – sober	0.50	0.07	-0.10[2]	0.24[2]	-0.27	-0.04
Aggressive – calm	-0.27[2]	-0.58[2]	0.47	0.31	0.17[1]	-0.44[1]
Ordinary – strange	-0.77[1]	-0.07[1]	0.43	-0.21	-0.03	0.00
Sexy - not sexy	0.00	-0.61	0.87	0.83	0.33	0.48
Masculine – feminine	-0.37[1]	0.29[1]	-0.23	-0.21	0.00	-0.30
Delicate – rugged	0.17	0.04	0.63	0.24	0.40	0.19
Disposable – lasting	0.53[1]	-0.21[1]	-0.63	-0.55	-0.17	-0.67
Formal – informal	-0.90[2]	-0.61[2]	0.80	0.39	0.53	-0.04
Cheap – expensive	0.30	-0.07	-1.10	-1.03	-0.43[2]	-0.81[2]
Classic – trendy	-0.27[1]	0.44[1]	0.34	-0.14	0.00	0.04
Traditional – modern	0.00[2]	0.32[2]	0.47[1, 2]	-0.17[1, 2]	-0.07[2]	0.30[2]
Honest – deceptive	-0.27	-0.41	-0.23[2]	-0.07[2]	-0.33	-0.11
Mature – youthful	-0.90[1]	-0.36[1]	0.40[2]	0.03[2]	0.43[1]	-0.11[1]

[1] Sign. (2-tailed) for T-test for Equality of Means (***p* < 0.05**).

[2] Equal variances not assumed (***p* < 0.05**).

2.5 Discussion

In order to facilitate their application in high-quality products, this study aims to understand the perception of three exemplary post-consumer recycled plastics. We have built upon existing frameworks in the context of Materials Experience to explore meaning creation of materials on the basis of sensorial attributes and interpretive characteristics to gain understanding into the way three specific recycled plastics are perceived by two main industrial stakeholder groups: material engineers and designers. In contrast to previous similar studies, one of the main contributions of this study is the focus on exemplary recycled plastics that are industrially processed and materialized in standard stimuli forms, and assessed by a considerably large participant group by means of standard measure scales. The results show differences and similarities between design and engineering respondents on the appraisal of recycled materials, and indicate which characteristics are most prominent in evaluating the material perception of post-consumer recycled plastics. Moreover, when a transition towards a valuable use of these materials is aimed for, different applications require different characteristics (both technical and experiential). Thus, the results of this study might indicate possible product applications of the three recycled plastics. As it is expected that we evolve to a better collection of plastic waste in the future, the amount of post-consumer recyclates will increase as well. Following this trend, it will be even more important to emphasize the intended material perception in order to differentiate different recycled material streams. Therefore, studies as presented here will have to be carried out repeatedly to facilitate the adoption of post-consumer plastics in meaningful applications, as was also done in previous research on emerging materials that focused on, for example, bioplastics (Karana, 2012) and natural fibre composites (Karana & Nijkamp, 2014; Rognoli, Karana, et al., 2011).

2.5.1 Identity of Recycled Plastics

Although no one-to-one rules exist that guarantee meaning-material relationships, certain patterns and defining characteristics (sensorial attributes and interpretive characteristics) of all three materials are detected. An overview of these trends within the design and engineering respondent group can be found in Figure 2.2, including the similarities between the recyclates (e.g. as expected, all three materials are evaluated as light and opaque). These insights can initiate future idea generation of high-quality applications. Overall, rABS is described as smooth, hard, and stiff, but brittle with an elegant, formal, and aloof character. Thus, rABS might be an interesting material for office supplies, as such products often require stiffness (e.g. perforator), and a smooth and formal appearance that fits in an office environment. The grey MPO variant is perceived matte, ductile, warm, and unbreakable, with a cheap and toy-like but rugged character. Thus, MPO grey might be convenient for outdoor toys and bicycle accessories that require high ductility, weather resistance, and must be/feel unbreakable and rugged. The black MPO edition is described smooth, glossy, and unbreakable, however still with a cheap and toy-like character. Thus, MPO black might be suitable for strong fitness or sports equipment, as these products require similar strength properties, but the black colour addition allows more high-end impression indoor.

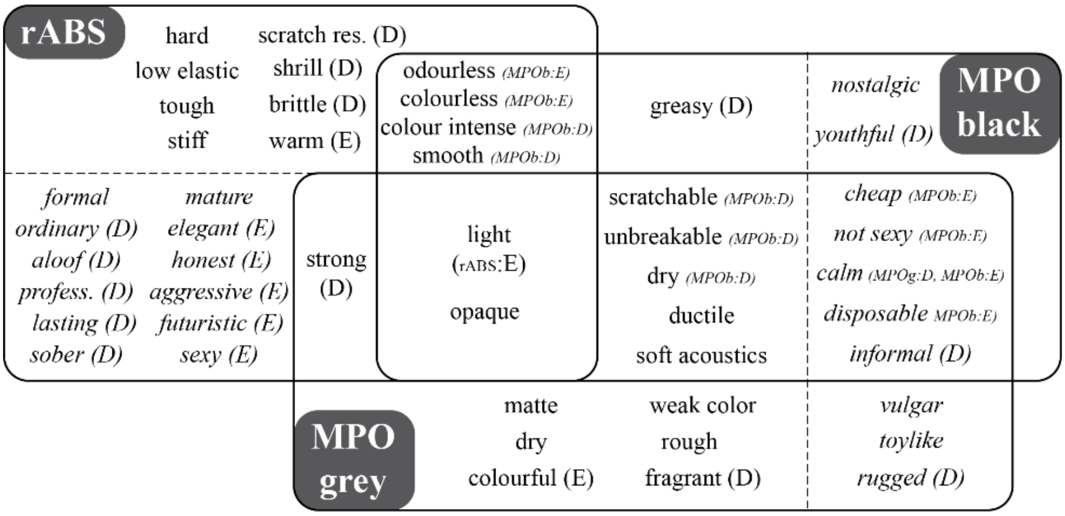


Figure 2.2. Diagram of defining material characteristics of the three recycled materials, according to designers (D) and engineers (E).

Next, Figure 2.3 takes a closer look at the sensorial attributes (Smooth-Rough, Matte-Glossy, Weak-Intense colour, Dry-Oily, Odourless-Fragrant) and interpretive characteristics (Sexy-Not sexy, Expensive-Cheap, Elegant-Vulgar) that show significant differences between the three recycled materials. In the context of sustainable perception of recyclates, the semantic pairs of Brittle-Unbreakable and Disposable-Lasting (partly reflecting high-quality perception) are also included, despite no significant differences between the two MPO materials for these characteristics. When plotting these characteristics against each other, correlations can be seen between an Expensive/Elegant/Sexy/Lasting look and a Cheap/Vulgar/Not sexy/Disposable look on the various sensorial attributes.

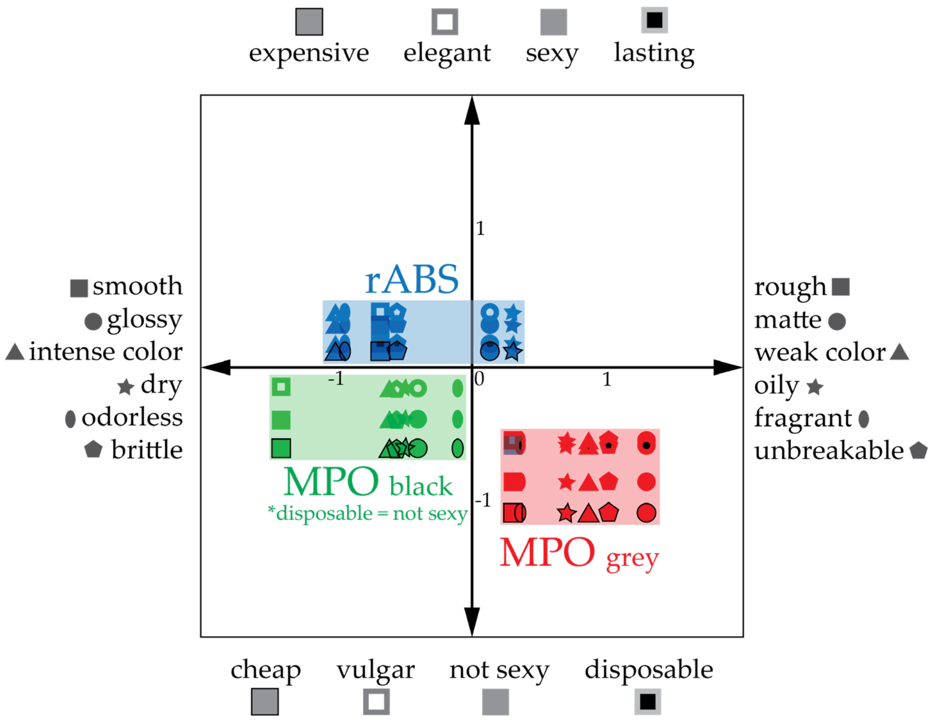


Figure 2.3. Plot of sensorial attributes and interpretive characteristics for three recycled materials.

This shows that, compared to the other materials, rABS is perceived as a rather expensive, elegant, sexy, and lasting material, which could be attributed to its oily and rather matte look. Moreover, we find a clear difference between the two MPO variants regarding their sensorial attributes. The black colour additive even affects several sensorial attributes that should have been the same from a theoretical, technical perspective for both grey and black MPO. A large difference is found concerning the glossiness, texture, odour, and greasiness. However, the black colour additive does not appear to be effective enough to completely convert the material perception of MPO to an expensive, elegant, sexy, or lasting look. Nevertheless, MPO grey is scored significantly lower than MPO black on these characteristics (except for Disposable-Lasting), which might indicate practical implications for industry and design. In addition, both smoothness and glossiness are actually expected to be the highest for rABS instead of black MPO, based on their technical datasheets. All in all, insights within this graph should be considered when applying these recycled materials in new products. Further research is needed to understand the relation between the interpretive and sensorial characteristics, and the effect of changing specific sensorial attributes on the perception of the interpretive characteristics.

2.5.2 Differences Between Stakeholders

The significant differences between engineers and designers could indicate which material characteristics both stakeholders would not easily agree upon during the design process. The results show that both the amount and the type of significantly different characteristics are very dependent on the material that is evaluated, as only weight induces significant differences for all materials, colourfulness for rABS and MPO grey, and Mature-Youthful for rABS and MPO black. In total, designers and engineers seem to have less significantly different perceptions of interpretive characteristics as compared to sensorial attributes. However, overall, as well as in the designer group, the results show a higher level of agreement on sensorial attributes.

We argue that designers in collaboration with material engineers can alter and influence the material perception (e.g. by adding colour additives, by in-/decreasing the sorting steps, alternative processing techniques, etc.) to increase valorisation and adoption of recycled plastics as sustainable and high-quality materials, as is shown by the contrasting results between the two variants of the MPO material, and by, for example, high standard deviations for Disposable-Lasting (low level of agreement). This raises the question whether the recycled look of these materials (e.g. speckles in grey MPO in playful outdoor toys) or rather the industrial quality through mass production must be emphasized (e.g. uniform colour and glossiness of black MPO in professional fitness accessories)?

2.5.3 Study Limitations and Further Research

There are limitations to the current study that could inspire further research. In this study, we only use three types of flat injection-moulded shapes, presented in an isolated setting to the participants, which is an incomplete approach for such non-technical material explorations. Future research could look into more appropriate forms for material evaluation, such as abstract forms that are more inspiring than flat shapes but do not evoke too many associations with existing products and contexts, or even a set of different types of real products that are materialized in various plastics, to the extent that this is practically feasible.

Next, similar to the education background effect, the influence of gender can be studied as well, but is found not valuable in this context because of the gender imbalance in the engineering respondent group, which is representative for students in this department.

Finally, this paper only focuses on three exemplary recycled materials; rABS, grey MPO, and black MPO. In further research, other recycled plastics should be studied as well, possibly exploring the difference between post-industrial and post-consumer plastics. Although designers and engineers are more familiar with the abstract concept of material samples and might experience fewer difficulties imagining materials in products, it would also be interesting to involve other stakeholders' perceptions as well. Therefore, future research should also replicate the current study to explore the perceptions of recycled materials by end consumers. Additionally, qualitative research techniques, such as interviews or workshops, could be used to develop a more in-depth understanding of the underlying reasons for the perception of recycled materials by engineers, designers and end consumers. This way, next research steps can contribute to further map the material perception of recycled plastics by all stakeholders, and the influence of industrial material alterations on the willingness to design (such as (Sauerwein et al., 2017)) or on the consumer/user perception (such as (Overvliet & Soto-Faraco, 2011)). Finally, further research should involve real products made of recycled plastics, as proposed in Section 2.5.1, in order to verify whether the expected or intended material perceptions effectively match with the perception of all stakeholders.

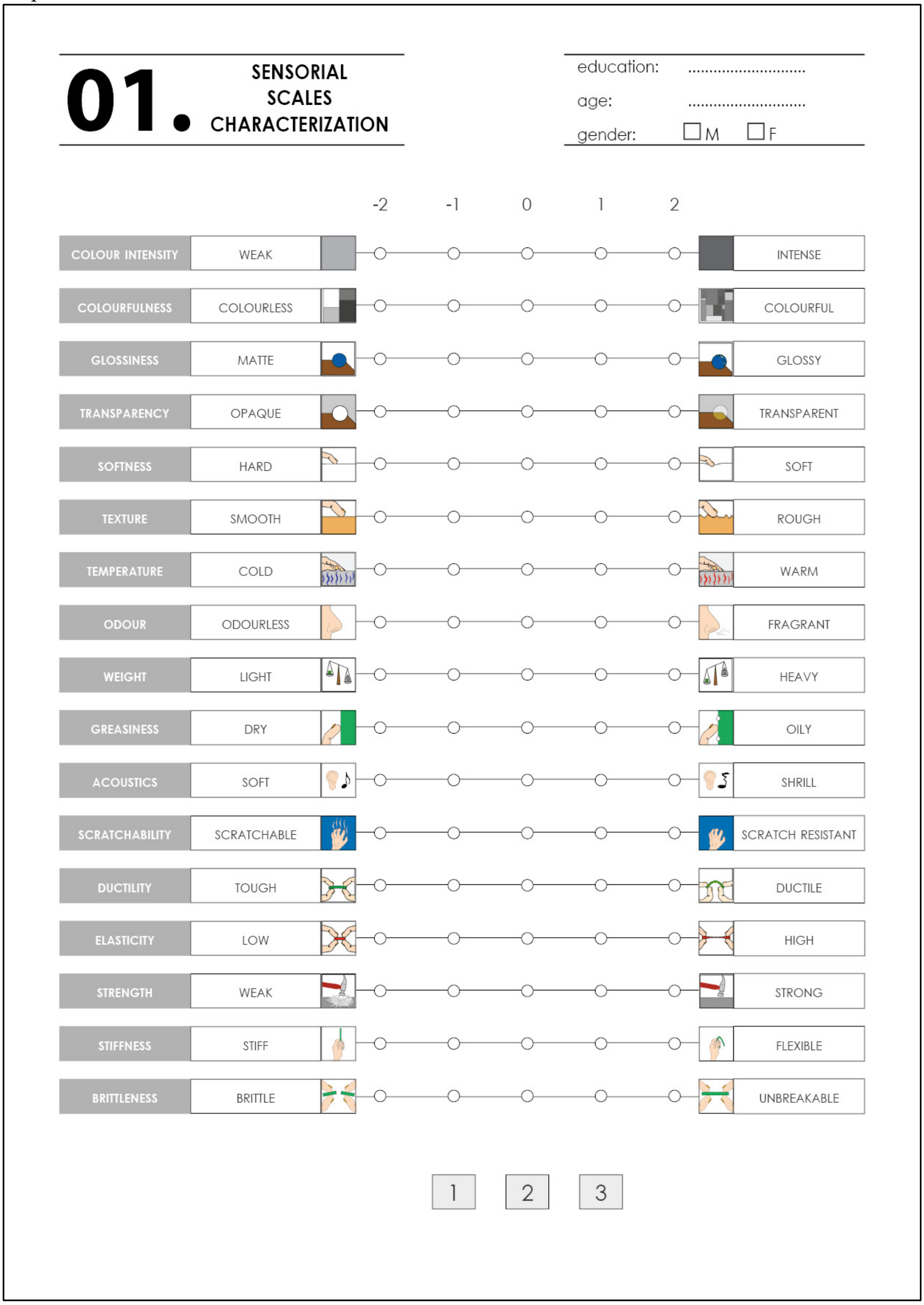
2.6 Conclusion

In conclusion, this paper aims to create an overview pattern based on 60 appraisals to initiate future idea generation for high-quality plastic recycled material applications (material driven design) in a circular economy. It contributes to insights into how these sustainable recyclates can be differentiated on the market by enhancing their experiential qualities in order to address the target users, regardless of their added value from a technical perspective, and to transition towards a valuable use. In practice, industry must not only consider technical properties that are required for application in specific products, but also consider the perception of experiential qualities that is aimed for. Overall, the perception of sensorial attributes and interpretive characteristics varies considerably between the studied recycled materials, which leads to different suitability for specific applications. In addition, substantial similarities between designers and engineers can facilitate the design process when these stakeholders already agree on particular experiential qualities. Therefore, this study suggests possible strategies for the companies involved and underpins the potential of this evaluation method. We propose that, when emphasizing certain desired meanings, designers can facilitate the valorisation and adoption of these undervalued materials, first by industry and ultimately by consumers as well.

Appendix 2A: Literature comparison and selection of sensorial attributes for the main study.

	List of sensorial properties (van Kesteren et al., 2007b)	**Sensorial scales** (Karana, 2009)	**List of sensorial properties & manuf. Processes** (Karana et al., 2009b)	**Selected sensorial attributes for the main study**
Reflection	Reflective - not reflective Glossy – matte Transparent – opaque Not bright – bright Regular – irregular texture	Not reflective - reflective Matte – glossy Opaque – transparent	Reflectiveness Glossiness (matteness) Transparency (opaqueness)	Glossiness: Glossy - matte Transparency: Transparent - opaque
Colour	Hue of colour One – many colours Colourless – colourful Dark – light Durable – faded colour Pattern		Colourfulness Colour intensity	Colourfulness: Colourful – colourless Colour intensity: Intense – Weak
Pressure	Denting – not denting Soft – hard Fast – slow dampening Massive – porous	Hard – soft	Hardness (softness)	Softness: Soft – Hard
Manipulation	Stiff – flexible Ductile – tough Brittle – tough Light – heavy	Tough – ductile Light – heavy Strong – weak Not elastic – elastic	Ductility Weight (lightness) Strength Elasticity	Stiffness: Stiff – flexible Ductility: Ductile – Tough Brittleness: Brittle – unbreakable Weight: Light – heavy Strength: Strong – weak Elasticity: High – low Scratchability: Scratchable - scratch resistant
Friction	Sticky – not sticky Dry – oily Rough – smooth	Smooth – rough	Roughness (smoothness)	Greasiness: Oily – dry Texture: Smooth – rough
Sound	Muffled - ringing Low – high pitch Soft – loud			Acoustics: Soft – shrill
Smell	Natural odour – fragrant Fragrance		Odorous	Odour: Odourless – fragrant
Taste	Flavour			
Temp-erature	Warm – cold	Cold – warm	Warmth (coldness)	Temperature: Cold - warm
Light radiation	Low – high light emission			

Appendix 2B: Evaluation sheets for the experiential evaluations: (**a**) Sensorial attributes; (**b**) Interpretive characteristics.



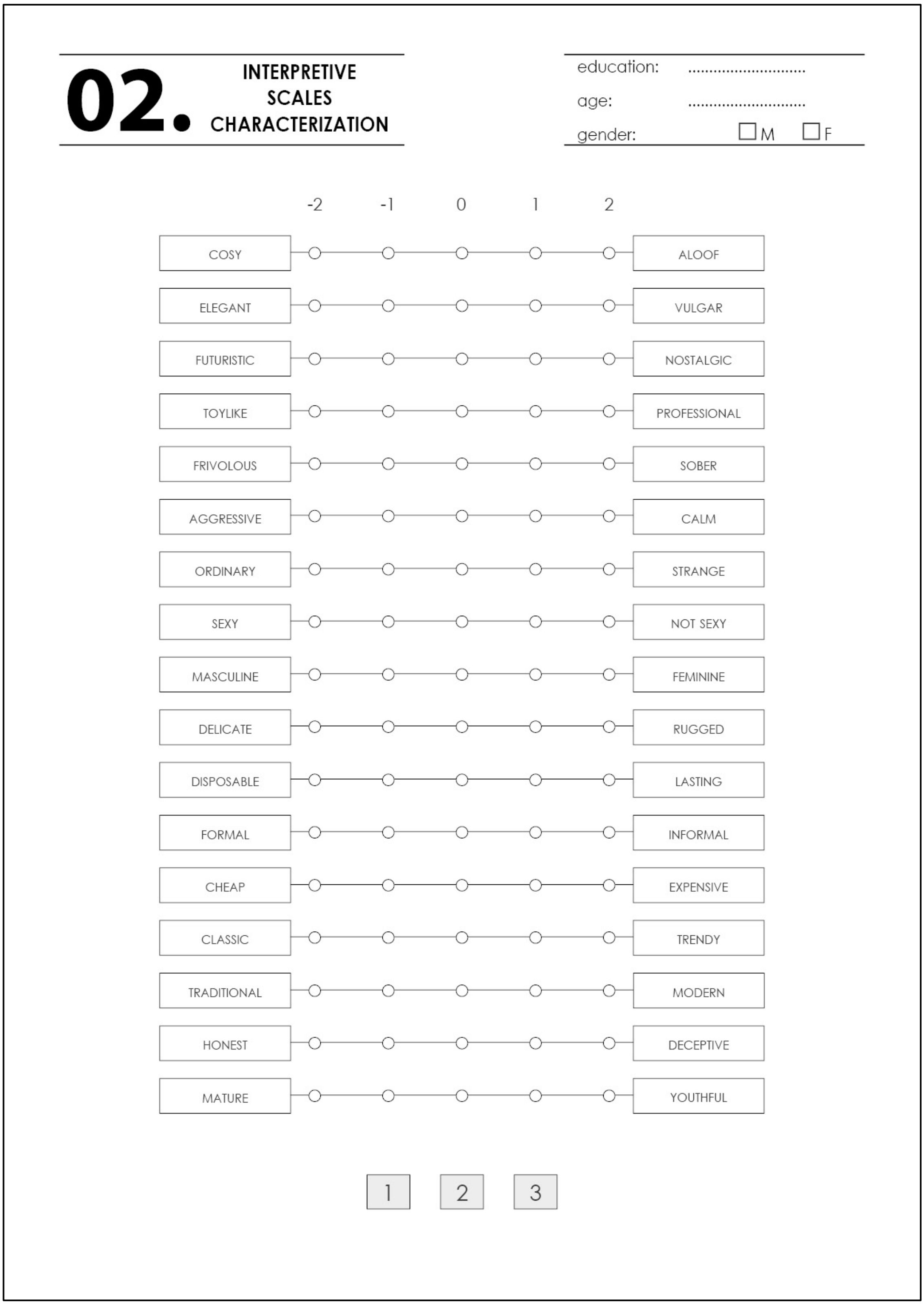
01. SENSORIAL SCALES CHARACTERIZATION

education: ....
age: ....
gender: ☐ M ☐ F

		-2	-1	0	1	2	
COLOUR INTENSITY	WEAK	○	○	○	○	○	INTENSE
COLOURFULNESS	COLOURLESS	○	○	○	○	○	COLOURFUL
GLOSSINESS	MATTE	○	○	○	○	○	GLOSSY
TRANSPARENCY	OPAQUE	○	○	○	○	○	TRANSPARENT
SOFTNESS	HARD	○	○	○	○	○	SOFT
TEXTURE	SMOOTH	○	○	○	○	○	ROUGH
TEMPERATURE	COLD	○	○	○	○	○	WARM
ODOUR	ODOURLESS	○	○	○	○	○	FRAGRANT
WEIGHT	LIGHT	○	○	○	○	○	HEAVY
GREASINESS	DRY	○	○	○	○	○	OILY
ACOUSTICS	SOFT	○	○	○	○	○	SHRILL
SCRATCHABILITY	SCRATCHABLE	○	○	○	○	○	SCRATCH RESISTANT
DUCTILITY	TOUGH	○	○	○	○	○	DUCTILE
ELASTICITY	LOW	○	○	○	○	○	HIGH
STRENGTH	WEAK	○	○	○	○	○	STRONG
STIFFNESS	STIFF	○	○	○	○	○	FLEXIBLE
BRITTLENESS	BRITTLE	○	○	○	○	○	UNBREAKABLE

1 2 3

(a)



02. INTERPRETIVE SCALES CHARACTERIZATION

education: ....
age: ....
gender: ☐ M ☐ F

	-2	-1	0	1	2	
COSY	○	○	○	○	○	ALOOF
ELEGANT	○	○	○	○	○	VULGAR
FUTURISTIC	○	○	○	○	○	NOSTALGIC
TOYLIKE	○	○	○	○	○	PROFESSIONAL
FRIVOLOUS	○	○	○	○	○	SOBER
AGGRESSIVE	○	○	○	○	○	CALM
ORDINARY	○	○	○	○	○	STRANGE
SEXY	○	○	○	○	○	NOT SEXY
MASCULINE	○	○	○	○	○	FEMININE
DELICATE	○	○	○	○	○	RUGGED
DISPOSABLE	○	○	○	○	○	LASTING
FORMAL	○	○	○	○	○	INFORMAL
CHEAP	○	○	○	○	○	EXPENSIVE
CLASSIC	○	○	○	○	○	TRENDY
TRADITIONAL	○	○	○	○	○	MODERN
HONEST	○	○	○	○	○	DECEPTIVE
MATURE	○	○	○	○	○	YOUTHFUL

1 2 3

(b)

Appendix 2C: Mean & Standard Deviation for each material characteristic, for each material, and for designers, engineers and total.

		rABS			MPO grey			MPO black		
		Designers	*Engineers*	**Total**	*Designers*	*Engineers*	**Total**	*Designers*	*Engineers*	**Total**
Colour intensity	*Mean*	1.00	1.04	**1.02**	-1.17	-0.55	**-0.86**	0.50	0.29	**0.40**
(weak – intense)	*St. Dev.*	0.947	0.999	**0.964**	0.592	1.088	**0.918**	0.974	1.410	**1.199**
Colourfulness	*Mean*	-1.20	-1.71	**-1.45**	0.13	-0.66	**-0.25**	-0.17	-0.71	**-0.43**
(colourless – colourful)	*St. Dev.*	1.031	0.659	**0.902**	1.383	1.233	**1.359**	1.367	1.357	**1.378**
Glossiness	*Mean*	0.07	-0.36	**-0.14**	-1.43	-1.10	**-1.27**	0.48	0.29	**0.39**
(matte – glossy)	*St. Dev.*	1.100	0.989	**1.060**	0.858	0.817	**0.848**	1.271	1.182	**1.221**
Transparency	*Mean*	-1.90	-1.96	**-1.93**	-1.93	-1.97	**-1.95**	-1.86	-1.96	**-1.91**
(opaque – transparent)	*St. Dev.*	0.305	0.189	**0.256**	0.254	0.186	**0.222**	0.441	0.192	**0.345**
Softness	*Mean*	-1.45	-1.18	**-1.32**	0.23	0.31	**0.27**	-0.13	0.00	**-0.07**
(hard – soft)	*St. Dev.*	1.055	0.863	**0.967**	1.165	1.105	**1.127**	1.332	1.277	**1.296**
Texture	*Mean*	-0.53	-0.79	**-0.66**	0.77	-0.17	**0.31**	-1.43	-1.39	**-1.41**
(smooth – rough)	*St. Dev.*	1.008	1.134	**1.069**	0.728	0.928	**0.951**	0.728	0.994	**0.859**
Temperature	*Mean*	-0.10	0.39	**0.14**	0.37	0.21	**0.29**	-0.03	-0.18	**-0.10**
(cold – warm)	*St. Dev.*	0.995	0.875	**0.963**	1.098	1.114	**1.099**	0.890	1.020	**0.949**
Odour	*Mean*	-1.20	-0.68	**-0.95**	0.17	0.55	**0.36**	-0.70	0.43	**-0.16**
(odourless – fragrant)	*St. Dev.*	0.887	1.278	**1.115**	1.177	1.121	**1.156**	1.208	1.289	**1.361**
Weight	*Mean*	-0.13	-0.79	**-0.45**	-0.53	-1.24	**-0.88**	-0.53	-1.11	**-0.81**
(light – heavy)	*St. Dev.*	1.306	1.031	**1.216**	1.252	0.872	**1.131**	1.074	0.875	**1.017**
Greasiness	*Mean*	-0.24	-0.36	**-0.30**	-0.80	-0.59	**-0.69**	1.20	-0.25	**0.50**
(dry – greasy)	*St. Dev.*	1.272	1.254	**1.253**	1.031	1.296	**1.163**	0.714	1.143	**1.188**
Acoustics	*Mean*	1.28	0.25	**0.77**	-1.07	-0.79	**-0.93**	-0.80	-1.00	**-0.90**
(soft – shrill)	*St. Dev.*	0.922	1.076	**1.118**	0.923	1.082	**1.006**	1.126	1.155	**1.135**
Scratchability	*Mean*	0.90	0.11	**0.51**	-0.66	-0.76	**-0.71**	-0.62	-0.39	**-0.51**
(scratchable – scratch resistant)	*St. Dev.*	1.047	1.133	**1.151**	1.111	1.244	**1.170**	1.265	1.370	**1.311**
Ductility	*Mean*	-1.20	-0.63	**-0.93**	0.97	1.29	**1.12**	1.00	1.07	**1.03**
(tough – ductile)	*St. Dev.*	0.714	1.245	**1.033**	1.129	0.659	**0.938**	0.743	1.016	**0.878**
Elasticity	*Mean*	-1.50	-0.89	**-1.21**	-0.23	0.28	**0.02**	-0.33	0.18	**-0.09**
(low – high)	*St. Dev.*	0.731	1.066	**0.951**	1.675	1.386	**1.548**	1.184	1.389	**1.302**
Strength	*Mean*	0.55	0.04	**0.30**	0.71	0.21	**0.46**	0.46	-0.22	**0.13**
(weak – strong)	*St. Dev.*	1.298	1.126	**1.235**	0.937	1.177	**1.087**	1.261	1.219	**1.277**
Stiffness	*Mean*	-1.40	-0.96	**-1.19**	0.17	0.41	**0.29**	0.23	0.43	**0.33**
(stiff – flexible)	*St. Dev.*	1.102	0.962	**1.051**	1.289	1.211	**1.246**	1.278	1.26	**1.262**
Brittleness	*Mean*	-0.7	-0.39	**-0.55**	1.00	1.07	**1.03**	0.87	0.22	**0.56**
(brittle – unbreakable)	*St. Dev.*	1.055	1.227	**1.142**	1.017	1.223	**1.114**	1.137	1.251	**1.225**

Cosy – aloof	*Mean*	1.23	0.36	**0.81**	-0.17	0.24	**0.03**	0.00	0.15	**0.07**
	St. Dev.	0.858	0.951	**0.999**	1.44	1.300	**1.377**	1.114	1.064	**1.083**
Elegant – vulgar	*Mean*	-0.43	-0.36	**-0.40**	0.67	0.41	**0.54**	0.07	0.22	**0.14**
	St. Dev.	1.223	0.731	**1.008**	1.061	0.946	**1.006**	1.285	1.05	**1.172**
Futuristic – nostalgic	*Mean*	-0.27	-0.46	**-0.36**	0.43	0.00	**0.22**	0.27	-0.30	**0.00**
	St. Dev.	1.143	1.036	**1.087**	1.223	0.707	**1.018**	0.980	0.775	**0.926**
Toy-like – professional	*Mean*	0.48	0.04	**0.26**	-0.67	-0.66	**-0.66**	-0.47	-0.41	**-0.44**
	St. Dev.	1.214	1.347	**1.289**	1.184	0.974	**1.077**	1.332	1.185	**1.254**
Frivolous – sober	*Mean*	0.50	0.07	**0.29**	-0.10	0.24	**0.07**	-0.27	-0.04	**-0.16**
	St. Dev.	1.106	1.120	**1.124**	1.372	0.988	**1.197**	1.143	0.980	**1.066**
Aggressive – calm	*Mean*	-0.27	-0.58	**-0.41**	0.47	0.31	**0.39**	0.17	-0.44	**-0.12**
	St. Dev.	1.363	0.945	**1.187**	1.137	0.891	**1.017**	1.136	1.013	**1.113**
Ordinary – strange	*Mean*	-0.77	-0.07	**-0.43**	0.43	-0.21	**0.12**	-0.03	0.00	**-0.02**
	St. Dev.	1.040	1.331	**1.230**	1.331	1.177	**1.288**	1.245	1.074	**1.157**
Sexy - not sexy	*Mean*	0.00	-0.61	**-0.29**	0.87	0.83	**0.85**	0.33	0.48	**0.40**
	St. Dev.	1.174	1.257	**1.243**	1.008	1.037	**1.014**	1.213	1.051	**1.132**
Masculine – feminine	*Mean*	-0.37	0.29	**-0.05**	-0.23	-0.21	**-0.22**	0.00	-0.3	**-0.14**
	St. Dev.	1.098	1.150	**1.161**	1.135	0.902	**1.018**	1.083	1.137	**1.109**
Delicate – rugged	*Mean*	0.17	0.04	**0.11**	0.63	0.24	**0.44**	0.40	0.19	**0.30**
	St. Dev.	1.391	1.319	**1.345**	0.999	0.951	**0.987**	1.248	1.001	**1.133**
Disposable – lasting	*Mean*	0.53	-0.21	**0.17**	-0.63	-0.55	**-0.59**	-0.17	-0.67	**-0.40**
	St. Dev.	1.224	1.134	**1.230**	1.273	1.378	**1.315**	1.315	1.074	**1.223**
Formal – informal	*Mean*	-0.90	-0.61	**-0.76**	0.80	0.39	**0.60**	0.53	-0.04	**0.26**
	St. Dev.	0.845	1.133	**0.997**	1.270	1.286	**1.283**	1.252	0.940	**1.142**
Cheap – expensive	*Mean*	0.30	-0.07	**0.12**	-1.10	-1.03	**-1.07**	-0.43	-0.81	**-0.61**
	St. Dev.	1.055	1.152	**1.109**	0.960	0.981	**0.962**	1.251	0.879	**1.098**
Classic – trendy	*Mean*	-0.27	0.44	**0.07**	0.34	-0.14	**0.10**	0.00	0.04	**0.02**
	St. Dev.	1.285	1.013	**1.208**	1.045	0.789	**0.949**	1.083	0.940	**1.009**
Traditional – modern	*Mean*	0.00	0.32	**0.16**	0.47	-0.17	**0.15**	-0.07	0.30	**0.11**
	St. Dev.	1.365	0.819	**1.136**	1.137	0.759	**1.014**	1.230	0.724	**1.030**
Honest – deceptive	*Mean*	-0.27	-0.41	**-0.33**	-0.23	-0.07	**-0.15**	-0.33	-0.11	**-0.23**
	St. Dev.	1.048	0.844	**0.951**	1.455	1.067	**1.271**	1.184	1.013	**1.102**
Mature – youthful	*Mean*	-0.90	-0.36	**-0.64**	0.40	0.03	**0.22**	0.43	-0.11	**0.18**
	St. Dev.	1.062	0.780	**0.968**	1.248	0.944	**1.115**	1.073	0.847	**1.002**

Appendix 2D: Significance levels (2-tailed) for T-Test for Equality of Means for each material.

Test Statistics	**rABS** *T-Test for Equality of Means Sig. (2-tailed)*	**MPO grey** *T-Test for Equality of Means Sig. (2-tailed)*	**MPO black** *T-Test for Equality of Means Sig. (2-tailed)*
Colour intensity (weak - intense)	0.889	**0.010**[1]	0.507[1]
Colourfulness (colourless - colourful)	**0.027**[1]	**0.025**	0.132
Glossiness (matte - glossy)	0.130	0.136	0.547
Transparency (opaque - transparent)	0.343	0.581	0.269[1]
Softness (hard - soft)	0.296	0.796	0.699
Texture (smooth - rough)	0.373	**<.001**	0.860
Temperature (cold – warm)	0.051	0.581	0.565
Odour (odourless - fragrant)	0.079[1]	0.204	**0.001**
Weight (light – heavy)	**0.039**[1]	**0.015**	**0.030**
Greasiness (dry - oily)	0.731	0.485	**<.001**[1]
Acoustics (soft - shrill)	**<.001**	0.301	0.507
Scratchability (scratchable - scratch resistant)	**0.008**	0.740	0.517
Ductility (tough - ductile)	**0.043**[1]	0.198	0.760
Elasticity (low - high)	**0.014**	0.208[1]	0.136
Strength (weak - strong)	0.120	0.078	**0.045**
Stiffness (stiff - flexible)	0.115	0.451	0.561
Brittleness (brittle - unbreakable)	0.310	0.814	**0.046**
Cosy – aloof	**0.001**	0.259	0.611
Elegant – vulgar	0.773[1]	0.339	0.621
Futuristic – nostalgic	0.494	0.101[1]	**0.020**
Toy-like – professional	0.193	0.968	0.860
Frivolous – sober	0.148	0.277[1]	0.421
Aggressive – calm	0.322[1]	0.560	**0.037**
Ordinary – strange	**0.030**	0.055	0.915
Sexy – not sexy	0.062	0.884	0.626
Masculine – feminine	**0.031**	0.922	0.318
Delicate – rugged	0.705	0.129	0.480
Disposable – lasting	**0.019**	0.814	0.124
Formal – informal	0.273[1]	0.230	0.059
Cheap – expensive	0.205	0.796	0.185[1]
Classic – trendy	**0.025**	0.052	0.891
Traditional – modern	0.279[1]	**0.014**[1]	0.176[1]
Honest – deceptive	0.582	0.622[1]	0.452
Mature – youthful	**0.032**	0.209[1]	**0.039**

[1] Equal variances not assumed ($p < 0.05$).

PART TWO

PART TWO focusses on the need for a standardized physical material demonstrator form that triggers consumers in holistic multimodal interactions, while minimizing the interference with product (function) and context associations, as discussed in Chapter 1.

First, Chapter 3 explores the conception of neutrality to create meaning-less or “neutral” demonstrator forms to objectively compare materials. It presents four neutral forms but concludes that more interactivity and complexity is needed to trigger consumers in interacting with material demonstrators for more extensive material exploration.

Therefore, Chapter 4 resumes the search for an appropriate demonstrator form, and aims to develop a standard, complex form or material demonstrator that is suitable for experiential material characterization by consumers through enabling tangible and rich interaction with materials. The proposed demonstrator form is found more appropriate for experiential material characterization than a standard flat plate. As a result, designers or design researchers can benefit from this demonstrator when they conduct consumer research, and it offers potential for generalizability within the field of materials experience as well.

Chapter 3 is based on:

Veelaert, L., Moons, I., Rohaert, S., & Du Bois, E. (2019). A Neutral Form for Experiential Material Characterisation. *Proceedings of the Design Society: International Conference on Engineering Design (ICED 2019)*, 1(1), 1743–1752. https://doi.org/10.1017/dsi.2019.180

3. A Neutral Form for Experiential Material Characterization

Veelaert Lore, Moons Ingrid, Rohaert Sarah, Du Bois Els

Abstract: Materials experience in design involves the meanings that materials convey to users through their expressive characteristics. Such meaning evoking patterns are influenced by parameters such as context, product (e.g. shape) and user. Consequently, there is a need to standardise experiential material characterization and large-scale data collection, by means of a meaning-less or "neutral" demonstrator to objectively compare materials. This paper explores the conception of this neutrality and proposes two opposing strategies: neutrality through complexity or through simplicity. In a pre-study with 20 designers, six associative pairs are selected as neutrality criteria, and shaped in 240 forms by 20 (non) designers in a main workshop. Following the simplicity strategy, these forms are averaged out in three steps by a team of five designers, based on a consensus on of delicate-rugged, aggressive-calm, futuristic-calm, masculine-feminine, traditional-modern, and toylike-professional, resulting in a selection of four averaged neutral forms. Finally, future research will focus on complexity to increase interactivity, so that consumers might be triggered in extensive material exploration.

Keywords: *user centred design, multisensory product experience, human behaviour in design, material demonstrator, materials experience*

3.1 Introduction

In our changing consumer market, marked by ever increasing expectations of users, industrial designers are challenged to develop products that go beyond mere product utility, functionality and performance. Indeed, from the perspective of user-centred design, there is a growing emphasis on the consumer in each step of the design process in order to design meaningful product experiences that appeal to the broad consumer market (Hassenzahl, 2013). Van Kesteren (2008, p. 23) states that "product designers have to use their experience, together with expertise from market researchers and consumers to predict and evaluate the user-interaction qualities with a product for predefined target groups".

Traditionally, design arises at the intersection of materials, shapes and technique (Ashby & Johnson, 2012). As product ideas are made physical by means of materials, materials are a basic attribute of products, and thus, materials selection plays a significant role in industrial design (Deng & Edwards, 2007; Hodgson & Harper, 2004).

Literature suggests multiple approaches for an ideal materials selection process (Ashby et al., 2004; Chiner, 1988; Farag, 2002; van Kesteren et al., 2006). However, they mostly originate from material science and mechanical engineering, that reflects on "what a material is and how it behaves" (Camere & Karana, 2018, p. 1), for example in terms of tensile strength, E-modulus, hardness, etc. In contrast, less attention is given to the field of 'materials experience', which involves the meanings that materials can convey to users through its expressive characteristics (Karana et al., 2010). This meaning driven materials selection builds upon four levels of experiential material characteristics such as sensorial attributes (e.g. soft, glossy, warm), interpretive (meanings or associations, e.g. masculine, futuristic, toy-like), affective (emotions, e.g. surprise, curiosity) and even performative characteristics (actions) (Camere & Karana, 2018). This paper aims to take the first steps in enhancing meaning driven materials selection for designers, by means of exploring possible standard, neutral forms that can be used for experiential material characterization at first, and potentially for materials selection in future research.

3.2 Challenges in Experiential Characterization of Materials

Despite the growing attention for the meanings that materials can express, there is still a need to standardise the data collection of experiential qualities, as they exist for the technical, economic and ecological characteristics that are mostly found in databases (Zarandi et al., 2011). In fact, we experience a drawback in the fundamental or systematic data collection on this level, since there is no equivalent support available for experiential characteristics (Ashby & Johnson, 2012). Most databases are information-based and provide an extensive amount of numerical, technical data for an excessive number of materials, such as the CES database (Ashby & Cebon, 2007), where you can select materials based on constraints. By contrast, inspiration-based databases usually involve a limited number of materials than can be explored and discovered in a more visual way, making it more attractive for designers, particularly in early design stages (Ramalhete et al., 2010). Moreover, such inspiration resources can occur both online and physical, going from CES' 'Product, Materials and Processes Database' (Granta, 2016) to an extensive website and exhibition events of Material District (Material District, 2019). Here, designers can experience innovative material samples first hand, making its properties more tangible. However, these samples are mostly semi-finished or final applications, and difficult to objectively compare, hence a standardised material sample demonstrator is required to evaluate experiential qualities.

For that matter, semantic differential scales are used in order to compare and characterise materials by means of scoring pairs of opposite adjectives, such as cold versus warm and aggressive versus calm (Karana et al., 2009a; Osgood et al., 1957). Currently, three main constraints can be found with regard to experiential material data collection: (i) data is merely collected on small-scale projects or workshops with specific material cases, (ii) assessment is usually done by a limited team of designers instead of consumers, and (iii) comparisons are mostly made between material families such as metal versus wood versus plastic (Crippa et al., 2012; Karana et al., 2009a).

The difficulty in generating knowledge on materials experience lies in the fact that these meaning evoking patterns are influenced by various subjective parameters such as the context (time, place, etc.), the product (including shape, function, brand, etc.) and the user him/herself (Karana, 2009). To that regard, Karana et al. (2007) conducted four studies to investigate the effect of form in particular on a material's meaning. Indeed, metal that is embodied in a rather sharp form may be more associated with aggressiveness than metal used in a soft-edged bowl for example. Form can be defined as "the boundary of matter by which we distinguish these objects from each other and their environment" (Karana et al., 2007; Muller, 2001).

Previous studies on experiential characterization of materials use different kinds of stimuli or sample demonstrators to conduct their experiments. At first, photographs or renders of material are used for easy online surveys (Agost & Vergara, 2014; Karana et al., 2007), and as in previous work (Veelaert et al., 2018) where different materials were rendered on abstract forms. However, this option offers no physical interaction with the material itself and makes it hard to compare within material classes.

Second, material samples made from a technical perspective can be employed, for example test bars from the injection moulding machine (Veelaert, Du Bois, et al., 2017) or a sample 'Determinator' (Veelaert, Hubo, et al., 2017) that illustrates different technical properties on different virgin and recycled plastics. The advantage here lies in the standardisation and thus comparability, since each sample has the exact same dimensions in each material. The disadvantage, however, is that these samples are not optimised for experiential characterization and are not attractive for consumers to interact with, as opposed to designers who have more experience in abstract thinking in this context.

Third, flat equal-sized samples are used, allowing participants to look at the material (Sauerwein et al., 2017; Wastiels et al., 2012b)), blindly touch the material (Etzi et al., 2014; Sakamoto & Watanabe, 2017; Zuo et al., 2001), and/or visually touch the material with their fingers (Piselli et al., 2018; Sauerwein et al., 2017; Wastiels et al., 2012b; Zuo et al., 2001). However, free exploration of the material is rather limited due to the flat, non-interactive form, which does not offer the consumer a real feel of the material but are rather seen as boring, as is also the case when using sphere forms that have only one view from each angle.

Fourth, sample demonstrators are also materialised in products (Fenko et al., 2010; Karana et al., 2009a). Of course, finding or making products in different materials within one class can be less feasible. For instance, Crippa et al. (2012) used nine bowls in different material families for their study on emotions. This familiar and simple-shaped object was chosen to freely experience the materials while maintaining the same function. Nevertheless, the bowl did not have exactly the same dimensions (partly as a consequence of the material and its production technique), and the function of a bowl could have elicited food-related associations. Indeed, wood might be considered less pleasant instead of ceramics in this context, although this might not be inherently true for this material. In contrast, literature indicates that more experiments with products are conducted with non-professional participants as well, illustrating their greater ability to attract consumers' interest.

To sum up, the results and discussions of previous studies confirm that material meanings are indeed influenced by user, form and function. There is a knowledge gap in experiential consumer data on materials, beyond existing data from small-scale workshops or specific material cases. Hence, if experiential material data is needed, how can we collect such data in an 'objective' and standardised manner? Moreover, when trying to collect such large-scale data not only from designers, but from consumers specifically, we encounter additional challenges; how to interact with him/her on such an abstract topic? Consequently, there is a clear need for a material sample demonstrator for user-centred or experiential evaluation of materials. First of all, this demonstrator must be a physical object to fully enable the sensorial experience. Next, in order to include the consumer in the characterization process, it must be attractive and accessible to non-designers; it must trigger them to interact with the sample object. Last, it must facilitate an objective comparison between materials, minimising external influences on associations, hence, the sample form must be as ‘neutral’ or 'meaning-less' as possible. On the basis of such standard form, 'neutral' material data can be collected. Moreover, materials can be envisioned in different contexts for objective, yet context-specific data as well. In this way, new contexts will not be excluded, and innovation is not impeded, while maintaining practical feasibility (physical samples, equal form, and simultaneously re-usable in different contexts).

Consequently, this paper elaborates on the exploration into material demonstrators according to a hypothesised simplicity strategy, as discussed in Section 4.3 that examines the concept of neutrality and proposes form-related criteria for neutrality in a pre-study. Next, a framing methodology of Research By Design is applied in Section 4.4 that describes four successive design phases in the creation of neutral demonstrators. Finally, Section 4.5 discusses the findings.

3.3 Exploring the Concept of Neutrality

In this regard, what is neutral? As human beings, we tend to give meaning to everything we see and experience, trying to categorise and identify it, hence, meaning is subjective and dynamic in its nature, and influenced by individual parameters (Krippendorff & Butter, 1984; Osgood et al., 1957). Consequently, we could reason that neutrality does not exist. For example, Thaler and Sunstein (2008, p. 3) state that "there is no such thing as a "neutral" design". However, we could also argue that things can be more or less neutral than others. Therefore, we hypothesise that two conceptions of neutrality can be formulated, and/or two opposing strategies can be followed to obtain neutrality: simplicity versus complexity.

- On the one hand, neutrality can be based on the idea of simplicity, meaning that the object does not evoke any feelings. It is neither one meaning (e.g. aggressive) nor the other (e.g. calm).
- On the other hand, conceiving neutrality as complexity means that the object has a wide range of meanings at the same time of which the user is not able to assign to known archetypes. The object elicits a combination of several meanings (e.g. aggressive and calm at the same time).

First, an exploration aims to corroborate the hypothesis about the two conceptions of neutrality by examining the concept of neutrality (both on a theoretical and a physical level) to further clarify the definitions and examples (see Figure 3.1). Second, this Section aims to select a set of associative pairs as criteria for (non) neutral forms.

3.3.1 Pre-study 1 - Two Conceptions of Neutrality

This pre-study intends to explore and define the concept of neutrality. Therefore, twenty design students (N=20) from the Department of Product Development of the University of Antwerp are asked an open-ended question about what neutrality means to them (*How would you define form neutrality?*). Next, 27 design students (N=27) of the second bachelor Product Development are asked to create a neutral form by means of plasticine, and to explain why they made that specific form. Design students were chosen as they are trained in abstract thinking in forms and shapes but can still relate sufficiently to consumers' experience.

In the first part, twelve out of twenty responses include references to the aspect of our simplicity definition (not choosing sides, simple, in the middle, not extreme, mean of extremes, etc.). Other respondents describe neutrality as objectivity, rational, impartial, etc. In contrast, the second part includes forms that can be classified in a simplicity group (fourteen results) and a complexity group (thirteen results). Figure 3.1 shows a couple of the created forms. Generally, simple forms show round edges in balls, spheres, or other basic forms, opposed to the complex forms.

Conclusively, the results of this first pre-study supports our hypothesis, emphasising the two ways of conception of neutrality; i.e. both as simplicity and as complexity.

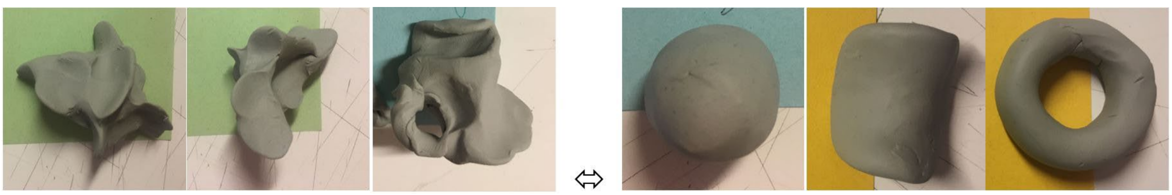


Figure 3.1. A selection of created neutral forms, based on complexity (left) or simplicity (right).

3.3.2 Pre-study 2 – Form Neutrality Criteria

As the previous study shows multiple mentions of no extremes, the middle/mean, or neither sides, we build upon the hypothesised simplicity strategy in the further course of this paper. Therefore, the next intermediate step is to define these extremes that must be avoided based on a list of semantic opposite pairs of meanings that are already used in experiential characterization of materials. However, these meanings are related to materials in general, and we are interested in the meanings that are mostly related to forms in particular. Thus, this pre-study aims to select a set of form-related (form-influenced) meanings of materials, that can be used as evaluation criteria for neutrality in the next Section.

Again, twenty design students (N=20) of Product Development are asked to select six out of seventeen semantic opposite pairs that are, according to them, most related to or influenced by form. The results are processed by means of a frequency table (see Figure 3.2). Consequently, the following characteristics are selected for the next research steps: Delicate-Rugged, Aggressive-Calm, Futuristic-Nostalgic, Masculine-Feminine, Traditional-Modern, and Toylike-Professional.

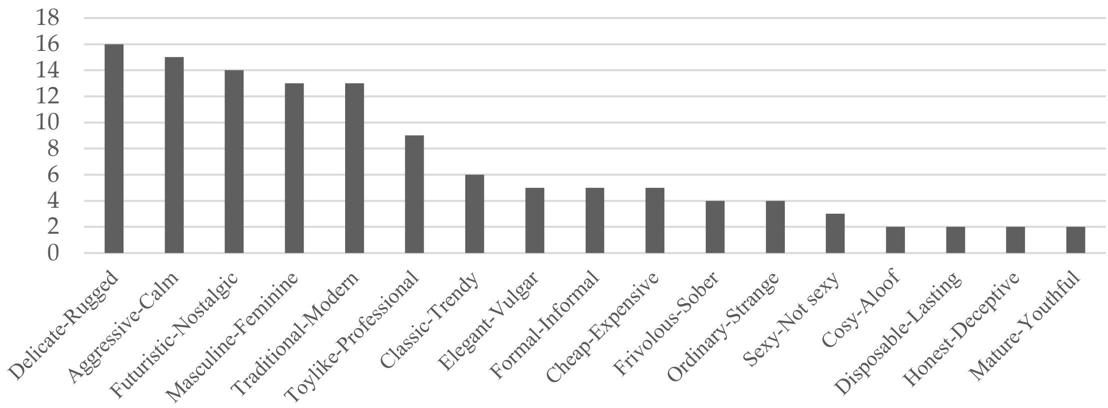


Figure 3.2. Frequency table of selected semantic pairs.

3.4 Approach Towards a Neutral Form

The previous Section explored how neutrality can be defined and characterised. However, in order to create a neutral form, we first have to understand what is not neutral. Therefore, the next Section follows a reverse approach and studies what forms are considered not neutral at all. In this regard, non-neutral forms are chosen as boundaries for the creation of neutral forms, as these extremes are the easiest to shape, yet offer potential to arrive at forms that surpass a plain sphere that offers merely one perspective from all angles. Building upon the simplicity strategy, this approach intends to transition from extreme to neutral by consecutively averaging forms. Figure 3.3 gives a visual overview of the process flow of the design phases building upon each other's outcomes. This layered structure of successive design steps consists of four phases:

- Phase A: creation of forms for each characteristic of a pair (6x2x20)
- Phase B: creation of average forms for each characteristic (6x2x1)
- Phase C: creation of average forms for each pair (6x1)
- Phase D: creation of average form proposals over all six pairs (4x)

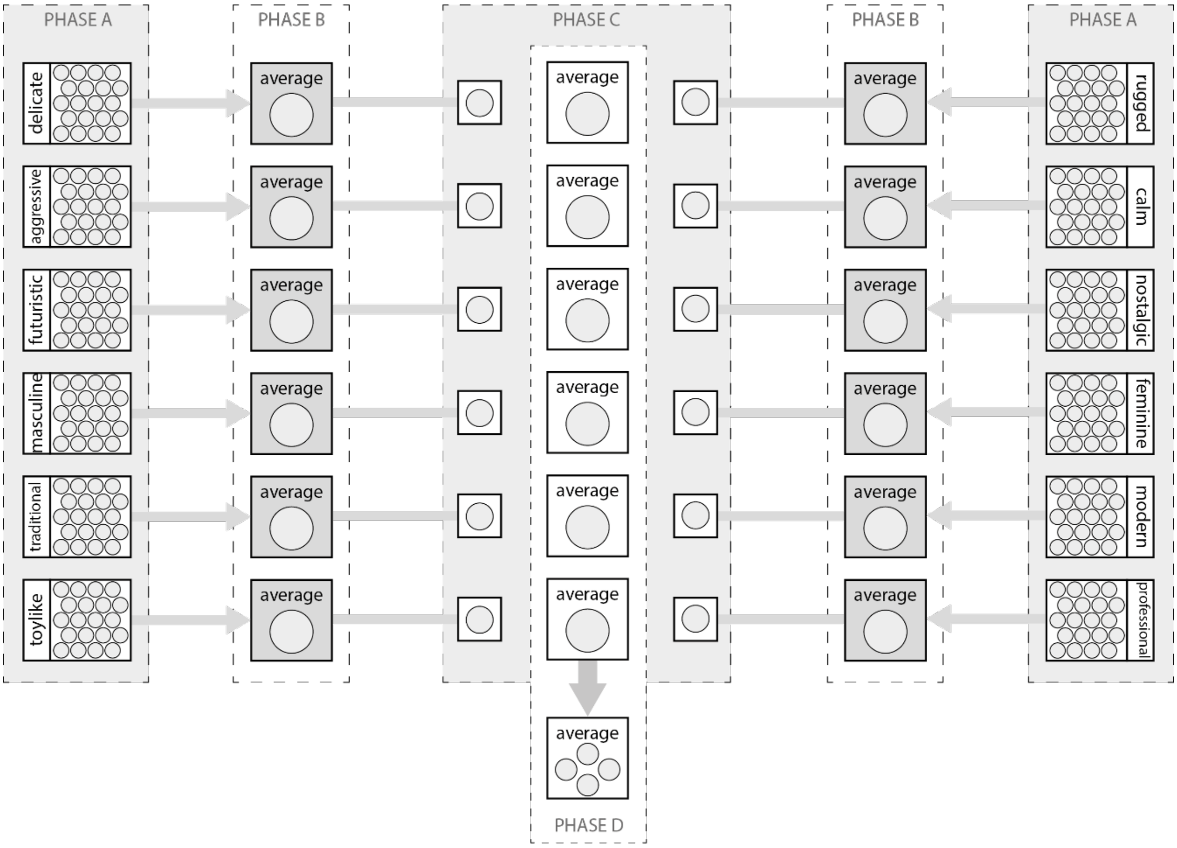


Figure 3.3. Overview of the different phases towards a neutral form.

3.4.1 Phase A

The first phase aims to understand what forms are not perceived as neutral by creating forms that are related to the six pairs of adjectives that were selected as 'criteria for neutrality' in Section 4.3.2. Ten designers and ten non-designers (N=20, 10 male and 10 female) voluntarily participate, and are asked to create a form with plasticine for each of twelve characteristics.

A selection of the range of the resulting 240 forms (6x2x20) of this first step are shown in Figure 3.4. A first look at the resulting forms shows that for some meanings similarities could be found (such as aggressive-calm), while other meanings (such as futuristic-nostalgic) resulted in a varied collection of rather different forms.

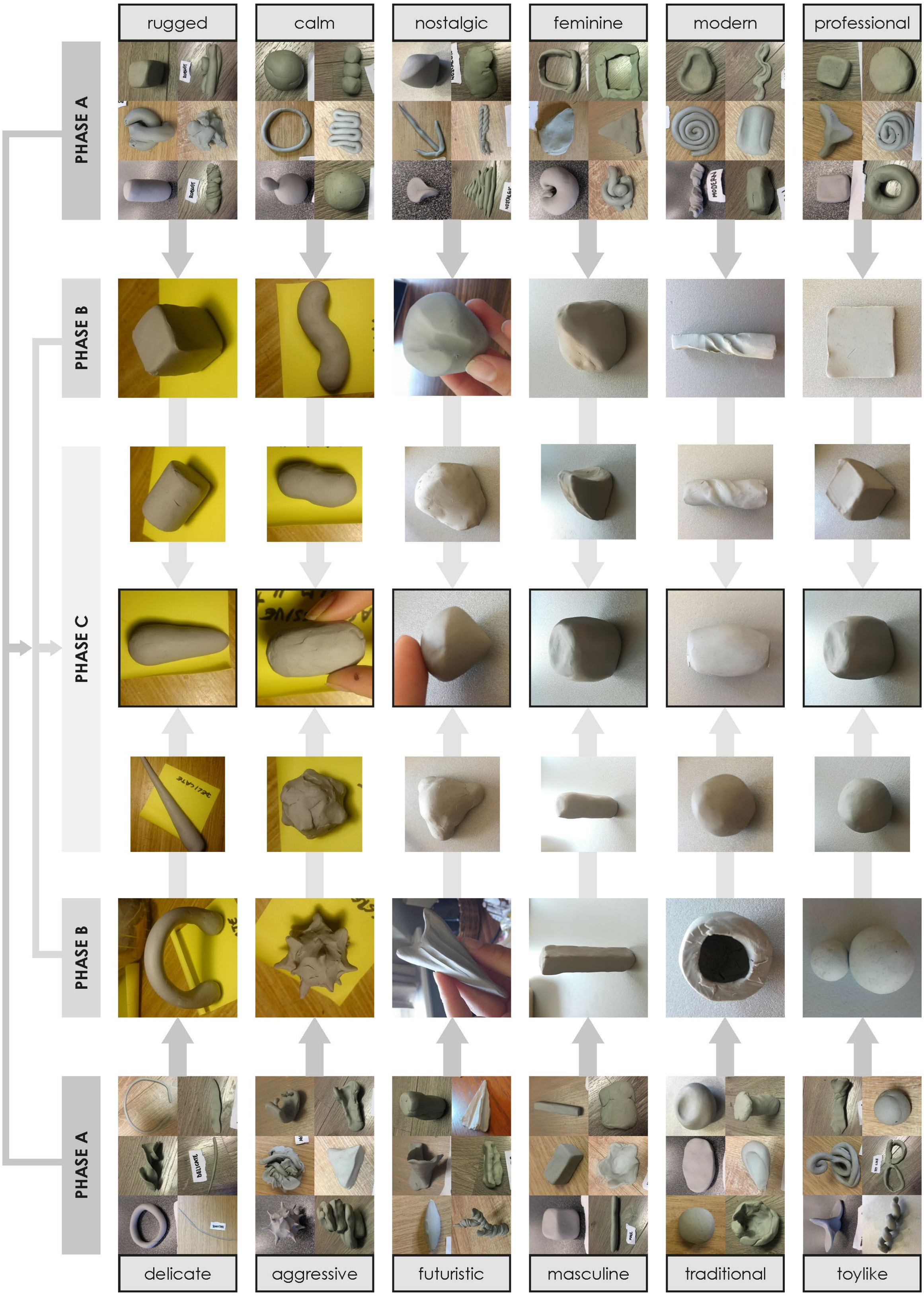


Figure 3.4. Selection of form results of phase A, B, and C.

3.4.2 Phase B

The second phase aims to combine the results of the previous phase (i.e. 20 forms per meaning) into an average form per characteristic. A research team of five designers (N=5, 2 male and 3 female) are asked to create a representative form with plasticine for each of twelve characteristics, relying on the forms of phase A. Discussion and collaboration increases the objectivity of the obtained results. This step results into twelve forms (6x2), each one describing an opposite adjective, that can be used as input for the next workshop. The twelve forms of phase B are also visualised in Figure 3.4.

3.4.3 Phase C

The third phase aims to bridge the two extreme forms of each set of opposite adjectives by creating an average form for each of the six semantic pairs. It is hypothesised that such an average form should inherit either both meanings at the same time, or none of them. The same five design students (N=5, 2 male and 3 female) are asked to merge the opposite average forms into one average plasticine form ('i.e. middle point') for each semantic pair, by means of a three-step process, leading to a representative form. Again, the final forms are obtained through discussion and collaboration of the team to increase objectivity. This phase resulted in six forms (6x1), each one representing neutrality according to one semantic pair, that can be used as input for the next workshop. Figure 3.4 shows the 3-step process from two opposite averages to one neutral form or 'middle point'.

3.4.4 Phase D

The fourth phase aims to create a final neutral form as the average of the six previously proposed 'middle points', combining the common aspects of these forms. The same five design students (N=5, 2 male and 3 female) each receive an overview of the results of the third phase and are asked to create four plasticine forms that could represent neutrality. Next, they are asked to evaluate the forms as a team and combine them to reduce the number of forms to four, according to the neutrality of the form.

3.4.4.1 Results

By means of an intermediate step, leading to twenty (5x4) preliminary neutral forms, this phase finally results in four forms that could all represent neutrality, yet offer more angles than a plain sphere. Figure 3.5 presents the four selected forms by means of 3D prints. *Form i* combines a sphere and a cone, which avoids sharp edges and vertex by including a transition between both shapes. By means of concave details it attempts to create interaction with the user and to invite them to touch and experiment with the form. *Form ii* is based on a pyramid but excluding the aggressive character by rounding the edges, transforming its lines into curves, and including slightly convex and concave surfaces. The interaction becomes intuitive by holding it with both hands, inviting the user to touch and turn. *Form iii* is a symmetric form based on a cylinder with flat endings that host special finger spots and texture surfaces. Its size and lines make it easy and comfortable to hold. Last, *Form iv* is a variation on form iii but includes a twist in the middle of the piece, eliminating the symmetry in one of the planes. This variation encourages the user to interact more with the form by turning it in contrast to the balance in the previous form.

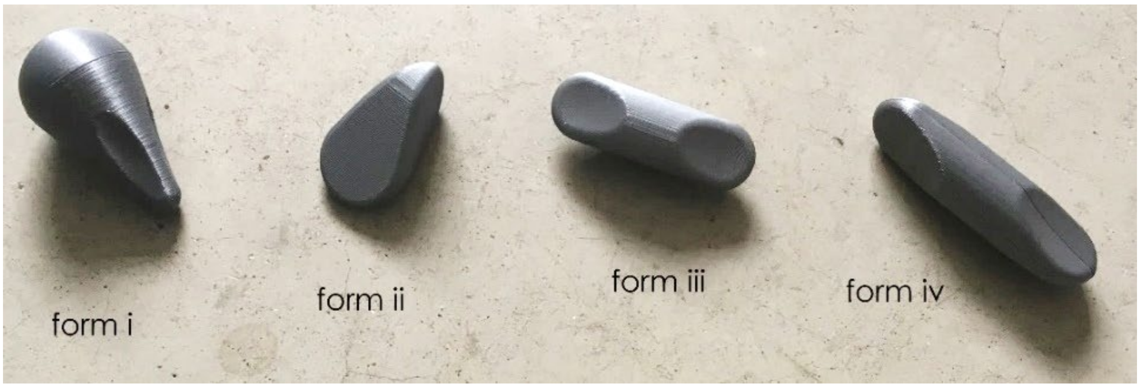


Figure 3.5. The final four propositions for a neutral material demonstrator form.

3.4.4.2 Preliminary Verification

A preliminary verification test with twenty design and non-design students was conducted to evaluate the four proposed forms based on the six criteria of Section 4.3.2. However, this showed highly dispersed results, showing no significant indications whether the forms were perceived neutral or non-neutral. However, it did reveal that non-designers consider the forms more neutral than designers in all cases. All in all, form iii - followed by the twisted form iv - showed the most relation to neutrality, although no significant claims can be made. We propose further studies that explore the complexity strategy as well, leading to potential neutral forms than can be compared to this study's generated forms, a plain sphere, and existing flat material demonstrators, in order to test the neutrality of all forms.

3.5 Discussion

Regarding the challenges in assessing material samples, the meaning of a material is influenced by context, user and product-related parameters such as product shape and function. Material data on technical properties is widely available, however, in order to provide equivalent data support on experiential material characteristics, a more standardised and objective way is required to assess such materials experience. One way to achieve a more valuable one-to-one comparison is through presenting different materials in one and the same form, with minimal associations to existing products or extreme meanings. Therefore, this paper reasoned upon the conception of neutrality in relation to material exploration and presented an experimental attempt to examine the potential of a neutral form for experiential material characterization.

As human beings, we tend to give meaning to everything we perceive, in fact, it is a fundamental trait of human intelligence. Thus, we argue that neutrality might not exist at all. We question if it is really possible to create a form that is neutral to everyone. However, things can be more or less neutral than others, and a form might still be neutral enough for material exploration.

Consequently, two opposing conceptions of neutrality were proposed as the base for the further study: neutrality through complexity versus neutrality through simplicity. In this study, we followed the latter strategy, and discussed the qualitative process towards four potential neutral material demonstrator forms, to better support experiential characterization studies of materials by means of a standardised form, i.e. material representation, allowing materials to be envisioned in different contexts. However, we argue that the followed simplicity methodology might cause too much simplification, and therefore loss of information, because of constantly averaging out. Hence, this research expresses that neutrality through simplicity is not the way to go, as it leads to rather 'boring' forms that conflict with the interactivity to attract and trigger consumers in engaging in extensive material exploration? Conversely, adding more interactivity to the material form might cause a transition to the complexity strategy.

Moreover, when conducting studies to examine how people experience certain materials, we expect other needs for consumer studies in contrast to designers studying materials themselves. Consumers might have a greater need for interaction to trigger their imagination and facilitate abstract thinking. Therefore, a compromise is required between the need for neutrality and the need for interactivity (i.e. having different perspectives from different viewing angles) when designing a material sample form that is interesting, yet neutral enough to minimise contextual influences.

At the present time, the resulting form proposals rely on a very qualitative approach, that might suffer from a bias using students as participants in the workshops. Yet, its value lies in the reasoning process and the preliminary insights it provided. In this way, we hope to facilitate the experiential characterization of materials by increasing the standardisation of the material representation, and consequently to facilitate materials selection focussing on a specific target user group. In the context of such standardisation, an additional step will have to focus on the manufacturability of the demonstrator form. For example, when focussing on the material family of plastics alone, the process of injection moulding could offer interesting possibilities once technical form-related issues are overcome. However, when potentially expanding to other material families, this aspect must be reconsidered from the perspective of another adequate processing technique.

Finally, further studies are planned, for example with experts on the field of form or design, in order to discuss what a material evaluation form or demonstrator needs to have or needs to be. Could one standardised form suffice, or does it need to consist of a set of forms, or even modular? As we recognise the fact that more interactivity should be included in a consumer-focused tool, we aim to examine the complexity strategy as well to increase the interactivity potential, and to compare the results with the simplicity strategy, and current material demonstrators.

3.6 Conclusion

In the context of meaningful materials experience in industrial design, there is a clear need for adequate support for experiential characterization. In order to facilitate systematic large-scale data collection with consumers, a one-to-one comparison of different materials in the same physical 'form' is required, i.e. a standardised material demonstrator that can be used as objective stimuli in experiments.

First of all, we proposed that this demonstrator form must be a physical object to fully enable the sensorial experience. Next, to include the end-user in the characterization process, it must be attractive and accessible to consumers; it must trigger them to interact with the sample object. Last, it must facilitate an objective comparison between materials, minimising external influences (such as context, product, shape etc.) on associations, hence, the sample form must be as ‘neutral’ or 'meaning-less' as possible. Therefore, this paper explored the conception of neutrality and proposed two opposing strategies: neutrality through complexity or through simplicity. More specifically, it presented the process of four successive design phases towards the creation of a neutral form, grounding on the latter strategy, that can serve as a material demonstrator in further research.

Consequently, four form proposals have been developed, and although the resulting forms - or the followed strategy - need further adjustments, this qualitative process was instructive and provided useful insights. In conclusion, we argued that the demonstrator form does not need to be neutral, but rather neutral enough for material exploration. As the followed simplicity strategy resulted in too much simplification and a loss of information, we proposed to increase the interactivity by means of the complexity strategy in further research, to trigger consumers in an extensive exploration of standardised material samples.

Chapter 4 is based on:

Veelaert, L., Moons, I., van Gogh, D., Vleugels, J., & Du Bois, E. (2022). A Physical Demonstrator Form for Experiential Material Characterization. *The International Journal of Designed Objects*, 16(1), 19–48. https://doi.org/10.18848/2325-1379/CGP/V16I01/19-48

And the demonstrator form is registered as non-written output:

Veelaert, L., Du Bois E., Moons, I., Van Gogh, D., Vleugels, J. (2021). Kunststof Demonstrator vorm (en spuitgietmal) = Plastic Demonstrator Form (and injection mould). Non-Written Output Toolkit, https://hdl.handle.net/10067/1830430151162165141.

4. A Physical Demonstrator Form for Experiential Material Characterization

Veelaert Lore, Moons Ingrid, Van Gogh Dirk, Vleugels Jochen, Du Bois Els

Abstract: Within product design, attention has grown towards experiential material characterization, as a supplement to technical material characterization. Within the essential translation of subjective experiences of consumers into meaningful material data, this paper investigates the need for a standardized physical material demonstrator form that triggers consumers in holistic multimodal interactions, while minimizing the interference with product (function) and context associations. A stepwise and mixed method methodology is employed, consisting of six qualitative and quantitative studies with form experts, designers, and consumers in order to create and verify potential forms. Conclusively, the proposed demonstrator form is found more appropriate for experiential material characterization (of plastic materials, including recycled and bioplastics), than standard flat plates that are used in most experiments.

Keywords: *product design, consumer perception, aesthetics, materials experience, experiential material characterization*

4.1 Introduction

Due to technical evolution, it is no longer sufficient for products to only meet functional specifications (Ranscombe et al., 2012; van Kesteren et al., 2008). In a competitive market, a successful product must be meaningful, evoke desired user interactions, and create the intended product experiences (Hassenzahl, 2013; van Kesteren, 2008). Nowadays, the aesthetic and symbolic experiences of a consumer product have a greater influence on its acceptance and appreciation than its functional capabilities (Bloch, 1995; Creusen & Schoormans, 2005; Crilly et al., 2004; Ranscombe et al., 2012).

From an engineering perspective, product design sets in at the junction of materials, forms and techniques (Ashby & Johnson, 2012). Materials embody the interaction between products and consumers (Ingold, 2007), and as such, fulfil both functional and experiential needs. Karana (2010) states that a material's meaning arises at the dynamic interaction between a material in a particular product and context, and a user with its characteristics. Thus, the evoked materials experience (Giaccardi & Karana, 2015; Karana et al., 2014; Karana & Hekkert, 2010) contributes to the product's experience, and can be defined as "how a material is received, what it makes people think, feel and do" (Camere & Karana, 2018, p. 2). Two main levels of experiential material qualities are sensorial attributes and interpretive characteristics – our focus within this paper - next to affective characteristics and performative actions. We build upon a list of semantic scales that are found in literature (Ashby & Johnson, 2012; Karana, 2009; Karana et al., 2009a; van Kesteren et al., 2007b). Sensorial attributes mentioned in at least two of these sources and interpretive characteristics mentioned herein, were already used in previous work (Veelaert, Du Bois, et al., 2020) in the context of characterizing recycled plastics, and are used again in this work (see Table 4.1). Moreover, in early work, Karana, van Weelderen, and van Woerden (2007) studied the effect of form on meaning with a short set of interpretive characteristics.

Table 4.1. Overview of sensorial attributes and interpretive characteristics of materials, data adapted from (Veelaert, Du Bois, et al., 2020).

Experiential qualities of materials	
Sensorial attributes	***Interpretive characteristics***
Glossiness (Matte – Glossy)	Aggressive – Calm
Transparency (Opaque – Transparent)	Masculine – Feminine
Colourfulness (Colourless – Colourful)	Delicate – Rugged
Colour intensity (Weak – Intense)	Elegant – Vulgar
Softness (Hard – Soft)	Toy-like - Professional
Stiffness (Stiff – Flexible)	Disposable – Lasting
Ductility (Tough – Ductile)	Cosy – Aloof
Brittleness (Brittle – Unbreakable)	Frivolous – Sober
Weight (Light – Heavy)	Futuristic – Nostalgic
Strength (Weak – Strong)	Ordinary – Strange
Elasticity (Low – High)	Sexy - Not sexy
Scratchability (Scratchable – Scratch Resistant)	Cheap – Expensive
Greasiness (Dry – Greasy)	Classic – Trendy
Texture (Smooth – Rough)	Honest – Deceptive
Acoustics (Soft – Shrill)	Mature – Youthful
Odour (Odourless – Fragrant)	Formal – Informal
Temperature (Cold – Warm)	Traditional - Modern

However, as complex phenomenon of materials experience is very dependent on contextual and temporal factors such as product functionality, technological processes, context of usage and socio-cultural aspects, no standard procedures or equivalent support to retrieve this subjective data are currently available. Within product design research, materials experience gained an increased interest over the last decade (Ashby & Johnson, 2012; Pedgley, 2014; Wilkes et al., 2016), leading to several tools for the exploration, assessment or manipulation of a materials' experiential qualities (Camere & Karana, 2018). However, they do not elaborate on the physical means or material representation to study materials experience. Currently, various types of material samples are used in each research, which does not allow generalization of the resulting material data to achieve extensive datasets of meaningful user-centred material characteristics (Veelaert, Du Bois, et al., 2020). In addition to technical data and context- or case-specific experiential data - which can be derived through e.g. the Material Driven Design method (Karana, Barati, et al., 2015) - generic material information obtained from consumers might offer useful and practical opportunities for designers early in the design process and/or when designing products with a focus on a specific target market (Flint, 2002).

Despite the various tools that have emerged for designers, the set-up of experiments for experiential material characterization induces many challenges as exposed in a previous literature review (Veelaert, Du Bois, et al., 2020). We build upon this work that identifies six needs within the experimental set-up of experiential material characterization studies in order to overcome its methodological challenges: need for (N1$_{MAT}$) within-material-class comparisons, e.g. comparing different plastics with each other, (N2$_{PHYS}$) physical material representations that can be assessed in real life instead of digital, (N3$_{MODAL}$) multimodal interaction with stimuli using multiple senses, (N4$_{EXP}$) complementary experimental set-up and methods that integrate previous needs, (N5$_{TEMP}$) studying temporality of materials experience through longitudinal studies, (N6$_{CONS}$) integration of extensive user aspects for consumer segmentation, e.g. personal values and personality traits as moderators of material meaning. One specific need that is also stated by Martín et al.(2015), will be discussed in the further course of this paper: the need for a standardized physical material representation ($N2_{PHYS}$) that is both abstract and interactive, to trigger consumers in a holistic multimodal interaction, while minimizing the interference with product (function) and context associations. However, when responding to this need, several of the other challenges will have to be addressed simultaneously as they serve as boundary requirements for a physical material representation.

4.2 Theoretical Background

4.2.1 Requirements for Physical Material Representations

Based on existing studies that were summarized in a previous literature review (Veelaert, Du Bois, et al., 2020) followed by an explorative pre-study (Veelaert et al., 2019), four requirements were identified that are crucial to characterize the needed physical material representation. First, the form must be "an equal and thus constant presentation of various materials, but varied in itself" (Veelaert, Du Bois, et al., 2020, p. 13). Second, the form should evoke interaction to fully understand material experience. Third, as it should also be used to involve end users or consumers, it must evoke empathy and interest. And last, practical production issues must be considered. Table 4.2 sums up the details and literature concerning these requirements.

Table 4.2. Explanation of four requirements (REQ) for a physical material representation.

Requirement	*Details*	*Sourced literature*
REQ1: Physical material representations	- Decontextualized samples or contextualized materials in products. - "A form that allows an equal and thus constant presentation of various materials, but is varied in itself"	(Piselli et al., 2018; Veelaert, Du Bois, et al., 2020)
REQ2: Evoke interaction, trigger to explore and manipulate to fully understand the material experience	- Trigger free exploration and "play" with it while manipulating - Multimodal: integrate all senses - All experiential level including performative - Most resembling to usage phase of a product/material	(Camere & Karana, 2018; Y. T. Chen & Chuang, 2014; Crilly et al., 2004, 2009; D'Olivo et al., 2013; Hope et al., 2012; Karana, 2009; Ludden & van Rompay, 2015; Sauerwein et al., 2017; Schifferstein & Wastiels, 2014)
REQ3: Involving end-users or consumers instead of designers	- Involving end-users or consumers instead of designers is considered understudied - Capturing consumer's empathy and interest in such abstract matter might be challenging	(Veelaert, Du Bois, et al., 2020)
REQ4: Controlled experimental conditions	- Independent of material-related production techniques - Ability to (re)produce the standard form in different materials	(Veelaert, Du Bois, et al., 2020)

4.2.2 Used Material Representations in Experiential Studies

In multimodal experiential material characterization, form does not only affect a material's meaning and experience (Karana et al., 2007; Karana & Hekkert, 2010) it also provokes certain interactions and manipulation gestures (Angelini et al., 2015; Giboreau et al., 2001), such as hand movements linked to (manual exploration for) haptic perception (Lederman & Klatzky, 2009). Previous studies have taken first steps in an attempt to overcome this issue regarding the form of a material sample when conducting their experiments. They each allow – to greater or lesser extent – to move, hold, touch (Angelini et al., 2015) or full-hand manipulate (Giboreau et al., 2001) the material sample. Table 4.3 gives an exploratory overview of a selection of material representations. Building upon the categorization of material representations in (Veelaert, Du Bois, et al., 2020), a distinction can be made between intangible text-digital models such as words, renders or photographs on the one hand, and physical decontextualized flat or blocked samples and contextualized products on the other hand. Additional features within the requirements are discussed within the research team and scored from '- -' to '+ +', such as the level of standardization and feasibility (i.e. including large scale experiments, within-material-class comparisons, etc.), the possibility for experiential characterization by consumers, the level of complexity that can be achieved, the level of minimal contextual influence (i.e. form, function, etc.), and the facilitation of multimodal interaction.

- Digital renders or photographs of different materials (Agost & Vergara, 2014; Karana et al., 2007; Veelaert et al., 2018) are used as these stimuli offer easy standardization and high feasibility in terms of large-scale online surveys. Despite these advantages, no physical or multimodal interaction is possible which disables the comparison of similar materials within the same class, such as plastics.
- Simple flat or blocked samples are most common in experiential characterization studies and can be stand-alone cut-outs (e.g. (Lindberg et al., 2013; Sauerwein et al., 2017; Wastiels et al., 2012b) or mounted on holders (e.g. (D'Olivo et al., 2013; Fujisaki et al., 2015)). Although standardization of equal-sized samples is rather simple and feasible, due to the low level of complexity, little experiential interaction is possible.
- Test bars intended for technical characterization, e.g. (Veelaert, Du Bois, et al., 2020), or even specifically designed forms, e.g. (Veelaert et al., 2018; Vyncke et al., 2018), that demonstrate technical properties and opportunities in the context of virgin and recycled plastics can be employed. However, these forms are optimized for engineers and designers, not for experiential characterization with consumers.
- Real products in different materials are used as they approach reality most, which can be interesting to attract consumers. However, the chosen product and its function largely influence the material perception and meaning, e.g. example e in Table 4.3 where a rubber bowl was found disgusting for food (Crippa et al., 2012). Moreover, when considering practical feasibility, it is not evident to produce a product sample in different materials on a small scale.
- Previous work (Veelaert et al., 2019) presents a first attempt to overcome the above contextual issues. The aim was to involve non-designers in the characterization process and objective comparison of plastics by means of a physical, standardized object that is attractive, accessible, and triggers interaction, while minimizing external influences (i.e. context, product function, etc.) on associations. Hence, their ideal sample form must be as 'neutral' or 'meaning-less' as possible. The authors explore the conception of neutrality and propose two opposing strategies, i.e. obtaining neutrality through simplicity (no meanings) versus through complexity

(multiple, simultaneous meanings). Following the former strategy, they present a set of four, simple form proposals for experiential material characterization. However, they conclude that their process of simplifying leads information loss and boring forms that do not engage consumers enough in interaction and exploration.

– Finally, we propose that a more suitable and standard material demonstrator form for experiential characterization by consumers should attempt to combine as many benefits as possible from the previous options. Hence, a physical, abstract, standard and complex form must be developed that involves consumers in a multimodal experiential characterization of materials (including within-class comparisons) in large scale experiments.

4.3 Research Aim

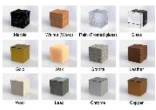
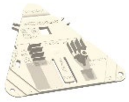
The previous Sections show that materials experience is a complex subject to study with many challenges concerning experiential characterization to control for contextual influences and allow material meaning to be projected more independently. Based on previous research, we argue that a standard form – that meets the needs and requirements as previously discussed and indicated by at least '+' in Table 4.3 – does not yet exist. Thus, the aim of this research is twofold: firstly, we aim to develop a standard, complex form or material demonstrator that is suitable for experiential material characterization by consumers through enabling tangible and rich interaction with materials. This way, designers or design researchers can benefit when they conduct these experiments with consumers, and it offers potential for generalizability within the materials experience community as well. Secondly, we aim to reuse this form to support and extend designers' material tinkering process during the design of new products.

Such a material demonstrator form itself should evoke as few (or as varied) inherent meanings and associations as possible and should be minimally linked to known contexts and functionalities, so that measured experiential qualities can be assigned to its material instead to the form (hence, our focus on interpretive characteristics to evaluate potential forms). In this way, we aim to contribute to experiential material characterization by responding to methodological challenges within the field. Therefore, the main research question states: *How should a physical material demonstrator form be developed to optimally support design professionals in conducting experiential material characterization experiments with consumers and other stakeholders?*

The overall aim of the experiment is to test differences in effectiveness of consumers assessing (sensorial and interpretive) experiential material qualities by means of a specific 3D form compared to a conventional flat plate sample. Qualification of the form is based on e.g. ease of assessing the material qualities, enjoyment of multimodal interaction, and ability to imagine the demonstrator's material in a product.

In order to narrow down the scope of this research, and to respond to the need of within-material-class comparisons, we focus on the material class of plastics. In the context of product design, experiential knowledge of plastics is valuable and can anticipate current issues concerning their (non) sustainable perception. For example, experiential data on recycled plastics or bioplastics can offer insight in how consumers perceive these materials and how they can be differentiated on the market. Moreover, this material class requires physical samples for experiential characterization as plastics are particularly difficult to compare with each other.

Table 4.3. Overview of material representations in previous experiments, including qualitative evaluation: a) Reprinted from (Veelaert et al., 2018), Copyright (2019), with permission from Springer Nature Switzerland AG. (b) Reprinted from (Lindberg et al., 2013), Copyright (2013), with permission from Elsevier. (c) Reprinted from (Veelaert, Du Bois, et al., 2020), in accordance with Creative Commons regulations. (d) Printed with permission from Vyncke (Vyncke et al., 2018). (e) Reprinted from (Crippa et al., 2012), in accordance with Creative Commons regulations. (f) Reprinted from (Karana & Nijkamp, 2014), Copyright (2014), with permission from Elsevier. (g) Authors.

Form Type & Example	*Form Details*	*Multimodal Interaction?*	*Level of Complexity?*	*Experiential Characterization?*	*Standardization?*	*Feasibility?*	*Minimal Effect of Context?*
Render  *(a)*	Digital: Abstract	--	-	-	++	+ +	+
Flat/blocked sample  *(b)*  *(c)*	Physical: Decontextualized	+ -	-	+ -	+	+	+
Test bar (c) 	Physical: Decontextualized	-	-	-	+ +	+	+ -
Determinator  *(d)*	Physical: Decontextualized	-	+	-	+	+ -	+ -
Bowls (e) 	Physical: Product	+ -	+ -	+ -	+ -	+ -	-
Cover (f) 	Physical: Product	+ -	+	+ -	+	-	--
Abstract forms (g) 	Physical: Abstract	+	-	+ -	+	+	+
Demonstrator Form	Physical: Abstract	+ +	+	+ +	+	+	+

4.4 Methodology

To answer the main research question above, a mixed method methodology is employed, combining both qualitative and (semi) quantitative studies with different stakeholders such as 'form experts' (e.g. artists, design teachers, professional designers), industrial experts (e.g. mould developer and CAD experts), and consumers. An iterative and step-by-step research is set up that builds upon the above discussed insights of our extensive literature review and preliminary exploration of simple form demonstrators. The following Sections discuss multiple sub-research questions in six consecutive studies and their intermediate results, as shown in Figure 4.1.

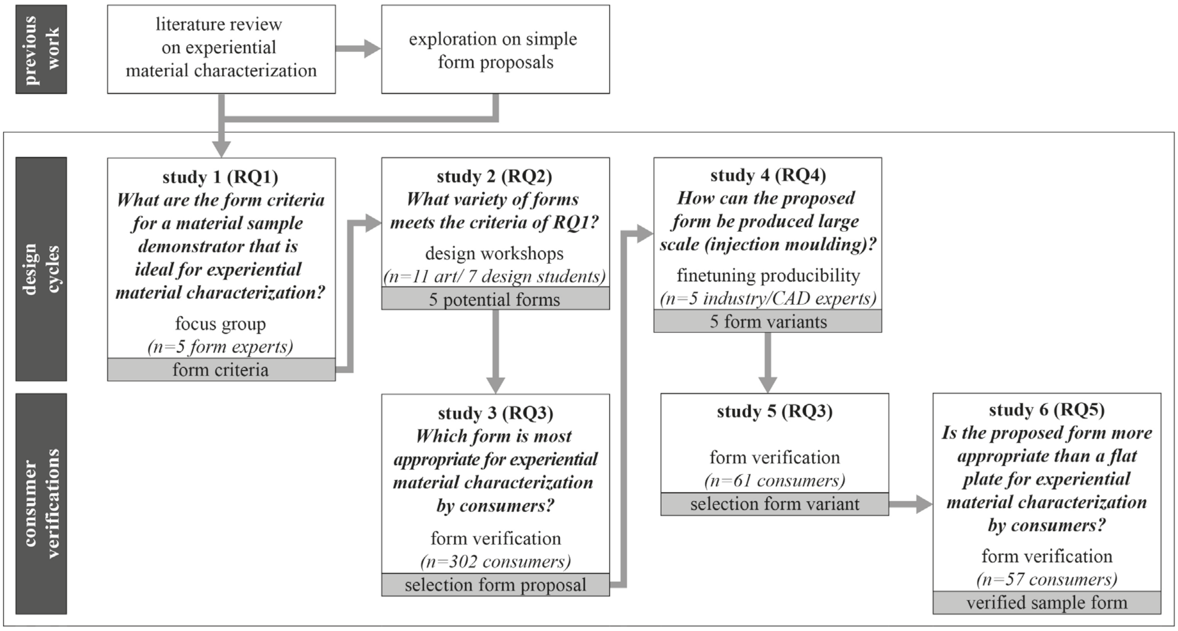


Figure 4.1. Reasoning model visualizing the flow of the consecutive studies within this research.

First, a qualitative focus group session with online questionnaire is organized with five 'form experts' to formulate criteria for a suitable, standard material demonstrator form (RQ1). Second, based on these insights, two workshops are carried out with art and design students to create a number of potential forms in clay, including peer evaluations. Five form proposals are selected based on the extent to which they meet the form criteria (RQ2). Third, a quantitative study with consumers is set up to verify which of these potential forms is most suitable for experiential material characterization by this target group (RQ3). Fourth, to increase the producibility of the selected form by industrial processes (i.e. injection moulding), this form is slightly adapted to five makeable variations by the research/design team (RQ4). Fifth, the form variants are compared with the selected form of study 3 in another quantitative study with other consumers to select the best variant (RQ3). Sixth, the suitability of the selected material demonstrator form is verified by a comparison with a flat plate sample that is commonly used in experiential material characterization (RQ5). Different participants are recruited in each stage to avoid bias of appraisals due to prior knowledge from the previous steps.

4.5 Procedure and Results

4.5.1 Study 1 – Focus Group Session With Form Experts

4.5.1.1 Aim and Participants

This focus group study aims to translate the six needs and the four requirements for a physical material representation into more concrete, defined form criteria to design a suitable material sample demonstrator for future research on experiential material characterization.

Through the network of the university's design department, five 'form experts' are recruited for the focus group. Age and gender are not considered as selection criteria. Two participants are part time design teachers and artists, one participant is a professional designer and design researcher, and two participants are full time design teachers.

4.5.1.2 Procedure

After welcoming, the 3-hour focus group session starts with an introduction to the field of materials experience, experiential qualities of materials, its evaluation based on the sensorial scales of Karana et al. (Camere & Karana, 2018; Karana et al., 2009a), and the contextual challenges involved as discussed previously. Next, the simplicity versus complexity theory (see Table 4.3) is explained and the simple form proposals that were created in previous, exploratory research (see Table 4.3 and Figure 4.2) are presented and discussed based on a limited set of six semantic pairs (Delicate-Rugged, Aggressive-Calm, Futuristic-Nostalgic, Masculine-Feminine, Traditional-Modern, Professional-Toy-like), as used in (Veelaert et al. 2019) in an attempt to create meaning-less forms.

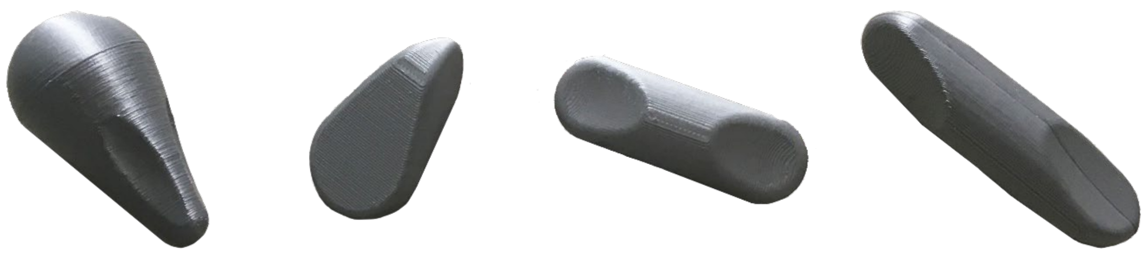


Figure 4.2. Four simple form proposals of the previous Study.

Subsequently, a set of questions and statements are discussed in group, concerning the needs and requirements. Finally, the experts are asked to discuss and extend the criteria for a material demonstrator form, and to conclude the focus group by creating suitable form proposals in clay themselves. Afterwards, the form criteria are summarized based on the transcriptions of the focus group, and verified with the participants by means of an online survey one week later, in which they are asked to approve, rewrite or discard each criterion, rank their selection, and indicate relevant interpretive characteristics as evaluation criteria for the final form (based on the list used in Table 4.1).

4.5.1.3 Results

Rather soon, the participants agreed that the initially proposed forms (see Figure 4.2) were not adequate for experiential material characterization by consumers, as they were found too simple and 'boring'. Although these forms might be experienced 'neutral' or meaning-less, they were considered not useful in this context. It was stated that it is highly important to trigger and engage consumers to explore a material by interacting with the material form; therefore it must be attractive as well.

A list of design criteria for a suitable material demonstrator form is compiled based on the transcribed information received during the session, which includes the descriptions of the participants' form proposals. Table 4.4 shows the form criteria and their frequency counts resulting from the online questionnaire (completed by four out of five participants). The bottom two criteria only receive one count as the participants mention that (i) an alternation of convex and concave is sufficient in contrast to double curvature, and (ii) a composition of volumes is not necessary as a mono volume with cavity suffices as well. To conclude, only the first nine criteria are taken into account for the next study.

Reflecting on this, the design criteria can be linked to the requirements. The requirement of a decontextualized form is largely contained in the form criterium of few associations. The criterium of aesthetic interest reflects the requirement of attracting consumers. The hand size criterium arises from the requirements of dynamic touch and involving consumers. The criteria of the radii, no symmetry, thick/thin, surface intersections, convex/concave, and cavity, all encompass form variety and as such reflect the requirement of complexity that is needed in a form.

Table 4.4. Form criteria based on transcription of focus group and frequency count.

Criterium	**Count**
'Comfortable hand size' (+- 7x4 cm) ('good fit for hand') [a]	4
Uniform & variable radius [a]	4
No symmetry (different perspectives) [a]	3
Thick & thin part (flexibility & light) [a]	3
Aesthetically interesting form [a]	3
Different surface intersections [a]	3
Convex & concave part [a]	3
Negative space (cavity) [a]	3
Provoke as few extreme associations as possible [a,b]	2
Double curvature	1
Composition of volumes	1

[a] *Selected form criteria for form evaluation in next study.*

[b] *This criterion has been further elaborated in the next step and Table 4.5, leaving eight form criteria.*

Next, the participants' indications of whether or not the interpretive characteristics are relevant in the evaluation of a suitable form are processed into frequency counts of the semantic pairs, as displayed in Table 4.5. The top five pairs are selected to serve as evaluation criteria of proposed forms in the next studies. Compared to previous work on the simple forms (Veelaert et al., 2019), the pair of Futuristic-Nostalgic is discarded and the pair of Traditional-Modern is replaced by Elegant-Vulgar.

Table 4.5. Frequency counts of semantic pairs that are relevant for form evaluation.

Semantic pair	Count
Aggressive-Calm [a]	4
Masculine-Feminine [a]	3
Delicate-Rugged [a]	3
Elegant-Vulgar [a]	2
Toy-like-Professional [a]	2
Sexy-Not sexy	1
Disposable-Lasting	1
Cheap-Expensive	1
Classic-Trendy	1
Traditional-Modern	1
Mature-Youthful	1
Cosy-Aloof	1
Ordinary-Strange	0
Formal-Informal	0
Honest-Deceptive	0
Futuristic-Nostalgic	0
Frivolous-Sober	0

[a] Selected semantic pairs for form evaluation in next study.

4.5.2 *Study 2 – Form Creation Workshops*

4.5.2.1 Aim and Participants

The aim of Study 2 is to create an extensive and varied set of forms that meet the criteria of Study 1 for a suitable material sample demonstrator form, during two creative workshops. In order to create a variety of potential forms, one workshop is organised at the Academy of Fine Arts in Ghent with eleven autonomous design/art master students participating, and another is organised at the department of Product Development at the University of Antwerp, with seven product design master students participating. These target groups have no prior knowledge of the subject and are chosen as they are expected to have insights in creating 3D forms and spatial awareness. The disciplines of art and design overlap and are intricately intertwined, however, art is more perceptual in contrast to product design that has a more holistic and rational approach.

4.5.2.2 Procedure

First, a concise introduction is given concerning materials experience, experiential characterization, and the purpose of the form, after which the nine form criteria are clarified. Next, participants are guided to the workshop room where they are provided with 200 grams of clay, sculpt and model tools, as well as a bowl with water to smooth out the clay. They are asked to *"Make one (or more) demonstrator forms that are useful to compare and evaluate experiential qualities (sensorial attributes and interpretive characteristics) of plastic materials by consumers. This form must engage and* *trigger consumers into an extensive tactile exploration of the material"*. Approximately twenty minutes are allowed to make one form proposal. When a form is finished, it is number coded, and photos are taken in a light box with white background.

Afterwards, the participant is asked to evaluate his/her form by means of five-point Likert scales to score each of the eight design criteria (see Table 4.4): *"To what extent does your form display each of the following criteria?"*. However, the criteria of variable & uniform radius, thick & thin part, and convex & concave part are split up in two sub scales, leading to a total of eleven items. In addition, not only the participant is asked to score his/her form on five-point semantic differential scales (-2,-1,0,1,2) for each of the five pairs as selected in Study 1 (see Table 4.5), also the researcher and one other random participant (different for each form) are requested to score the form on these scales: *"Assess your form according to the following sets of meanings"*. Thus, three gradings are made per form (participant-maker, researcher and participant-scorer). As a limitation, only three evaluations might reduce the power of the study, however, it is aimed to counteract priming effects (both in time and repetition) and achieve a reasonable balance between power and the duration of the workshop. Finally, this process is repeated until up to three forms per participant are created, as participants can acquire new insights and ideas when going through this process. Figure 4.3 shows the set-up of the workshops and the documenting of the resulting forms.

Figure 4.3. Form creation workshops and documenting of the resulting forms.

During processing, a first disqualification is done of the forms that do not meet one or more of the objective form criteria (e.g. no cavity), based on the scores given by the participant/maker. Next, four calculations are performed for the remaining forms: (i) the total sum of the participant's scores on the form criteria, (ii) the total number of neutral 0-scores on the scales of the interpretive characteristics, (iii) the average of the absolute values of the average of each interpretive characteristic, and (iv) the average of the standard deviations of each interpretive characteristic. We reason that an appropriate form could show either a large variance or a small variance on each of the interpretive pairs and over the three respondents, as long as the mean of each scale stays close to the neutral zero point. A high score on the form criteria equals a high suitability, with a threshold of at least 44 (i.e. a mean score of at least 4 on each of the 11 criteria). With regard to the interpretive characteristics (scores of the participant, researcher and co-participant on the five semantic scales), a high number of 0-scores indicates few extreme associations (threshold on higher than 7, i.e. at least half of the items are score zero or neutral), as well as a low score on the average (threshold on lower than 0.5), and in combination with either a low or high standard deviation (threshold on lower than 0.5 or higher than 0.8). The forms that perform best on all four aspects are being selected for the next study.

4.5.2.3 Results

Thirty-eight clay forms resulted from the two workshops, each including their evaluation on the form criteria and the interpretive semantic pairs (an overview of all scores can be requested from the authors). Overall, a clear difference is detected between the forms of the art versus design students as the former's forms show more artistic features and the latter more organic and less experimental characteristics. First, five forms are disqualified as they did not have a cavity (E2, E3, F2, I2, K1), and three more forms that failed on the symmetry (A1) or thin/thick parts (D1, Q2). Next, Table 4.6 shows that 24 of the 38 forms have a total score of higher than 44 on the form criteria (i.e. mean score of 4 on 11 criteria).

Five forms are scoring reasonably on all four calculations mentioned in the procedure and are selected to proceed to the next study. Finally, to ensure equal finish and quality in the next study, these forms are 3D scanned, smoothened in CAD and 3D printed to compare with the original clay forms, see Figure 4.4.

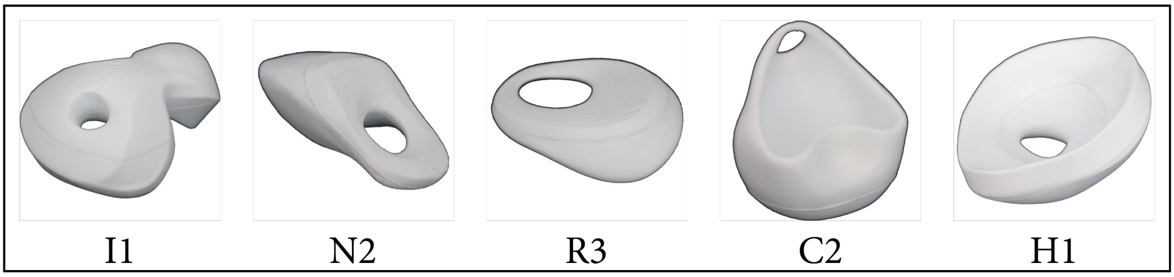


Figure 4.4. 3D prints after 3D scanning of the five selected forms of Study 2.

Table 4.6. Resulting scores on the form criteria (incl. sum) and semantic pairs (incl. sum and average).

Form	**Scores on form criteria**											**Calculations on scores of semantic pairs**				**Total**
	Hand size	*No symmetry*	*Aesthetically interesting*	*Uniform radius*	*Variable radius*	*Thick part*	*Thin part*	*Surface intersections*	*Concave part*	*Convex part*	*Negative space*	***Sum of scores on form criteria (threshold > 44)***	*Total frequency of 0-scores > 7*	*Average of the absolute values of the averages of each pair > 0.5*	*Average of the standard deviations of each pair < 0.5 or > 0.8)*	***Total number of thresholds met***
A1	4	2	3	5	5	5	5	2	5	5	5	**46**	6	0.73	0.54	1
A2	4	3	3	4	3	4	4	3	4	3	5	40	7	0.73	0.54	0
B1	4	5	4	4	4	4	3	4	5	5	4	**46**	6	**0.40**	0.61	2
B2	4	5	5	4	4	4	4	4	4	4	5	**47**	7	**0.40**	0.67	2
C1	5	3	5	4	3	5	3	3	4	5	4	44	11	**0.27**	**0.38**	2
C2[1]	5	3	5	5	5	5	5	5	5	5	5	**53**	**8**	**0.47**	**0.47**	**4**
C3	5	5	4	3	5	5	5	4	5	5	5	**51**	6	0.60	**0.38**	2
D1	5	5	5	3	4	5	0	5	5	5	5	**47**	7	0.73	**0.35**	2
D2	3	3	4	4	3	4	3	3	4	3	5	39	6	0.67	**0.47**	1

Form	**Scores on form criteria**											**Calculations on scores of semantic pairs**				**Total**
	Hand size	*No symmetry*	*Aesthetically interesting*	*Uniform radius*	*Variable radius*	*Thick part*	*Thin part*	*Surface intersections*	*Concave part*	*Convex part*	*Negative space*	***Sum of scores on form criteria (threshold > 44)***	*Total frequency of 0-scores > 7*	*Average of the absolute values of the averages of each pair > 0.5*	*Average of the standard deviations of each pair < 0.5 or > 0.8)*	***Total number of thresholds met***
E1	4	5	3	4	4	5	5	3	5	5	5	**48**	6	0.53	0.54	1
E2	2	3	5	4	3	5	3	3	2	5	2	37	6	0.80	0.63	0
E3	3	0	5	5	1	5	3	4	0	5	1	32	6	0.67	0.70	0
F1	4	5	4	3	5	5	4	3	4	4	5	**46**	3	0.53	**1.11**	0
F2	4	3	3	4	3	4	4	3	5	5	0	38	**8**	0.53	0.54	1
F3	3	5	5	3	5	4	4	3	5	5	4	**46**	4	0.60	**0.35**	2
G1	4	5	3	4	4	5	4	4	4	4	5	46	**8**	0.53	**0.38**	2
G2	3	4	3	4	3	4	3	3	4	5	5	41	4	0.67	0.52	0
H1[1]	4	4	3	4	5	5	5	4	4	4	5	**47**	**8**	**0.47**	**0.38**	**4**
H2	5	5	4	3	5	5	5	5	5	5	5	**52**	5	0.53	0.76	1
I1[1]	5	4	4	4	4	4	3	4	5	5	5	**47**	**8**	**0.47**	**0.47**	**4**
I2	5	1	2	5	3	5	0	4	3	5	2	35	5	1.00	0.63	0
J1	3	4	4	4	4	4	5	3	4	3	5	43	**8**	**0.33**	**0.38**	2
K1	3	5	4	4	5	5	1	3	5	5	1	41	5	0.53	**0.38**	1
L1	4	3	4	3	5	4	3	4	5	5	5	**45**	3	0.80	0.75	1
L2	3	5	4	5	4	4	5	3	4	5	4	**46**	5	**0.47**	0.63	2
M1	4	5	3	4	3	5	4	3	4	4	5	44	2	0.60	**0.82**	1
M2	5	5	4	5	4	5	5	3	4	5	5	**50**	6	0.60	**0.86**	2
N1	4	5	4	4	5	5	3	5	5	5	5	**50**	5	0.60	0.76	1
N2[1]	5	4	4	4	4	5	4	5	5	5	5	**50**	**8**	**0.33**	**0.47**	**4**
O1	4	5	4	5	4	4	4	5	5	4	5	**49**	3	0.93	0.60	1
O2	3	4	3	4	3	4	4	5	4	3	4	41	6	0.53	**0.81**	1
P1	3	4	3	4	5	4	4	3	5	5	5	**45**	3	0.93	0.79	1
P2	5	3	5	4	4	5	5	3	4	3	5	**46**	4	0.60	0.80	1
Q1	4	5	5	4	3	4	3	3	4	4	5	44	6	**0.47**	0.67	3
Q2	5	5	5	4	5	5	2	2	3	4	4	44	4	0.73	0.82	0
R1	4	5	4	3	5	5	4	5	5	5	5	**50**	6	0.53	0.63	1
R2	4	5	4	4	3	4	5	3	3	5	5	**45**	3	**0.20**	0.95	2
R3[1]	5	5	5	5	5	5	5	3	4	4	5	**51**	**8**	**0.47**	**0.38**	**4**

4.5.3 *Study 3 – Form Verification*

4.5.3.1 Aim and Participants

Building upon the needs and requirements for a physical material representation and consumer involvement, the aim of Study 3 is to compare the five resulting forms of Study 2 (see Figure 4.4) to verify which form is most appropriate for experiential characterization of materials by consumers, i.e. which form induces most significant differences between materials on various experiential qualities (i.e. sensorial attributes and interpretive characteristics)? We assume that the more a form reveals differences between disparate materials, the smaller the effect that the form has on the experiential qualities of the material, which makes it more useful for experiential characterization, in contrast to forms that show little difference between materials and thus outweigh the material's experiential qualities.

As physical interaction and tactility is crucial to manipulate and assess the forms, a face-to-face study was set up. In total, 302 consumers participated in this study, whereof 46% were male. They were recruited by means of stratified convenience sampling. Table 4.7 shows the distribution of gender over three targeted age categories (18-34, 35-54, and above 55).

Table 4.7. Gender and age distribution of participants in Study 3.

Gender	**Age**				**Total**
	18-34	*35-54*	*55+*	*Unknown*	
Male	87	30	23	0	140
Female	94	35	24	1	154
Unknown	3	1	3	1	8
Total	184	66	50	2	302

4.5.3.2 Stimuli

For the purpose of this verification, each of the five resulting forms of the previous study (F3a to F3e) is 3D printed in four different materials (M1 to M4), resulting in 20 stimuli, see Figure 4.5. It is intended that these materials show as much variance on sensorial attributes as possible within 3D print materials, however, keeping their colour rather constant (black). Material 1 represents a very flexible and pliable material, Material 2 represents a high gloss material, while Material 3 represents a matte surface material. Material 4 represents a wood-look material. For easy understanding throughout the paper, these materials are referred to as Flex, Gloss, Matte and Wood respectively.

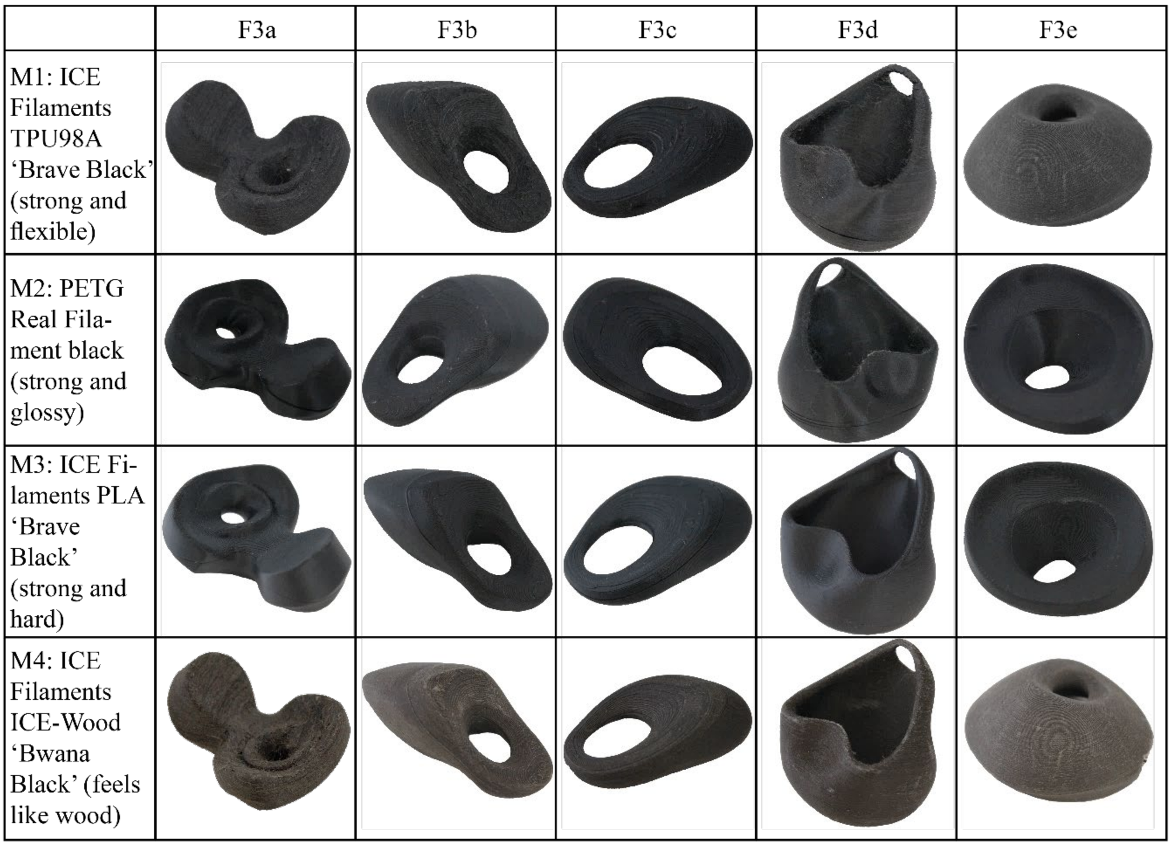


Figure 4.5. Five forms in four different materials, used in Study 3.

4.5.3.3 Procedure

Each participant randomly receives one of the 20 combinations of form – material, and is instructed to evaluate the material of the stimulus using all his/her senses to score the material on five-point bipolar semantic differential scales (-2, -1, 0, 1, 2). These scales comprise a list of 13 sensorial attributes and 13 interpretive characteristics to measure the experiential qualities of the four materials (*To what extent does the material express the following characteristics?*). We build upon the items used in a previous study (see Table 4.1), but discard the sensorial attributes of Transparency, Colourfulness, Greasiness and Odour to shorten the list and because these attributes are expected to show little variance between the materials used. To achieve a list of 13 interpretive characteristics, we also discard the characteristics of Honest-Deceptive, Mature-Youthful, Formal-Informal, and Traditional-Modern.

Next, to assess the preference of the respondents and the degree to which a form stimulates their imagination, three five-point Likert scales are scored to determine (i) to what extent the form appeals to him/her to get an idea about the potential material experience, (ii) to what extent the material would be suitable for manufacturing an existing product (e.g. smartphone cover, tray, digital camera, water kettle, sunglasses, vase, etc.), and more importantly, (iii) how hard he/she found it to answer the latter question. Afterwards, this is repeated for one more random combination of form – material per participant. In addition, gender and age category are requested.

4.5.3.4 Results

To select the form that is most appropriate for experiential material evaluation, an analysis is performed to detect the significant differences between the four materials in each form. We reason that the form that induces the most significantly different scores on the 26 items (material qualities), least affects the perception of the material. First, a Levene's Test of Homogeneity of Variances (based on median) is conducted to check if the population variances are equal.

Second, a One-way ANOVA (in case of equal variances) or a Welch's T-test (in case of assumption violated) is performed, and third, a Post Hoc Bonferroni or Games-Howell test respectively is conducted to find the number of significant differences. The full test results can be requested from the authors, whereof the number of significant differences (based on F value and $p<0.05$) is summarized in Table 4.8.

Table 4.8. Number of significant differences between materials for each form.

Dependent Variables	**Number of Significant Differences Between Materials (Number of Significant Post-hoc Tests p>0.05)**				
	F3a	*F3b*	*F3c*	*F3d*	*F3e*
Sensorial Attributes	30	31	33	41	28
Interpretive Characteristics	14	11	5	18	17
Idea About Potential Materials Experience	0	3	2	3	2
Difficulty of Envisioning Material in Existing Product	3	3	0	2	2
Column Total[a]	47	48	40	64	49
Column Total[a] (%)	28%	29%	24%	38%	29%

[a] *Column percentage is calculated on a maximum of 168 counts per form of possible significant differences between four materials (i.e. total of 78 for sensorial attributes, 78 for interpretive characteristics, 6 for materials experience, and 6 for envisioning).*

Form F3d induces the most significant differences in the scores on the material qualities, both for sensorial attributes and for interpretive characteristics. Forms F3a, F3b and F3e score similarly, while form F3c clearly performs the lowest. Consequently, form F3d is selected to proceed to the next study.

Moreover, the number of significant differences between materials over all five forms also differs per material quality, going from 1 to 22 counts. The top five material qualities that induce significant differences between materials are Glossiness (22x), Texture (19), Ductility (17x), Colour Intensity (16x) and Acoustics (15). The high counts for the first four qualities are expected as the five materials objectively are supposed to differ based on their technical datasheets. Apart from Softness (4x), all sensorial attributes (8-22x) induce more significant differences than the interpretive characteristics (1-8x).

4.5.4 Study 4 – Investigation of the Producibility of the Form

4.5.4.1 Aim and Participants

The material sample form is only useful if it is also feasible to (re)produce on a large scale so that standardization is possible with a great variety of plastic materials, as seen in the final requirement of feasibility. In this case, high-quality and great range of materials (e.g. virgin plastics, recycled plastics, bioplastics) can be achieved by means of injection moulding (Lerma Valero, 2020). Thus, the aim of Study 4 is to transform the selected form of Study 3 (F3d) into a producible form that meets the requirements for mass production (including various plastics with the same mould), while keeping the distinct features of the original form of Study 3.

For this study, the research team contacted three experts from industry (including a mould maker and injection moulders) to discuss the points of attention for injection moulding and to give feedback on intermediate, producible form proposals, as well as three 3D modelling experts to properly draw up 3D CAD files of producible form variants.

4.5.4.2 Procedure

In contrast to the other studies within this research paper, Study 4 builds upon a research through design approach (Savic & Huang, 2014; Zimmerman et al., 2010). First, experts within the industry (n=3) are questioned during an open interview about the possibilities and limitations of injection moulding, in terms of price, feasibility, form, complexity, and other restrictive design criteria that need to be taken into account. Experts are consulted and asked to apply their material and production knowledge on the selected form of Study 3 (F3d) and indicate which design rules need to be applied to adapt the form into a producible variant.

Second, based on this input, the original form (F3d) is discussed within the research team and the 3D experts (n=3). By reasoning with consequences, different directions or strategies are followed to adapt the form in line with the moulding design criteria. In this way, various producible form variants are developed and evaluated through an iterative design process. Intermediate feedback of the industrial experts is requested to finetune the form variants in 3D. Finally, five final form variants that incorporate a balanced combination of technical requirements, a resemblance to original form, and a link with the predefined form criteria of Study 1, are selected and 3D printed.

4.5.4.3 Results

First, several design criteria are summed up by the experts that must be met by the producible form variants. To ensure an affordable mould, the starting point is a two-part mould without sliders to reduce the cost of the mould and increase the producibility of all types of plastics with one and the same mould (including contaminated recyclates), and a restricted projected area (which corresponds with the compact hand size that was already required). Thus, an approximately equal wall thickness of 2-3 mm must be obtained, as well as a draft angle of 1.5° and no back cuts.

Second, several adaptations are tried out by the 3D experts. For the ease of communication, Figure 4.6 indicates a “top” and “front”. In the first loop, both the inside and the front are hollowed out to minimise the wall thickness, but keeping the draft angle in mind. In the second loop, ribs are added to retain the illusion or contour of the original form and to increase firmness. In the third loop, new dents are created at the back that do not preclude the required draft angles. In the fourth loop, the edges at the top are finetuned to emphasize the combination of both uniform and variable radii.

Finally, after four iterative loops of prototyping in 3D, five usable form proposals (see Figure 4.6) are composed that embody different combinations of variations in terms of the location and distribution of the ribs (front versus bottom, equal versus unequal), and of the dents (one versus two). In this way, the effect of these form adaptations on the experiential characterization of materials can be explored in the next study.

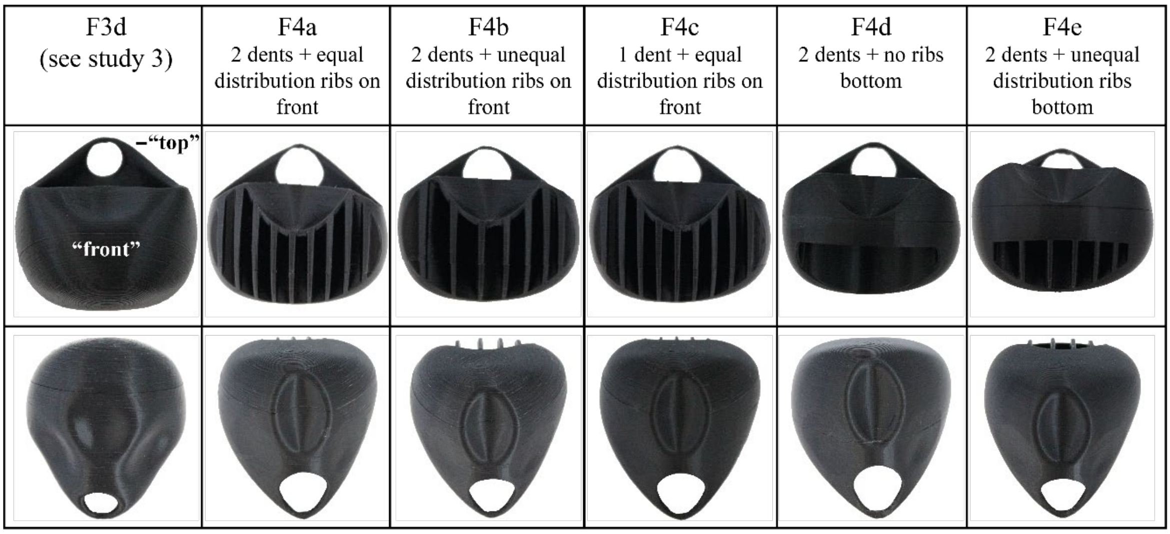


Figure 4.6. Original form of Study 3 (F3d) and five producible form variants (F4a-F4e) (photo from two different perspectives). For the ease of communication, a "Top" and "Front" are indicated.

4.5.5 Study 5 – Form Verification

4.5.5.1 Aim and Participants

The aim of Study 5 is to verify which producible form variant of Study 4 (see Figure 4.6) is most similar to the original best form of Study 3 (see Figure 4.6: form F3d), in terms of emphasizing a material's experiential qualities. We assume that the form variant that shows the least significant differences on both sensorial attributes and interpretive characteristics of different materials, is an appropriate and producible substitute for the original form.

In total, 61 consumers participated in this study, whereof 46% were male. They were recruited by means of stratified convenience sampling. Table 4.9 shows the distribution of gender over three targeted age categories (18-34, 35-54, and above 55).

Table 4.9. Gender and age distribution of participants in Study 5.

Gender	Age			Total
	18-34	*35-54*	*55+*	
Male	7	12	9	28
Female	16	9	8	33
Total	23	21	17	61

4.5.5.2 Stimuli

For the purpose of this verification, the selected best form of Study 3 (F3d) and each of the five form variants of Study 4 (F4a, F4b, F4c, F4d, F4e) are 3D printed in four different materials, resulting in 24 stimuli, see Figure 4.7. The same materials of Study 3 are used again, however, due to technical difficulties with the Matte material, this one is replaced by a new material that contains a sparkle: Material 1 (Flex), Material 2 (Gloss), Material 3 (Wood) and Material 4 (Sparkle: Prusament PLA Prusa 'Galaxy Black' (hard and tough).

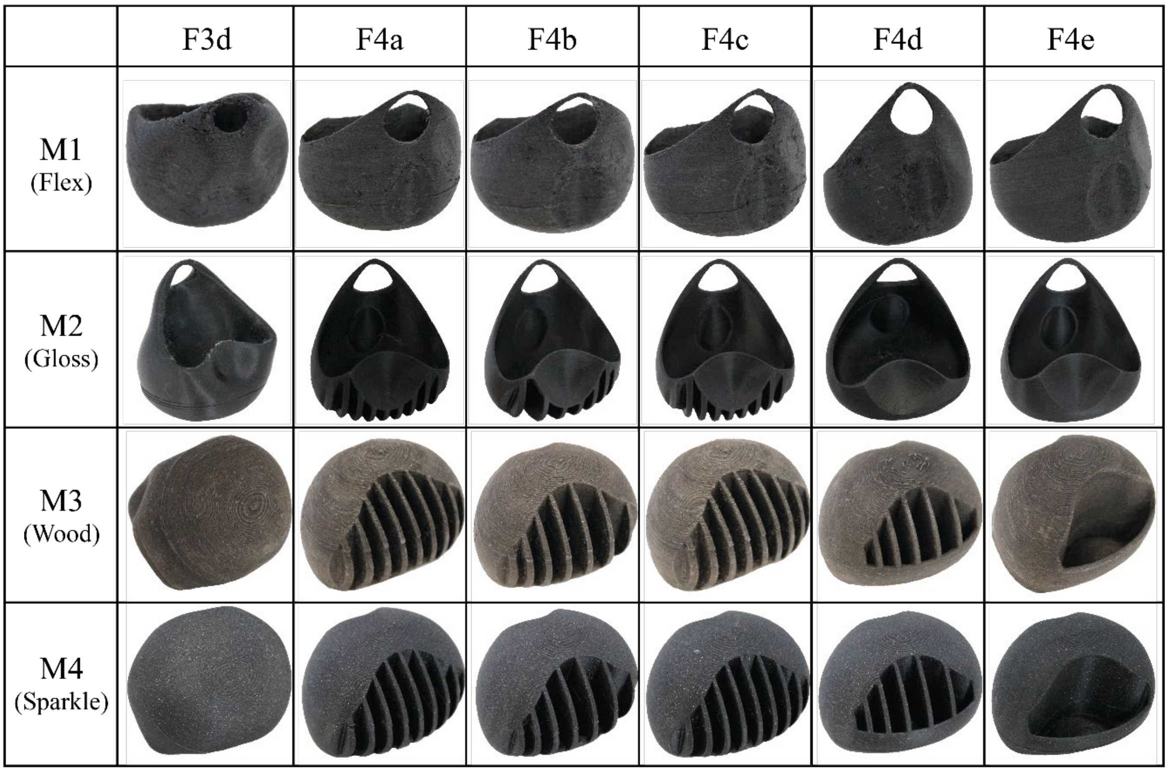


Figure 4.7. Six 3D-printed forms in four different materials, used in Study 5.

4.5.5.3 Procedure

Each participant receives one of the 6 forms in each of the 4 materials in a random order, and is instructed to evaluate the material of the stimuli using all his/her senses to score each material on five-point bipolar semantic differential scales (-2, -1, 0, 1, 2): *"To what extent does the material express the following characteristics?"*. These scales comprise a short list of 5 interpretive characteristics (based on Study 1 and 2, see Table 4.1) and 5 sensorial attributes to measure the experiential qualities of the four materials. Based on the material's technical datasheets, the selected sensorial attributes are expected to induce the greatest (objective) differences between the used 3D print materials: Glossiness (Matte-Glossy), Softness (Hard-Soft), Ductility (Tough-Ductile), Texture (Smooth-Rough), and Acoustics (Soft-Shrill).

This evaluation is repeated three times for another random combination of the same form in another material. Next, to assess the preference of the respondents and the degree to which a form stimulates their imagination, three five-point Likert scales are scored to determine (i) to what extent the form appeals to him/her to get an idea about the potential material experience, (ii) to what extent the material would be suitable for manufacturing an existing product (e.g. smartphone cover, tray, digital camera, water kettle, sunglasses, vase, etc.), (iii) how hard he/she found it to answer the latter question. In addition, gender and age category are requested.

4.5.5.4 Results

To make a substantiated choice for the best form variant compared to the original form (F3d), an Independent-Samples T-Test is performed to detect significant differences on material quality scores between the form variants (F4a to F4e) and F3d. When equal variances are not assumed according to a Levene's Test of Homogeneity of Variances (based on median), a corrected significance value is used. Table 4.10 reports the resulting significance levels for each material characteristic for each material, including the total sum of significant differences per form variant ($p<0.05$).

These results indicate that form variant F4b shows no significant differences on any of the sensorial attributes or interpretive characteristics and for each of the four materials, compared to the original form F3d. In addition, form F4b performs best on giving an idea of the potential materials experience (M=3.60, SD=1.35), even better – although not significantly (p=0.857) – than the original form F3d (M=3.50, SD=1.08). However, original form F3d accomplishes the lowest difficulty in envisioning its material in a real product (M=1.70, SD=0.95), followed by F4a, F4c, F4d and only then by F4b that significantly differs from F3d (p=0.042).

Table 4.10. Significance levels of Independent-Samples T-Test between form variants and original form, including total sum of significant differences (p<0.05), mean and standard deviation of Likert scales.

Material		*Dependent Variable*	*Significance Levels of Differences Between Forms*				
			F3d ⬄ F4a Sig. (2-tailed)	*F3d ⬄ F4b* Sig. (2-tailed)	*F3d ⬄ F4c* Sig. (2-tailed)	*F3d ⬄ F4d* Sig. (2-tailed)	*F3d ⬄ F4e* Sig. (2-tailed)
M1	Sensorial	Glossiness	.848	.058	.632	.691	.331
		Texture	.556	.476	.535	.018	.033 [a]
		Ductility	.749	.764	.433	.755	.605
		Softness	.778	.081	.592	.227	.652
		Acoustics	.033 [a]	.538	.230	.342	.157
	Interpretive	Male-Female	1.000	.878	.245	.845	.119
		Aggressive-Calm	.824	.828	.247	.146	.024 [a]
		Delicate-Rugged	1.000	.198	.543	.066	.453
		Elegant-Vulgar	.552	.253	.187	.274	.673
		Toy-like-Professional	.207	.556	.220	.289	.298
M2	Sensorial	Glossiness	.439	.137	.572	.268	.687
		Texture	.439	.587	.761	.418	.884
		Ductility	.018 [a]	.077	.216	.618	.261
		Softness	.026 [a]	.723	.055	.857	.724
		Acoustics	.121	.230	.005 [a]	.251	.244
	Interpretive	Male-Female	.724	.868	.733	1.000	.040 [a]
		Aggressive-Calm	.107	1.000	.435	.123	.940
		Delicate-Rugged	.622	.535	1.000	.476	.216
		Elegant-Vulgar	1,000	.476	.412	.388	.209
		Toy-like-Professional	.874	.613	.311	1.000	.152

M3	Sensorial	Glossiness	.777	1.000	.649	.660	.931
		Texture	.274	1.000	.801	.343	.144
		Ductility	.202	.202	.362	.062	.357
		Softness	.020 [a]	.475	.259	.517	.388
		Acoustics	.322	.232	.407	.210	.066
	Interpretive	Male-Female	.660	.268	.770	.140	.080
		Aggressive-Calm	.534	.598	.722	.309	1.000
		Delicate-Rugged	.315	.191	.681	.115	.360
		Elegant-Vulgar	.331	.183	.331	.043 [a]	.258
		Toy-like-Professional	.253	.299	.306	.027 [a]	.188
M4	Sensorial	Glossiness	.584	.076	.719	.610	.654
		Texture	.053 [b]	.053 [b]	.476	.517	.148
		Ductility	.567	1.000	.795	.722	.868
		Softness	.534	.391	.731	.844	.613
		Acoustics	.605	.120	.874	.152	.644
	Interpretive	Male-Female	.833	.676	.512	.057	.106
		Aggressive-Calm	.063	.107	.652	.718	.923
		Delicate-Rugged	.775	.563	1.000	1.000	.593
		Elegant-Vulgar	.806	1.000	.476	.119	.377
		Toy-like-Professional	.864	.745	1,000	.203	.475
Total Number of Sign. Differences			**4**	**0**	**1**	**3**	**3**
		Of Which Sensorial Attributes	4	0	1	1	1
		Of Which Interpretive Characteristics	0	0	0	2	2
Likert scales			**Mean** (st.dev.)	**Mean** (st.dev.)	**Mean** (st.dev.)	**Mean** (st.dev.)	**Mean** (st.dev.)
Idea About Materials Experience			3.30 (1.25)	3.60 (1.35)	3.10 (0.99)	2.90 (1.37)	2.91 (1.30)
Difficulty Survey			2.20 (1.32)	2.90 [a] (1.45)	2.30 (1.34)	2.80 [a] (0.92)	3.36 [a] (1.36)

[a] Significant at $p<0.05$
[b] Significant at $p<0.05$

4.5.6 Study 6 – Final Form Verification

4.5.6.1 Aim and Participants

The aim of Study 6 is to compare the selected form of Study 5 (F4b) with a flat plate sample (F2) that is usually employed in experiential studies (see Introduction), and verify whether the proposed form is found more appropriate for experiential characterization of materials by consumers, and/or which form consumers prefer to explore when evaluating each experiential material quality.

In total, 57 consumers participated in this study, whereof 44% were male. They were recruited by means of stratified convenience sampling. Table 4.11 shows the distribution of gender over three targeted age categories (18-34, 35-54, and above 55).

Table 4.11. Gender and age distribution of participants in Study 6.

Gender	Age			Total
	18-34	*35-54*	*55+*	
Male	11	7	7	25
Female	18	8	6	32
Total	29	15	13	57

4.5.6.2 Stimuli

The selected best form of Study 5 (F4b) and a square flat plate are 3D printed in six materials, as shown in Figure 4.8. As this study does not focus on a material (evaluation), this time, it is attempted to create more variety between the materials, mainly on colour.

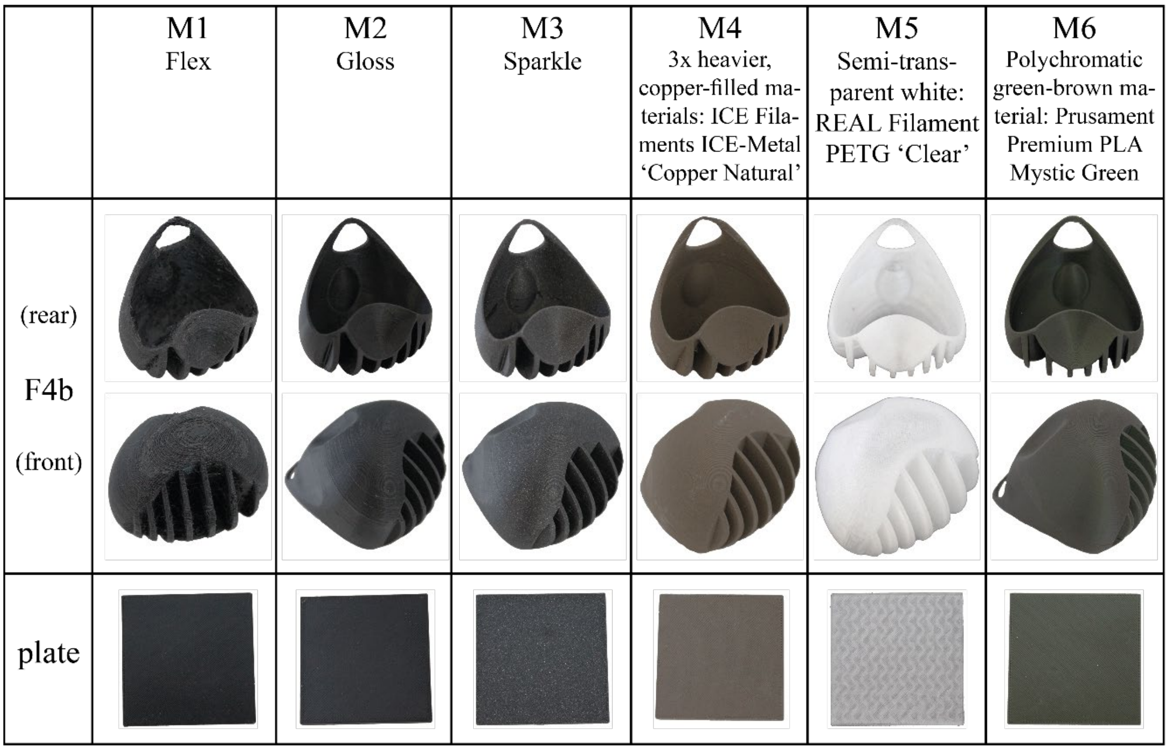


Figure 4.8. Two forms (F4b shown rear and front versus flat plate) in six different materials, used in Study 6.

4.5.6.3 Procedure

First, it is aimed to reduce the list of attributes to minimize fatigue and combine similar sensorial attributes of Table 4.1. Therefore, a Bivariate Correlations Analysis is performed on the data of Study 3 on all sensorial attributes and interpretive characteristics, and for each of the materials. For all materials, this shows significant and moderately strong correlations ($p<0.001$ and $r>0.450$) between Elasticity and Ductility (M1: r=0.635, M2: r=0.598, M3: r=0.590, M4: r=0.570), between Stiffness and Ductility (M1: r=0.661, M2: r=0.619, M3: r=0.623, M4: r=0.469), and between Stiffness and Elasticity (M1: r=0.554, M2: r=0.514, M3: r=0.649, M4: r=0.477). Thus, these three attributes are now combined in one item, i.e. Ductility. In addition, Brittleness is discarded as this attribute is contained within Strength ($p<0.005$, M1: $r=0.532$, M2: $r=0.367$, M3: $r=0.416$, M4: $r=0.253$) and Delicate-Rugged.

In this study, each participant receives a set of one demonstrator form (F4b) and one flat plate in one of the six materials, and is instructed to evaluate the material and score it on five-point bipolar semantic differential scales (-2, -1, 0, 1, 2) of 14 sensorial attributes and 16 interpretive characteristics, in a random order *("To what extent does the material express the following characteristics?")*. In addition, participants are asked to indicate which form they prefer to evaluate each experiential quality (F4b, plate, both forms, none of the forms). In order to minimize fatigue and to stimulate participants to continue exploring the material with all senses for each characteristic, they receive a new stimulus set in another material after every set of ten randomized semantic scales, thus each participant receives three (out of six) different materials in total. Finally, to assess the preference of the respondents and the degree to which a form stimulates their imagination, two five-point Likert scales are scored to determine (i) to what extent both forms gave an idea about the potential materials experience, (ii) to what extent the (last) material could be envisioned in a real product by means of both forms (e.g. smartphone cover, tray, digital camera, water kettle, sunglasses, vase, etc.). Participants are also requested to indicate which of the forms they find most inspiring. In addition, gender and age category are requested.

4.5.6.4 Results

Frequencies are counted for each experiential quality to verify whether the developed form F4b is preferred over a standard flat plate to evaluate experiential qualities of materials. Table 4.12 shows the row percentages for both sensorial attributes and interpretive characteristics, each ordered from a high cumulative percentage (for F4b + both forms) to a low percentage to indicate a positive preference. Although Scratchability has a low score of 56%, all other qualities show a high percentage between 67% and 89%. Furthermore, for only five experiential qualities, a higher preference for the plate instead of F4b is found: Scratchability, Transparency, Ductility, Softness, and Texture, however, the highest preference here is still given to both forms.

When comparing the average percentage of all sensorial attributes versus all interpretive characteristics, the latter show less variations and a much higher preference for F4b, while the former is more balanced and can be evaluated by both forms. Finally, 72% of the participants find form F4b more inspiring than a flat plate.

To conclude this experiment, a Paired-Samples T-Test and a Post-Hoc Bonferroni Test is the performed on the Likert scale questions that ask to what extent either form gives an idea about the potential materials experience, and how hard it is to envision a material in a real product. Form F4b ($M=3.84$, $SD=0.960$) gives a significantly greater idea about the materials experience than the flat plate ($M=3.26$, $SD=1.094$): $t(56) = -2.746$, $p=0.008$. Form F4b ($M=3.77$, $SD=1.035$) marginally significantly allows more than the flat plate ($M=3.44$, $SD=0.964$) to envision its material in a real product ($t(56) = -1.936$, $p=0.058$).

Table 4.12. Preference frequencies (expressed in row %) of F4b (demonstrator form) and a flat plate, both or none of the forms.

Experiential Quality		F4b %	Both forms %	Cumulative (F4b+both) %	Plate %	None of Forms %
Sensorial Attributes	Acoustics (Soft-Shrill)	35%	54%	*89%*	5%	5%
	Odour (Odourless-Fragrant)	18%	68%	*86%*	12%	2%
	Weight (Light-Heavy)	37%	47%	*84%*	16%	0%
	Temperature (Cold-Warm)	25%	56%	*81%*	16%	4%
	Colourfulness (Colourless-Colourful)	21%	58%	*79%*	21%	0%
	Colour Intensity (Weak-Intense)	23%	54%	*77%*	21%	2%
	Transparency (Opaque-Transparent)	16%	60%	*75%*	25%	0%
	Greasiness (Dry-Greasy)	37%	37%	*74%*	25%	2%
	Glossiness (Matte-Glossy)	28%	44%	*72%*	26%	2%
	Softness (Hard-Soft)	25%	47%	*72%*	28%	0%
	Strength (Low/Breakable-High/Unbreakable)	33%	39%	*72%*	28%	0%
	Texture (Smooth-Rough)	25%	46%	*70%*	28%	2%
	Ductility (Low/Stiff-High/Flexible)	23%	44%	*67%*	32%	2%
	Scratchability (Scratchable-Scratch resistant)	12%	44%	*56%*	42%	2%
Interpretive Characteristics	Futuristic-Nostalgic	44%	46%	*89%*	9%	2%
	Honest-Deceptive	37%	49%	*86%*	5%	9%
	Delicate-Rugged	39%	46%	*84%*	14%	2%
	Mature-Youthful	30%	54%	*84%*	16%	0%
	Toy-like-Professional	37%	44%	*81%*	18%	2%
	Disposable-Lasting	26%	54%	*81%*	16%	4%
	Elegant-Vulgar	37%	42%	*79%*	18%	4%
	Cosy-Aloof	30%	49%	*79%*	18%	4%
	Aggressive-Calm	33%	44%	*77%*	16%	7%
	Male-Female	42%	33%	*75%*	21%	4%
	Ordinary-Strange	40%	33%	*74%*	25%	2%
	Classic-Trendy	35%	37%	*72%*	21%	7%
	Frivolous-Sober	33%	37%	*70%*	21%	9%
	Sexy-Not sexy	33%	35%	*68%*	21%	11%
	Cheap-Expensive	33%	35%	*68%*	30%	2%
	Formal-Informal	25%	44%	*68%*	21%	11%
Total % Experiential Qualities		**30%**	**46%**	***76%***	**20%**	**3%**
	Total % Sensorial Attributes	25%	50%	*75%*	23%	2%
	Total % Interpretive Characteristics	35%	43%	*77%*	18%	5%
Most Inspiring Form		**72%**			**28%**	

4.6 Discussion

The aim of this research is to fill the existing gap in how to study experiential qualities of materials. Based on an extensive literature review, the need for an appropriate demonstrator form became obvious. Although the proposed final form is not the ultimate and only form, it does, however, meet the requirements as detected in previous research (Veelaert, Du Bois, et al., 2020).

Furthermore, the practical contribution comprises a standardized form that can be mass produced by injection moulding to facilitate large scale experiments to study materials experience and perception of various plastic materials. The proposed form embodies more complexity and various perspectives, which triggers consumers more into a multimodal experiential characterization of materials.

The resulting demonstrator form delivers a great added value to the evaluation of interpretive characteristics, as shown in Study 6. It enables further investigation of material meaning creation. However, when only a brief study is required on a small set of basic sensorial attributes, a standard flat plate may still be sufficient when evaluating attributes such as Scratch resistance, Gloss, and Texture. We assume that a flat surface might be easier to scratch with your fingernail, and might be more straightforward, as a curved surface shows more differences and perspectives that influence gloss and perceived texture. Nevertheless, the demonstrator form can be considered closer to real life products as compared to stand alone material plates.

Although our research aimed for a constant form in order to detect the perception of experiential qualities related to material instead of form, we must acknowledge that certain interactional effects exist between sensorial attributes (such as transparency or acoustics) and the 3D form of the demonstrator, as van Kesteren (2010) already concluded in her research. However, when using a standardized form to assess the perception of these sensorial attributes, the effect of form is eliminated, making sure that the retrieved evaluations can be generalized and compared with each other.

Regarding limitations of this study, we emphasize the aspect of subjectivity and contextual influence in materials experience, in contrast to objective technical material properties. For example, we did not study the influence of the used production technique of the material stimuli. Since we used 3D printing instead of injection moulding in our experiments, this had an influence on the form (e.g. visual dividing line, surface details). Furthermore, the final form proposal is specifically developed for multiple plastic materials (virgin, recycled and bioplastics) and injection moulding. We realize that when the aim is to compare plastics with metals by using the same form, additional influence of the production technique must be taken into account (Crilly et al., 2009).

Although our research presented focused on plastic materials, the obtained form offers potential to be translated to other materials (and production techniques) as well, such as metal (casting) or wood (milling). The advantage of plastics is that within product design, this versatile material is still popular and can take all forms, however, it is a difficult material class to compare themselves mutually (Veelaert, Du Bois, et al., 2020). When aiming for a different material class, of course the proposed methodology to arrive at a suitable standard form can be applied by design researchers on other materials as well, as a suitable material demonstrator for consumer evaluation should incorporate similar characteristics for interaction.

Once this demonstrator form is available, new opportunities for further research arise. As Karana and Hekkert (2010) demonstrated, a material's meaning is also shaped by the gender and culture of the user, especially when also taking into account the aspect of form. In addition, over time, material perceptions can change or differ. Using this standard demonstrator form, further exploration can be done without influence of form, product, or context.

Finally, the existence of plastic demonstrator forms has practical implications for material libraries as well. Due to the current focus on technical demonstrators, datasheets and (semi-) finished products, designers often only visit a material library toward the end of the design process. By adding the experiential perspective (forms and data), designers can involve materials selection early in the design process, using data of consumers. Continuous experiential data collection and the results can be included in existing material libraries. In the future, user segmentation linked to perception of material qualities can offer marketing and branding opportunities as well, which can be valuable in the context of recyclates and bioplastics.

4.7 Conclusions

In addition to technical material characterization, attention has grown for materials experience and experiential material characterization. However, there is a gap in the translation of subjective experiences of materials into meaningful data. To solve methodological challenges, this paper investigates the need for a standardized physical material representation that is both abstract and interactive, to trigger consumers in a holistic multimodal interaction, while minimizing the interference with product (function) and context associations. In this paper, a stepwise and mixed method methodology with various stakeholders is employed to develop a material demonstrator form for experiential material characterization by consumers, see Figure 4.9.

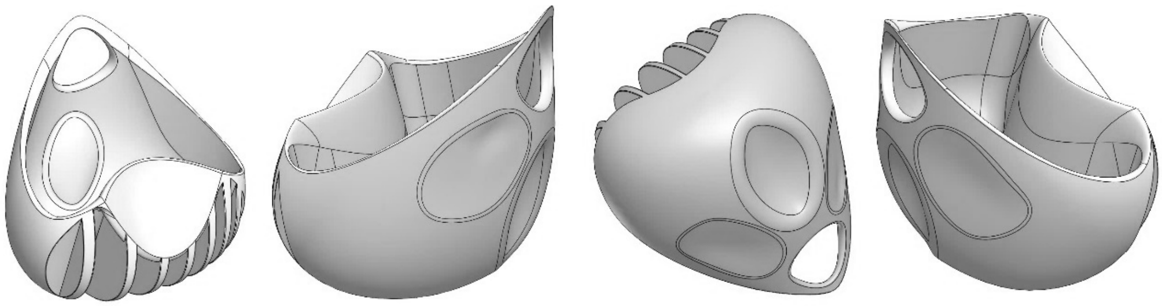


Figure 4.9. The final form proposal in 3D, from different perspectives.

Conclusively, the proposed demonstrator form is found more appropriate for experiential material characterization than a standard flat plate that is currently used in most experiments. The resulting demonstrator form aims to address the six needs and the four requirements:

- The form itself is a physical ($N2_{PHYS}$) and decontextualized (REQ1) expression of a material's experiential qualities. Given the effect of context, this offers a higher control or independency than the bowls or phone covers used in (Crippa et al., 2012) and (Karana & Nijkamp, 2014).
- The form is complex enough to allow multimodal interaction ($N3_{MODAL}$) and dynamic touch as was explored and verified in the consecutive studies (REQ2). This offers an added value as to the flat or blocked samples used in (Lindberg et al., 2013) and (Veelaert, Du Bois, et al., 2020) and the simple and abstract forms in (Veelaert et al., 2019).
- With a physical and complex form, within-material-class comparisons ($N1_{MAT}$) become possible. For example, the plastics ABS and PP can only be distinguished

from each other in a physical and multimodal way, and can be effectively compared when presented in the exact same, abstract form. This offers a great advantage over the material renders used in (Veelaert et al., 2018).

- Consumers are involved in multiple verification studies (REQ3) to achieve a form that is interesting and complex enough to attract their interest and facilitate extensive exploration, so that further studies can incorporate user segmentation data as well ($N6_{CONS}$). This lowers the threshold for consumers in contrast to the determinator form used in (Vyncke et al., 2018) that is aimed at engineers.
- The impetus for the need for a complementary experimental set-up ($N4_{EXP}$ and REQ4) has already been given through the previous aspects, but needs to be further explored and finetuned in a follow-up study, which will also contribute to the requirement of feasibility and efficiency.
- By means of the developed form, it is more feasible to also study the temporality of materials experience ($N5_{TEMP}$) in the future, as identical studies can be repeated with the standardized form.

The next step within our research is the production of the resulting form proposal in various plastic materials by means of high-quality injection moulding, so that future studies can be set up to generate extensive material data on well-known virgin plastics, as well as recycled plastics and bioplastics, and insight in the perceptual differences between these materials. Thus, we aim to integrate our generalizable material demonstrator form in a standardized user-centred and experiential material characterization method, and ultimately to generate large data sets to test the applicability of experiential material data in design contexts.

4.8 Ethical clearance

The experiments that were carried out, were approved by the Ethics Committee for the Social Sciences and Humanities (SHW_17_24_02 and SHW_18_56).

PART THREE

PART THREE deals with the need of Chapter 1 of including user aspects in experiential material characterization. It investigates how consumers can be clustered in meaningful segments that prefer the same material qualities and differ in this preference with other segments. Leading up to a large-scale survey, two explorations are carried out from the perspective of individual self-expressive values based on personal values (Chapter 5) as well as on personality traits (Chapter 6).

Based on the insights of the previous two chapters, Chapter 7 discusses a large scale quantitative study, including individual self-expressive values (personal values, brand personality traits, environmental concern, green self-identity, innovativeness, aesthetic experience, and materialism) that are considered relevant to reflect on consumer segments that are expected to differentiate in the way they prefer experiential material qualities. Four segments are detected that significantly differ in terms of preferences of experiential (sensorial and interpretive) material qualities, and create a suitable foundation for the inclusion of extensive user aspects (through consumer segmentation) in future research and data generation through experiential material characterization.

Chapter 5 is based on:

Veelaert, L., Moons, I., Coppieters, W., & Du Bois, E. (2018). Exploring the Fit Between Materials' Expressive Values and the Self-expression of the End-User. *Proceedings of 20th Congress of the International Ergonomics Association*, 2045–2066.

5. Exploring the Fit Between Materials' Expressive Values and the Self-Expression of the End-User

Veelaert Lore, Moons Ingrid, Coppieters Werner, Du Bois Els

Abstract: In industrial design, materials selection plays an important role. Being the interface of a product, a material does not only have to meet technical-functional requirements, but also has to include intended experiential qualities. Unfortunately, there is no one-to-one correspondence between materials and their expressive value, since a material's perceived character is influenced by multiple contextual factors that are product-related (shape, function), user-related (gender, culture, etc.), and context-related (time, place, etc.). Our current research aims to explore possible relationships between materials, their expressive value and the link with self-expression of the end-user. It defines expressive value in terms of Schwartz end values. Consequently, this paper reveals insight in the expressive values that twelve pre-selected materials evoke in itself and in interaction with different pre-selected forms. Moreover, respondents are classified in meaningful self-expressive categories, based on their value orientation. For each of these segments, the materials and form-material combinations were investigated, both indirectly and directly, in relation to the fit between the expressive value of the material and the self-expression. Relationships were found between the self-perception and a material's fit with the self-expression, and between materials and their perceived expression of values.

Keywords: *product design, consumer perception, aesthetics, materials experience, experiential material characterization*

5.1 Introduction

In industrial design, materials selection plays an important role (Deng & Edwards, 2007; Hodgson & Harper, 2004). Being the interface of a product, a material does not only have to meet technical-functional requirements, but also has to include intended experiential qualities such as user interactions, meanings, and sensorial attributes (Giaccardi & Karana, 2015; Karana, 2010; van Kesteren, 2008). First of all, a product should always function the way users would like it to work (van Kesteren et al., 2008), however, consumers demand more from a product than simple functionality.

Hence, both technical and intangible experiential material aspects need to be integrated to design successful products (Hasling, 2016). Indeed, designers spend an increasing amount of time on the design and the accompanying materials and the emotions the products arouse amongst the users (Jordan, 1998; Pedgley, 2010; van Kesteren et al., 2008). This shift to a user-centred focus represents a softer or 'human touch' to materials in industrial design. Sensory and formable aspects of the materials are being consciously or unconsciously perceived by the users and influence its user experience. As such, the consumer is capable of making a first judgment of the product, which - amongst others - will determine whether he/she will buy or use the product. Therefore, it is crucial for designers to realise that they have to think and work on a multi-sensory design in order to be successful. (Balaji et al., 2011; Crilly et al., 2004; Zuo, 2010)

People interact with an extensive number of diverse products on a daily basis, and expect a product to have a right amount of interaction and stimulation of senses. Moreover, they like to identify themselves with the products they want to use (Choi, 2017; Zuo, 2010). Karana, Hekkert and

Kandachar (2010, p. 293) state that "products are differentiated not only by their technical functions, but also by what the materials they are made of mean to the user".

Unfortunately, there is no one-to-one correspondence (Karana et al., 2010) between materials and their expressive value, since a material's perceived character is influenced by multiple contextual factors that are product-related (shape, function), user-related (gender, culture, etc.), and context-related (time, place, etc.) (van Kesteren, 2010). Recently, research started investigating how materials affect meaning creation (Karana, 2010; Karana et al., 2009b), however, the subjective matter remains particularly difficult to research, leading to a substantial call in scientific research to explore this topic.

5.2 Bridging Theoretical Frameworks

5.2.1 Materials Selection

The increasing amount of different available materials – each with their specific advantages and disadvantages – makes the process of choosing the best material a multi-objective and thus complicated, time-consuming process (Rao & Davim, 2008; Sapuan, 2001). Historically, materials selection is addressed from a technical and analytical perspective, leading to mostly engineering based tools that are dominated by numerical material data, which can be found in datasheets and handbooks (Ashby, 1999; Farag, 1989). However, these material properties, such as tensile strength, stiffness, melt temperature etc., are mostly of use in the later, detailed phases of the design process.

Continuing on this engineering perspective, most of these properties can be brought back to the physical structure of a material on an atomic and electronic level, whereupon a classification is developed in materials science (Ashby & Johnson, 2010). Consequently, materials can be categorised on three levels: Families (atoms and bonding, e.g. polymers), Classes (variants, e.g. thermoplastics), and Members (composition variants, e.g. polyethylene). Thus, the main material families are the following: Metals, Polymers and Elastomers, Ceramics and Glasses, Organic/Natural materials (such as woods and textiles), and Composites.

By contrast, Ashby & Johnson (2010) that "for materials and design, it is the combination of elements of art and science that make it work. Materials are not simply numbers on a datasheet and design is not a meaningless exercise in styling and it is not an isolated exploration of technology. What matters is the process of finding solutions that are meaningful to people, that enable new experiences and inspire and create positive impact in society and in our own daily lives" (Ashby & Johnson, 2010).

5.2.2 Materials Experience

As previously mentioned, in order to be successful on the market as a mass consumer product with many technically equivalent competitors, it must stand out "through its visual and tactile appeal, an exploration of other senses or emotional connection, the associations it carries, the way it is perceived and the experiences it enables" (Ashby & Johnson, 2010). Consequently, a product's materials have a twofold role to play: on the one hand they must assure technical functionality, whilst on the other hand, they must create products that are meaningful for the consumer in terms of fit with their personality and values .

Product personality contributes to product experience, and since materials are an aspect of product personality, materials as well play a substantial role in the experience that users have with products (Jordan, 2002; Karana, 2009; van Kesteren et al., 2005), and can as such be influenced by designers. Hence, design research has already been carried out on perceived product personality, (Govers, 2004; Mugge et al., 2009) (using personality adjectives such as cheerful, cute, dominant, serious, etc.) and on emotional effects (Desmet, 2002) (such as surprise, disgust, curiosity, etc.).

As described in the Ma2E4 Toolkit (Camere & Karana, 2017), the different aspects of materials experience can be subdivided into four main levels . First, the performative level describes what you can do with a material; e.g. pressing folding, squeezing, etc. Second, the sensorial level contains various visual and tactile attributes, such as glossiness, flexibility, surface roughness, etc. Third, the affective level expresses the emotions a material elicits, which can be pleasant or unpleasant. Fourth, the interpretive level defines associations and meanings of the material, e.g. sexy, robust, nostalgic, aggressive, etc. As such, one can unravel the experiential qualities of a material, and the link between the more tangible levels, which can be objectively manipulated, and the more subjective intangible levels. These later levels are very much related to past experiences of the user and the context in which the embodied material is found (Karana et al., 2007).

With regard to this subjectivity issue, like expressed personality and materials experience, they can be affected by elements such as function, use, context, user, etc., as defined in the Meaning of Materials model (Karana et al., 2010). In addition, appearance features such as shape, texture and colour are also influential (Creusen, 1998; Govers, 2004). Indeed, Karana et al. (2007) showed that form has a crucial effect on meanings of materials. In their empirical studies, they created various forms based on dimensional, additive and subtractive transformations of three basic forms, which will be built upon later in this paper. Since the aim is of this paper is to explore the underlying meaning of materials (however focusing on visual perception only, no tactile perception), one challenge of this paper is to cope with the interference of the context and the shape in which the material is presented.

5.2.3 The Intangible Level: Expressive Value

In the context of product design and consumer behaviour, we can consider the products that we (want to) own to be a part of who we are, and how we see ourselves, i.e. they reflect as well as contribute to our identities (Belk, 1988; Govers, 2004). Rosenberg (1979, p. 7) defines this self-concept as "the totality of an individual's thoughts and feelings having reference to himself as an object". Furthermore, a consumer's preference for a certain product or variant is influenced by the extent to which that product's personality is consistent with the self-concept of the end-user, which is called self-consistency (Belk, 1988; Govers, 2004; Sirgy, 1982, 2015).

Within this context, the expression of the self (Hosany & Martin, 2012; Sirgy, 2015) can be referred to by attitudes, beliefs, traits, norms or values, each differing in the way they are measured and scaled (Schwartz, 2012). For example, expressive value can be defined in terms of personality traits, as presented by the Big Five or the Five-Factor Model (Aaker, 1997; Geuens et al., 2009; Goldberg, 1981; McCrae & Costa, 1987), and can be found universally across various age, linguistic, and cultural groups. Such traits "describe what people are like, rather than what people consider important" (Schwartz, 2012) (i.e. thoughts, feelings, actions), and can present more or less frequent and intense throughout one's lifetime.

In contrast, self-expression can also be guided by motivational values, that may vary on importance attached to by individuals. Schwartz (2012) states that "values are used to characterise cultural groups, societies, and individuals, to trace change over time, and to explain the motivational bases of attitudes and behaviour". Moreover, such Schwartz values showed consistent relationships with aspects such as gender, study background, environmental attitudes, the Big Five personality traits, and many more (Lindeman & Verkasalo, 2005).

In order to use this value theory as a basis in research practice, most commonly literature refers to the Schwartz's Value Survey (SVS) (Goldberg, 1981; Krystallis et al., 2012; Lindeman & Verkasalo, 2005; Schwartz, 1992) which is validated through several studies. It comprises 57 value items - clustered in ten motivational values - that need to be rated on importance as a guidance for one's life.

In his value theory, Schwartz identified a set of ten all-encompassing, basic values that are recognized in all cultures (Schwartz, 1992). Figure 5.1 visualises the dynamics between these ten values by means of two bipolar dimensions: 'openness to change' versus 'conservation' values, and 'enhancement' versus 'self-transcendence' values.

This paper builds on this value theory to explore the values expressed by different materials and the effect of the link between one's own values and the perceived material values on the fit of a material with the self-expression.

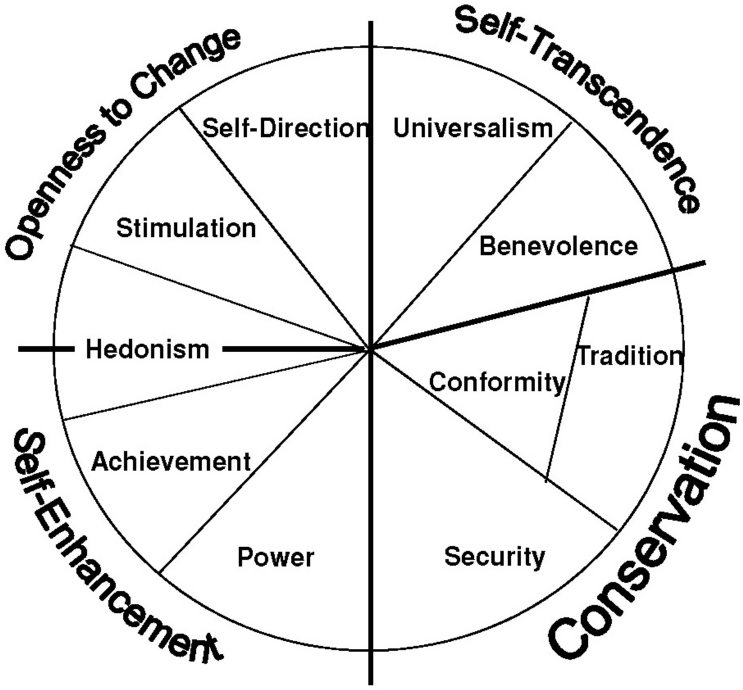


Figure 5.1. Theoretical model of relations among ten motivation types of value, including two bipolar dimensions. Reprinted from (Schwartz, 2012), in accordance with Creative Commons regulations.

Conclusively, a link has been found between personalities and products (and thus materials), which in most studies translates to the use of everyday personality adjectives, as with Govers (2004), based on the Big Five personality traits (Brunel & Kumar, 2007). However, personality traits and their relative importance are considered to be evolving throughout a lifetime. In the context of product design, we are looking for a more stable way to define self-expression, hence; we explore whether we can apply the same principle on personal values as well? End values of people are assumed to be more stable over time, predominant, and motivational drivers for the choice process of the consumer (Rokeach, 1973; Schwartz, 1992). Therefore, as this research focusses on the targeted end-users, we aim to study the effect of the relation between the perceived material values and the values of the end-user on a material's fit with the self-expression.

5.3 Research Aim

In this paper, we aim to explore possible relationships between materials, their expressive value and the link with self-expression of the end-user, whereas the expressive value is defined in terms of Schwartz end values (Schwartz, 2012). To that end, we focus merely on the visual perception, and make abstraction of smell, touch, sound, etc. in order to focus on one sense in this explorative study. We assume that (a) end-users may see personal values reflected in materials, and that (b) a material's fit with their self-expression may be linked to these expressive values of materials. As previous research by Karana et al. (2007) showed that form has a significant effect on the perception of materials, we aim to include the aspect of form in our reasoning model. Consequently, the following research questions can be stated:

- RQ1: Can the value-based framework of Schwartz be applied to identify different material expressions?
- RQ2: How does the end-user's self-expression, adhering to different personal (Schwartz) values, affect the fit with a material?
- RQ3: What is the relationship between the material(s) that best fit with the self-expression of the end-users, and the expressive values that they see reflected in materials?

5.4 Methodology

The purpose of this study is to reflect upon how materials selection in product design can be enhanced. Therefore, we build upon the end-users' value orientation and the expressive value of materials. Considering the challenges in assessing material samples, users' perception is influenced by shape and product-context associations. Consequently, experiments are set up as a methodology to cope with these problems. We exclude the product-context association that are not related to the material itself by presenting materials in an abstract way, which means that the materials are not embedded in products. Moreover, we intend to exclude the effect of form on reflected expressive values and a material's fit with the self-expression by means of evaluating the materials across different forms, i.e. combining the results of all forms into the equation.

Our research set up consists of four parts (see Figure 5.2 for an overview), i.e. we conducted two pre-studies and a two-part main study in order to explore the relationship between materials and personal values. Therefore, the most crucial stimuli that are needed are (i) a set of personal values based on the Schwartz value framework, (ii) a set of visually clear and recognizable 'abstract' materials, and (iii) a set of distinctive forms.

Study	Participants	Input	Output
Pre-study 1	Designers	25 materials (rendered on cube), based on (Ashby & Johnson, 2010) and limitations of used software	Set of 12 visually clear and recognizable materials
Pre-study 2	Designers	30 abstract 3D-modelled forms (Karana et al., 2007)	Set of 4 distinctive forms
Main study 1	End-users	Online SSVS survey results & 12 materials rendered on the 4 forms	Indirect Classification of 12 materials in 4 Schwartz value groups
Main study 2	End-users	Online survey with 12 materials rendered on a sphere & list of Schwartz values	Direct classification of 12 materials in four Schwartz value groups.
Comparison		Results of main studies	Distinct view on relation between materials and Schwartz groups

Figure 5.2. Overview of the conducted studies.

Work of Karana et al. (2007, p. 16) demonstrates that 'form' has a significant effect on the perception of materials: "People attribute different meanings to materials embodied in various shapes". Thus, in order to find a significant relationship between materials and personal values, the aspect of form is included in our research design. With regard to obtaining a set of the most distinctive forms that can be used in the main study, pre-study 2 is conducted with designers. Out of 30 different abstract forms (Karana et al., 2007), designers chose the form that was most representative for a group of forms and that was most distinguishing from the other selected forms.

Consequently, the main study uses the stimuli selected in the two pre-studies to question end-users indirectly and directly about the relationship between materials and personal values. The questionnaire for the main study is made up of two parts. In the first part, an indirect relationship is examined between personal values and materials. Each participant is assigned to a Schwartz value group, based on their value orientation score. Then, respondents are asked to choose two materials that match with their self-expression. In the second part of the main study, a more direct manner to examine the relationship between personal values and materials is used. Participants are asked to link each of the twelve materials directly to a Schwartz value group. Finally, the results of these two parts of the main study are compared, leading to the conclusions of this exploratory research.

5.5 Results

5.5.1 Pre-Study 1: Selection of 12 Visually Clear and Recognizable Materials

5.5.1.1 Aim

In order to facilitate the finding of relationships between personal values and materials, and to limit and efficiently set-up the main study, this first pre-study aimed to select twelve visually clear and recognizable materials, taking into account the limitations of the 3D software package, and to maintain the set of materials comprehensible and manageable. We opt to take not more than 12 materials along our main study as to avoid a decrease of reliability due to a long final questionnaire.

We opt though for at least 12 material items as to have a sufficient variety in material/form combinations as stimuli for our main research.

5.5.1.2 Stimuli

Because this study wants to exclude context effects that might be evocated by the integration of materials in products, materials have to be presented in a neutral way, keeping their natural colour and texture. A preliminary set of 25 materials (divided over the previously mentioned material classes, and based on the material collection of the 3D software) was modelled on a neutral cube using 3D software. Three professional designers agreed on the use of the selection of these 25 materials to include in the further study based on a broad variety of materials from all different families: natural materials (wood and textile), metal, plastics, composites, glass and ceramics – that could be visualised clearly and unambiguously through render software (Figure 5.3). All cubes were printed on the same size (A5 paper) in high quality mode. Note that the use of digitalised pictures lead to a merely visual, and not tactile evaluation. Therefore, we tried to maintain the authentic colour of the materials as much as possible.

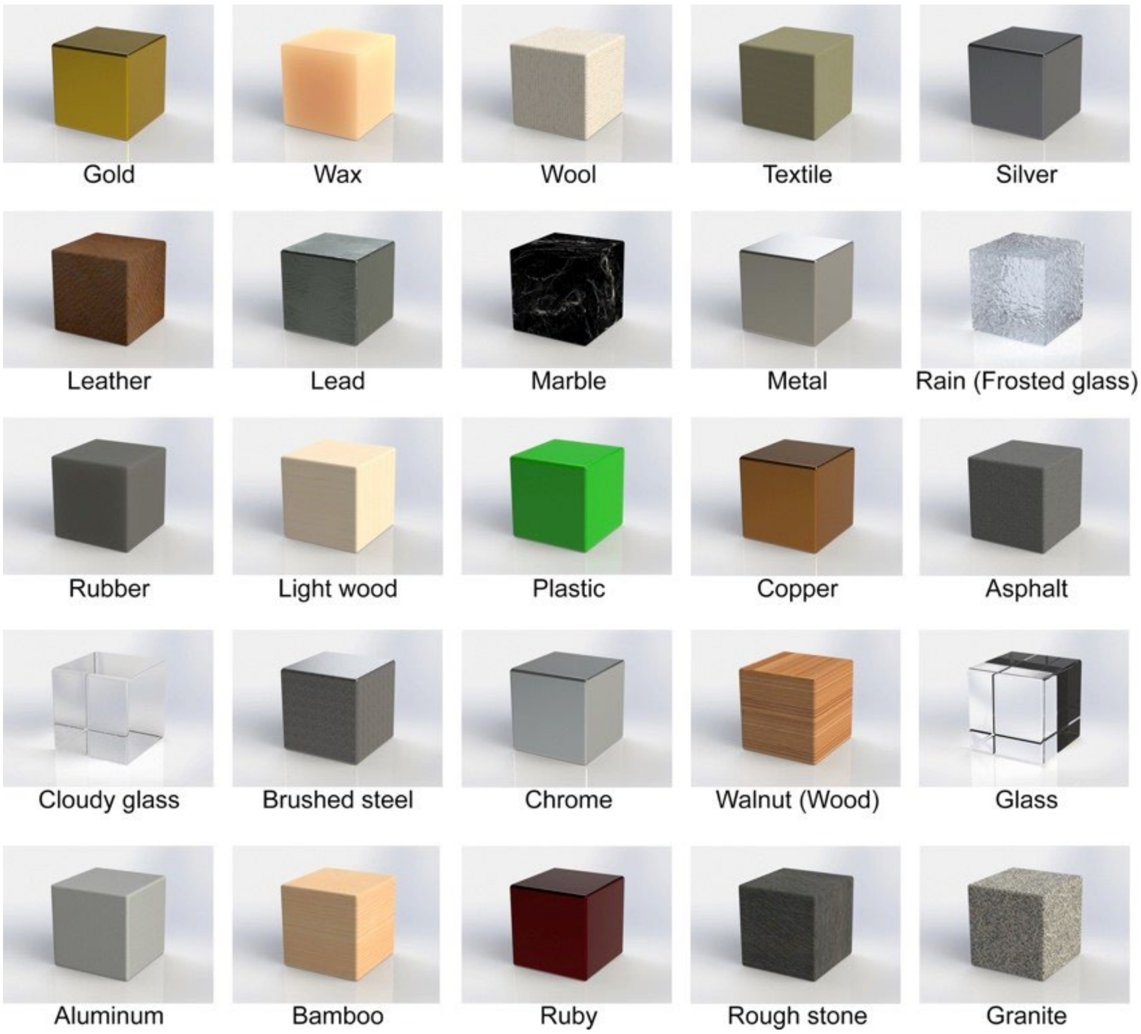


Figure 5.3. Preliminary set of 25 rendered materials.

5.5.1.3 Participants

The subject sample consisted of ten groups of two design students (N=20, 10 male, 10 female), randomly composed over the two genders. Subjects were first Bachelors up to first Masters of Product Development at the University of Antwerp, and participated in a voluntary manner without prior knowledge of the study. The test took place in a classroom at the Product Development department in November 2017.

5.5.1.4 Procedure

The printed pictures (without material names) of the 25 materials were randomly presented to all teams. With their basic knowledge of materials in mind, they were asked to select 12 materials that were most visually clear and recognizable. A qualitative card sorting method was used, as a technique to a coherent classification of items, leaving participants with the freedom to choose their own selection method while discussing with each other. Since this pre-study was done in an inductive manner, and in teams of two people who could consult and discuss, decisions were substantiated and clearly founded.

5.5.1.5 Results

The way of working in the teams was clearly different. In some teams the most obvious materials were chosen quickly, and more time was spent on the remaining materials. Others worked rather slowly but very thoughtfully with well-founded decisions from the start. One team first divided the 25 materials into small groups, and then chose the most recognizable material per group until a set of twelve materials was obtained, which was broad yet comprehensible enough.

The frequency diagram in Figure 5.4 shows the total number of times each material was chosen as most clear and recognizable, and as such part of a set of twelve materials. Marble was the clear winner in this test; each team put this material in their set. In addition, materials such as Walnut (wood), Rain (frosted glass), Glass, Wax, Gold, Granite, Leather, Wool, Textile, Lead, Chrome, and Copper showed high frequencies. Other materials were not chosen frequently enough to be part of the final set of materials, thus are excluded for the next part of the research.

However, two materials ended ex aequo on the bottom places (12th and 13th) of the selection list. The final decision on which material to drop from the list was discussed with the research team. Since Textile and Wool are part of the same category, and because the category Metal - which is more important in product design - is less represented, we decided to exclude Textile (10th) and to include both Copper and Chrome. Hence, the final set of twelve representative materials can be found in Figure 5.4 and 5.5.

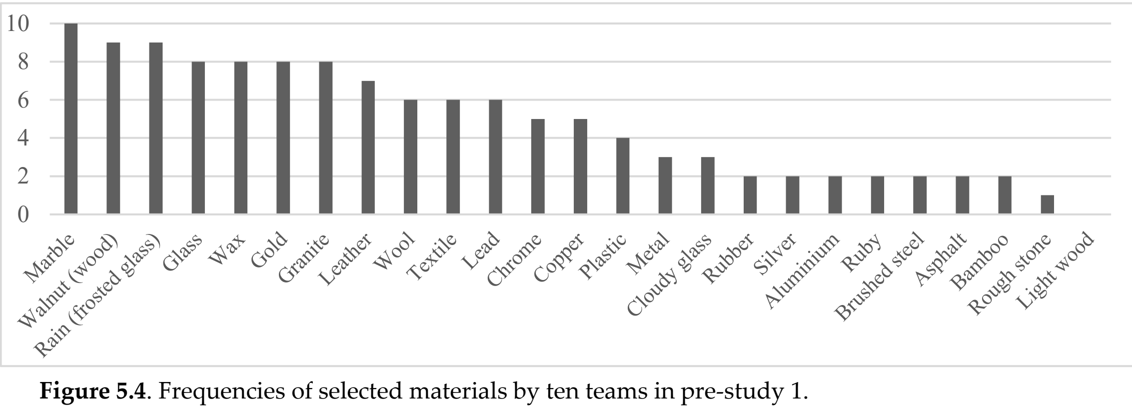


Figure 5.4. Frequencies of selected materials by ten teams in pre-study 1.

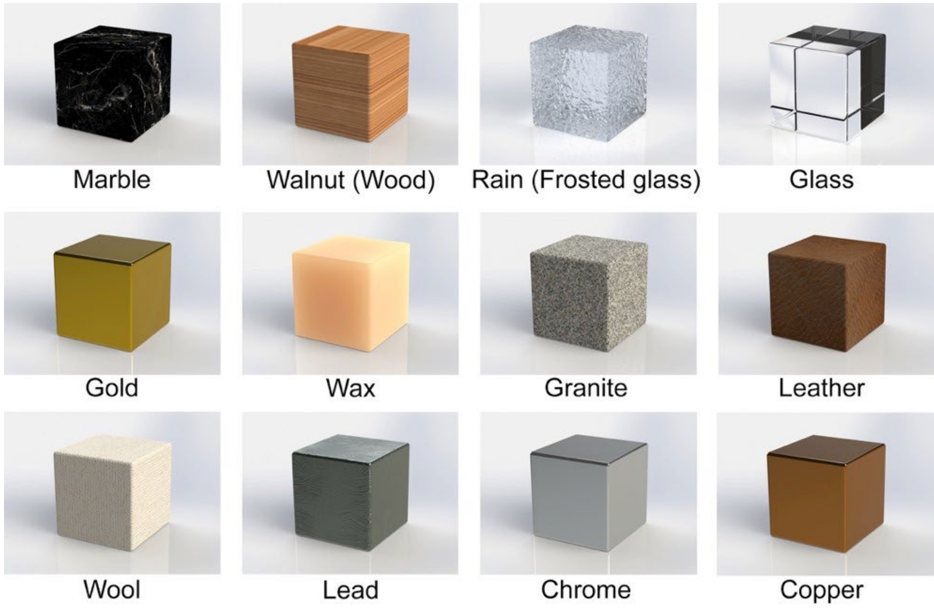


Figure 5.5. Final selection of twelve representative materials for the main study.

Most of the material families are quite well represented in the final set, for example different types of wood, glass, ceramics and metals are part of the set. Unfortunately, plastics are not represented as this material was not chosen frequently enough. A possible explanation could be that plastics are less distinctive, especially in printed renders. Indeed, some participants remarked that often it was not easy to figure out which material was presented to them through the printed cube figures. To that end, it helped to have two students in each team so they could discuss the different materials and come to a final agreement.

5.5.2 Pre-Study 2: Selection of a Set of 4 Distinctive Forms

5.5.2.1 Aim

As discussed in the introduction, form has an effect on the perception of a material and is therefore included in this research. Consequently, pre-study 2 aimed to find four abstract, generic forms that represent a broad variety, but would not compromise the comprehensibility of the main study. In this way, the interference of the contextual variable 'form' with the expressive value of a material could be taken into account.

5.5.2.2 Stimuli

We relied on earlier work of Karana et al. (2007), evaluating 41 different forms based on six primitive, geometrical shapes. Based on their conclusions, we pre-selected 30 forms which were clear, easy to reproduce and hard to link to an existing object (as this could influence the test results, by evocating specific context effects). Through 3D software, we modelled these forms and neutrally rendered them without a designated material (Figure 5.6). Again, all forms were printed on the same size (A5 paper) in high quality mode.

Figure 5.6. Preliminary set of 30 rendered forms.

5.5.2.3 Participants

The subject sample consisted of eight groups of two design students (N=16, 8 male, 8 female). Subjects were first Bachelors up to first Masters of Product Development at the University of Antwerp, and participated in a voluntary manner without prior knowledge of the study. The test took place in a classroom at the Product Development department in November 2017.

5.5.2.4 Procedure

The course of the test was similar to the procedure by Karana et al. (2007). All 30 forms were randomly presented to the teams. They were asked to intuitively categorise the forms into four self-chosen groups, and to name each group, based on their similar form characteristics Subsequently, the participants were asked to rank the forms within each group based on a possible fit within that group. Since this pre-study was done in teams of two people who could consult and discuss, decisions were substantiated and clearly founded.

5.5.2.5 Results

Several groups were often represented, although under different names. For example, the group 'Organic forms' emerged in seven of eight teams, while the 'Geometric forms' was noted by half of the groups. Within many teams, a group of long and small forms was presented with different names: cylindrical forms, conical forms, long and small, etc. Finally, we noted a group of pointed, angular forms (i.e. pointed, angular, sharp), which was chosen by half of the test groups. Conclusively, the four elected groups in this pre-study are the following: (i) organic forms, (ii) geometric forms, (iii) conical/long/small forms, and (iv) pointed/angular forms. These groups are slightly different then the outcome of the reference study (Karana et al., 2007) that concluded with the categories of geometric-sharp, geometric-rounded, hybrid, and organic.

Next, as participants also ranked the forms based on their best fit or representativeness within each form group, the frequency of all top three forms was calculated and shown in Figure 5.7. Twelve forms were chosen by at least half of the teams, and therefore again distributed among the four form groups, leading to the final four forms (circled) – as most representative for their group – that could be used for the main study.

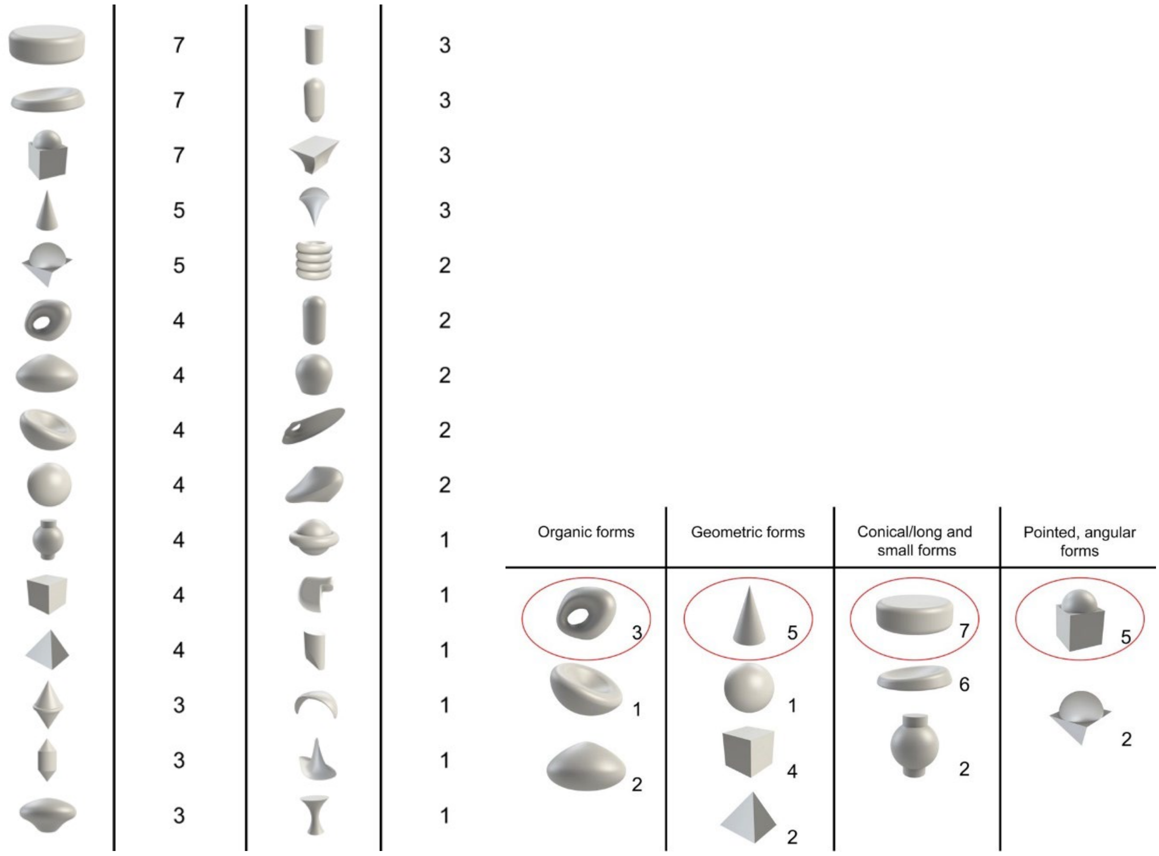


Figure 5.7. Frequency of top three forms in pre-study 2, including distribution among form groups.

5.5.3 Main Study Part 1: Indirect Relation between Materials and Schwartz Groups

5.5.3.1 Aim

The first part of the main study aims to examine to what extent a relationship can be found between the self-expression of the user in terms of personal values and their preference for a material, i.e. an indirect link between materials and Schwartz groups.

5.5.3.2 Stimuli

The main study was conducted through an online survey in Qualtrics, an online survey tool. As the first part questioned participants indirectly about the relationship between their personal values and the materials suiting and fitting their own value orientation, the used stimuli are the four selected forms (pre-study 2) upon which the twelve selected materials (pre-study 1) were modelled and rendered, in order to take the effect of form into account. Each form/material combination had the same size and quality, and was presented randomly in the online survey.

5.5.3.3 Participants

The main study questions the expressive value of materials by end-users. The online survey was completed in December 2017 by 70 Flemish respondents (28 male, 42 female), with different backgrounds, however excluding people with a design-related profession or students studying design sciences. 40 respondents were aged 16-25 years old, 15 respondents 26-45 years old, and 15 respondents were aged above 45.

5.5.3.4 Procedure

Schwartz end values are usually measured through the Schwartz's Value Survey (SVS) with a 57-item scale. However, in the context of this empirical research, using this many items in a survey is too time- and place-consuming. The work of Lindeman and Verkasalo (Lindeman & Verkasalo, 2005) aimed to shorten the original questionnaire, leading to the development of the Short Schwartz's Value Survey (SSVS) with only ten items, responding directly to the ten main values. The SSVS scale proved to be reliable, valid, consistent and the SSVS scores showed a high correlation with the SVS. Therefore, the SSVS will be used as a practical and compact alternative for measuring personal values and assigning users to the four main Schwartz value groups. Consequently, participants first filled in the Short Schwartz Value Survey (SSVS), taken from the research of Lindeman and Verkasalo (Lindeman & Verkasalo, 2005). The ten values listed below were shown randomly in the survey to the participants, including their value items between brackets. Respondents were asked to rate each of the following values' importance in their lives on a Likert scale from 0 to 8, from 'opposed to my principles' to 'supreme importance'.

- Power (social power, authority, wealth);
- Achievement (success, capability, ambition, influence on people and events);
- Hedonism (gratification of desires, enjoyment in life, self-indulgence);
- Stimulation (daring, a varied and challenging life, an exciting life);
- Self-Direction (creativity, freedom, curiosity, independence, choosing one's own goals);
- Universalism (broadmindedness, beauty of nature and arts, social justice, a world at peace, equality, wisdom, unity with nature, environmental protection);
- Benevolence (helpfulness, honesty, forgiveness, loyalty, responsibility);
- Tradition (respect for tradition, humbleness, accepting one's portion in life, devotion, modesty);
- Conformity (obedience, honouring parents and elders, self-discipline, politeness);
- Security (national security, family security, social order, cleanliness, reciprocation of favours).

Next, the four forms were shown one by one in a randomised order, by means a neutral render and twelve material/form renders (also in a randomised order). For each form, participants were asked to select two renders, i.e. two materials, fitting their value orientation best. As such, participants chose four times x two materials that would represent the best fit with their self-expression .

5.5.3.5 Results

For each participant, the SSVS resulted in a score between 0 and 8 for each of the ten values. These ratings were further analysed using the formula of Lindeman and Verkasalo (2005). As a result, each participant could be categorised in one of the four Schwartz Value groups with the following distribution:

- Conservation: 18 respondents
- Openness to Change: 10 respondents
- Self-Enhancement: 34 respondents
- Self-Transcendence: 8 respondents

Although we realise that an equal distribution over the four groups is not to be expected in our society, the obtained distribution from this survey was particular and needs to be taken into account in the further analysis. An increased number of survey participants could possibly normalise the distribution.

All participants chose two materials for each form, fitting best to their value orientation, by answering the Short Schwartz Value Survey questions. By evaluating the preferred materials across all forms – i.e. combining the results of the four forms into the equation – we aimed to exclude the effect of form on material perception. To find a relationship between the eight chosen materials and the Schwartz groups of the participants, a cross tabulation was done with the obtained data in Table 5.1, using a statistical software program (SPSS). We coupled each test person to the chosen material eight times resulting in a total of 560 results (70 participants x 8 selected materials), that could be placed in 48 cells (12 materials x 4 Schwartz groups) of the cross tabulation. For each value (observed count) in the cross tabulation, the expected count and the adjusted standardized residual was calculated. The latter is similar to z-scores, and normalizes data in e.g. chi square testing. It shows "the ratio of the difference between the observed and the expected count to the standard deviation of the expected count in chi-square testing" (Glen, 2017). In general, a residual smaller than -2 means that the observed count is smaller than the expected count. A residual greater than +2 means that the observed count is greater than the expected count.

Table 5.1. Cross tabulation of obtained data in Main Study Part 1.

	Conservation			**Openness to Change**			**Self-Enhancement**			**Self-Transcendence**			Total
Material	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*
Chrome	6	12,6	-2,3	5	7,0	-,9	32	23,8	2,5	6	5,6	,2	49
Glass	13	14,9	-,6	9	8,3	,3	27	28,2	-,3	9	6,6	1,0	58
Gold	4	8,2	-1,8	3	4,6*	-,8	24	15,5	3,1	1	3,7*	-1,5	32
Granite	20	9,8	3,9	1	5,4	-2,1	11	18,5	-2,5	6	4,3*	,9	38
Copper	10	13,9	-1,3	9	7,7	,5	30	26,2	1,1	5	6,2	-,5	54
Leather	5	5,9	-,4	10	3,3*	4,1	6	11,2	-2,2	2	2,6*	-,4	23
Lead	7	12,3	-1,8	8	6,9	,5	28	23,3	1,4	5	5,5	-,2	48
Marble	10	14,4	-1,4	11	8,0	1,2	34	27,2	1,9	1	6,4	-2,4	56
Rain	16	17,2	-,4	7	9,6	-1,0	33	32,5	,1	11	7,7	1,4	67
Carpet	9	7,2	,8	4	4,0*	,0	9	13,6	-1,8	6	3,2*	1,7	28
Walnut	30	19,5	3,0	8	10,9	-1,0	29	36,9	-2,0	9	8,7	,1	76
Wax	14	8,0	2,5	5	4,4*	,3	9	15,1	-2,2	3	3,5*	-,3	31
Total	144			80			272			64			560

Note that there are nine cells (grey*) in this cross tabulation that have an expected count less than five, partly as a consequence of the unequal distribution of the respondents across the four Schwartz groups. This means that there were not enough participants within that group that chose a particular material, leading to insufficient data to do valuable statistics. However, we did try to run the test, despite the fact that the obtained information will not be statistically correct, unless the test is repeated with a larger sample size.

The data analysis was done according to the methods of Beasley and Schumacker (1995), using a multiple regression approach to analysing contingency tables and post hoc tests. We did not test homogeneity by evaluating the overall Chi square, instead we calculated the Chi square value for each cell in order to determine where significant differences can be found. Since we did 48 analysis simultaneously, one per cell, no conclusions can be drawn immediately from these adjusted residuals. To avoid a type 1 error, we applied a correction to these values and take statistically conclusions from the calculated P-values. Thus, for all adjusted standardized residuals, which are basically z-scores, we calculated the P-value by first multiplying the adjusted residuals with their own value (= Chi square values), and subsequently transforming these Chi square values into P-values via the Significance Chi Square function (see Table 5.2, in which the grey boxes show the invalid combination according to the previous table).

Table 5.2. P-values of each Material/Schwartz group combination in Main Study Part 1.

	Conservation	Openness to Change	Self-Enhancement	Self-Transcendence
Chrome	0,02382	0,39533	0,01429	0,84931
Glass	0,54186	0,77948	0,74140	0,30301
Gold	0,07841	0,41222	**0,00207****	0,12851
Granite	**0,00008***	0,03317	0,01207	0,37886
Copper	0,20408	0,59611	0,28014	0,59611
Leather	0,65271	**0,00004***	0,02781	0,67449
Lead	0,06431	0,62413	0,15561	0,81809
Marble	0,15561	0,22628	0,05486	0,01685
Rain glass	0,71138	0,33706	0,90448	0,17069
Carpet	0,42371	1,00000	0,07508	0,08727
Walnut	0,00318	0,31250	0,05118	0,90448
Wax	0,01077	0,76418	0,02509	0,74897

In order to use these P-values to show a significant relation, they were compared to the significance level of this test, set to 5% (α=0,05). Since 48 analysis were done simultaneously, this value needed correction and was thus divided by 48, leading to an adjusted P-value of 0,00104167 (=0,05/48). P-values lower than this value show a significant Material/Schwartz group combination (*): *Granite* significantly matched with the Conversation group, and *Leather* with the Openness to Change (although its expected count was actually too low). Since the adjustment led to a rather strict level, the significance could be increased to 10% (α= 0,10 and adjusted P-value=0,00208333), resulting in *Gold* that would match with Self-Enhancement (**) as well. Other materials did not meet any Schwartz group significantly according to this indirect method. They might by (too) universally accepted to be classified within one specific Schwartz value group.

5.5.4 Main Study Part 2: Direct Relation between Materials and Schwartz Groups

5.5.4.1 Aim

The second part of the main study aimed to examine to what extent a relationship can be found between the self-expression of the user in terms of personal values, and the expressive values that people see reflected in a material, i.e. a direct link between materials and Schwartz values.

5.5.4.2 Stimuli

The twelve selected materials of pre-study 1 were modelled and rendered in high quality on a sphere in a neutral environment, and shown in the online survey in a randomised order by means of high-quality pictures of the same size, as exemplified in Figure 5.8.

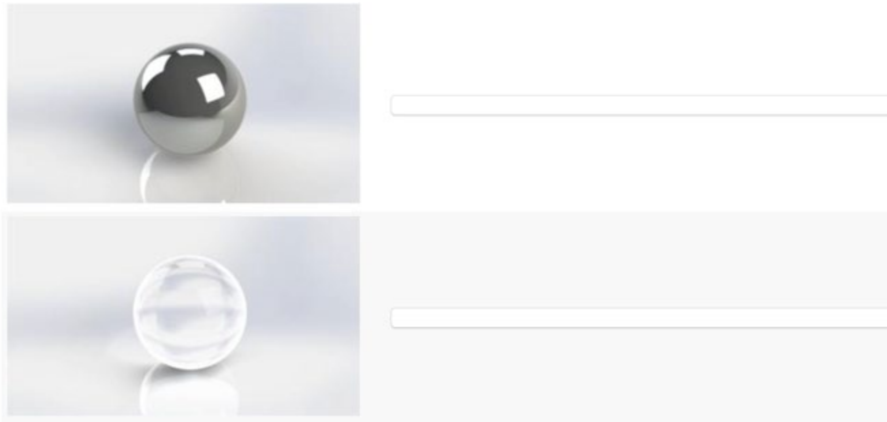


Figure 5.8. Example of two materials rendered on a sphere in the survey.

5.5.4.3 Participants

The same respondents filled in the second part of the main study using the same online survey as the first part, and was thus completed in December 2017 by the same 70 Flemish respondents (28 male, 42 female), with different background, however excluding people with a design-related profession or students studying design sciences. 40 respondents were aged 16-25 years old, 15 respondents 26-45 years old, and 15 respondents were aged above 45.

5.5.4.4 Procedure

Following the first part of the main study in the survey, for each of the twelve randomly shown materials, participants were asked to select an expressive Schwartz value that they see most reflected in the material through a drop-down menu. As such, we received twelve results for each participant, i.e. twelve Material-Schwartz group combinations.

5.5.4.5 Results

840 results were collected (70 participants x 12 chosen material-Schwartz group combinations), and analysed in statistical software similar to the first part of the main study. To determine whether certain Material/Schwartz group combinations were chosen significantly more than others, again we composed a cross tabulation with the obtained data, see Table 5.3. To that extent, we coupled each material 70 times to the chosen group. These 840 results could, as before, be placed in 48 cells (12 materials x 4 Schwartz groups) of the cross tabulation. For each value in the cross table, also the percentage and the adjusted standardised residual was calculated.

Note that in this cross tabulation, no cells with an expected count less than five were found, meaning statistical analysis may be carried out. This is done according to the same method as in Main Study 1 (Beasley & Schumacker, 1995), consequently, the corrected P-values can be found in Table 5.4.

Table 5.3. Cross tabulation of obtained data in Main Study Part 2.

	Conservation			**Openness to Change**			**Self-Enhancement**			**Self-Transcendence**			Total
Material	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*	*Expected Count*	*Adjusted Residual*	*Observed Count*
Chrome	24	24,2	-0,04	6	11,4	-1,83	26	19,8	1,73	14	14,7	-,20	70
Glass	10	24,2	-3,72	17	11,4	1,89	14	19,8	-1,59	29	14,7	4,40	70
Gold	9	24,2	-3,98	6	11,4	-1,83	50	19,8	8,39	5	14,7	-2,97	70
Granite	47	24,2	6,00	7	11,4	-1,49	5	19,8	-4,09	11	14,7	-1,12	70
Copper	16	24,2	-2,14	17	11,4	1,89	31	19,8	3,12	6	14,7	-2,66	70
Leather	37	24,2	3,37	7	11,4	-1,49	5	19,8	-4,09	21	14,7	1,94	70
Lead	22	24,2	-,57	12	11,4	,20	30	19,8	2,84	6	14,7	-2,66	70
Marble	17	24,2	-1,88	18	11,4	2,22	28	19,8	2,29	7	14,7	-2,35	70
Rain	15	24,2	-2,41	20	11,4	2,90	15	19,8	-1,32	20	14,7	1,64	70
Carpet	32	24,2	2,06	10	11,4	-,48	12	19,8	-2,15	16	14,7	,41	70
Walnut	32	24,2	2,06	9	11,4	-,82	8	19,8	-3,26	21	14,7	1,94	70
Wax	29	24,2	1,27	8	11,4	-1,15	13	19,8	-1,87	20	14,7	1,64	70
Total	290			137			237			176			840

Table 5.4. P-values of each Material/Schwartz group combination in Main Study Part 2.

	Conservation	**Openness to Change**	**Self-Enhancement**	**Self-Transcendence**
Chrome	0,96809	0,06725	0,08363	0,84148
Glass	**0,00020***	0,05876	0,11183	**0,00001***
Gold	**0,00010***	0,06725	**0,00000***	0,00298
Granite	**0,00000***	0,12622	**0,00004***	0,26271
Copper	0,03235	0,05876	0,00181**	0,00781
Leather	**0,00075***	0,13622	**0,00004***	0,05238
Lead	0,56868	0,84148	0,00451	0,00781
Marble	0,06011	0,02642	0,02202	0,01877
Rain glass	0,01595	0,00373	0,18684	0,10101
Carpet	0,03940	0,63123	0,03156	0,68181
Walnut	0,03940	0,41222	0,00111**	0,05238
Wax	0,20408	0,25014	0,06148	0,10101

In order to use these P-values to show a significant relationship, they were compared to the significance level of this test, set to 5% (α=0,05). Again, these values were corrected as consequence of the 48 simultaneous analysis, leading to an adjusted P-value of 0,00104167 (=0,05/48). P-values lower than this value show a significant result – and thus a significant Material-Schwartz group combination (*): *Glass* significantly matched with the Conservation and Self-Transcendence group, and both *Gold, Granite* and *Leather* with the Conservation and Self-Enhancement group. If the significance level would be increased to 10% (α=0,10 and adjusted P-value=0,00208333), *Copper* and *Walnut* as well would match with Self-Enhancement (**). Other materials did not meet any Schwartz group significantly according to this direct method. Table 5.4 also shows that both Conservation and Self-Enhancement lead to the most significant matches compared to Self-Transcendence (1 match) and Openness to Change (no matches). This might be explained by the fact that less respondents were found in these groups, which made it more difficult to match materials to these Schwartz values.

5.5.5 Comparison of indirect and direct classification of Main Study 1 and 2

Finally, we compared the results of the two parts of the Main study in Figure 5.9 (materials between brackets only represent a match at a significance level of 10%). According to both the indirect and direct method, *Granite* still fits with Conservation and *Gold* with Self-Enhancement, but according to the direct method, Granite showed an additional fit with Self-Enhancement, and Gold with Conservation. *Leather* was only matched with Openness to Change in the first, indirect test, in contrast to the direct test where it paired with Conservation as well as Self-Enhancement. The other significant matches were not found through the indirect method. This means that Openness to Change and Self-Transcendence (the two Schwartz groups with the least respondents) did not show any matches between the two methods. Possibly, other materials besides the twelve selected ones might represent a better fit.

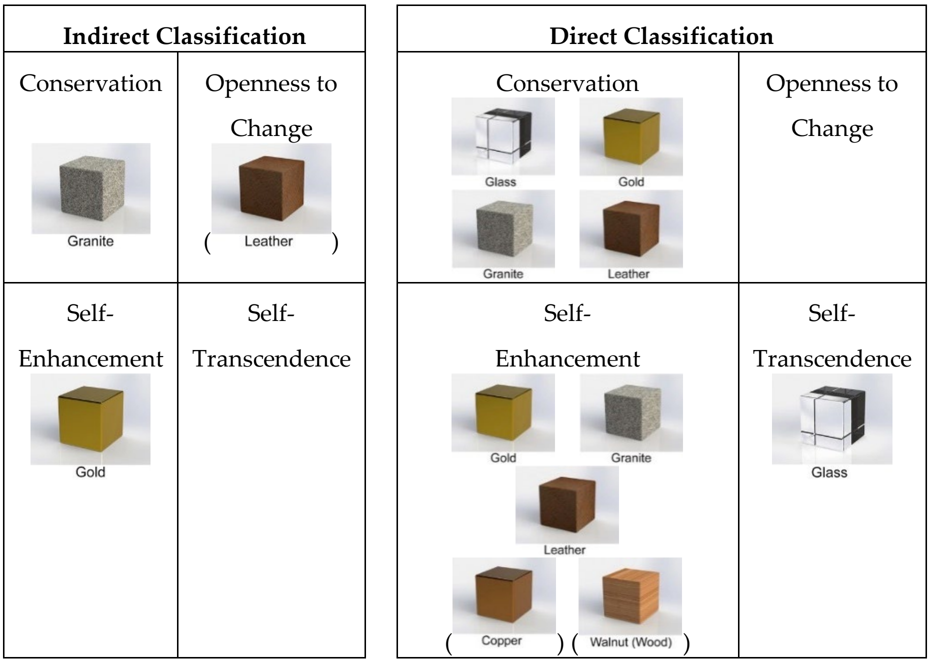


Figure 5.9. Visual comparison of resulting Material/Value combinations of two Main Study parts.

5.6 Discussion

Considering the challenges in assessing material samples, perception is influenced by shape and product-context associations. Therefore, this paper presented several experimental set-ups as a methodology to cope with these problems in order to examine the relationship between the expressive value of end-users and their material preference. In the conducted explorative studies, we focussed on the aspect of sight, i.e. the evaluation of visually recognizable materials, without already involving the tactual manipulation of materials. Only sight was thus incorporated in the online survey, as a means to evaluate whether it was a valuable direction to explore this path of self-expression with personal end values, instead of personality adjectives.

In this regard, an important limitation was experienced in the use of printouts and digital 3D renders instead of physical material samples. Although this decision made it possible to efficiently examine our experiment set-up through an online survey, more profound and effective results might have been found when conducting the experiment again in a real-life context that facilitates physical exploration of the different materials. This would, of course, increase the time-consuming nature of the experiment and the collection of respondents, even more when aiming for a greater sample size for the main studies as well (which is needed for the statistical processing of the results of Main Study part 1). Furthermore, we must note that a material's colour could also be influential, although we tried to maintain the authentic colours of the used materials.

In addition, we must note that we employed the Short Schwartz Value Survey (SSVS) instead of 57 separate value items in order to maintain a manageable survey. Naturally, this method is less accurate than the full Schwartz Value Survey (SVS), however, it provided a valuable framework that was validated in other studies and that proved useful in assessing the expressive value of both end-users and materials. Furthermore, we could reconsider the representation of the ten Schwartz values; not only with words but also by meaningful mood boards or personas, which might facilitate the survey for the respondents and make it less abstract.

Unfortunately, no plastics were represented in the main studies as this material was not chosen frequently enough in Pre-Study 1. A possible explanation could be that plastics – 'the chameleon among materials' – are less distinctive than e.g. wood or metal, especially in the context of printed 3D renders as compared to physical material samples. Nevertheless, as plastics are prominent in product design, for further research we could recommend to repeat the study with a different set of materials, for example with a focus on plastics specifically, investigating their research potential within the use of physical samples.

Finally, the presented research set-up defined expressive value in terms of Schwartz value groups. By contrast, the effectiveness of personality traits such as Soto's Big Five (C. J. Soto & John, 2017) or the brand personality traits of Geuens, Weijters and De Wulf (2009) could be examined as well in future research, and compared to the current results.

5.7 Conclusion

From a material perspective, the design of successful products depends on the integration of both technical and experiential material characteristics. Thus, a product should not only assure technical functionality, but should also be meaningful to the consumer by including the intended sensorial attributes (e.g. glossiness or texture), meanings or associations (e.g. aggressive or nostalgic), emotions and user interactions. As people interact daily with an extensive number of products, in the context of product design and consumer behaviour, we can consider the products that we (want to) own to be a part of who we are, and how we see ourselves, i.e. they reflect as well as contribute to our identities. However, there is no one-to-one correspondence between materials and their expressive value, since a material's perceived character is influenced by multiple contextual factors that are mainly product-related (shape, function) and user-related (gender, culture, etc.).

Therefore, this research focused on the end user-attributes and as such revealed insight in the expressive values that twelve pre-selected materials (such as wood, wool, chrome, etc.) evoke in itself and in interaction with four pre-selected forms. The main research question concerned the link between the expressive values of the stimuli and the user's self-expression. Thus, for each of these segments, the materials and form-material combinations were investigated, both indirectly and directly, in relation to the fit between the expressive value of the material and the self-expression. In this regard, respondents were assigned to meaningful self-expressive categories, based on their Schwartz value orientation (Conservation, Openness to Change, Self-Enhancement, or Self-Transcendence).

To sum up, relationships were found between the self-perception in terms of values and a material's fit with the self-expression, and between materials and their perceived expression of values. Hence, the link between the material fit and the values that one strives for, partly corresponds to the expressive value that one sees in the material. These relationships have now been explored on a small scale, but this explorative study indicates the usefulness of a follow-up study with a larger sample.

More in particular, according to both the indirect and direct method, Granite fits with Conservation and Gold with Self-Enhancement, but according to the direct method, Granite showed an additional fit with Self-Enhancement, and Gold with Conservation. Leather was only matched with Openness to Change in the first, indirect test, in contrast to the direct test where it paired with Conservation as well as Self-Enhancement. The other significant matches were not found in the first Main Study. This means that Openness to Change and Self-Transcendence (the two Schwartz groups with the least respondents) did not show any matches between the two methods. We must note that other materials (not incorporated in this study design, such as plastics) might represent a better fit and can thus be attributed to the remaining Schwartz groups. Therefore, additional investigation on this matter would be recommended.

Conclusively, this research paper attempted to contribute to the further enhancement of materials selection in product design, building upon the target users' value orientation.

Chapter 6 is based on:

Veelaert, L., Du Bois, E., Herweyers, L., & Moons, I. (2021). Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality. *Sustainable Production, Life Cycle Engineering and Management*, 61–77. https://doi.org/10.1007/978-981-15-6775-9_5

6. Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality

Veelaert Lore, Du Bois Els, Herweyers Laure, Moons Ingrid

Abstract: In order to contribute to a circular economy, as designers, we can aim to assure an extended product lifetime, which can be done following a strategy of creating product attachment. From a consumer perspective, people tend to identify themselves with the products they (want to) own and use, reflecting their identities, who they are and how they see themselves. Thus, product attachment can be positively affected by the congruity with one's personality. A successful product needs to fulfil the user's needs, create meaningful experiences and evoke emotions to survive in the competitive market, which also counts for the materials that the product is made of. These materials can be considered from both a technical engineering (production, durability, waste, etc.) and a user-centred experiential perspective (material perception). Therefore, this qualitative research aims to explore the consumers' perception of plastic materials in everyday products and its link with their own personality. The paper describes the results of a survey in which respondents (n=195, average age of 29 years) were asked to upload a picture of their most and least favourite, plastic product that they use in everyday life, to describe the material(s) it is made of and explain why it (does not) fit with their personality. By means of content analysis, a categorization was made of the uploaded products and the various characteristics that described the materials and attributed to the personality fit, and a cluster analysis was done to create four personality clusters of consumers and their associated material descriptions. We suggest that insights in the relationship between the consumer's personality and his/her material preference will support designers in choosing appropriate materials to create desirable products with a prolonged lifetime.

Keywords: *material perception, plastics, personality, product attachment, product lifetime*

6.1 Introduction

Within a circular economy, one way to extend the life-time of products is by simply using a product for a longer time (Ellen MacArthur Foundation & McKinsey & Company, 2012). Creating product attachment is one strategy to attain such a prolonged product use (Bakker & Schuit, 2017; Mugge et al., 2005). Product attachment is defined as "the emotional bond a consumer experiences with a product" (Mugge et al., 2005; Schifferstein & Zwartkruis-Pelgrim, 2008) and can be positively affected by the congruity with a person's personality. A successful product needs to fulfil the user's needs, create meaningful experiences and evoke emotions in order to survive in the competitive market (Karana et al., 2014). In addition to a product's form or brand, the perception of the user is also influenced by the materials that a product is made of and the resulting materials experience. Hence, a product's material that enhances an emotional bond and suits the user's personality, can also attribute to longer product use (Mugge et al., 2005; Norman, 2004).

Today, materials are a substantial aspect of sustainable design in a circular economy. However, materials can be regarded from both a technical engineering (production, durability, waste, etc.) and a user-centred experiential perspective (Karana et al., 2010; van Kesteren, 2010). From a material perspective, various experiential levels can attribute to a material's expression, and the most well-known levels are defined by Camere & Karana (2017) as sensorial attributes (e.g. gloss, texture, colour), associative (e.g. cheap, male, nostalgic), emotional (e.g. surprising, boring), and performative (e.g. stroking, folding). However, no one-to-one correspondence can be found between these expressive values and a certain material, as a material's perception is influenced by product, user and context related factors, making this subjective topic rather complex to study (Karana, 2010; Karana et al., 2010; van Kesteren, 2010).

From a consumer perspective, people tend to identify themselves with the products they (want to) own and use (Choi, 2017; Zuo, 2010), they reflect their identities, who they are and how they see themselves (Belk, 1988; Govers, 2004). The preference of a consumer for a particular product, and the materials it is made of, is influenced by the fit or consistency with the self of the consumer (Hosany & Martin, 2012; Sirgy, 2015). This expression of the self can be described by attitudes, beliefs, norms, values or traits. Regarding the latter, personality traits are considered universally across diverse cultural and age groups and "describe what people are like, rather than what people consider important" (Schwartz, 2012) (i.e. thoughts, feelings, actions). Throughout one's lifetime, these traits can occur in varying frequency and intensity. The most widely accepted personality traits are the "Big Five" dimensions or the Five-Factor Model of Costa and McCrae (Brunel & Kumar, 2007; McCrae & Costa, 1987), Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. In addition, relationships between products and personalities (and thus, materials) have been found as well, and are translated into everyday personality adjectives by Govers and Mugge (Govers, 2004; Mugge et al., 2009). Finally, Aaker (1997) extended the Big Five structure to brand personality, including socio-demographic aspects such as gender and social class, which was adapted by Geuens et al. (2009) to a new and cross-cultural validated brand personality measure that is easy to comprehend: Responsibility, Activity, Aggressiveness, Simplicity, and Emotionality.

From a product perspective, a critical market is that of Fast Moving Consumer Goods (FMCG) and other everyday consumer products that are sold rather quickly and at a relative low cost, and are most often materialized by plastics (Çelen et al., 2005). The perception of plastics materials has known a changing path, as it was introduced as an imitation material in the '50, then re-valued as a versatile material thanks to Tupperware (Manzini, 1986), but is nowadays regarded as the cause for many environmental issues such as the plastic soup. However, plastics can still offer valuable sustainable opportunities, when used smartly and correctly, i.e. when a designer can create product life extension through meaningful materials experience.

6.2 Research Aim

In this paper, we aim to explore possible relationships between (plastic) materials, found in everyday products, their expressive value and the link with the personality of the consumer, whereby personality in this research is defined in terms of the five brand personality traits (Geuens et al., 2009). Figure 6.1 visualises the reasoning model that involves everyday products as moderator of the perception of a plastic material, which mediates the perceived fit of the plastic with the consumer's personality. The following research question can be formulated: *"How does the consumer's personality influence the perception of a material and the perceived fit with the personality?"*. Based on new insights on how consumers describe materials in relation to their personality, this qualitative exploratory research intends to provide guidance for future quantitative research on materials from the perspective of consumer personality segmentation.

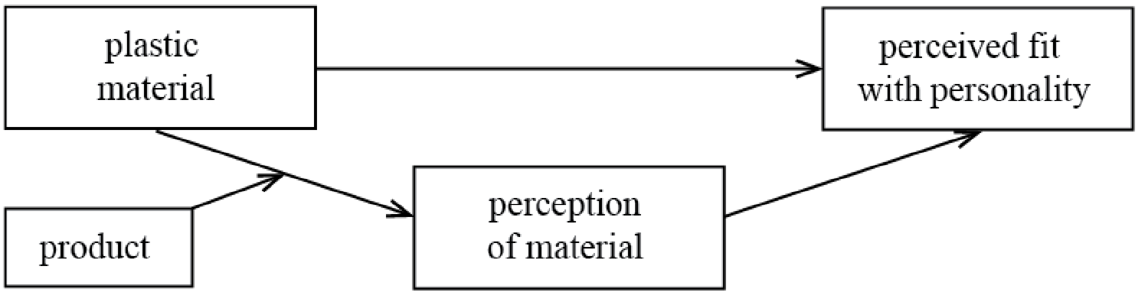


Figure 6.1. Reasoning model.

6.3 Methodology

6.3.1 Procedure

For this study, a collaboration was set up with an agile market research firm. They provide a survey tool with live community access through their mobile phone application. This way, respondents' experiences can be surveyed at the moment of the experience itself. Thus, in order to provide an answer to the proposed research question, a "mobile application survey" was prepared to collect the required data on material perception and consumer personality. This survey consisted of two parts. First, members of the consumer panel were invited to participate in the first part through their account on the mobile survey application. They were shown a short introductory movie with subtitles that introduced them to the number of materials of the products that we see and touch in our daily life. Afterwards they were asked to prepare themselves for the second part by looking for daily consumer products made in (hard) plastic materials that would either fit – or not fit at all – with their personality.

Second, respondents were asked to upload a picture or photograph of a plastic product that they use in everyday life that fits with their personality and self-identity. In addition, in two open ended questions, they were asked to describe the material(s) it is made of and explain why it fits with their self. This was repeated for a product that did not fit at all with their personality.

Third, respondents were asked to score five brand personality items on a five-point Likert scale, based on (Aaker, 1997; Geuens et al., 2009): Responsibility, Activity, Aggressiveness, Simplicity, Emotionality.

6.3.2 Respondents

195 respondents participated in a "mobile survey" that was conducted in collaboration with a consumer panel company. The average age of the respondents was 29 years ($\sigma = 10$), ranging from 16 to 61 years, and 106 respondents were male, 73 were female and 16 undefined. Regarding the validity of the respondent's submissions, depending on the question, at least 173 valid inputs were recorded.

6.3.3 Processing

Demographic data such as gender and age were collected in an Excel file through the consumer panel database and were used for descriptive analysis. This data was complemented with the uploaded pictures, the descriptions of the respondents, and their scores on the brand personality scales.

Next, a content analysis (Erlingsson & Brysiewicz, 2017) was chosen as a flexible method to analyse text-based results, and to transform qualitative data into more quantifiable data. A group of five design researchers determined a set of categories based on the overall answers for both the material descriptions and fit descriptions, largely based on categories commonly found in literature (Camere & Karana, 2017; Karana et al., 2008a). Next, each researcher individually assessed each respondent's answer – divided into separate sub-answers – and coded which categories that were applicable to each (sub) answer. Afterwards, possible disagreements were discussed in group to finalize the categorization and allow frequency count. Table 6.1 gives an overview of the categories, their descriptions and some examples that were found in the data.

Table 6.1. Descriptive categories derived from results of material description and fit description.

Descriptive category	Material description	Fit description	Explanation	Examples
Sensorial	X	X	Vision, sound, touch, etc.	Warm, soft, light, flexible, glossy
Associative	X	X	Meanings, interpretations	Cheap, clean, robust, nostalgic
Ecological	X	X	Sustainable characteristics	Durable, reusable, recycled
Functional	X	X	Usability and utilitarian aspects	Handy, versatile, user friendly
Personality	X	X	Human traits	Friendly, sincere, cheerful, vain
Shape	X		Form-related characteristics	Rounded, sharp-edged, square
Habit/Interest		X	Habitual and interest aspects	Fun for me, don't like, use a lot

Furthermore, by means of a similar procedure, all uploaded pictures were assessed to appoint the displayed products and to count their frequencies. For increased comprehensibility, these products were summarized in several product categories, as shown in Table 6.2, complemented with product examples from the data.

Finally, the respondent's scores on the five brand personality traits were used in a cluster analysis to create consumer segments that can be built upon in further analysis. Based on an outlier assessment, five respondents were discarded as they did not score the personality items, leading to 190 valid data inputs that were used.

Table 6.2. Examples within product categories.

Consumables	Plastic bag, bottle, can, packaging, straw, shampoo bottle
Kitchen utensils	Bread box, water bottle, oven mitt, coffee machine, soap dispenser
Electronics	Computer, remote, headphone, vacuum cleaner, power bank
Office	Pen, paper cutter, calculator
Interior	Chair, doorknob, light switch, lamp, table
Personal/Fashion	Shoe, glasses, watch, backpack
Toys	Dice, Playmobil
Transport	Car steering, handlebar, helmet
Garden	Flowerpot, watering can
Other	3D print, car key, CD, artwork

6.4 Results

6.4.1 Development of Four Personality Clusters

A hierarchical cluster analysis was performed on the five brand personality traits. Four clusters of a similar size were identified, and their cluster means on the personality traits are shown in Figure 6.2. Based on the analysis of the material and personality fit descriptions, these clusters will be further detailed throughout the next Sections.

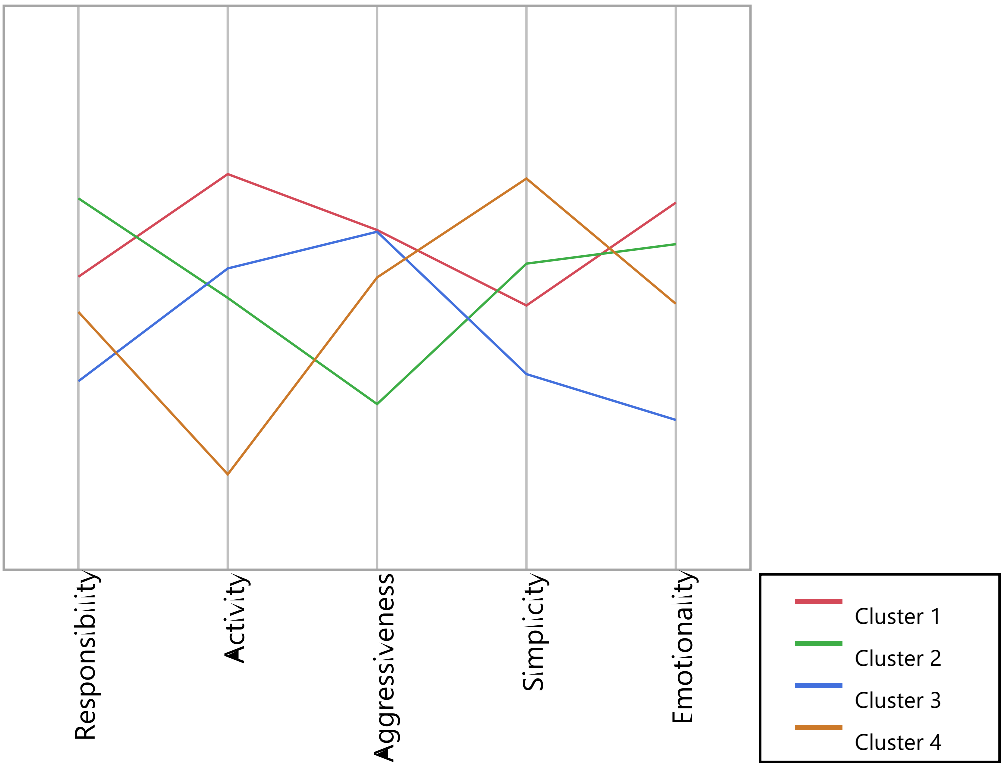


Figure 6.2. Cluster means diagram.

6.4.2 Descriptive Categories

The results of the two open-ended questions for a positive and negative fit with the personality were processed into descriptive categories by means of content analysis. Table 6.3 shows the frequencies of descriptions within each category for all four questions.

Table 6.3. Frequencies and relative counts of descriptive categories for materials and fit within the four clusters.

		Cluster	Sensorial		Associative		Ecological		Functionality		Personality		Shape		Habit/ Interest		**Total per cluster**		**Total**
			N	R%	N	R%	N	R%	N	R%	N	R%	N	R%	N	R%	**N**	%	
Positive fit	Material descr.	**C1**	50	47,6	29	27,6	7	6,7	11	10,5	7	6,7	1	1,0	-	-	105	25,4	**413**
		C2	96	67,1	22	15,4	9	6,3	10	7,0	3	2,1	3	2,1	-	-	143	34,6	
		C3	55	60,4	21	23,1	4	4,4	4	4,4	6	6,6	1	1,1	-	-	91	22,0	
		C4	53	71,6	7	9,5	4	5,4	5	6,8	2	2,7	3	4,1	-	-	74	17,9	
		T	254	61,5	79	19,1	24	5,8	30	7,3	18	4,4	8	1,9	-	-			
	Fit description	**C1**	7	10,3	13	19,1	14	20,6	8	11,8	19	27,9	-	-	7	10,3	68	27,6	**246**
		C2	15	19,2	14	17,9	12	15,4	9	11,5	22	28,2	-	-	6	7,7	78	31,7	
		C3	12	20,7	17	29,3	6	10,3	5	8,6	14	24,1	-	-	4	6,9	58	23,6	
		C4	9	21,4	6	14,3	8	19,0	7	16,7	8	19,0	-	-	4	9,5	42	17,1	
		T	43	17,5	50	20,3	40	16,3	29	11,8	63	25,6	-	-	21	8,5			
Negative fit	Material descr.	**C1**	61	56,0	33	30,3	9	8,3	5	4,6	1	0,9	0	0,0	-	-	109	29,2	**373**
		C2	47	41,2	45	39,5	14	12,3	5	4,4	2	1,8	1	0,9	-	-	114	30,6	
		C3	43	56,6	22	28,9	6	7,9	2	2,6	1	1,3	2	2,6	-	-	76	20,4	
		C4	52	70,3	12	16,2	6	8,1	0	0,0	1	1,4	3	4,1	-	-	74	19,8	
		T	203	54,4	112	30,0	35	9,4	12	3,2	5	1,3	6	1,6	-	-			
	Fit description	**C1**	22	27,8	18	22,8	15	19,0	1	1,3	16	20,3	-	-	7	8,9	79	30,6	**258**
		C2	12	15,4	22	28,2	22	28,2	5	6,4	14	17,9	-	-	3	3,8	78	30,2	
		C3	10	17,9	15	26,8	13	23,2	0	0,0	16	28,6	-	-	2	3,6	56	21,7	
		C4	7	15,6	8	17,8	15	33,3	2	4,4	8	17,8	-	-	5	11,1	45	17,4	
		T	51	19,8	63	24,4	65	25,2	8	3,1	54	20,9	-	-	17	6,6			
Total		C1	**140**	**38,8**	**93**	**25,8**	**45**	**12,5**	**25**	**6,9**	**43**	**11,9**	**1**	**0,3**	**14**	**3,9**	**336**		**1290**
		C2	**170**	**41,2**	**103**	**24,9**	**57**	**13,8**	**29**	**7,0**	**41**	**9,9**	**4**	**1,0**	**9**	**2,2**	**413**		
		C3	**120**	**42,7**	**75**	**26,7**	**29**	**10,3**	**11**	**3,9**	**37**	**13,2**	**3**	**1,1**	**6**	**2,1**	**281**		
		C4	**121**	**51,5**	**33**	**14,0**	**33**	**14,0**	**14**	**6,0**	**19**	**8,1**	**6**	**2,6**	**9**	**3,8**	**235**		

First of all, this frequency table shows that the material description questions delivered more (partial) descriptions compared to the fit questions, which could reflect the fact that they were easier to elaborate on. Overall, the categories of Sensorial, Associative, Ecological and Personality descriptions were most common. Next, the two experiential levels (Sensorial and Associative descriptions) were most common when describing the materials of the chosen products. However, in case of the fit description questions, more Ecological descriptions appeared, as well as Personality descriptions, which was expected. However, Ecological characteristics were cited more in the context of the negative fit question (e.g. not recyclable, not reusable, disposable, waste, etc.), whereas in the context of a positive fit, it was more related to their personality or values (e.g. I try to live sustainably). As the focus of this survey was on products materialized in plastic materials, the descriptions related to ecology surfaced spontaneously, which could fit within the current social debate.

6.4.3 Product Categories

Similar to the previous procedure, the uploaded pictures of plastic products were assessed visually and appointed to one of ten product categories in order to facilitate a comprehensive overview and to count the occurring frequencies. A typical product category that could be expected in the context of plastic materials, is that of Consumables which often contain single use plastics.

Several types of products were uploaded by different respondents. For example, regarding a positive personality fit, 13% of the respondents chose a re-usable water bottle, 6% a bread box, 4% a smartphone cover, computer or tv remote, and 3% a cup or flowerpot. By contrast, regarding a negative personality fit, 11% of the respondents chose a plastic bag or a bottle, 7% packaging, 4% a bread box or pot, and 3% a cup or a storage box.

Between the four clusters, small differences were detected on the top two of chosen products, however, the re-usable water bottle and bread box were most popular for a positive fit, as well as the plastic bag and bottle for a negative fit.

Table 6.4 depicts the counts of uploaded products within each product category and within a positive or negative fit with the personality. Overall, the three first categories in the table were uploaded most often. The greatest difference between a positive and negative fit could be found within the product category of Consumables that were most often negatively associated with the self. In addition, Electronics, Kitchen Utensils and Personal/Fashion items were found more within a positive fit compared to a negative fit.

Table 6.4. Frequencies and relative counts of the product categories for a positive and negative fit within the four clusters.

Product category	**Positive fit**										**Negative fit**									
	C1		**C2**		**C3**		**C4**		**Total**		**C1**		**C2**		**C3**		**C4**		**Total**	
	N	C%	N	C%	N	C%	N	C%	**N**	**C%**	N	C%	N	C%	N	C%	N	C%	**N**	**C%**
Consumables	5	9,8	3	5,9	4	8,5	3	8,8	**15**	**8,2**	15	30,6	24	49,0	9	22,0	10	33,3	**58**	**34,3**
Kitchen utensils	17	33,3	13	25,5	12	25,5	10	29,4	**52**	**28,4**	8	16,3	7	14,3	13	31,7	10	33,3	**38**	**22,5**
Electronics	9	17,6	13	25,5	8	17,0	11	32,4	**41**	**22,4**	6	12,2	6	12,2	1	2,4	2	6,7	**15**	**8,9**
Office	4	7,8	1	2,0	1	2,1	2	5,9	**8**	**4,4**	3	6,1	3	6,1	1	2,4	5	16,7	**12**	**7,1**
Interior	4	7,8	2	3,9	2	4,3	3	8,8	**11**	**6,0**	6	12,2	1	2,0	3	7,3	0	0	**10**	**5,9**
Pers./Fashion	4	7,8	6	11,8	6	12,8	2	5,9	**18**	**9,8**	4	8,2	2	4,1	1	2,4	1	3,3	**8**	**4,7**
Toys	0	0	2	3,9	2	4,3	1	2,9	**5**	**2,7**	1	2,0	1	2,0	1	2,4	0	0	**3**	**1,8**
Transport	1	2,0	2	3,9	1	2,1	0	0	**4**	**2,2**	0	0	0	0	0	0	0	0	**0**	**0,0**
Garden	0	0	2	3,9	4	8,5	0	0	**6**	**3,3**	0	0	0	0	0	0	0	0	**0**	**0,0**
Other	7	13,7	7	13,7	7	14,9	2	5,9	**23**	**12,6**	6	12,2	5	10,2	12	29,3	2	6,7	**25**	**14,8**
Total counts	**51**		**51**		**47**		**34**		**183**		**49**		**49**		**41**		**30**		**169**	

6.4.4 Descriptive Categories x Product Categories

In order to gain more insights in the relation between Material and Fit descriptions, the relative count of each description category (e.g. Sensorial) within each product category was calculated for both the positive fit (Table 6.5) and the negative fit (Table 6.6).

6.4.4.1 Positive Fit

When describing materials that fit their personality, respondents tend to refer in more than half of the times to sensorial attributes such as gloss, colour, flexibility, etc, but also with associative characteristics such as robust, high-quality, cheap, etc. In contrast, when describing the reason for a material's fit with the self, the distribution over the different descriptive categories is more even, with upmost attributes referring to personality characteristics, followed by associative, sensorial and ecological characteristics.

When taking a closer look at the different product categories, Consumables were mostly described with sensorial and functionality descriptions, and their fit with personality and habit/interest descriptions. Kitchen utensils and their fit were mostly described with sensorial, associative (not fit) and ecological descriptions. Electronics and Office items and their fit were mostly described with sensorial and associative descriptions, although the former's fit was described with personality instead of associative descriptions. Interior and Personal/Fashion items were described with sensorial and associative descriptions, whereas the fit of the former was described with associative, personality and functionality descriptions, and that of the latter with personality descriptions.

Regarding the descriptive categories specifically, Sensorial descriptions were found most for Electronics, Office and the Office fit. Associative descriptions occurred mainly for Interior and Personal/Fashion products, and the fit of Office products. Ecological descriptions were used most in the case of Kitchen utensils and their fit. Functionality descriptions were found primarily for Consumables and the fit of Interior products. Finally, personality descriptions were used approximately half of the times for the fit description of Consumables and Personal/Fashion. The latter could be expected as such products are cherished and closely linked to the identity of people.

Table 6.5. Relative count of description categories per product category within a positive fit.

Product category	**Material description**							**Fit description**						
	Sensorial	Associative	Ecological	Functionality	Personality	Shape	**Total**	Sensorial	Associative	Ecological	Functionality	Personality	Habit/Interest	**Total**
Consumables	61%	4%	9%	17%	4%	4%	**100%**	7%	7%	7%	0%	50%	29%	**100%**
Kitchen utensils	57%	17%	16%	7%	1%	2%	**100%**	23%	9%	36%	18%	10%	4%	**100%**
Electronics	68%	16%	0%	8%	6%	2%	**100%**	27%	12%	8%	13%	29%	12%	**100%**
Office	68%	21%	5%	0%	0%	5%	**100%**	33%	50%	0%	0%	8%	8%	**100%**
Interior	46%	38%	0%	8%	8%	0%	**100%**	6%	35%	0%	24%	35%	0%	**100%**
Personal/Fashion	55%	32%	3%	8%	3%	0%	**100%**	10%	19%	10%	5%	52%	5%	**100%**
Toys	78%	0%	0%	6%	11%	6%	100%	20%	0%	0%	40%	20%	20%	100%
Transport	57%	29%	0%	7%	7%	0%	100%	29%	57%	0%	0%	14%	0%	100%
Garden	63%	31%	0%	0%	6%	0%	100%	0%	33%	17%	0%	17%	33%	100%
Other	68%	14%	4%	7%	5%	2%	100%	3%	38%	17%	3%	34%	3%	100%
Total counts	**255**	**77**	**25**	**30**	**17**	**8**	**412**	**44**	**47**	**41**	**29**	**61**	**19**	**241**

6.4.4.2 Negative Fit

When describing materials that do not fit with their personality, in two third of the cases respondents refer again to sensorial attributes, followed by associative and ecological characteristics. In contrast, when describing the fit reason, the descriptive categories are again more evenly distributed, with a focus on ecological, associative and personality characteristics. It is striking that ecological aspects are – spontaneously – often considered in the context of materials that do not suit one's personality.

All product categories were mainly described with sensorial characteristics, but also with associative descriptions in the case of Consumables, Kitchen utensils, and Electronics. The fit of Consumables was mostly described with ecological descriptions, the fit of Kitchen utensils with ecological, associative and personality descriptions, the fit of Electronics with sensorial descriptions, the fit of Office products with sensorial and personality descriptions, the fit of Interior products with sensorial, associative and personality descriptions, and finally the fit with Personal/Fashion items with associative descriptions.

Regarding the descriptive categories specifically, sensorial descriptions were found most for Office products and the fit of Electronics. Associative descriptions occurred mainly for Electronics and the fit of Personal/Fashion items. Ecological descriptions were used primarily for Consumables and their personality fit. Personality descriptions were found most for the fit of Interior products.

Table 6.6. Relative count of description categories per product category within a negative fit.

Product category	Material description							Fit description						
	Sensorial	Associative	Ecological	Functionality	Personality	Shape	**Total**	Sensorial	Associative	Ecological	Functionality	Personality	Habit/Interest	**Total**
Consumables	50%	27%	19%	3%	1%	1%	**100%**	11%	17%	48%	2%	20%	2%	**100%**
Kitchen utensils	51%	35%	10%	3%	0%	1%	**100%**	7%	29%	31%	2%	24%	7%	**100%**
Electronics	50%	44%	0%	0%	3%	3%	**100%**	42%	17%	4%	4%	17%	17%	**100%**
Office	83%	3%	0%	7%	0%	7%	**100%**	35%	18%	18%	0%	24%	6%	**100%**
Interior	65%	18%	0%	6%	6%	6%	**100%**	33%	27%	7%	7%	27%	0%	**100%**
Personal/Fashion	62%	33%	0%	5%	0%	0%	**100%**	25%	50%	0%	8%	8%	8%	**100%**
Toys	33%	33%	0%	33%	0%	0%	100%	20%	40%	0%	0%	0%	40%	100%
Other	83%	8%	7%	1%	1%	1%	100%	0%	31%	31%	13%	5%	21%	100%
Total counts	**430**	**109**	**51**	**13**	**5**	**8**	**616**	**37**	**57**	**70**	**11**	**42**	**21**	**238**

6.4.5 Positive Versus Negative Fit

The greatest increase or decrease of material descriptions between a positive and a negative fit could be found in the case of Toys and sensorial and associative attributes, however, this was a rather small product category. More differences could be found in the fit descriptions concerning the personality characteristics that were attributed to Consumables and Personal/Fashion products, concerning the ecological properties of Consumables, concerning the functionality characteristics of Toys, and finally concerning the associative characteristics of Office, Personal/Fashion products and Toys.

6.4.6 Link to Personality Clusters

Based on the obtained information of the previous Sections, the four personality clusters could be further detailed and described.

6.4.6.1 Cluster 1 – Active Functionalists

Respondents within Cluster 1 are **active** and emotional personalities that focus mainly on **functionality** aspects of materials in relation to themselves, as well as associative characteristics. Cluster 1 represents a rather **young** target group (mean age = 25 years) with a 59/41 ratio of male/female. Regarding plastic materials in products that reflect their personality, they refer to Consumables and functional products in a Kitchen or Office environment, such as a re-usable bottle (17%) and a bread box (4%), whereas in case of a negative fit, Electronics, Interior and Personal/Fashion items are mentioned.

6.4.6.2 Cluster 2 – Responsible Ecologists

Respondents within Cluster 2 are **responsible** and emotional personalities that focus mainly on **ecological** and associative aspects of materials in relation to themselves, supplemented with a few personality descriptions. Cluster 2 is the only cluster with a majority of **females** (55%) and its mean age is 31 years. Regarding plastic materials in products that do not reflect their personality, they clearly refer to non-sustainable and disposable Consumables and to Electronics, while Kitchen products suit their personality better, such as a re-usable bottle (15%), a bread box (4%), but also a smartphone cover (6%). Cluster 2 respondents dislike disposable plastic bags (13%) and bottles (11%).

6.4.6.3 Cluster 3 – Personality-Oriented People

Respondents within Cluster 3 are active but have a predominantly **aggressive** personality and focus mainly on **personality** and **associative** aspects of materials in relation to themselves. Cluster 3 consists mainly of **men** (77%) and is mean age is 29 years. Regarding plastic materials in products that reflect their personality, they refer to Personal/Fashion items and Kitchen utensils, such as a re-usable bottle (10%), a bread box (6%) and a flowerpot (8%).

6.4.6.4 Cluster 4 – Rational & Hands-on Simplists

Respondents within Cluster 4 appreciate **simplicity** and little activity. They are rational and hands-on and describe materials in relation to themselves with tangible **sensorial** characteristics, **shape** and habit aspects. When describing their positive or negative fit, they also mention ecological descriptions. Cluster 4 has a rather equal gender distribution (53/47 male/female) and a mean age of 31 years. Regarding plastic materials in products that reflect their personality, they refer to practical Kitchen utensils, Electronics and Interior items, such as a bread box (11%) and a re-usable bottle (9%), whereas in case of a negative fit, disposable bottles (14%) and plastic bags (9%) are mentioned.

6.5 Discussion

The presented research aimed to explore possible relationships between (plastic) materials, their expressive value and the link with the personality of the consumer, whereby personality in this research was defined in terms of the five brand personality traits. However, these five traits might be too limited for a meaningful cluster analysis as they are derived from a more extensive set of personality traits. Building upon the frequent ecological descriptions that emerged in this survey, additional segmentation items could be added to include sustainable behaviour, such as items of the NEP scale as a benchmark for pro-environmental attitudes (Anderson, 2012), in order to create a more elaborate cluster analysis.

Regarding the survey methodology, a collaboration was set-up with the mobile tool of a survey company that provided fast access to respondents through their mobile app. Therefore, the context or environment in which a respondent is using the app might influence their responses. The effect of this environment has been toned down by first notifying the respondents of the interview and telling them by means of a video to get ready and look for a suitable product. Even with this measure, still a lot of the received products seem to be related to their desk or a break, places where a many of the users use the app. This might also explain the high frequency of uploaded products such as a bread box (lunch break), tv remote (near sofa) or computer mouse (office environment).

This exploration has shown some interesting opportunities for further research. Material descriptions consisted mainly of sensorial, associative and ecological characteristics, while fit descriptions included personality traits, ecological, sensorial and associative characteristics. Therefore, these four descriptive categories might offer an interesting base for next studies, using the four product categories that occurred most often (i.e. Consumables, Kitchen utensils, Electronics and Personal/Fashion items) as concrete cases in the experimental set-up. In this context, specific products such as the bread box, re-usable bottle, smartphone cover or flowerpot could also be further explored.

6.6 Conclusion

In a circular economy, one of the strategies to extend a product's lifetime is by creating product attachment, which can be positively affected by the congruity with one's personality. As materials are one of the building blocks of products, this qualitative exploratory research investigated the material perception of plastic everyday consumer products, and the link with the fit with the personality of the consumer.

The main output of this research resulted in four consumer clusters based on their personality and their material (fit) descriptions: (i) a younger cluster that is active and emotional and focusses on functionality, (ii) a predominantly female cluster that are responsible ecologists, (iii) a predominantly male cluster that is rather aggressive and focusses on personality and associations, and (iv) a simple and rational cluster that uses hands-on sensorial and shape-related descriptions.

Overall, sensorial, associative, personality and ecological characteristics are used most commonly in describing materials and their fit with one's personality. In addition, frequent product categories are Consumables, Kitchen utensils and Electronics, with a high occurrence of re-usable drinking bottles and bread boxes, that could be interesting product cases for further studies.

Conclusively, based on these new insights on how consumers describe materials in relation to their personality, this paper provides guidance for future quantitative research on materials from the perspective of consumer personality segmentation.

Chapter 7 is submitted as an article for publication in Journal of Design Research.

7. The Effect of Consumer Segmentation and Product Types on Experiential Material Preferences

Veelaert Lore, Du Bois Els, De Pelsmacker Patrick, Moons Ingrid

Abstract: Besides functional and technical material properties, experiential material qualities are receiving more attention in product design. However, the effect of user characteristics on perceptions about materials is understudied and usually limited to demographic variables. Combining insights from design research and consumer behaviour research, this paper aims to develop a rich segmentation of consumers based on seven individual self-expressive values (personality traits, personal values, environmental concern, green self-identity, consumer innate innovativeness, materialism, and aesthetic experience). It investigates the effect of these segments as well as four product types (Informative, Affective, Habitual, and Satisfaction products) on the preferences for experiential material qualities. Four user segments are identified that differ in preferred experiential qualities, and can as such be used in future studies: Traditional Curiosity Seekers, Realistic Go-Getters, Green Experience Lovers, and Humdrum Familiars. Moreover, preferences for materials also differ across product types. Materials selection in future projects can build upon these segments and product types in order to better reach the target group and acquire a better position in the heart and mind of consumers.

Keywords: *Materials Experience, Experiential Material Qualities, Consumer Segmentation, Material Preferences, Individual Self-Expressive Values, Product Types*

7.1 Introduction

Developing superior materials as better alternatives to convention is the aim of material research. It is of great importance to get insights into material selection (taking advantage of capabilities of materials), in how to design with emerging materials (finding appropriate and innovative applications), and in developing new materials (emerging design challenges and interventions) (Jansen & TU Delft, 2021). Designers select or design with materials not only for their technical and functional capabilities (Ashby & Johnson, 2012), but also for what they express and elicit to users. Indeed, alike the products they are embodied in, materials comprise both physical or tangible properties and symbolic characteristics (Arabe, 2004; Hasling, 2016; Ljungberg & Edwards, 2003; Manzini, 1986; Pedgley, 2009; van Kesteren, 2008).

The functional/technical properties of materials are already extensively investigated, for example in the context of the production process and mechanical feasibility. In contrast, the user-centred characteristics or experiential qualities (symbolic value), have received less attention, but are gaining a growing interest in product design (Giaccardi & Karana, 2015; Karana et al., 2014). A product's appearance determines a great part of its attractiveness at the first encounter. A product is often preferred over others when it is aesthetically appealing and when it is carrying the appropriate symbolic value (van Rompay et al., 2009). Hence, to appeal to consumers, it is important to respond to symbolic/experiential as well as to functionally value (Creusen & Schoormans, 2005; Giaccardi et al., 2014; Giaccardi & Karana, 2015; Haase & Wiedmann, 2018; Karana, 2009). Indeed, experiential qualities drive attitude formation, preference, decision making, and product adoption (Hassenzahl, 2013; Schmitt et al., 2015).

A relevant framework that presents a comprehensive understanding of material-people relationships within a design context is the Materials Experience Framework (Karana et al., 2014). It comprises four experiential levels that are interrelated and as a whole create our materials experiences (Giaccardi & Karana, 2015). Karana (2010, p. 276) states that there is a "dynamic action between a user and a material in which the material obtains its meaning". Since the product in which the material is embodied affects this relation as well, influential variables can be derived from both product and user perspective (Rognoli, 2010). The former relates to a product's function or form (Kapkın & Joines, 2018; Karana et al., 2007), while the latter refers to factors such and a user's age, gender (Karana & Hekkert, 2010), culture (Karana, 2004; Karana & Hekkert, 2010; Ljungberg & Edwards, 2003), personal values (Veelaert et al., 2018), or personality (Veelaert et al., 2021).

As opposed to a mass marketing approach, market segmentation is one of the fundamental strategic tools to address the diverse needs of consumers today (Berson et al., 2000; Myers, 1996). Market segmentation aims at identifying consumer groups or clusters who share similar needs and characteristics (Dibb & Simkin, 1996; Punj & Stewart, 1983). Although the importance of user aspects has been recognized and demonstrated in literature, their effect on materials experience is under-researched, and studies that consider consumer characteristics often remain limited to demographic variables (Veelaert, Du Bois, et al., 2020).

Using psychographic user aspects such as norms, self-identity considerations and values, would add to a richer insight and a better understanding of user segments and will offer valuable opportunities for both marketeers and product designers when selecting appropriate materials for successful and meaningful products.

Encounters with materials in our everyday life most often happen through products we interact with. Users develop different kinds of relationships with products they use, and therefore, the meaning of the product may also interact with the experiential meaning of the material it is made of (Fenko et al., 2010; Karana, 2010; Karana, Pedgley, et al., 2015; Pedgley, 2014). Beside the dichotomy that is often used based on functional versus symbolic product meaning, previous research has tried to grasp the user-product relationship by dividing products into product categories based on consumers' involvement with the product and their rational or emotional relation with them (Berger, 1986; Hong, 2006; Vaughn, 1980). The type of product influences the way a material is perceived and experienced to great extent, and vice versa (Arabe, 2004; Hope et al., 2012; Karana & van Kesteren, 2006).

The current study aims at developing a rich segmentation of consumers based on individual self-expressive values (including personality traits, norms and self-identity considerations), and at testing how these different segments perceive the experiences with materials differently. Additionally, we explore the effect of the type of product on the preference for materials experiences, and how the type of product moderates the relationship between consumer characteristics and materials experience. Our work is exploratory, and therefore guided by the following research questions:

- RQ1: Based on psychographic characteristics, how can consumers be divided into meaningful clusters that relate to experiential material preferences?
- RQ2: How can consumers be allocated to segments in future studies?
- RQ3: What is the relation between segments of consumers and preferred experiential qualities of materials?
- RQ4: What is the effect of product types on preferred experiential qualities of materials?

- RQ5: Is the relation between user segments and preference for experiential qualities different for different product types?

The current paper adds to existing knowledge in several ways. It combines insights from design research and consumer behaviour research. It develops an integrated model of psychographic consumer characteristics (individual self-expressive values) related to materials experience and their relation with the well-known Materials Experience framework that captures consumers' symbolic experiential responses to these materials. Furthermore, it provides the design and consumer behaviour insight that product type is an important determinant of how consumers experience materials.

Van Kesteren (2008, p. 23) emphasizes that "product designers have to use their experience, together with expertise from market researchers and consumers to predict and evaluate the user-interaction qualities with a product for predefined target groups". The current study informs and helps designers. It provides insight into consumer characteristics grouped in well-defined and approachable market segments that drive experiential perceptions of materials, and the effect of product types on these perceptions. Delivering value-related needs and wants of end-users is considered as a key to a long term customer relationship (Kotler & Armstrong, 2017). Materials selection can be deployed to better reach a target group, to increase involvement, build a better relationship and thus acquire a better position in heart and mind (Ko et al., 2018).

In what follows, the conceptual framework is discussed in Section 2. Section 3 explains the method of the study and Section 4 reports the analyses and results. In Section 5, a discussion of the results and the implications of the study are highlighted, and Section 6 brings together the research conclusions.

7.2 Conceptual Framework

7.2.1 Materials Experience

In the current study, we build on a framework and measurement instrument that presents a comprehensive understanding of material-people relationships in a design context: the Materials Experience Framework (Karana et al., 2014). It comprises four experiential levels that are interrelated and as a whole create our materials experiences (Karana et al., 2014). First, the sensorial level reflects the experiences of our senses with materials (e.g. is it smooth or hard), second, the interpretive level includes meanings and associations (e.g. to what extent is it masculine or cheap), third, the affective level entails emotions (e.g. pleasure or surprise), and fourth, the performative level refers to actions with materials (e.g. bending or stroking). These four levels have been integrated in the Ma2E4 toolkit (Karana et al., 2014); an instrument to explore a material's experiential qualities and their interrelationships. However, the first two levels – sensorial and interpretive – are most elaborated and quantifiable (using semantic scales) as compared to the last two levels for which there are less substantiated or validated vocabularies available. Therefore, in the context of the current quantitative approach, our study focuses on these two main levels that can be appropriately measured by means of well-established scales (see Appendix 7A). Also other authors have developed similar scales that measure, for instance, sensorial attributes and interpretative characteristics of materials, e.g. (Ashby & Johnson, 2012; Sauerwein et al., 2017; Veelaert, Du Bois, et al., 2020). They will also be taken into account in the empirical study.

7.2.2 User Characteristics that Relate to Materials Experience

In the context of materials experience, several characteristics on the basis of which people may differ, are considered relevant for user segmentation as we expect them to influence the way consumers react to materials. All chosen characteristics relate to the way people tend to express themselves (individual self-expressive values). We consider three types of self-expressive values in the context of materials experience. Based on previous work (Veelaert et al., 2018, 2021), we include personality traits as well as personal values which are considered as drivers of material preferences. Second, we include environmental concern and green self-identity to build a link with sustainable perception of materials. Third, as materials are embodied in products, we include product-related personal values such as innovativeness, aesthetic experience and materialism.

7.2.2.1 Personality Traits

Personality traits describe what people are like (Schwartz, 2012). They reflect people's characteristic patterns of thoughts, feelings, and behaviours. Although such traits can fluctuate in frequency and intensity during a lifetime, they are consistent and stable, and they are considered to be universal across age and culture. Geuens et al. (2009) developed a personality traits measurement scale that is validated across products and cultures, and comprises the following dimensions: Responsibility, Activity, Aggressiveness, Simplicity, and Emotionality. This scale is considered useful for measuring human as well as product personalities (Moons et al., 2020). Personality traits have been applied in relation to material perception before (Choi, 2017). As materials contribute substantially to product experience, thoughts, feelings and behaviours, we expect that personality traits of consumers will influence these experiences.

7.2.2.2 Personal Values

Rokeach (1973) defines values as beliefs that lead to end states or behaviour that are desirable, and that vary in importance or priority. They are motivational goals, transcending specific situations. Building upon the work of Rokeach, Schwartz (1992) and Schwartz and Sagiv (1995) developed a framework of ten motivational values that can be used to characterise cultural groups, societies, and individuals, to trace change over time, and to explain the motivational bases of attitudes and behaviour. Each type of motivation is related to two bipolar dimensions: 'openness to change' (Hedonism, Stimulation, Self-Direction) versus 'conservation' (Security, Conformity, Tradition) values, and 'enhancement' (Achievement, Power) versus 'self-transcendence' (Universalism, Benevolence) values.

Several studies illustrate the link between personal values and perceptions of materials and products. For instance, Scherer, Emberger-Klein, & Menrad (2018) found that higher values for universalism and benevolence (self-transcendent values) are related to a higher interest of consumers in bio-based plastic sports equipment. Veelaert et al. (2018) found links between materials' perceived expressive values and consumers' personal values. For example, the material granite showed a high fit with conservation values, while gold fitted with self-enhancement values that people adhere to and also see expressed in these materials. Agost and Vergara (2014) found that personal values can modify the relationship between meanings, emotions, and product preferences. Kitsawad and Guinard (2014) found a strong link between Openness to Change, and to a lesser extent also between Conservatism, and several sensory properties of chips and juice products.

Additionally, values also appear to be related to several other user characteristics we use in our study, such as personality traits (e.g., the 'conscientiousness' trait positively correlates with achievement and conformity values (Roccas et al., 2002)), environmental attitudes (e.g., more environmentally concerned consumers are mainly found in the self-transcendence domains and openness to change, as compared to conservation and self-enhancement (Grunert & Juhl, 1995)), ecological consumer behaviour (e.g. González, Felix, Carrete, Centeno, & Castaño (2015) suggest that values and environmentally friendly behaviours are related, e.g. non-ecological consumers show low openness to change values), and green self-identity (Barbarossa et al., 2017). We thus expect that personal values relate to materials experience.

7.2.2.3 Environmental Concern

Consumers have different evaluative responses towards environmental issues (Fransson & Gärling, 1999; Schultz, 2001). The New Environmental Paradigm (NEP) (Dunlap, 2008) is a widely used environmental concern framework and measurement scale. The NEP contains five dimensions: balance of nature, limits to growth, human domination (anti-anthropocentrism), anti-exceptionalism, and ecocrisis (Amburgey & Thoman, 2012; Dunlap, 2008; Dunlap, Liere, et al., 2000). Environmental concern has been identified as an antecedent of many consumer responses and behaviours, such as environment protection (Kaiser et al., 1999), household energy use (Poortinga et al., 2004), recycling, purchasing environmentally friendly products (Bamberg, 2003; Bamberg & Möser, 2007) and sustainable transport policies (J. J. Soto et al., 2021). Høibø, Hansen and Nybakk (2015) found a link between environmental attitudes and material preferences in the context of wood as a building material; consumers with strong environmental values would be the best target for wood-based housing. Since materials and products can trigger different perceptions and meanings related to their environmental impact, we expect that environmental concern has an impact on how materials are experienced.

7.2.2.4 Green Self-Identity

Following the identity theory (Stryker & Burke, 2000), consumer behaviour and attitudes are motivated by self-identity, i.e. how one sees himself/herself as occupant of specific roles (Barbarossa et al., 2015; Stets & Burke, 2000). People aim to be consistent with an identity standard by behavioural actions to meet accompanying expectations (Arnocky et al., 2007). Barbarossa et al. (2015, p. 150) define green self-identity as "an individual's overall self-perception based on his/her mental identification with the typical green consumer (Sparks & Shepherd, 1992)". Green self-identity has been shown to predict material- and product-related perceptions. For instance, Confente, Scarpi, & Russo (2020) found that higher green self-identity leads to higher value perceptions of bioplastic products. Moreover, green self-identity is linked to other characteristics used as potential segmentation variables in the current study. For instance, Barbarossa et al. (2017) studied personal values and green self-identity as predictors of electrical car adoption, and found that Schwartz's four value domains affect green self-identity effects, e.g. conservative consumers convert their green self-identity less into adoption intentions. Consequently, green self-identity can actuate pro-environmental or eco-friendly consumption behaviour, which might also be reflected in the perception and meaning of products and their materials, for example a preference for recycled or other sustainable materials.

7.2.2.5 Consumer Innate Innovativeness

Consumer innate innovativeness is defined by Steenkamp et al. (1999, p. 25) as "the importance people attach to buying new products at an early stage rather than remaining with previous choices and consumption patterns". Some scholars consider consumer innovativeness as domain-specific (Gatignon & Robertson, 1991), but it is mostly seen as a personal trait (Cestre, 1966; Midgley & Dowling, 1978; Roehrich, 2004; Steenkamp et al., 1999). Innovativeness has been conceptualized and measured in different ways (Raju, 1980; Roehrich, 2004). Roehrich's (1995) scale combines two dimensions: social innovativeness based on the need for uniqueness (Snyder & Fromkin, 1980), and hedonist innovativeness based on the need for stimulation (Berlyne, 1960). Innovativeness has been found to be relevant in various consumer behaviour domains. For instance, Mishra (2014) used different consumer decision styles and consumer innovativeness to build five homogeneous segments. Morton, Anable, & Nelson (2017) defined market segments for electric vehicles through cluster analysis, and found Car Enthusiasts and Early Adopters to have a high innate innovativeness compared to Weekend drivers and Keen Greens. Osburg, Strack and Toporowski (2015) found that high consumer innovativeness led to an increased acceptance of wood-polymer composites and other eco-innovation materials. Similarly, innovativeness can be expected to relate to perceptions, sensory experiences and meanings about materials.

7.2.2.6 Aesthetic Experience

Aesthetic Experience is defined as the appreciation of beauty by the consumer (Wagner, 1999) and refers to the pleasure that the appearance or look of a product can evoke independent of its utility (Holbrook, 1980). Materials are the physical building blocks of products and as such have a great influence on the aesthetic value of a product (Fleming, 2014; Zuo et al., 2013). Products that are most aesthetically appealing will be generally preferred over alternatives that have a similar function and price. Thus, the perceived experiential qualities of a material will also influence whether a product will be bought are not (Zuo, 2010). However, the sensory experience and meaning of materials may be perceived differently depending on a person's aesthetic experience. Hung and Chen (2012) found a relationship between aesthetic preference and novelty/typicality of products (chairs) and emphasized the importance of trendiness/modernity as a factor affecting the perception of consumers. In the context of art and architecture, Cleridou and Furnham (2014) found the personality trait of openness to experience to be the best predictor of aesthetic preferences. We therefore expect a relation between aesthetic experience and materials perception.

7.2.2.7 Materialism

Belk (1984, 1985) defines Materialism as "the importance a consumer attaches to worldly possessions; at the highest levels of materialism, such possessions assume a central place in a person's life and are believed to provide the greatest sources of satisfaction and dissatisfaction in life" (Belk, 1984, p. 291). Richins & Dawson (1992, p. 307) define materialism as a value: "the importance ascribed to the ownership and acquisition of material goods in achieving major life goals or desired states". Their material value scale comprises three dimensions of possessions – 'centrality', 'success', and 'happiness'. People that are more materialistic, value tangible products more than intangible experiential products (Nicolao et al., 2009). Tian and Lu (2015) found that materialism influences consumers' preferences for materials-based products, similar to Zarco (2014) who studied the influence of materialism on consumer preferences and product attributes. So, in our research we explore to what extent materialism is related to experiential material qualities (i.e. sensorial attributes and interpretive characteristics).

7.2.3 Product Types

Considering the effect of the context in which a product is used, we assume that the type of product also influences perceptions of materials. A popular product classification model in consumer research that is often used for strategic marketing and research purposes (Cheong & Cheong, 2021) is the FCB grid (Berger, 1986; Vaughn, 1980). This framework consists of four quadrants that represent four different product categories based on "the consumer's mind space"

(Ratchford & Vaughn, 1989). The grid classifies products on the basis of two dimensions, i.e. whether a purchase requires high versus low involvement and whether thinking versus feeling is dominant in the decision process, resulting in four types of product: (i) informative products for high involvement and rational thinking, (ii) affective products for high involvement and emotional feeling, (iii) habitual products for low involvement and rational thinking, and (iv) satisfaction products for low involvement and emotional feeling (Ratchford & Vaughn, 1989). For example, Chien et al. (2014) investigated the impact of product style (i.e. form, material and colour) on the perceptions of rationality versus emotion, while Martin (1998) explored product attributes of high-involvement products. Since materials are embedded in products, our research takes this product context into account to explore how this context affects preferences for materials in the four FCB product types.

7.3 Method

We first explain the procedure by means of which we developed stimuli for the four product types that were later on used in the main study. In subsequent sections, we describe the procedure of the main study, the measures used, and the analyses we did.

7.3.1 Development of Stimuli for the Different Product Types

In order to study the role of product types, we developed stimuli that represent the four types of products in the FCB grid. A set of familiar everyday consumer products was collected based on a pre-study with colleagues at the departments of Product Development and Marketing (n=16), who were asked to list one or more products that they consider as emotional (feeling), rational (thinking), high involvement, and low involvement purchases. This resulted in a list of 115 products, of which 20 products were proposed multiple times (2 to 8 times each). Next, to select exemplary everyday consumer products for each of the quadrants of the FCB grid, an online survey with 66 participants (35 male, 31 female, average age of 36) of the same departments was conducted. For each of the 20 products, a mood board was composed with various examples. They were asked to evaluate a random set of half of these products, presented in a random order, and to indicate whether it was an emotional/rational product, and a low vs. high involvement product on a dichotomous scale. In total, each product was evaluated by 31 to 36 participants, and a percentage was calculated for the frequencies of each choice (high versus low involvement, and feeling versus rational). The following products scored highest in their category: eyeglasses frame (91.1% emotional, 82.4% high involvement), flower pot (80.0% emotional, 81.8% low involvement), vacuum cleaner (93.9% rational, 75.6% high involvement), and shower wiper (88.6% rational, 91.4% low involvement). Figure 7.1 shows the four selected product categories by means of various types of each product, that were used in the main study.

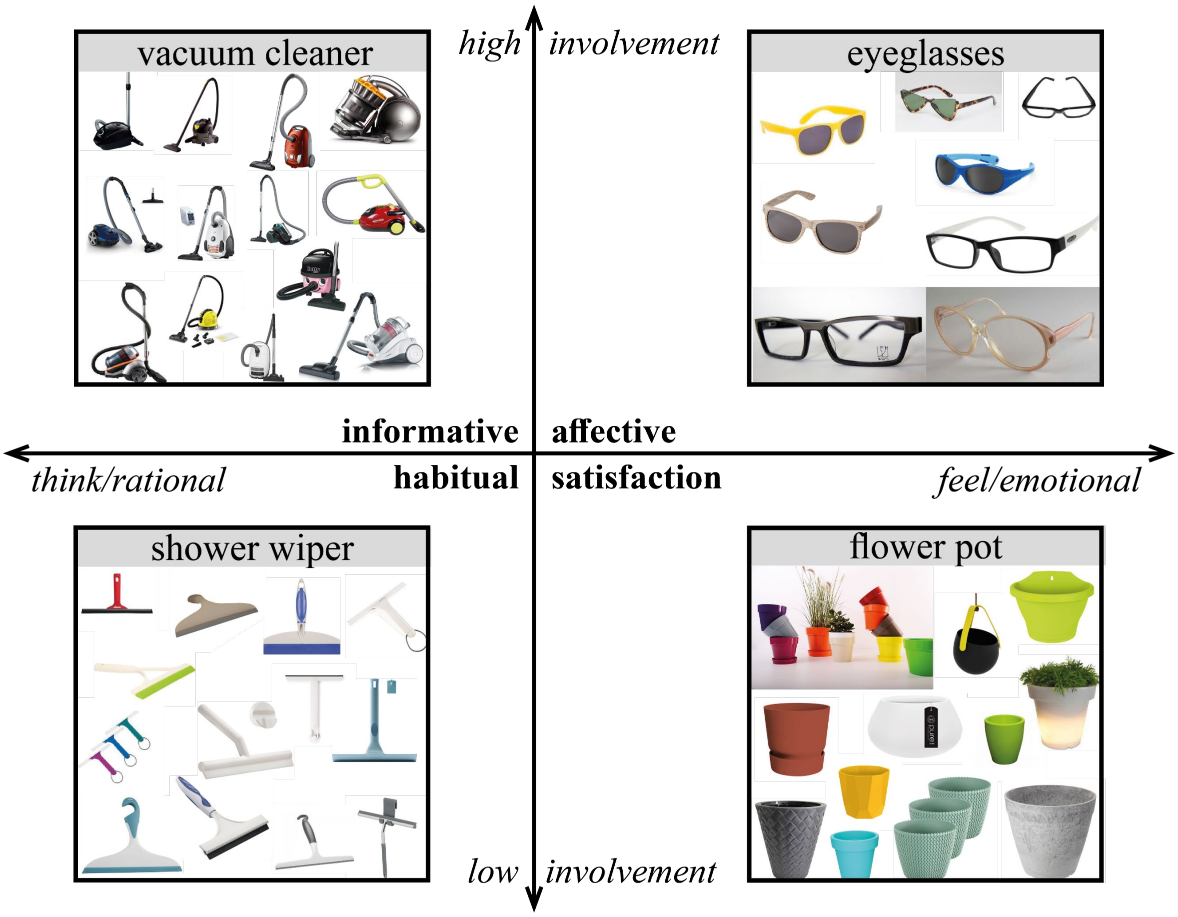


Figure 7.1. Compilation of products for each of the four product categories.

7.3.2 Procedure of Main Study

In December 2019, data was collected by means of an online survey in a quota sample of 1500 consumers through collaboration with a market research agency. After data collection, respondents were removed that did not pass the attention check (n=30), the minimal duration check of 7 minutes (n=25), and a straight liner check (n=136). The final sample thus consisted of 1309 respondents. Appendix 7B shows the socio-demographic composition of the sample. The sample was representative of the Flemish population in Belgium with respect to age, gender, and social class. First, participants scored the different scales for each indivual self-expressive value included in our study (personality traits, personal values, environmental concern, green self-identity, consumer innate innovativeness, aesthetic experience, and materialism). The order of the measurement scales as well as the order of the scale items within each scale were randomized. Next, participants were randomly exposed to one of the product type stimuli (four-level between-subjects design). They then scored the stimuli on their preference for the sensorial and interpretive material characteristics, again presented in a randomized order. Afterwards, participants answered a set of questions related to the product type stimuli manipulation check. Finally, socio-demographics were asked, such as age, gender, education, region, income, and household composition.

7.3.3 Measures

The constructs were measured as described below. All scales and items can be found in Appendix 7C and 7D. For every multi-item construct, a factor analysis was used to reduce the scale while minimizing the loss of variance in order to facilitate the interpretation of underlying constructs and cluster analysis later on (Rummel, 1970). We used principal components analysis with Varimax rotation, using the following decision rules:

- Individual items should have communalities > .200 (Child, 2006).
- All factor loadings of an individual item should not be < .320 (Tabachnick & Fidell, 2007).
- Items that load high on multiple factors should have cross loadings < 75% (Samuels, 2017).
- Preferably, factors should have an Eigenvalue > 1 according to the criterium of Kaiser (Conway & Huffcutt, 2003).
- The Kaiser-Meyer-Olkin (KMO) test should indicate values > .500 (Avkiran, 1994; Cerny & Kaiser, 1977; Field, 2013), and for the Bartlett's test of sphericity the p-value should be <.05 (Grace & O'Cass, 2004).
- Lower values on communalities and factor loadings could be accepted as the sample is relatively large (Stevens, 2012).

Additionally, for all remaining multi-item scales (see Appendix 7D), a Cronbach's Alpha analysis was carried out, and in case of Alpha >.60, a mean score of their items was calculated to arrive at the variables used in further analyses. Hair et al. (2019) and Barbarossa et al. (2017) qualify an Alpha >.60 as 'moderate' or 'acceptable' in case of scales with a small number of items.

7.3.3.1 Dependent Variables

The dependent variables were 30 items in two dimensions: a set of 14 sensorial attributes and 16 interpretive characteristics as representation of the experiential qualities of materials. Respondents were asked to indicate to what extent they preferred each of the 30 items on a five-point bipolar semantic scale (e.g. -2 very matte, -1, 0, 1, +2 very glossy). As product categories are used as stimuli in a large online survey, preference for experiential qualities was questioned, instead of actual perception of these qualities in a real life, tactual set-up.

The 14-item scale to measure sensorial attributes of materials was based on (Ashby & Johnson, 2012; Karana, 2009; Karana et al., 2009a; van Kesteren et al., 2007b; Veelaert, Du Bois, et al., 2020). For a clearer understanding of participants' perceptions and to avoid respondent fatigue, we condensed the technical attributes of elasticity, stiffness, ductility and brittleness mentioned in the literature into one item 'deformability'. The 16-item scale for interpretive characteristics was based on Karana's (2009) nine material meanings, extended with a selection of items taken from Ashby and Johnson (2012) and van Kesteren, de Bruijn, & Stappers (2007b). All items can be found in Appendix 7D.

PCAs were conducted separately for the sensorial and the interpretative items. They did not lead to a meaningful factor structure. Consequently, all 30 items were used as separate dependents in subsequent analyses.

7.3.3.2 Self-expressive Values as User Characteristics

The measures for the user characteristic constructs were (modifications of) existing Likert scales used in earlier comparable research settings (see Appendix 7C and 7E). All items were randomized for each construct, and also constructs were randomized to neutralize order effects.

Personality traits: A 12-item scale was used to measure Geuens, Weijters, and De Wulf's personality scale (2009). Respondents were asked to indicate to what extent the characteristics matched their personality on a 5-point Likert scale. A PCA with Varimax rotation was conducted, confirming this five-factor structure. All items loaded sufficiently exclusive on one factor (Activity, Responsibility, Emotionality, Simplicity, and Aggressiveness) (66.1% of variance explained). However, three factors showed Alphas lower than 0.6 and therefore we retained the single items. The final variables to be used in further analysis were: (1) Activity: Active, Dynamic, Innovative, (2) Responsibility: Responsible, Down to earth, Stable, (3) Romantic, (4) Sentimental, (5) Ordinary, (6) Simple, (7) Aggressive, and (8) Bold.

Personal values: Schwartz' (1992) short value scale (SVS) of 10 items was used to measure to what extent respondents find each of the ten value orientations important in their life (Goldberg, 1981; Krystallis et al., 2012; Lindeman & Verkasalo, 2005; Schwartz, 1992). Each value was rated on a 9-point importance scale: 'as a guiding principle in my life, this value is': -1=opposed to my values, 0=not important, 3=important, 6=very important, 7=of supreme importance (Hansla et al., 2008; Schwartz & Sagiv, 1995).

A PCA with Varimax rotation was carried out on the scores of the ten value items, and revealed three relevant factors (60% of variance explained). This structure was different from the initial four dimensions as defined by Schwartz (1992). The final variables to be used in further analysis were called: (1) Intrinsic Fulfilment: Self-Direction, Universalism, Benevolence, (2) Conservation: Security, Tradition, Conformity, and (3) Extrinsic Augmentation: Stimulation, Hedonism, Achievement, Power.

Environmental concern: To measure environmental concern, the New Environmental Paradigm (NEP) Scale was used (Dunlap, 2008), which is comprised of fifteen items. Respondents were asked to indicate the strength of their agreement or disagreement with the statements on a 7-point Likert scale. A principal components analysis with Varimax rotation showed four factors and multiple items that did not exclusively load on one factor and had low Alphas. However, as the Alpha of the total set of items was high with a value of 0.829, we decided to continue with one variable in further analysis, i.e. the mean of all NEP items. Combining all items into a single measure for environmental concern is consistent with other previous studies (Dunlap, Van, et al., 2000).

Green Self-Identity: A three item 5-point Likert scale was used to measure Green Self-Identity (Whitmarsh & O'Neill, 2010). The PCA resulted into all items loading on one factor (77.8% of variance explained). The Alpha of the scale was 0.854. The scores on the items were thus averaged and this mean score was used in further analyses.

Consumer Innate Innovativeness: The measure for innovativeness was based on Roehrichs' (2004) scale. To measure the respondents' attraction towards buying and consuming new products, a four-item 5-point Likert scale was used. The PCA resulted into all items loading on one factor (69.1% of variance explained). The Alpha of the scale was 0.849. The scores on the items were thus averaged and this mean score was used in further analyses.

Aesthetic Experience: A three item 5-point Likert scale was used to measure the respondents' aesthetic experience, based on Charters (2006). The PCA resulted into all items loading on one factor (72.3% of variance explained). The Alpha of the scale was 0.809. The mean score across the items was used in further analyses.

Materialism: A selection of six items representing three dimensions (Success, Centrality, Happiness) of the Material Values Scale (Richins, 2004; Richins & Dawson, 1990, 1992) was used to measure materialism on 5-point Likert scales. The PCA resulted into all items loading on one factor (42.9% of variance explained). The Alpha of the scale was 0.728. The scores on the items are thus averaged and this mean score was used in further analyses.

7.4 Analyses and Results

The results of the main study are reported in five parts. First, a manipulation check is carried out on the four product type stimuli with regard to high versus low involvement and emotional versus rational purchase. Second, a cluster analysis is performed on the user characteristics in order to identify meaningful and homogeneous segments of consumers (RQ1). Third, a validation is done to check the internal cluster consistency of the cluster solution. Fourth, regression analysis is carried out to predict the probability of a respondent belonging to each cluster (RQ2). Fifth, the main effects of the clusters (RQ3) and product types (RQ4) and their interaction (RQ5) on material preference are tested.

7.4.1 Manipulation Check of Product Conditions

In the study, the four product type stimuli (see Figure 7.1) were randomly allocated to participants such that each participants was exposed to one stimulus (between-subjects design). The manipulation check was carried out by means of two 5-point bipolar scale questions: "A (PRODUCT CONDITION) to me is…

- … An unimportant purchase decision ⇔ … A very important purchase decision."
- … Something I feel weak emotions for ⇔ … Something I feel strong emotions for."

Table 7.1 shows the means and standard deviations for each manipulation scale and for each of the four product types.

Table 7.1. Mean and standard deviation for each product type and each manipulation scale.

	Involvement		Emo - Ratio	
	M	SD	M	SD
Vacuum cleaner	3.40	1.128	1.86	1.054
Eyeglasses	3.85	1.136	2.70	1.138
Shower wiper	2.04	1.184	1.57	0.925
Flower pot	2.46	1.097	2.32	1.138

A One-way ANOVA with Bonferroni Post Hoc test reveals that significant differences ($p<0.05$) are found between the high involvement and low involvement products: vacuum cleaner versus shower wiper ($p<0.001$), vacuum cleaner versus flower pot ($p<0.001$), eyeglasses versus shower wiper ($p<0.001$), and eyeglasses versus flower pot ($p<0.001$). An additional Bonferroni Post Hoc test reveals that significant differences ($p<0.05$) are found between the emotional and rational products as well: eyeglasses versus vacuum cleaner ($p<0.001$), eyeglasses versus shower wiper ($p<0.001$), flower pot versus vacuum cleaner ($p<0.001$), and flower pot versus shower wiper ($p<0.001$). The manipulation is thus successful and the products used in the study can be considered as representations of the four product types: Habitual (shower wipe), Satisfaction (flower pot), Affective (eyeglasses), Informative (vacuum cleaner).

7.4.2 Development of Four Consumer Segments

To answer RQ1, a cluster analysis was carried out with each of the self-expressive values as cluster variables. First, a correlation analysis was performed on all 16 variables: Brand Personality Traits (Activity, Responsibility, Romantic, Sentimental, Ordinary, Simple, Aggressive and Bold), Schwartz Personal Values (Intrinsic Fulfilment, Conservation and Extrinsic Augmentation), Environmental Concern, Green Self-identity, Consumer Innate Innovativeness, Materialism, and Aesthetic Experience. These scores were first standardized as different scales are used (e.g. 5-point, 7-point and 9-point scales). Only moderate correlations were found between Green Self Identity and NEP (r=47%), Green Self Identity and Extrinsic Augmentation (r=40%), Activity and Responsibility (r=36%), and between Material Value Scale and Conservation (r=36%).

Second, a hybrid clustering method combining Hierarchical with Partitioning K-means Clustering was used to expose the structure in the data, and group individual respondents with similar characteristics (Hair et al., 2013). The hierarchical cluster analysis was based on Ward's method and Squared Euclidean distance, in order to select the appropriate number of clusters (based on the elbow method and aiming for a relatively equivalent distribution of respondents across clusters). This number served as input for the K-means cluster analysis, and an ANOVA is performed to check whether all cluster variables significantly differ between clusters ($p<0.05$).

The selection of the final cluster solution is based on (i) the number of iterations until convergence occurs (<20 iterations), (ii) minimum distance between initial centres, (iii) a relatively balanced distribution of respondents across clusters, (iv) a meaningful interpretation of the cluster item values plotted in a visual graph, and (v) the percentage of significant differences between clusters on the experiential qualities (>50% for sensorial attributes and >70% for interpretive characteristics). Table 7.2 shows the final cluster centres based on the K-means cluster analysis, and the number of respondents in each cluster. Its visualization in a graph can be found in Appendix 7F and the dendrogram of the chosen cluster solution based on the hierarchical method in Appendix 7G. The chosen cluster solution leads to significant differences between clusters for 57% of the sensorial attributes and for 75% of the interpretive characteristics. An ANOVA reveals that all variables significantly differ between clusters ($p<0.001$). Based on their distinctive characteristics, we labelled the clusters as following:

- Cluster 1 "Traditional Curiosity Chasers": these respondents are very active, bold and conservative, and they value innovativeness, materialism and aesthetic experience.
- Cluster 2 "Realistic Go-Getters": these respondents are very passive and irresponsible, they attach little importance to extrinsic values, and have a low green self-identity.
- Cluster 3 "Green Experience Lovers": these respondents are very unconventional and complex, they attach little importance to intrinsic values and materialism, have a large environmental concern and high green self-identity.
- Cluster 4 "Humdrum Familiars": these respondents are very responsible, ordinary, simple, calm and cautious, they attach great importance to intrinsic values but little to innovativeness.

Table 7.2. Final Cluster Centres of final cluster solution (based on standardized Z-scores), including p-values of the ANOVA.

		Final Cluster Centres				ANOVA
		1	**2**	**3**	**4**	**Sig.**
Personality Traits	Activity	.59024	-.72817	.13329	-.11070	<.001
	Responsibility	.16514	-.69696	.00749	.50728	<.001
	Romantic	.35072	-.44329	-.12917	.13233	<.001
	Sentimental	.20539	-.39163	-.20564	.33115	<.001
	Ordinary	-.22544	-.14556	-.35992	.75913	<.001
	Simple	-.07721	-.12469	-.48646	.66373	<.001
	Aggressive	.19972	.18941	-.06337	-.39200	<.001
	Bold	.38636	-.20214	.29905	-.54732	<.001
Schwartz Values	Intrinsic Fulfilment	.42182	-.40448	-.83675	.63757	<.001
	Conservation	.81722	-.30036	-.46229	-.30649	<.001
	Extrinsic Augmentation	.32429	-.99287	.35654	.29955	<.001
NEP	Environmental Concern	-.24931	-.50350	.71206	.19793	<.001
GSI	Green Self Identity	.03685	-.72239	.76595	.01479	<.001
CII	Consumer Innate Innovativeness	.73804	-.09564	-.35170	-.51800	<.001
MVS	Material Value Scale	.55840	.14107	-.65839	-.26100	<.001
AE	Aesthetic Experience	.62109	-.33101	-.20777	-.25530	<.001
Number of respondents in cluster		**396**	**316**	**279**	**321**	

7.4.3 Cluster Validation

In order to evaluate the internal consistency and robustness of the cluster solution, a validation with a split-run procedure was performed. The dataset was randomly split into two equal validation parts to which the cluster analysis procedure was repeated with the same number of four clusters. Afterwards, the cluster compositions from both validation parts were compared with the original cluster solution by calculating the number of correctly classified respondents. The split-run analysis showed high correlations between the clusters obtained from the whole dataset and the clusters from the two subsets. Subset 1 classifies 508 out of 648 respondents correctly (78.4%), while subset 2 classifies 534 out of 660 respondents correctly (80.9%). The internal cluster consistency is considered to be suitable for further use.

7.4.4 Predicting Cluster Membership

In order to translate the results of the cluster analysis into a workable tool to classify consumers into one of the four defined clusters in future research (RQ2), a logistic regression analysis was carried out for each cluster to predict the probability of a respondent belonging to that cluster. All variables used in the cluster analysis were included as independent variables, and the cluster membership as the dependent variable. With regard to potential multicollinearity, all variance inflation factors (VIF) were close to 1 and < 1.600, and all tolerances are > .625. Thus, only limited dependence among predictors is detected. Table 7.3 sums up the overall percentage of correctly predicted memberships to each cluster. As all percentages are above 90%, classification is concluded to be excellent. Table 7.4 shows the unstandardized regression weights (B) of each variable for each cluster, as well as the significance levels. These B-values can be used in a regression formula in order to predict cluster membership in future studies.

Table 7.3. Overall percentage of correctly predicted memberships to each cluster.

	Traditional Curiosity Chasers	Realistic Go-Getters	Green Experience Lovers	Humdrum Familiars
Overall percentage correctly predicted	92.1 %	94.6 %	91.8 %	90.9 %

Table 7.4. Unstandardized regression weights (B) of each variable for each cluster, including significance levels.

Effect	Traditional Curiosity Seekers		Realistic Go-Getters		Green Experience Lovers		Humdrum Familiars	
	B	Sig.	B	Sig.	B	Sig.	B	Sig.
Activity	1.470	<.001	-2.730	<.001	.500	.022	-.007	.973
Responsibility	.565	.016	-3.124	<.001	-.077	.740	1.794	<.001
Aggressive	.497	.001	.425	.017	-.214	.186	-.783	<.001
Bold	.725	<.001	-.405	.020	.760	<.001	-1.277	<.001
Ordinary	-.425	.003	-.429	.020	-.373	.010	1.365	<.001
Simple	-.233	.056	-.393	.007	-1.182	<.001	1.164	<.001
Romantic	.733	<.001	-.994	<.001	-.043	.761	-.035	.786
Sentimental	.338	.013	-.919	<.001	-.238	.074	.677	<.001
Intrinsic Fulfilment	.849	<.001	-.440	<.001	-1.415	<.001	1.006	<.001
Conservation	1.659	<.001	-.297	.072	-.683	<.001	-.422	<.001
Extrinsic Augmentation	.233	.092	-2.352	<.001	.608	<.001	.556	<.001
NEP	-.918	<.001	-1.733	<.001	1.552	<.001	.568	.002
GSI	.223	.194	-1.613	<.001	1.836	<.001	-.509	.002
CII	2.266	<.001	.275	.195	-.903	<.001	-1.238	<.001
MBS	1.615	<.001	.400	.134	-1.527	<.001	-.667	.001
AE	1.793	<.001	-.679	<.001	-.398	.011	-.317	.024
Constant	-35.463	<.001	54.011	<.001	-1.694	.299	-17.663	<.001

7.4.5 Effects of Clusters and Product Types on the Preference for Material Qualities

This section describes to what extent people belonging to each cluster express different preferences for experiential material qualities (RQ3), to what extent product types lead to different preferences for experiential material qualities (RQ4), and the moderating effect of product types on the relation between clusters and experiential materials qualities (RQ5). Thirty two-way ANOVA analyses were carried out with cluster membership and product type as the independent variables, and the 30 material quality preference variables as dependents. Bonferroni Post Hoc tests were carried out to assess the differences between each pair of clusters and each pair of product conditions.

7.4.5.1 Effects of clusters on preference for material qualities (RQ3)

The main effects for the factor 'cluster' are reported in Table 7.5, and the post-hoc tests in Appendix 7H. No significant differences (p>0.05) between clusters were found for Softness, Temperature, Odour, Greasiness, Strength, Deformability, Transparency, Male/Female, Delicate/Rugged, Formal/Informal, and Mature/Youthful. For all other material qualities, the main effect of the factor 'cluster' was significant (p<0.05).

Table 7.5. Results of ANOVA for main effects of clusters on material quality preferences.

Dependent variable	df	F	Sig.
Colour Intensity	3	9.298	<.001
Colourfulness	3	5.021	0.002
Glossiness	3	4.05	0.007
Softness	3	0.519	0.669
Scratchability	3	8.036	<.001
Texture	3	5.761	0.001
Temperature	3	1.821	0.141
Odour	3	3.79	0.010
Weight	3	4.548	0.004
Greasiness	3	1.662	0.173
Acoustics	3	3.172	0.023
Strength	3	1.596	0.189
Deformability	3	0.558	0.643
Transparency	3	0.493	0.687

Dependent variable	df	F	Sig.
Male/Female	3	0.625	0.599
Aggressive/Calm	3	11.01	<.001
Delicate/Rugged	3	0.787	0.501
Elegant/Vulgar	3	6.848	<.001
Toy-like/Professional	3	10.23	<.001
Sexy/Not sexy, dull	3	8.517	<.001
Cheap/Expensive	3	4.538	0.004
Disposable/Durable	3	11.06	<.001
Honest/Misleading	3	8.563	<.001
Cosy/Aloof, distant	3	6.425	<.001
Futuristic/Nostalgic	3	13.02	<.001
Frivolous/Sober	3	10.61	<.001
Formal/Informal	3	1.44	0.229
Ordinary/Strange	3	17.98	<.001
Classic/Trendy	3	6.242	<.001
Mature/Youthful	3	1.192	0.311

The Traditional Curiosity Chasers (C1) significantly prefer more sexy materials than the other clusters, more scratch resistant, smoother, more elegant, and more professional materials than the Realistic Go-Getters (C2) and Green Experience Lovers (C3), more intensely coloured and trendier materials than the Realistic Go-Getters (C2) and Humdrum Familiars (C4), and more expensive materials than the Green Experience Lovers (C3) and Humdrum Familiars (C4).

The Realistic Go-Getters (C2) significantly prefer materials of daily products to be less honest compared to other clusters. They prefer less scratch resistant, less smooth, less elegant, less professional, and less cosy materials than C1 and C4, and less durable materials than C3 and C4.

The Green Experience Lovers (C3) significantly prefer less scratch resistant, less elegant and less professional materials than C1 and C4.

The Humdrum Familiars (C4) significantly prefer calmer, more nostalgic, more sober and more ordinary materials than the other clusters. They prefer more durable materials than C1 and C2, less intensely coloured materials than C1 and C3, and more scratch resistant, lighter, more elegant, more professional and cosier materials than C2 and C3.

7.4.5.2 Effects of product types on preference for material qualities (RQ4)

The main effects for the factor 'product type' are reported in Table 7.6 and the post-hoc tests in Appendix 7I. No significant differences (p>0.05) between product types are found for Colour Intensity, Colourfulness, Male/Female, Odour, and Classic/Trendy. For all other material qualities, the factor 'product type' is significant (<0.05).

Table 7.6. Results of ANOVA for main effects of product conditions on material quality preferences.

Dependent variable	**df**	**F**	**Sig.**
Colour Intensity	3	0.819	0.483
Colourfulness	3	1.89	0.129
Glossiness	3	6.993	<.001
Softness	3	65.68	<.001
Scratchability	3	12.91	<.001
Texture	3	29.33	<.001
Temperature	3	12.66	<.001
Odour	3	2.556	0.054
Weight	3	54.96	<.001
Greasiness	3	3.547	0.014
Acoustics	3	32.94	<.001
Strength	3	15.46	<.001
Deformability	3	54.35	<.001
Transparency	3	39.52	<.001

Dependent variable	**df**	**F**	**Sig.**
Male/Female	3	1.519	0.208
Aggressive/Calm	3	5.102	0.002
Delicate/Rugged	3	31.54	<.001
Elegant/Vulgar	3	35.13	<.001
Toy-like/Professional	3	10.97	<.001
Sexy/Not sexy, dull	3	37.38	<.001
Cheap/Expensive	3	14.78	<.001
Disposable/Durable	3	6.197	<.001
Honest/Misleading	3	8.186	<.001
Cosy/Aloof, distant	3	46.82	<.001
Futuristic/Nostalgic	3	22.49	<.001
Frivolous/Sober	3	4.211	0.006
Formal/Informal	3	4.228	0.006
Ordinary/Strange	3	13.89	<.001
Classic/Trendy	3	2.086	0.100
Mature/Youthful	3	9.322	<.001

All in all, only two experiential qualities (Softness and Sexy/Not sexy) show significant differences between all four product types. For the habitual product type (P3: shower wiper), softer materials are preferred, while for the other product types, respondents prefer rather hard to in between materials (the hardest for the satisfaction product type (P4: flower pot), then informative product type (P1: vacuum cleaner), and closest to medium the affective product type (P2: eyeglasses)). For the emotional product types (P2 and P4), respectively rather sexy to neutral materials are preferred, compared to respectively not sexy to neutral materials for the rational product types (P3 and P1).

For the informative product type (P1: vacuum cleaner), respondents significantly prefer softer sounding and more rugged materials compared to the other product types. They prefer less warm materials compared to affective (P2) and habitual (P3) products, more professional materials compared to habitual (P3) and satisfaction (P4) products, and more futuristic materials compared to affective (P2) and satisfaction (P4) products.

For the affective product type (P2: eyeglasses), respondents significantly prefer more scratch resistant, less rugged, and more elegant materials compared to the other product types. They prefer cosier and more sober materials compared to the informative (P1) and habitual (P3) products, and stronger, more professional, more expensive, and more mature materials compared to the habitual (P3) and satisfaction (P4) products.

For the habitual product type (P3: shower wiper), respondents significantly prefer more flexible and cheaper materials compared to the other product types. They prefer less durable and less honest materials compared to informative (P1) and affective (P2) products.

For the satisfaction product type (P4: flower pot), respondents significantly prefer less smooth, less light, stiffer, more elegant, cosier, and less ordinary materials compared to the other product types. They prefer less mature materials compared to informative (P1) and affective (P2) products, and more matte and more nostalgic materials compared to informative (P1) and habitual (P3) products.

7.4.5.3 Interaction effects between clusters and product types (RQ5)

Only three significant Cluster x Product type interaction effects are found: for the experiential qualities of Strength, Male/Female, and Cosy/Aloof (Table 7.7). Thus, overall, differences between clusters are not substantially qualified by product type.

Table 7.7. Results of ANOVA for interaction effects between clusters and product conditions on material quality preferences.

Dependent variable	df	F	Sig.
Colour Intensity	3	0.899	0.526
Colourfulness	3	0.829	0.589
Glossiness	3	1.61	0.107
Softness	3	1.321	0.221
Scratchability	3	1.312	0.226
Texture	3	1.658	0.094
Temperature	3	1.254	0.258
Odour	3	0.972	0.461
Weight	3	0.426	0.922
Greasiness	3	1.01	0.430
Acoustics	3	0.982	0.453
Strength	3	2.157	0.023
Deformability	3	1.04	0.405
Transparency	3	1.093	0.364

Dependent variable	df	F	Sig.
Male/Female	3	2.215	0.019
Aggressive/Calm	3	1.634	0.100
Delicate/Rugged	3	1.685	0.088
Elegant/Vulgar	3	1.021	0.421
Toy-like/Professional	3	0.685	0.723
Sexy/Not sexy, dull	3	1.397	0.184
Cheap/Expensive	3	1.751	0.073
Disposable/Durable	3	0.924	0.503
Honest/Misleading	3	1.135	0.334
Cosy/Aloof, distant	3	2.815	0.003
Futuristic/Nostalgic	3	0.771	0.643
Frivolous/Sober	3	0.612	0.787
Formal/Informal	3	0.586	0.809
Ordinary/Strange	3	1.353	0.205
Classic/Trendy	3	2.086	0.100
Mature/Youthful	3	9.322	<.001

7.5 Discussion

The results of the ANOVAs show that self-expressive values are indeed highly related to materials experience preferences in terms of sensory perception and meaning, as suggested in Karana's (2010) Meanings of Materials (MOM) model. Moreover, Ulusoy and Nilgün (2017) state that meanings or interpretive characteristics are more sensitive to cultural and societal aspects than sensorial attributes. Our work confirms these findings on the level of individual self-expressive values: 75% of interpretive characteristics show one or more significant differences in preferences between the clusters, compared to 57% of the sensorial attributes.

There are significant differences between the preferred experiential material qualities across consumer segments. Consumers belonging to the cluster of Traditional Curiosity Chasers (C1) prefer more expensive and trendy materials for their products, which might be related to their materialistic and aesthetic values. Consumers belonging to the cluster of Realistic Go-Getters (C2) prefer materials of daily products to be less calm (more aggressive), which is in line with their own aggressive personality trait. Consumers belonging to the cluster of Green Experience Lovers (C3) prefer more durable and honest materials as well as less sober or ordinary materials, which might also be related to their green and sophisticated profile. And finally, consumers belonging to the cluster of Humdrum Familiars (C4) prefer materials of daily products to be more calm, nostalgic, sober and ordinary compared to other consumers, which is conform to their passive, ordinary and simple character.

A remarkable observation is that only the scores of the experiential qualities of Colour Intensity, Sexy/Not sexy, Cheap/Expensive and Classic/Trendy are located around the neutral centre of the scale. Consequently, clusters of respondents express (relatively) outspoken preferences for qualities in the materials of their everyday products.

In addition, also the factor 'product type' significantly affects the preference of experiential material qualities for all qualities, except for Colour Intensity, Colourfulness, Male/Female, Odour, and Classic/Trendy. Although both consumer segment and product type affect the experiential material preference, nearly no interaction effects are found (only three out of thirty).

All in all, the four clusters and the four product types form a suitable basis for future research and data generation through experiential material characterization with real, tactile materials (e.g. with a dedicated demonstrator form as developed in (Veelaert et al., 2022)). An adaptive, growing database with experiential material preferences can be built with a continuously increasing sample of respondents that can be classified into the given clusters, so that the link between individual self-expressive values and material preferences gains validity.

7.5.1 Contributions

By combining insights from design and consumer behaviour research, we developed contributions to knowledge by means of an integrated model of individual self-expressive values related to materials experience preference, and their relation with a well-known design framework that captures consumers' symbolic experiential responses to these materials. Moreover, the importance of product type as a determinant of materials experience is highlighted.

In practice, both marketeers and product designers can benefit from a better insight and understanding of these user segments and product types when selecting appropriate materials for meaningful products and relevant market segments to increase their market success. This way, they can better predict the user-interaction qualities with a product for predefined market segments, increase involvement and product attachment, and a prolonged product use.

7.5.2 Limitations and Future Research

Considering the limitations of our work, the main survey was conducted in a sample of Flemish respondents. Future research could corroborate our findings in different contexts, and explore to what extent cultural differences influence consumers' preferences for materials.

Another limitation can be seen in the fact that the main study was conducted by means of an online survey, in order to achieve a large sample. Therefore, we had to use pictures of products and question the respondent's preference for a set of material qualities, instead of evaluating direct perception of real materials in real products in a tactile manner. Of course, we must take into account that given product types might also bias respondents, as they reflect on what material qualities can be expected for that specific product (instead of overall product category). Nevertheless, over the four product types, we still found significant differences in preferences between the four consumer segments. As a next step, future studies building upon this segmentation, should involve the perceived qualities of real and physical materials and products.In a such physical and more qualitative context, it would be possible to also investigate the last two experiential levels and explore whether consumer clusters also differ in terms of emotions elicited by materials and performative actions.

We used extensive measurements scales in our survey, which makes subsequent research based on our method time-consuming and may lead to decreased motivation and attention of respondents.

Therefore, we suggest to explore to what extent the segmentation survey could be shortened or even build around visualisation of the crucial segmentation elements (personas) without a reduction in correctly allocating respondents to one of the clusters (e.g. less questions or items, in combination with four visual personas).

Studies on experiential material qualities and efforts to grasp the link with consumer segments are scarce. A wide variety of research digging deeper in this topic can be placed on the agenda. These insights are helpful for designers from the early stages of the design process onwards. Better materials selection related to the needs and desires of the a target group may help to establish a more tied user-product relationship, which in turn is an antecedent of product longevity (Cooper, 2016). This pathway may be worth studying.

As we included twelve brand personality traits to represent a respondent's personality, this leaves opportunities to be consistent in future research, and investigate the link between consumer personality and perceived personality of brands and materials.

Studying the link between consumer segments, perceived experiential qualities and sustainable perception of materials can also be topic of future research. A deeper understanding of these consumer drivers can indeed stimulate the development of new (sustainable) materials that connect with consumer acceptance. This could be particularly interesting for example with the emerging of recycled plastics and bio-based plastics versus virgin plastics.

7.6 Conclusion

In addition to technical material properties, the characterization of experiential qualities of materials is receiving more attention in product design. However, the effect of user characteristics on material perceptions is understudied and usually limited to demographic variables. Therefore, the current research aimed to develop a rich segmentation of consumers based on seven individual self-expressive values (personality traits, personal values, environmental concern, green self-identity, consumer innate innovativeness, materialism, and aesthetic experience), and to predict how these different segments appreciate the experiential qualities of materials differently. The study resulted in the formation of four consumer segments that differ in preferred experiential qualities, and can as such be used in future studies: Traditional Curiosity Seekers, Realistic Go-Getters, Green Experience Lovers, and Humdrum Familiars. Additionally, we explored how the type of product affect these preferences (informative, affective, habitual, and satisfaction products).

This research adds to a richer insight and a better understanding of product types and user segments, and offers valuable opportunities for both marketers and product designers when selecting or developing appropriate materials for successful and meaningful products. Differences in material preferences between the four clusters, as well as between the four product types, indicate that further studies on materials experience can build upon this segmentation to achieve a higher involvement of psychographic user characteristics, beyond merely gender, age or culture, and in consideration of the type of product that is to be designed.

7.7 Appendices

Appendix 7A. Initial measures for experiential qualities within materials experience framework.

<table>
<tr><th colspan="2">Constructs, measurement & source</th><th>Items</th></tr>
<tr><td rowspan="2">Experiential Material Qualities</td><td>Sensorial attributes

5-point Likert scale
-2 = very … ;
0 = neutral;
+2 = very …

(Camere & Karana, 2018)</td><td>Softness (hard/soft)
Texture (smooth/rough)
Glossiness (matte/glossy)
Reflectiveness (not reflective/reflective)
Temperature (cold/warm)
Elasticity (not elastic/elastic)
Transparency (opaque/transparent)
Ductility (tough/ductile)
Strength (weak/strong)
Weight (light/heavy)
Texture (regular texture/irregular texture)
Fibreness (fibred/non-fibred)</td></tr>
<tr><td>Interpretive characteristics

5-point Likert scale
-2 = very … ;
0 = neutral;
+2 = very …

(Camere & Karana, 2018)</td><td>Aggressive/calm
Cosy/aloof
Elegant/vulgar
Frivolous/sober
Futuristic/nostalgic
Masculine/feminine
Ordinary/strange
Sexy/not sexy
Toy-like/professional
Natural/innatural
Hand-crafted/manufactured</td></tr>
</table>

Appendix 7B. Socio-demographic composition of the sample of the main study.

N		**1309**	**100%**
Age	18-34	349	26.7%
(Mean age=49)	35-54	476	36.4%
(SD=16)	55+	484	37.0%
Gender	Male	637	48.7%
	Female	672	51.3%
Family income	Low	207	15.8%
	Average	818	52.5%
	High	283	21.6%
Education	High school or less	434	33.1%
	Bachelor	488	37.3%
	Master	388	29.6%
Region	Countryside	516	39.5%
	Suburbs	566	43.2%
	City	227	17.3%
Children	No children	512	39.1%
	1 child	207	15.8%
	2 children	390	29.8%
	3+ children	201	15.4%

Appendix 7C. Initial constructs, measurement, items and sources of independents variables in main study.

	Constructs, measurement & source	Factors	Items
Personality Traits	5-point Likert scale 1= fully disagree; 5= fully agree (Geuens et al., 2009)	Activity	**Active** **Dynamic** **Innovative**
		Responsibility	**Responsible** **Down to earth** **Stable**
		Emotionality	**Romantic**
			Sentimental
		Simplicity	**Ordinary**
			Simple
		Aggressiveness	**Aggressive**
			Bold
Personal Values	9-point importance scale 'as a guiding principle in my life, this value is': -1=opposed to my values, 0=not important, 3=important, 6=very important, 7=of supreme importance (Schwartz, 1992)	Self-Enhancement	**Achievement** *(SV1: to have success, be competent, ambitious, have influence on people and events)* ***Power*** *(SV2: obtaining social status, the achievement of prestige, control or dominating others)*
		Conservation	**Security** *(SV3: national security', security for the family, order in society, reciprocate favours)* **Tradition** *(SV4: respect for tradition, humbleness, accept life, moderation)* **Conformity** *(SV5: obedience, respect for parents and elder people, self-discipline, politeness)*
		Self-Transcendence	**Benevolence** *(SV6: to be helpful, honest, forgiving, loyally lo friends, responsible)* **Universalism** *(SV7: to be broad-minded, loving a world full of beauty, social justice, peace, equality, wisdom, unity with nature, care for nature and the environment)*
		Opennes to Change	**Self-Direction** *(SV8: creativity, curiosity, freedom to choose your own goals)* **Stimulation** *(SV9: excitement, novelty, and challenge in life)* **Hedonism** *(SV10: to enjoy life, self-indulgence, fun)*
Environmental Concern	7-point Likert scale 1= fully disagree; 7= fully agree (Dunlap, 2008)	Balance of nature	**NEP3**: *When humans interfere with nature it often produces disastrous consequences.* **NEP8**: *The balance of nature is strong enough to cope with the impacts of modern industrial nations. (R)* **NEP13**: *The balance of nature is very delicate and easily upset.*
		Ecocrisis	**NEP5**: *Humans are seriously abusing the environment.* **NEP10**: *The so-called "ecological crisis" facing humankind has been greatly exaggerated. (R)* **NEP15**: *If things continue on their present course, we will soon experience a major ecological catastrophe.*

		Anti-exemptionalism	**NEP4**: *Human ingenuity will insure that we do not make the Earth unliveable. (R)* **NEP9**: *Despite our special abilities, humans are still subject to the laws of nature.* **NEP14**: *Humans will eventually learn enough about how nature works lo be able to control it. (R)*
		Limits to growth	**NEP1**: *We are approaching the limit of the number of people the Earth can support.* **NEP6**: *The Earth has plenty of natural resources if we just learn how to develop them. (R)* **NEP11**: *The Earth is like a spaceship with very limited room and resources.*
		Anti-anthropocentism (humand domination)	**NEP2**: *Humans have the right to modify the natural environment to suit their needs. (R)* **NEP7**: *Plants and animals have as much right as humans to exist.* **NEP12**: *Humans were meant to rule over the rest of nature. (R)*
Green Self-Identity	5-point Likert scale 1= fully disagree; 5= fully agree (Sparks & Shepherd, 1992)	GSI	**GSI1**: *I think of myself as someone who is concerned about environmental issues.* **GSI2**: *I think of myself as a "green" consumer.* **GSI3**: *I would describe myself as an ecologically conscious consumer.*
Consumer Innate	5-point Likert scale 1= fully disagree; 5= fully agree (Roehrich, 2004)	CII	**CII1**: *I am more interested in buying new products instead of products that I already know.* **CII2**: *I like to buy new products.* **CII3**: *I am usually among the first to try new products.* **CII4**: *I know more than others on latest new products.*
Aesthetic Experience	5-point Likert scale 1= fully disagree; 5= fully agree (Charters, 2006)	AE	**AE1**: *I think the design (look & feel) of products is important.* **AE2**: *I think it is important that a product fits aesthetically with myself, my products and my interior.* **AE3**: *I think it is important that a product expresses who I am.*
Materialism	5-point Likert scale 1= fully disagree; 5= fully agree (Richins, 2004; Richins & Dawson, 1990, 1992)	MVS	**MVS1**: *The things someone owns say a lot how well he/she is doing in life.* **MVS2**: *I admire people who own expensive homes, cars, clothes.* **MVS3**: *Buying things gives me a lot of pleasure.* **MVS4**: *I like a lot of luxury in my life.* **MVS5**: *I try to keep my life simple, as far as possessions are concerned. (R)* **MVS6**: *It bothers me that I can't afford to buy things I'd like.*

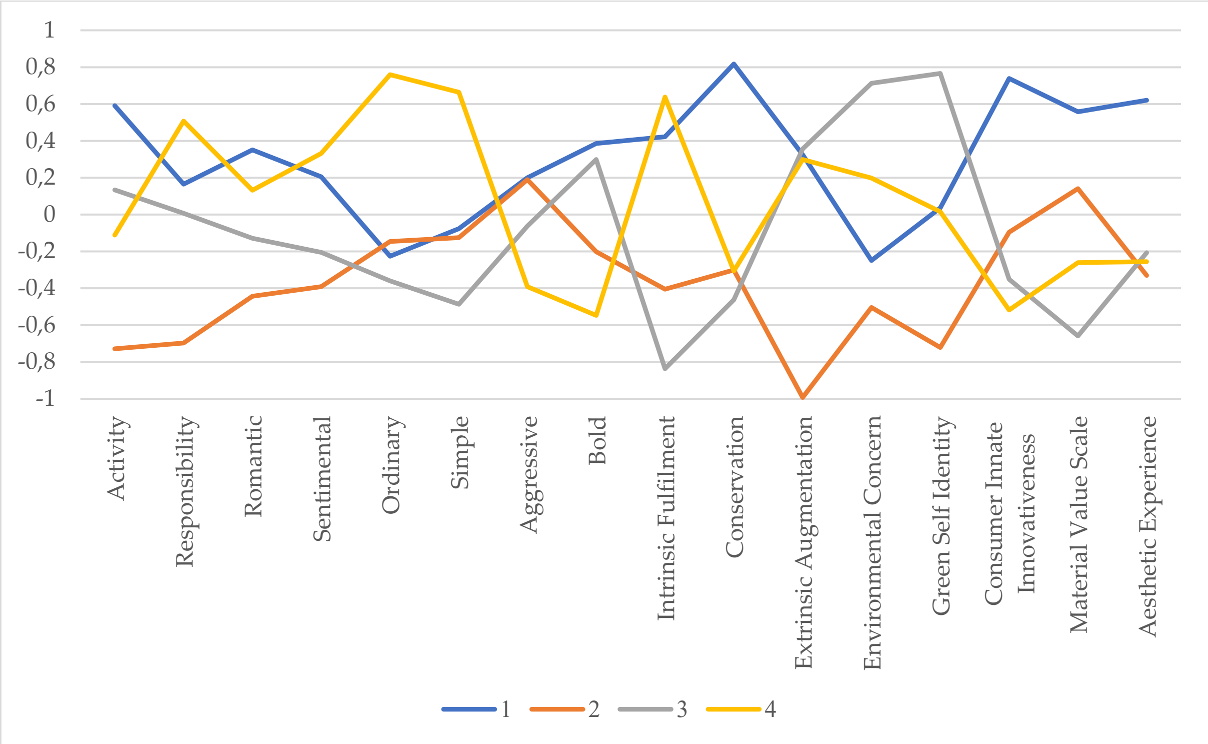
Appendix 7D. Final dependent variables as used in the main study.

Construct	Measuremen & source	Dimension	Items
Experiential Material Qualities	5-point bipolar scale -2= very 'matte' -1= 'matte' 0= neutral 1= 'glossy' 2= very 'glossy' (Ashby & Johnson, 2012; Karana, 2009; Karana et al., 2009a; van Kesteren et al., 2007b; Veelaert, Du Bois, et al., 2020)	Sensorial attributes	**Colour intensity** (weak/intense) **Colourfulness** (colourless/colourful) **Glossiness** (matte/glossy) **Softness** (hard/soft) **Scratchability** (scratchable/scratch resistant) **Texture** (smooth/rough) **Temperature** (cold/warm) **Odour** (odourless/fragrant) **Weight** (light/heavy) **Greasiness** (dry/oily) **Acoustics** (soft/shrill) **Strength** (weak or fragile/strong or unbreakable) **Deformability** (low or stiff/ high or flexible) **Transparency** (opaque/transparent)
	5-point bipolar scale -2= very 'cosy' -1= 'cosy' 0= neutral 1= 'aloof' 2= very 'aloof' (Ashby & Johnson, 2012; Karana, 2009; van Kesteren et al., 2007b)	Interpretive characteristics	**Aggressive/calm** **Cosy/aloof** **Elegant/vulgar** **Frivolous/sober** **Futuristic/nostalgic** **Male/female** **Ordinary/strange** **Sexy/not sexy or dull** **Toy-like/professional** **Delicate/rugged** **Cheap/expensive** **Disposable/durable** **Honest/misleading, distant** **Formal/informal** **Classic/trendy** **Mature/youthful**

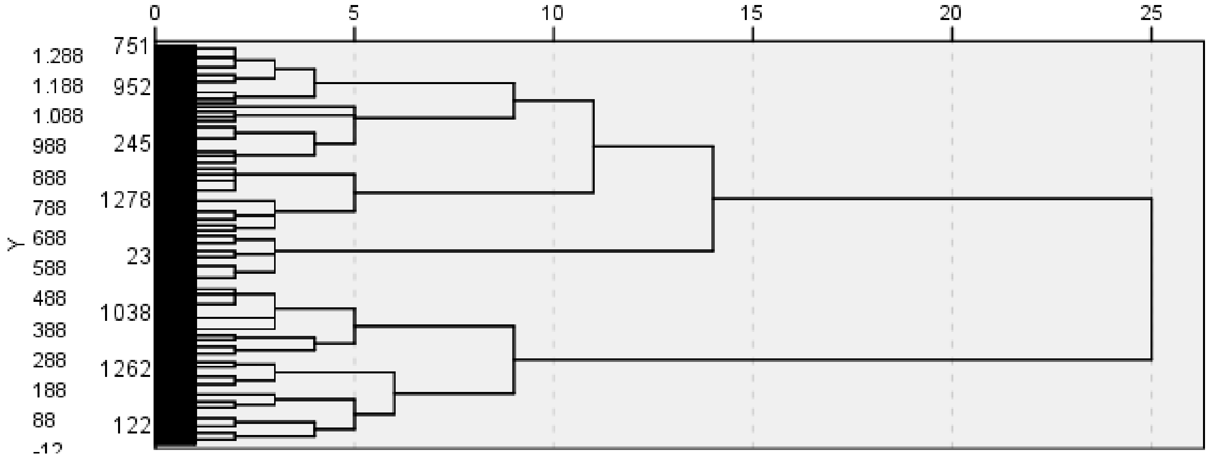
Appendix 7E. Final independent variables after factor analysis as used in the cluster analysis, including mean, standard deviation and Alpha.

Constructs	**Factors**	**Items**	**Mean**	**Std**	**Alpha**
Personality Traits	Activity	**Active** **Dynamic** **Innovative**	3.348	0.707	0.614
	Responsibility	**Responsible** **Down to earth** **Stable**	4.066	0.596	0.698
		Romantic	3.14	0.981	
		Sentimental	3.29	1.064	
		Ordinary	3.70	0.974	
		Simple	2.86	1.133	
		Aggressive	1.70	0.842	
		Bold	2.65	0.968	
Personal Values	Intrinsic Fulfilment	**Self-Direction** *(SV8)* **Universalism** *(SV7)* **Benevolence** *(SV6)*	4.696	1.154	0.595
	Conservation	**Conformity** *(SV5)* **Tradition** *(SV4)* **Security** *(SV3)*	4.327	1.361	0.714
	Extrinsic Augmentation	**Power** *(SV2)* **Achievement** *(SV1)* **Hedonism** *(SV10)* **Stimulation** *(SV9)*	2.958	1.207	0.663
Environmental Concern	NEP	**NEP1-NEP15**	4.905	0.773	0.829
Green Self-Identity	GSI	**GSI1-GSI3**	3.084	0.917	0.854
Consumer Innate Innovativeness	CII	**CII1-CII4**	2.437	0.849	0.849
Aesthetic Experience	AE	**AE1-AE3**	2.902	0.904	0.809
Materialism	MVS	**MVS1-MVS6**	2.786	0.667	0.728

Appendix 7F. Graph of final cluster solution based on cluster centres of Table 7.2.



Appendix 7G. Dendrogram of cluster solution using Ward Linkage (rescaled distance cluster combine).



Appendix 7H. Bonferroni Post Hoc tests indicating the significance of differences between clusters on material quality preferences.

Sensorial Attributes						Interpretive Characteristics					
	Cluster	***Cluster***	*Mean Difference (I-J)*	*Std. Error*	*Sig.*		***Cluster***	***Cluster***	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
Colour intensity	1	2	0.23	0.077	0.018	Male/Female	1	2	0.07	0.066	1.000
		3	0.16	0.08	0.266			3	0.02	0.069	1.000
		4	0.4	0.078	<.001			4	-0.01	0.067	1.000
	2	1	-0.23	0.077	0.018		2	1	-0.07	0.066	1.000
		3	-0.07	0.084	1.000			3	-0.04	0.072	1.000
		4	0.17	0.082	0.199			4	-0.08	0.07	1.000
	3	1	-0.16	0.08	0.266		3	1	-0.02	0.069	1.000
		2	0.07	0.084	1.000			2	0.04	0.072	1.000
		4	0.24	0.085	0.028			4	-0.03	0.073	1.000
	4	1	-0.4	0.078	<.001		4	1	0.01	0.067	1.000
		2	-0.17	0.082	0.199			2	0.08	0.07	1.000
		3	-0.24	0.085	0.028			3	0.03	0.073	1.000
Colourfulness	1	2	0.21	0.083	0.067	Aggressive/Calm	1	2	0.12	0.065	0.427
		3	0.17	0.087	0.287			3	0.01	0.068	1.000
		4	0.3	0.084	0.002			4	-0.27	0.066	<.001
	2	1	-0.21	0.083	0.067		2	1	-0.12	0.065	0.427
		3	-0.04	0.09	1.000			3	-0.11	0.071	0.770
		4	0.09	0.088	1.000			4	-0.39	0.069	<.001
	3	1	-0.17	0.087	0.287		3	1	-0.01	0.068	1.000
		2	0.04	0.09	1.000			2	0.11	0.071	0.770
		4	0.13	0.092	0.885			4	-0.28	0.072	0.001
	4	1	-0.3	0.084	0.002		4	1	0.27	0.066	<.001
		2	-0.09	0.088	1.000			2	0.39	0.069	<.001
		3	-0.13	0.092	0.885			3	0.28	0.072	0.001
Glossiness	1	2	0.14	0.077	0.466	Delicate/Rugged	1	2	0.06	0.074	1.000
		3	0.27	0.081	0.006			3	-0.08	0.077	1.000
		4	0.18	0.079	0.119			4	-0.04	0.075	1.000
	2	1	-0.14	0.077	0.466		2	1	-0.06	0.074	1.000
		3	0.13	0.084	0.703			3	-0.13	0.081	0.571
		4	0.05	0.082	1.000			4	-0.1	0.079	1.000
	3	1	-0.27	0.081	0.006		3	1	0.08	0.077	1.000
		2	-0.13	0.084	0.703			2	0.13	0.081	0.571
		4	-0.09	0.085	1.000			4	0.04	0.082	1.000
	4	1	-0.18	0.079	0.119		4	1	0.04	0.075	1.000
		2	-0.05	0.082	1.000			2	0.1	0.079	1.000
		3	0.09	0.085	1.000			3	-0.04	0.082	1.000

Softness	1	2	0.03	0.084	1.000	Elegant/Vulgar	1	2	-0.18	0.059	0.016
		3	0.1	0.088	1.000			3	-0.18	0.062	0.029
		4	-0.02	0.086	1.000			4	0.04	0.06	1.000
	2	1	-0.03	0.084	1.000		2	1	0.18	0.059	0.016
		3	0.07	0.092	1.000			3	0	0.065	1.000
		4	-0.05	0.089	1.000			4	0.22	0.063	0.003
	3	1	-0.1	0.088	1.000		3	1	0.18	0.062	0.029
		2	-0.07	0.092	1.000			2	0	0.065	1.000
		4	-0.12	0.093	1.000			4	0.22	0.066	0.005
	4	1	0.02	0.086	1.000		4	1	-0.04	0.06	1.000
		2	0.05	0.089	1.000			2	-0.22	0.063	0.003
		3	0.12	0.093	1.000			3	-0.22	0.066	0.005
Scratchability	1	2	0.28	0.066	<.001	Toy-like/Professional	1	2	0.23	0.064	0.002
		3	0.21	0.069	0.012			3	0.29	0.067	<.001
		4	0	0.067	1.000			4	-0.04	0.065	1.000
	2	1	-0.28	0.066	<.001		2	1	-0.23	0.064	0.002
		3	-0.06	0.072	1.000			3	0.06	0.07	1.000
		4	-0.27	0.07	0.001			4	-0.27	0.068	<.001
	3	1	-0.21	0.069	0.012		3	1	-0.29	0.067	<.001
		2	0.06	0.072	1.000			2	-0.06	0.07	1.000
		4	-0.21	0.073	0.026			4	-0.33	0.071	<.001
	4	1	0	0.067	1.000		4	1	0.04	0.065	1.000
		2	0.27	0.07	0.001			2	0.27	0.068	<.001
		3	0.21	0.073	0.026			3	0.33	0.071	<.001
Texture	1	2	-0.29	0.073	<.001	Sexy/Not sexy. dull	1	2	-0.24	0.065	0.002
		3	-0.24	0.077	0.011			3	-0.24	0.068	0.003
		4	-0.04	0.075	1.000			4	-0.3	0.066	<.001
	2	1	0.29	0.073	<.001		2	1	0.24	0.065	0.002
		3	0.05	0.08	1.000			3	0	0.071	1.000
		4	0.25	0.078	0.009			4	-0.06	0.069	1.000
	3	1	0.24	0.077	0.011		3	1	0.24	0.068	0.003
		2	-0.05	0.08	1.000			2	0	0.071	1.000
		4	0.2	0.081	0.098			4	-0.06	0.072	1.000
	4	1	0.04	0.075	1.000		4	1	0.3	0.066	<.001
		2	-0.25	0.078	0.009			2	0.06	0.069	1.000
		3	-0.2	0.081	0.098			3	0.06	0.072	1.000
Temperature	1	2	0.03	0.064	1.000	Cheap/Expensive	1	2	0.1	0.065	0.678
		3	-0.02	0.067	1.000			3	0.2	0.068	0.019
		4	-0.12	0.065	0.441			4	0.19	0.066	0.023
	2	1	-0.03	0.064	1.000		2	1	-0.1	0.065	0.678
		3	-0.04	0.07	1.000			3	0.1	0.071	0.993
		4	-0.14	0.068	0.213			4	0.09	0.069	1.000

	3	1	0.02	0.067	1.000		3	1	-0.2	0.068	0.019
		2	0.04	0.07	1.000			2	-0.1	0.071	0.993
		4	-0.1	0.071	0.989			4	-0.01	0.072	1.000
	4	1	0.12	0.065	0.441		4	1	-0.19	0.066	0.023
		2	0.14	0.068	0.213			2	-0.09	0.069	1.000
		3	0.1	0.071	0.989			3	0.01	0.072	1.000
Odour	1	2	0.02	0.079	1.000	Disposable/Durable	1	2	0.15	0.058	0.071
		3	0.2	0.083	0.087			3	-0.15	0.061	0.088
		4	0.19	0.08	0.094			4	-0.17	0.059	0.026
	2	1	-0.02	0.079	1.000		2	1	-0.15	0.058	0.071
		3	0.19	0.086	0.183			3	-0.3	0.064	<.001
		4	0.18	0.084	0.201			4	-0.32	0.062	<.001
	3	1	-0.2	0.083	0.087		3	1	0.15	0.061	0.088
		2	-0.19	0.086	0.183			2	0.3	0.064	<.001
		4	-0.01	0.087	1.000			4	-0.02	0.065	1.000
	4	1	-0.19	0.08	0.094		4	1	0.17	0.059	0.026
		2	-0.18	0.084	0.201			2	0.32	0.062	<.001
		3	0.01	0.087	1.000			3	0.02	0.065	1.000
Weight	1	2	-0.17	0.072	0.101	Honest/Misleading	1	2	-0.24	0.064	0.001
		3	-0.09	0.075	1.000			3	-0.03	0.067	1.000
		4	0.15	0.073	0.215			4	0.1	0.065	0.736
	2	1	0.17	0.072	0.101		2	1	0.24	0.064	0.001
		3	0.08	0.078	1.000			3	0.21	0.07	0.014
		4	0.32	0.076	<.001			4	0.34	0.068	<.001
	3	1	0.09	0.075	1.000		3	1	0.03	0.067	1.000
		2	-0.08	0.078	1.000			2	-0.21	0.07	0.014
		4	0.24	0.079	0.015			4	0.13	0.071	0.444
	4	1	-0.15	0.073	0.215		4	1	-0.1	0.065	0.736
		2	-0.32	0.076	<.001			2	-0.34	0.068	<.001
		3	-0.24	0.079	0.015			3	-0.13	0.071	0.444
Greasiness	1	2	-0.06	0.071	1.000	Cosy/Aloof. distant	1	2	-0.17	0.062	0.042
		3	0.11	0.074	0.821			3	-0.17	0.065	0.064
		4	0.01	0.072	1.000			4	0.02	0.063	1.000
	2	1	0.06	0.071	1.000		2	1	0.17	0.062	0.042
		3	0.17	0.077	0.143			3	0	0.068	1.000
		4	0.07	0.075	1.000			4	0.19	0.066	0.026
	3	1	-0.11	0.074	0.821		3	1	0.17	0.065	0.064
		2	-0.17	0.077	0.143			2	0	0.068	1.000
		4	-0.1	0.078	1.000			4	0.19	0.069	0.039
	4	1	-0.01	0.072	1.000		4	1	-0.02	0.063	1.000
		2	-0.07	0.075	1.000			2	-0.19	0.066	0.026
		3	0.1	0.078	1.000			3	-0.19	0.069	0.039

Acoustics	1	2	-0.15	0.066	0.153	Futuristic/Nostalgic	1	2	-0.12	0.062	0.306
		3	-0.06	0.069	1.000			3	0.01	0.065	1.000
		4	0.09	0.067	1.000			4	-0.34	0.064	<.001
	2	1	0.15	0.066	0.153		2	1	0.12	0.062	0.306
		3	0.08	0.072	1.000			3	0.13	0.068	0.345
		4	0.24	0.07	0.005			4	-0.22	0.066	0.006
	3	1	0.06	0.069	1.000		3	1	-0.01	0.065	1.000
		2	-0.08	0.072	1.000			2	-0.13	0.068	0.345
		4	0.15	0.073	0.229			4	-0.35	0.069	<.001
	4	1	-0.09	0.067	1.000		4	1	0.34	0.064	<.001
		2	-0.24	0.07	0.005			2	0.22	0.066	0.006
		3	-0.15	0.073	0.229			3	0.35	0.069	<.001
Strength	1	2	0.16	0.071	0.149	Frivolous/Sober	1	2	0	0.058	1.000
		3	0.13	0.074	0.457			3	0.1	0.061	0.694
		4	0.05	0.072	1.000			4	-0.25	0.059	<.001
	2	1	-0.16	0.071	0.149		2	1	0	0.058	1.000
		3	-0.03	0.077	1.000			3	0.1	0.064	0.731
		4	-0.1	0.075	0.982			4	-0.25	0.062	<.001
	3	1	-0.13	0.074	0.457		3	1	-0.1	0.061	0.694
		2	0.03	0.077	1.000			2	-0.1	0.064	0.731
		4	-0.08	0.078	1.000			4	-0.35	0.065	<.001
	4	1	-0.05	0.072	1.000		4	1	0.25	0.059	<.001
		2	0.1	0.075	0.982			2	0.25	0.062	<.001
		3	0.08	0.078	1.000			3	0.35	0.065	<.001
Deformability	1	2	0.08	0.088	1.000	Formal/Informal	1	2	0.07	0.067	1.000
		3	0.16	0.092	0.441			3	-0.08	0.07	1.000
		4	0.07	0.089	1.000			4	-0.03	0.068	1.000
	2	1	-0.08	0.088	1.000		2	1	-0.07	0.067	1.000
		3	0.09	0.096	1.000			3	-0.15	0.073	0.226
		4	-0.01	0.093	1.000			4	-0.09	0.071	1.000
	3	1	-0.16	0.092	0.441		3	1	0.08	0.07	1.000
		2	-0.09	0.096	1.000			2	0.15	0.073	0.226
		4	-0.09	0.097	1.000			4	0.06	0.074	1.000
	4	1	-0.07	0.089	1.000		4	1	0.03	0.068	1.000
		2	0.01	0.093	1.000			2	0.09	0.071	1.000
		3	0.09	0.097	1.000			3	-0.06	0.074	1.000
Transparency	1	2	0.03	0.076	1.000	Ordinary/Strange	1	2	0.06	0.065	1.000
		3	0	0.08	1.000			3	-0.07	0.069	1.000
		4	0.05	0.078	1.000			4	0.41	0.067	<.001
	2	1	-0.03	0.076	1.000		2	1	-0.06	0.065	1.000
		3	-0.03	0.083	1.000			3	-0.13	0.071	0.361
		4	0.02	0.081	1.000			4	0.35	0.07	<.001

	3	1	0	0.08	1.000
		2	0.03	0.083	1.000
		4	0.05	0.085	1.000
	4	1	-0.05	0.078	1.000
		2	-0.02	0.081	1.000
		3	-0.05	0.085	1.000

	3	1	0.07	0.069	1.000
		2	0.13	0.071	0.361
		4	0.48	0.073	<.001
	4	1	-0.41	0.067	<.001
		2	-0.35	0.07	<.001
		3	-0.48	0.073	<.001
Classic/Trendy	1	2	0.28	0.08	0.003
		3	0.21	0.084	0.066
		4	0.32	0.081	0.001
	2	1	-0.28	0.08	0.003
		3	-0.07	0.087	1.000
		4	0.04	0.085	1.000
	3	1	-0.21	0.084	0.066
		2	0.07	0.087	1.000
		4	0.1	0.089	1.000
	4	1	-0.32	0.081	0.001
		2	-0.04	0.085	1.000
		3	-0.1	0.089	1.000
Mature/Youthful	1	2	-0.01	0.071	1.000
		3	-0.14	0.074	0.410
		4	0.02	0.072	1.000
	2	1	0.01	0.071	1.000
		3	-0.13	0.077	0.574
		4	0.03	0.075	1.000
	3	1	0.14	0.074	0.410
		2	0.13	0.077	0.574
		4	0.16	0.079	0.250
	4	1	-0.02	0.072	1.000
		2	-0.03	0.075	1.000
		3	-0.16	0.079	0.250

Appendix 7I. Bonferroni Post Hoc results indicating the significance of differences between product types on material quality preferences.

Sensorial Attributes						Interpretive Characteristics					
	Product	***Product***	*Mean Difference (I-J)*	*Std. Error*	*Sig.*		***Product***	***Product***	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
Colour intensity	1	2	0.05	0.079	1.000	Male/Female	1	2	-0.01	0.068	1.000
		3	0.01	0.08	1.000			3	-0.07	0.069	1.000
		4	-0.07	0.079	1.000			4	-0.14	0.068	0.278
	2	1	-0.05	0.079	1.000		2	1	0.01	0.068	1.000
		3	-0.04	0.081	1.000			3	-0.06	0.07	1.000
		4	-0.12	0.08	0.727			4	-0.12	0.069	0.433
	3	1	-0.01	0.08	1.000		3	1	0.07	0.069	1.000
		2	0.04	0.081	1.000			2	0.06	0.07	1.000
		4	-0.09	0.081	1.000			4	-0.07	0.07	1.000
	4	1	0.07	0.079	1.000		4	1	0.14	0.068	0.278
		2	0.12	0.08	0.727			2	0.12	0.069	0.433
		3	0.09	0.081	1.000			3	0.07	0.07	1.000
Colourfulness	1	2	0.13	0.086	0.819	Aggressive/Calm	1	2	-0.16	0.067	0.118
		3	0.1	0.087	1.000			3	0.09	0.068	1.000
		4	-0.05	0.086	1.000			4	-0.07	0.067	1.000
	2	1	-0.13	0.086	0.819		2	1	0.16	0.067	0.118
		3	-0.03	0.088	1.000			3	0.25	0.069	0.002
		4	-0.18	0.087	0.232			4	0.09	0.068	1.000
	3	1	-0.1	0.087	1.000		3	1	-0.09	0.068	1.000
		2	0.03	0.088	1.000			2	-0.25	0.069	0.002
		4	-0.15	0.088	0.524			4	-0.16	0.069	0.106
	4	1	0.05	0.086	1.000		4	1	0.07	0.067	1.000
		2	0.18	0.087	0.232			2	-0.09	0.068	1.000
		3	0.15	0.088	0.524			3	0.16	0.069	0.106
Glossiness	1	2	0.2	0.08	0.084	Delicate/Rugged	1	2	0.72	0.076	<.001
		3	0.04	0.081	1.000			3	0.37	0.077	<.001
		4	0.32	0.08	<.001			4	0.49	0.076	<.001
	2	1	-0.2	0.08	0.084		2	1	-0.72	0.076	<.001
		3	-0.16	0.082	0.309			3	-0.36	0.078	<.001
		4	0.13	0.081	0.710			4	-0.23	0.077	0.017
	3	1	-0.04	0.081	1.000		3	1	-0.37	0.077	<.001
		2	0.16	0.082	0.309			2	0.36	0.078	<.001
		4	0.29	0.082	0.003			4	0.12	0.078	0.666
	4	1	-0.32	0.08	<.001		4	1	-0.49	0.076	<.001
		2	-0.13	0.081	0.710			2	0.23	0.077	0.017
		3	-0.29	0.082	0.003			3	-0.12	0.078	0.666

Softness	1	2	-0.28	0.087	0.009	Elegant/Vulgar	1	2	0.46	0.061	<.001
		3	-0.93	0.088	<.001			3	-0.14	0.062	0.151
		4	0.28	0.087	0.009			4	0.25	0.061	<.001
	2	1	0.28	0.087	0.009		2	1	-0.46	0.061	<.001
		3	-0.65	0.089	<.001			3	-0.6	0.063	<.001
		4	0.55	0.088	<.001			4	-0.21	0.062	0.004
	3	1	0.93	0.088	<.001		3	1	0.14	0.062	0.151
		2	0.65	0.089	<.001			2	0.6	0.063	<.001
		4	1.21	0.089	<.001			4	0.38	0.063	<.001
	4	1	-0.28	0.087	0.009		4	1	-0.25	0.061	<.001
		2	-0.55	0.088	<.001			2	0.21	0.062	0.004
		3	-1.21	0.089	<.001			3	-0.38	0.063	<.001
Scratchability	1	2	-0.36	0.068	<.001	Toy-like/Professional	1	2	0.08	0.067	1.000
		3	-0.11	0.069	0.683			3	0.33	0.067	<.001
		4	0.03	0.068	1.000			4	0.32	0.066	<.001
	2	1	0.36	0.068	<.001		2	1	-0.08	0.067	1.000
		3	0.25	0.07	0.002			3	0.25	0.068	0.002
		4	0.39	0.069	<.001			4	0.24	0.067	0.002
	3	1	0.11	0.069	0.683		3	1	-0.33	0.067	<.001
		2	-0.25	0.07	0.002			2	-0.25	0.068	0.002
		4	0.14	0.07	0.269			4	0	0.068	1.000
	4	1	-0.03	0.068	1.000		4	1	-0.32	0.066	<.001
		2	-0.39	0.069	<.001			2	-0.24	0.067	0.002
		3	-0.14	0.07	0.269			3	0	0.068	1.000
Texture	1	2	0.15	0.076	0.276	Sexy/Not sexy. dull	1	2	0.46	0.067	<.001
		3	0.24	0.077	0.011			3	-0.22	0.068	0.008
		4	-0.44	0.076	<.001			4	0.28	0.067	<.001
	2	1	-0.15	0.076	0.276		2	1	-0.46	0.067	<.001
		3	0.09	0.078	1.000			3	-0.68	0.069	<.001
		4	-0.6	0.077	<.001			4	-0.19	0.068	0.039
	3	1	-0.24	0.077	0.011		3	1	0.22	0.068	0.008
		2	-0.09	0.078	1.000			2	0.68	0.069	<.001
		4	-0.68	0.078	<.001			4	0.49	0.069	<.001
	4	1	0.44	0.076	<.001		4	1	-0.28	0.067	<.001
		2	0.6	0.077	<.001			2	0.19	0.068	0.039
		3	0.68	0.078	<.001			3	-0.49	0.069	<.001
Temperature	1	2	-0.39	0.066	<.001	Cheap/Expensive	1	2	-0.09	0.067	0.989
		3	-0.22	0.067	0.005			3	0.35	0.068	<.001
		4	-0.06	0.066	1.000			4	0.1	0.067	0.775
	2	1	0.39	0.066	<.001		2	1	0.09	0.067	0.989
		3	0.17	0.068	0.090			3	0.44	0.069	<.001
		4	0.33	0.067	<.001			4	0.2	0.068	0.025

	3	1	0.22	0.067	0.005		3	1	-0.35	0.068	<.001
		2	-0.17	0.068	0.090			2	-0.44	0.069	<.001
		4	0.17	0.068	0.085			4	-0.24	0.069	0.003
	4	1	0.06	0.066	1.000		4	1	-0.1	0.067	0.775
		2	-0.33	0.067	<.001			2	-0.2	0.068	0.025
		3	-0.17	0.068	0.085			3	0.24	0.069	0.003
Odour	1	2	0.15	0.082	0.385	Disposable/Durable	1	2	0.06	0.06	1.000
		3	-0.03	0.083	1.000			3	0.25	0.061	<.001
		4	-0.07	0.082	1.000			4	0.12	0.06	0.252
	2	1	-0.15	0.082	0.385		2	1	-0.06	0.06	1.000
		3	-0.18	0.084	0.212			3	0.19	0.062	0.013
		4	-0.22	0.083	0.044			4	0.07	0.061	1.000
	3	1	0.03	0.083	1.000		3	1	-0.25	0.061	<.001
		2	0.18	0.084	0.212			2	-0.19	0.062	0.013
		4	-0.05	0.084	1.000			4	-0.12	0.062	0.275
	4	1	0.07	0.082	1.000		4	1	-0.12	0.06	0.252
		2	0.22	0.083	0.044			2	-0.07	0.061	1.000
		3	0.05	0.084	1.000			3	0.12	0.062	0.275
Weight	1	2	0.07	0.074	1.000	Honest/Misleading	1	2	-0.01	0.067	1.000
		3	-0.06	0.075	1.000			3	-0.29	0.067	<.001
		4	-0.79	0.074	<.001			4	-0.15	0.066	0.126
	2	1	-0.07	0.074	1.000		2	1	0.01	0.067	1.000
		3	-0.14	0.076	0.410			3	-0.29	0.068	<.001
		4	-0.86	0.075	<.001			4	-0.14	0.067	0.191
	3	1	0.06	0.075	1.000		3	1	0.29	0.067	<.001
		2	0.14	0.076	0.410			2	0.29	0.068	<.001
		4	-0.72	0.076	<.001			4	0.14	0.068	0.240
	4	1	0.79	0.074	<.001		4	1	0.15	0.066	0.126
		2	0.86	0.075	<.001			2	0.14	0.067	0.191
		3	0.72	0.076	<.001			3	-0.14	0.068	0.240
Greasiness	1	2	-0.11	0.073	0.846	Cosy/Aloof. distant	1	2	0.29	0.064	<.001
		3	-0.23	0.074	0.012			3	-0.02	0.065	1.000
		4	-0.12	0.073	0.609			4	0.62	0.064	<.001
	2	1	0.11	0.073	0.846		2	1	-0.29	0.064	<.001
		3	-0.12	0.075	0.621			3	-0.31	0.066	<.001
		4	-0.01	0.074	1.000			4	0.33	0.065	<.001
	3	1	0.23	0.074	0.012		3	1	0.02	0.065	1.000
		2	0.12	0.075	0.621			2	0.31	0.066	<.001
		4	0.11	0.075	0.851			4	0.64	0.066	<.001
	4	1	0.12	0.073	0.609		4	1	-0.62	0.064	<.001
		2	0.01	0.074	1.000			2	-0.33	0.065	<.001
		3	-0.11	0.075	0.851			3	-0.64	0.066	<.001

Acoustics	1	2	-0.52	0.068	<.001	Futuristic/Nostalgic	1	2	-0.34	0.065	<.001
		3	-0.27	0.069	<.001			3	-0.17	0.065	0.065
		4	-0.65	0.068	<.001			4	-0.5	0.065	<.001
	2	1	0.52	0.068	<.001		2	1	0.34	0.065	<.001
		3	0.24	0.07	0.003			3	0.17	0.066	0.059
		4	-0.13	0.069	0.329			4	-0.17	0.065	0.066
	3	1	0.27	0.069	<.001		3	1	0.17	0.065	0.065
		2	-0.24	0.07	0.003			2	-0.17	0.066	0.059
		4	-0.38	0.07	<.001			4	-0.34	0.066	<.001
	4	1	0.65	0.068	<.001		4	1	0.5	0.065	<.001
		2	0.13	0.069	0.329			2	0.17	0.065	0.066
		3	0.38	0.07	<.001			3	0.34	0.066	<.001
Strength	1	2	-0.08	0.073	1.000	Frivolous/Sober	1	2	-0.17	0.06	0.033
		3	0.18	0.074	0.090			3	0.06	0.061	1.000
		4	0.37	0.073	<.001			4	-0.04	0.06	1.000
	2	1	0.08	0.073	1.000		2	1	0.17	0.06	0.033
		3	0.26	0.075	0.004			3	0.23	0.062	0.002
		4	0.45	0.074	<.001			4	0.13	0.061	0.186
	3	1	-0.18	0.074	0.090		3	1	-0.06	0.061	1.000
		2	-0.26	0.075	0.004			2	-0.23	0.062	0.002
		4	0.19	0.075	0.071			4	-0.09	0.062	0.765
	4	1	-0.37	0.073	<.001		4	1	0.04	0.06	1.000
		2	-0.45	0.074	<.001			2	-0.13	0.061	0.186
		3	-0.19	0.075	0.071			3	0.09	0.062	0.765
Deformability	1	2	-0.08	0.091	1.000	Formal/Informal	1	2	-0.08	0.069	1.000
		3	-0.38	0.092	<.001			3	-0.11	0.07	0.723
		4	0.78	0.091	<.001			4	-0.24	0.069	0.003
	2	1	0.08	0.091	1.000		2	1	0.08	0.069	1.000
		3	-0.29	0.093	0.010			3	-0.03	0.071	1.000
		4	0.86	0.092	<.001			4	-0.16	0.07	0.140
	3	1	0.38	0.092	<.001		3	1	0.11	0.07	0.723
		2	0.29	0.093	0.010			2	0.03	0.071	1.000
		4	1.15	0.093	<.001			4	-0.13	0.071	0.374
	4	1	-0.78	0.091	<.001		4	1	0.24	0.069	0.003
		2	-0.86	0.092	<.001			2	0.16	0.07	0.140
		3	-1.15	0.093	<.001			3	0.13	0.071	0.374
Transparency	1	2	-0.19	0.079	0.092	Ordinary/Strange	1	2	-0.1	0.068	0.931
		3	0.01	0.08	1.000			3	0.05	0.069	1.000
		4	0.62	0.079	<.001			4	-0.38	0.068	<.001
	2	1	0.19	0.079	0.092		2	1	0.1	0.068	0.931
		3	0.2	0.081	0.070			3	0.15	0.069	0.203
		4	0.81	0.08	<.001			4	-0.28	0.069	<.001

	3	1	-0.01	0.08	1.000
		2	-0.2	0.081	0.070
		4	0.6	0.081	<.001
	4	1	-0.62	0.079	<.001
		2	-0.81	0.08	<.001
		3	-0.6	0.081	<.001

	3	1	-0.05	0.069	1.000
		2	-0.15	0.069	0.203
		4	-0.43	0.069	<.001
	4	1	0.38	0.068	<.001
		2	0.28	0.069	<.001
		3	0.43	0.069	<.001
Classic/Trendy	1	2	-0.04	0.083	1.000
		3	0.05	0.084	1.000
		4	-0.14	0.083	0.498
	2	1	0.04	0.083	1.000
		3	0.09	0.085	1.000
		4	-0.1	0.084	1.000
	3	1	-0.05	0.084	1.000
		2	-0.09	0.085	1.000
		4	-0.19	0.085	0.150
	4	1	0.14	0.083	0.498
		2	0.1	0.084	1.000
		3	0.19	0.085	0.150
Mature/Youthful	1	2	0.17	0.073	0.126
		3	-0.06	0.074	1.000
		4	-0.23	0.073	0.008
	2	1	-0.17	0.073	0.126
		3	-0.23	0.075	0.015
		4	-0.4	0.074	<.001
	3	1	0.06	0.074	1.000
		2	0.23	0.075	0.015
		4	-0.18	0.075	0.115
	4	1	0.23	0.073	0.008
		2	0.4	0.074	<.001
		3	0.18	0.075	0.115

PART FOUR

PART FOUR concludes this thesis, and provides a theoretical conclusion based on the insights of all previous parts that are translated to guidelines for future experiential material characterization, and an answer to the four main research questions. In addition, it provides a designerly conclusion that describes the implications, practical recommendations and future visions in the context of experiential material characterization.

Chapter 8 summarizes the reasoning process and argumentation regarding the experimental set-up and its parameters of a concrete case of plastic material demonstrator forms that are assessed by consumers. It aims to identify a set of appropriate methodological choices as a first step towards streamlined future material characterizations to build up an experiential 'database' of various plastic materials.

Finally, **Chapter 9** reflects on the research that is done and the limitations of the dissertation. Next, a theoretical conclusion is formulated as well as propositions for each research question and in general. Building upon the reflections, this chapter also defines what the opportunities are for future research. Finally, this thesis ends with designerly conclusions from both a consumer and designer perspective, and elaborates on a future vision of a materials experience library and other opportunities.

Chapter 8 is based on:

Veelaert, L., Moons, I., & Du Bois, E. (2021). Formulating Guidelines for the Systematic Set-up of Experiential Material Characterization Studies: A Case of Plastic Demonstrators. *Proceedings of the Design Society (ICED 2021)*, 1, 1587–1596. https://doi.org/10.1017/PDS.2021.420

8. Formulating Guidelines for the Systematic Set-up of Experiential Material Characterization Studies: a Case of Plastic Demonstrators

Veelaert Lore, Moons Ingrid, Du Bois Els

Abstract: Materials can be considered from a technical and experiential perspective. However, the latter perspective is more complex to study systematically. Four intertwined experiential levels describe the overall materials experience: sensorial, interpretive, affective, and performative level. Building upon the need in experiential material characterization for comparable physical material representations to enable within-material-class comparisons and the inclusion of extensive user aspects, this paper sums up the reasoning process regarding the understanding and design of an experimental set-up and its parameters of a specific case. The case objective is to formulate guidelines for the designer/researcher to set up experiential material characterization experiments with (i) plastic demonstrator forms and (ii) by consumers. Following elements are discussed: Assessors, Stimuli, Interaction Modalities, Dependent variables, Method, and Practical considerations. Next, future experiments can be carried out in order to generate holistic plastic material data on a larger scale, that can be collected in an experiential database and used by designers throughout the design process.

Keywords: *multisensory product experience, experiential material characterization, materials experience, emotional design, human behaviour in design*

8.1 Introduction

In product design, materials can be considered both from a technical and an experiential perspective. This dualist understanding of materials has gained increased interest over the years (Ashby & Johnson, 2010; Camere & Karana, 2018; Karana et al., 2014) and led to a new field of materials experience both in design research and practice (Veelaert, Du Bois, et al., 2020). Thus, a holistic approach within the design process does not only require material characterization knowledge with regard to technical properties, manufacturability and functionality that can be historically found in datasheets based on standardized tests (Ashby & Johnson, 2010; Jahan et al., 2010). In addition, the experiences that materials can elicit through physical products should be considered as well to increase commercial success of both products and materials in a competitive market (Giaccardi & Karana, 2015; Karana, Pedgley, et al., 2015).

When aiming for a circular economy (Ellen MacArthur Foundation & McKinsey & Company, 2012) within engineering design, different focuses can be found related to materials, going from materials production, selection and the impact on future waste, to elongating the product use phase through product attachment by means of products and materials that suit the user's personality (Mugge et al., 2005; Norman, 2004). This leads to an increased search for new and alternative materials that are more sustainable and suiting in a circular economy, e.g. natural material, bioplastics, recycled plastics and so on. However, these material's origin impacts both their properties and perceived aesthetics (Dehn, 2014; Karana, 2012; Schifferstein & Wastiels, 2014). Often, such new materials struggle for adoption when introduced in the market, partly due to the lack of knowledge or data on how they are perceived and experienced by people as they are frequently implemented as surrogates or substitute materials (Salvia et al., 2011; Sauerwein et al., 2017; Vezzoli, 2014).

Following the Meanings of Materials Model (Karana, 2010), it is the interaction between the user and a material that defines a material's meaning or meanings. However, various factors continuously influence this meaning creation, such as the product in which the material is embodied, its shape and brand, the time and context in which it is used, the background of the user (i.e. gender, age, culture, etc.), and of course the technical properties and experiential qualities of the material itself.

Considering the latter, four experiential levels are defined in literature that are intertwined and as such describe the overall materials experience (Camere & Karana, 2018; Giaccardi & Karana, 2015; Karana, Pedgley, et al., 2015). The three first levels address the cognitive aspects of experiences, while the final level encompasses the behavioural aspects. First, the sensorial level encompasses the first encounter of our senses with a material and is as such inherently part to human experience (e.g. is the material perceived glossy or light). Within this level, the visual perception of materials and its attributes is highly important in recognizing materials, even without touching (Fleming, 2014, 2017). Second, the interpretive level follows the sensorial encounter and involves the interpretations and meanings people attribute to materials (e.g. is the material associated with masculinity or nostalgia). Third, the affective level includes the emotions that material can unconsciously elicit (e.g. does the material make me feel surprised or fascinated). Fourth, the performative level reflects our physical response or actions to the previous levels (e.g. does the material invite to caress or to fold). Camere and Karana (2018) state that: "The experiential characterization of materials … concerns investigating how a material is received, what it makes people think, feel and do. … Accordingly, the experiential characterization of materials should provide designers with an understanding of what people experience when they encounter a material (e.g. they find it 'surprising', or 'cosy'), to what extent they agree with each other (e.g. how many of them are 'fascinated' by the material), and why they experience a material in the way they do (e.g. what sensorial qualities of the material elicit 'surprise')".

However, Camere and Karana (2018) acknowledge that "materials experiences can be quite challenging to study and research, and it requires a delicate balance between studies that provide both a holistic perspective … and detailed, specific information". Indeed, a large gap is found in equivalent data support on experiential material knowledge (Piselli et al., 2018; Veelaert, Du Bois, et al., 2020; Wilkes et al., 2016). Therefore, they developed the Ma2E4 toolkit for design professionals to facilitate experiential characterization of materials in an agile and inspiring matter. However, the toolkit is rather focused on specific material cases than on large scale material data that is needed for designers. Although the toolkit pays profound attention to the evaluation of various experiential material qualities, it does not involve the physical means or material samples to do so, nor a more structured analysis that can be useful for data driven design.

Conclusively, this paper aims to formulate guidelines for the systematic set-up of experiential material characterization experiments. By streamlining these studies, material characterizations on a large and standard scale can lead to an experiential database of various materials, helping designers in their design and materials selection process as they are backed by data on materials and target audience (consumers).

When looking at domains such as food science, well-founded tests and statistical procedures for sensory profiling have been embraced (Reinbach et al., 2014; Sidel & Stone, 1993; Varela & Ares, 2012). These have been recently utilized for visual and tactile material characteristics as well (Faucheu et al., 2015; Piselli et al., 2018). Within (interior) architecture, the link between warmth/roughness perception and technical properties of building materials has also been investigated (Wastiels et al., 2012a, 2012b). Conclusively, an extensive literature review (Veelaert, Du Bois, et al., 2020) describes how various researchers respond to the methodological challenges involved in experiential material characterization studies, and articulates the need to find "abstract forms or products that do not carry too much meanings in itself so that material meaning can be projected more independently" (Veelaert, Du Bois, et al., 2020). To achieve a more holistic understanding of materials' experiential qualities, a transition to straightforward and streamlined set-ups of experiential material characterization studies on a larger scale - facilitating data driven design - is still a stumbling block for many material/design researchers.

8.2 Case

Multiple studies emphasize the specific context or objectives within materials experience studies that require different approaches for this experimental set-up of experiential material characterization (Camere & Karana, 2018; Karana & Hekkert, 2010). Next to context-specific material data, generic data of experiential material qualities can also offer insights for designers in the beginning of their design process (Veelaert, Du Bois, et al., 2020). Hence, experiential studies can start from contextualized materials in a specific product (e.g. (Crippa et al., 2012; Karana et al., 2009a)), or can employ abstract, decontextualized samples (e.g. (D'Olivo et al., 2013; Wastiels et al., 2012b)). This way, experimental conditions are easier to control as the material is assessed independent of context. Therefore, this paper builds upon a specific case that arises from previous experiences and needs defined in (Veelaert, Du Bois, et al., 2020): (i) need for within-material-class comparisons, (ii) need for physical material representations, and (iii) need for integration of extensive user aspects. First, as little comparisons within material classes can be found - and especially within plastic materials - this case will focus on the facilitation of comparing plastic materials (i.e. virgins, recycled plastics, bioplastics, etc.) that face issues within a circular economy such as sustainable perception or being identity-less imitation materials (Karana & Nijkamp, 2014; Rognoli, Salvia, et al., 2011; Veelaert, Du Bois, et al., 2020). Furthermore, Fisher (2004) addresses the specific significance of plastic materials for consumers' perception of objects, and its affective consequences. Second, this case employs a standard demonstrator form that is developed in previous research (Veelaert et al., 2022), see Figure 8.1, as an answer to the proposed "abstract in-between form that allows an equal and thus constant presentation of various materials, but is varied in itself" (Veelaert, Du Bois, et al., 2020). Such a complex demonstrator form allows for more controlled experimental conditions while still facilitation multimodal free exploration of its material.

Third, as a large number of studies involve designers in characterization experiments or limited user aspects beyond age and gender, this case will take on the challenge to specifically address and trigger consumers in a dynamic experiential material characterization as end-users of products/materials. This way, future large-scaled studies can be combined with consumer segmentation for marketing purposes.

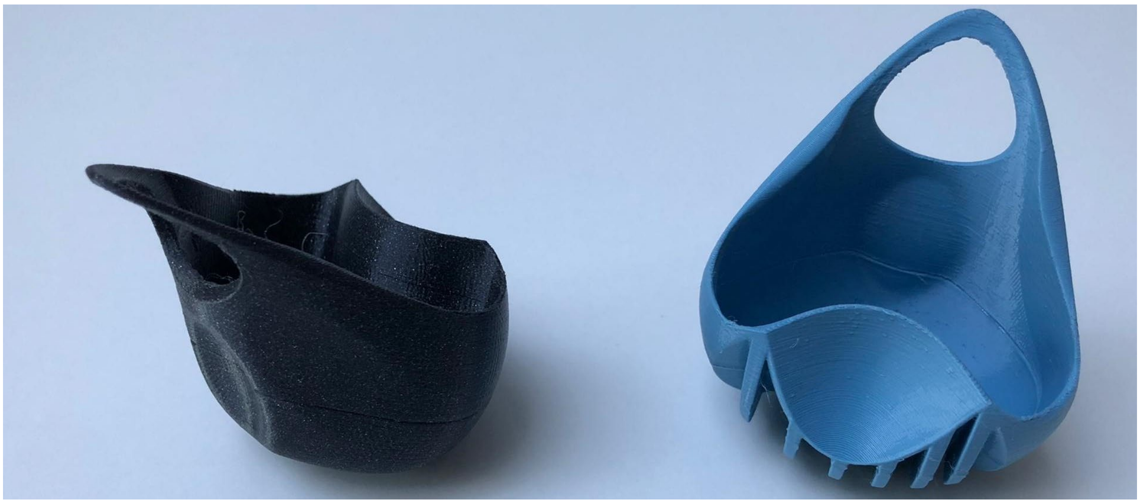


Figure 8.1. Demonstrator forms shown from two perspectives, based on (Veelaert et al., 2022).

8.3 Research aim

This paper summarizes the reasoning process and argumentation regarding the experimental set-up and its parameters of a concrete case within materials experience studies. The objective is to formulate guidelines for the designer to systematically set up experiential material characterization experiments with (i) plastic demonstrator forms and (ii) by consumers. Therefore, this research aims to identify a set of appropriate methodological choices as a first step towards streamlined future material characterizations to build up an experiential 'database' of various plastic materials such as virgins, recycled plastics, bioplastics, etc. To structure the work, the next Section is based on the encryption categories of a previous literature review on this matter (Veelaert, Du Bois, et al., 2020) and a practical handbook on sensory evaluation (Kemp et al., 2018): (i) stimuli, (ii) interaction modalities, and (iii) dependent variables, (iv) assessors, and (v) method.

8.4 Guidelines for Experimental Set-up: Experiential Material Characterization of Plastic Demonstrators by Consumers

8.4.1 Assessors

As previously stated, this case focuses on **consumers** as participants, as compared to designers or expert sensory panels. Since consumers can be considered as naïve and untrained assessors, and can also be involved in affective judgements. In addition, **large-scaled** experiential studies with consumers can also offer segmentation opportunities when including extensive user aspects beyond merely age and gender, such as culture, personality traits and values. In the case of continuous experiments over time, a large panel size of consumers can be achieved to generalize findings. The higher the number of assessors, the higher the power of the statistical test that can be performed to analyse the data and improve discrimination between the material stimuli (Kemp et al., 2018). Even for preliminary results, at least thirty assessors per cell are recommended (e.g. at least thirty man and thirty women when comparing material perception based on gender), or preferably even hundred participants (Brysbaert, 2019; Sitanshu Sekhar Kar & A. Ramalingam, 2013; Wilson Vanvoorhis & Morgan, 2007).

8.4.2 Stimuli

Within experiential characterization, the greater part of studies involve **physical samples** (Veelaert, Du Bois, et al., 2020) that are stated by Martín et al. (2015) to be still the standard. However, physical stimuli can reveal themselves in both contextualized product samples and decontextualized abstract samples. For greater experimental control, abstract shaped specimens are often recommended (Piselli et al., 2018; Veelaert et al., 2019, 2022). As clarified in the previous Sections, the physical stimuli in this case involve a set of standard demonstrator forms that are developed specifically for **one material class: plastics**. However, within-material-class comparisons in this case can still be going from well-known virgin plastics (e.g. PP, PE, ABS), to recycled plastics (both pure and mixed virgins) and bioplastics (e.g. PLA). This material class is chosen as it is not yet studied on its own within experiential characterization although it represents a material class that is familiar and widely used in everyday products. The demonstrator forms shown in Figure 8.1 is designed to be injection moulded so that high-end quality can be achieved (Veelaert et al., 2022).

8.4.3 Interaction Modalities

As this case is characterized by physical material samples for within-class comparisons (see Section 10.2), the experiment's interaction context is of great importance. Although various interaction modalities and senses can be employed or combined, touch and vision are found to be most dominant within the appraisal of materials (Karana, 2009; Sauerwein et al., 2017; Schifferstein & Wastiels, 2014). This is in contrast to the fact that it is hard to isolate the senses as human behaviour and perception are intrinsically multisensory (Dacleu Ndengue et al., 2017; Schifferstein, 2010). Based on literature (Y. T. Chen & Chuang, 2014; Veelaert, Du Bois, et al., 2020) and the developed demonstrator form (Veelaert et al., 2022), this case focuses on **multimodality** through dynamic touch (Hope et al., 2012) and free exploration, and thus approaches the actual phase of use of a product and its material (Crilly et al., 2009; D'Olivo et al., 2013). Conclusively, the complex demonstrator form is aimed at evoking a holistic, multisensory interaction, triggering participants into extensive exploration and manipulation of its materials using all senses (Veelaert et al., 2022). This way, it is possible to facilitate the understanding of all experiential levels, including performative actions such as rubbing, playing, picking up or grabbing a sample (Camere & Karana, 2018; Y. T. Chen & Chuang, 2014).

8.4.4 Dependent Variables

Following the Materials Experience Framework (Karana et al., 2014) and its practical translation into the Ma2E4 toolkit (Camere & Karana, 2018), four experiential levels can be incorporated as dependent variables within experiential characterization of materials: sensorial, interpretive, affective, and performative. However, the two first levels are most commonly involved in past experiments (Veelaert, Du Bois, et al., 2020) and in the development of the demonstrator form (Veelaert et al., 2022), as they are usually more approached from a semi-quantitative perspective in contrast to a more qualitative evaluation of emotions or the observation of performative actions.

The vocabulary of the Ma2E4 toolkit mentions twelve **sensorial** attributes (hard/soft, smooth/rough, matte/glossy, not reflective/reflective, cold/warm, not elastic/elastic, opaque/transparent, tough/ductile, strong/weak, light/heavy, regular texture/irregular texture, fibred/not-fibred), eleven **meaning** sets (aggressive/calm, cosy/aloof, elegant/vulgar, frivolous/sober, futuristic/nostalgic, masculine/feminine, ordinary/strange, sexy/not sexy, toy-like/professional, natural/unnatural, hand-crafted/manufactured), twenty **emotions** (frustration, boredom, disappointment, reluctance, confusion, rejection, disgust, melancholy, distrust, doubt, love, amusement, surprise, confidence, enchantment, respect, attraction, curiosity, fascination, comfort), and proposes twenty-two **actions** (pressing, rubbing, grazing, compressing, poking, caressing, fiddling, pounding, pushing, folding, lifting, weighting, bending, flexing, picking, squeezing, smelling, holding, seizing, pinching, grabbing, grasping…), see also (Angelini et al., 2015; Cutkosky, 1989; Lederman & Klatzky, 2009). However, additional experiential qualities can be interesting for characterization experiments too, as used in previous work focussing on (recycled) plastics (Veelaert, Du Bois, et al., 2020; Veelaert et al., 2022).

A final consideration relates to assessing the experiential levels one by one or randomly mixing them together. For the ease of understanding for consumers, and following the structure of the Ma2E4 toolkit, we propose to sequentially assess attributes per experiential level in the context of this specific case.

8.4.5 Method

8.4.5.1 Measurement of Constructs

Although some experiential qualities might be less relevant in the context of plastics, a more important consideration comes into play, next to the extensive list of attributes available. The measurement of these experiential constructs can be done in different ways, but should ideally be streamlined for future database building. Largely derived from marketing research and sensory evaluation within food science, four main categories of sensory tests can be distinguished: descriptive testing, discrimination testing, hedonic test, and free impressions. However, within experiential material characterization, descriptive scaling method by means of the **semantic differential scaling method** (SDM) (Osgood et al., 1957) is most frequently used (Hsu et al., 2000; Petiot & Yannou, 2004; Veelaert, Du Bois, et al., 2020). It has also been applied in the sensorial scales of Karana et al. (Karana et al., 2009a, 2010) and within the Ma2E4 toolkit for the characterization of sensorial attributes (using clarifying pictograms for untrained respondents) and interpretive characteristics (Camere & Karana, 2018). To provide a midpoint for neutrality, an odd number of scale points is preferred (Lilley et al., 2016) and approaches a more interval-based scale. Moreover, odd scales are used in 85% of past experiential scaling experiments (Veelaert, Du Bois, et al., 2020) that employ usually five (preferred for translation into experiential characterization map; (Camere & Karana, 2018)) or seven points (for more detail).

With regard to this paper's case, we propose to stay consistent and adopt these unstructured scales with pairs of bipolar adjectives at the beginning and end of the scales (Ledahudec et al., 1992). However, in order to converge interval-based statistical potential, equal distances should be emphasized by using signed numbers between the opposite pairs, preferably with a continuous slider as well so that participants can select any point between 1 and 5 or between -2 and +2. For example, the scale of the sensorial attribute Glossiness looks like "Very glossy -2, -1, 0, 1, 2 Very matte".

8.4.5.2 Experimental Design Structure

Randomisation is an important factor to consider in the experimental design of material characterization studies, especially in large-scaled experiments. In order to minimize fatigue and order effects it is recommended to randomize (i) the selection, (ii) the order, and (iii) the position (left versus right) of the experiential qualities/pairs. Of course, this implies that it is more easily done through a digital survey as compared to characterization exercises on paper. Section 10.4.4 already summed up the extensive list of experiential qualities over four levels, but only a selection can be questioned at once per participant, leading to a between-subjects design that is easier to set up, shorter and slightly minimizes learning and transfer across conditions (Charness et al., 2012). Moreover, when the aim is to experientially characterize 'all plastics', i.e. a great variety of plastic variations over time, a random selection of available material stimuli must be made as well, leading to another between-subjects factor. This combination is defined as a balanced incomplete block (BIB) design and requires specific data analysis such as analysis of variance or ANOVA (Kemp et al., 2018).

With regard to sample presentation techniques, a serial or sequential monadic design is most common, in which material samples are presented independently, one after another (Kemp et al., 2018). However, for within-material-class comparisons of plastic demonstrators in this case, a reference framework by means of a simultaneous **comparative design** could be more beneficial for untrained consumers that might find it easier to asses stimuli in relation to each other instead of absolute (Cleaver, 2018), since human perception is inherently holistic and comparative (Pagès et al., 2010). Thus, this way participants are given a random set of material demonstrators that each need to be assessed are allowed to reassess and compare multiple materials with each other.

8.4.5.3 Factors Affecting Measurements

Consumer judgements can be easily influenced by bias due to psychological factors, as summed up by (Kemp et al., 2018). In the context of experiential material characterization, several errors can be expected of which one should be aware in setting up experiments. First, **stimulus errors** occur when assessors focus on prior knowledge when rating a sample (clues such as packaging or style), instead of their perception of the material itself. We aim to diminish this effect by providing standard demonstrator forms so that irrelevant influence of contextual factors is downsized or at least kept constant over multiple materials. Second, **halo effects or proximity errors** occur when (untrained) assessors score consecutive attributes in a similar way as compared to when these attributes would be questioned separately. This effect can be expected with untrained assessors, but can be countered by involving a limited number of attributes, separating sensorial attributes versus interpretive characteristics, and randomising their order. Third and similarly, **order effects** occur when an assessor is influenced by the order of questions, samples or attributes. This can be decreased by randomizing the order of material sample presentation. Fourth, **central tendency errors** occur when participants avoid extremes and prefer scale middle points, but can be reduced by exposing them to a wide range of samples and a large enough scale. Overall, the combination of using the proposed standard demonstrator forms as material stimuli (Section 10.4.2), as well as a randomisation of both stimuli and attributes (Section 10.4.5.2), is expected to reduce these errors in experiments of experiential material characterization.

8.4.5.4 Practical

Finally, practical considerations also count in setting up experiential material characterization experiments. Both budget and feasibility depend on the timing or test **duration** that is possible and desirable. Previous literature review (Veelaert, Du Bois, et al., 2020) reveals that the number of stimuli in experiential material characterization experiments varies between 3-96 material samples with a median of 10 samples. The number of scale items differs between 1-34 items with a median of 10 items. When taking into account both the number of stimuli and the number of semantic scales that need to be assessed for each material sample, a delicate balance must be intended. Therefore, we propose to aim for 3-5 material samples that are assessed on 5-10 experiential attribute pairs, balancing a total of 25-30 assessments to be made by each participant. Overall, a maximum total time of twenty minutes per experiment seems achievable, including segmentation questions. When the motivation of the consumer can be increased by appropriate feedback or fun elements, different scenarios could be proposed, i.e. a short, medium and long version of the test, so that one can choose to repeat the experiment with additional materials and/or attributes.

8.5 Discussion

Although this paper presents guidelines for an experimental design that is limited to our own case of experiential material characterization, several aspects can be generalized within this scenario. First of all, it is important to define the aim of the experiential study: is the objective to generate qualitative experiential information about one new material that can be applied in a specific project (e.g. Material Driven Design), or is it to compare a broad set of different materials with one another? The former option is more case-specific and allows to go more in detail and collect more qualitative material information, while the later sprouts from a more holistic perspective to collect data on a large scale which offers opportunities to link this data to consumer segmentation information. Overall, we see opportunities in always comparing materials in the beginning of setting up an experiential database, while in the end when a basic amount of data has been generated, new data can be added by means of specific material studies.

In addition, when focussing on a holistic or generic perspective when collecting experiential material data, it is important to consider the importance of context within materials experience. Indeed, meanings of materials are influenced by contextual factors such as the products they are embodied in, where these products are used. To overcome this context issue, the proposed guidelines build upon the use of an abstract demonstrator form that is aimed to be independent of context, to allow controlled experimental conditions. However, when conducting characterization experiments with these demonstrator forms, it is possible to include "envisioning factors" by asking participants to envision the demonstrator's material in a particular product or situation. Thus, the abstract form can offer flexibility despite standardization of the form, and as such increase time efficiency and practical difficulties.

Conclusively, the next step in future research should be to start carrying out experiential characterization studies following the proposed guidelines and thus, gather experiential data on a large set of plastic materials such as virgins, bioplastics and recycled plastics (data-driven design). Together with large-scale information on user aspects (of consumers), relationships can be sought between different types of plastics and their (sustainable) perception in order to facilitate their commercial success in a circular economy.

8.6 Conclusion

In this paper, we presented a selection of experimental guidelines that can be further used by designers to set up experiential material characterization studies within a specific case in which we focus on plastic materials (virgins, recycled, bioplastics, etc.), made physical by means of standard demonstrator forms, and assessed by consumers. A schematic overview of these guidelines is presented in Figure 8.2.

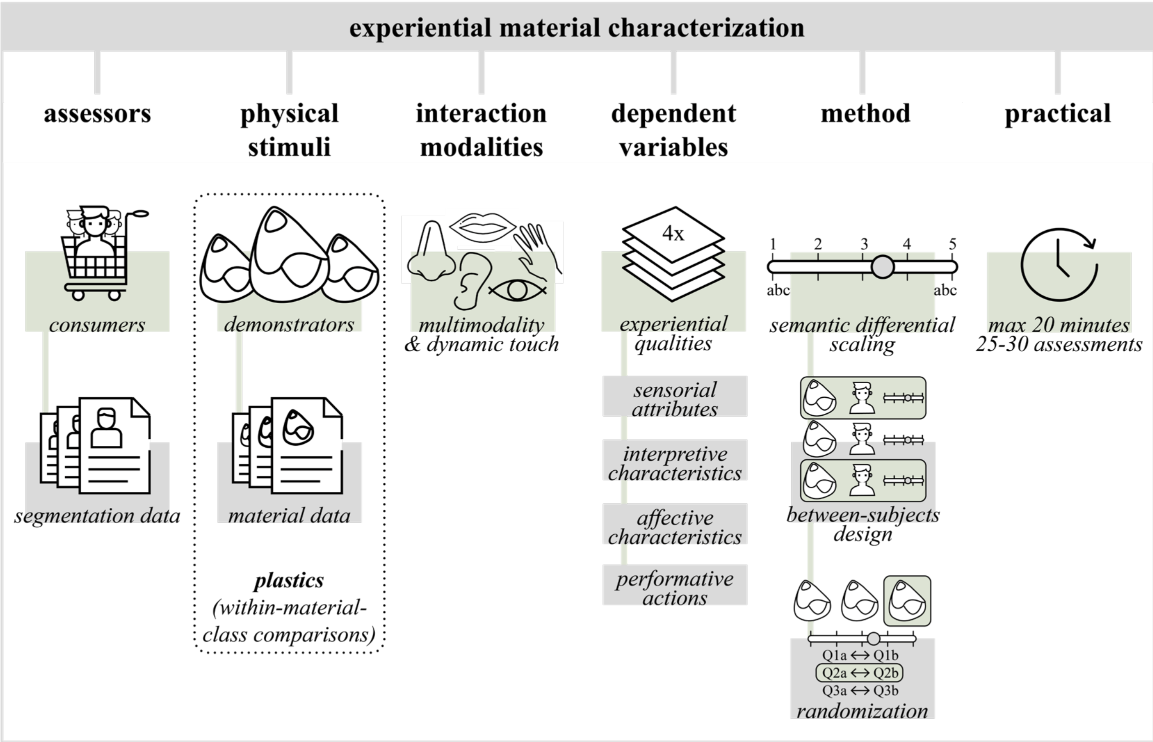


Figure 8.2. Schematic overview of guidelines for experiential characterization studies.

To sum up, an experimental design involving the following elements was proposed: (i) experiential characterization by consumers in large-scales studies for segmentation opportunities based on more extensive user aspects, (ii) standard physical demonstrator form in various plastics for greater experimental control and within-material-class comparisons, (iii) approaching use phase through multimodality and dynamic touch to offer an holistic, multisensory interaction with extensive material exploration to facilitate the characterization of all experiential levels, (iv) assessing qualities within these experiential levels separately instead of mixed together to ease understanding, (v) and by using the semantic differential scaling method with five-point scales, a continuous slider and signed numbers between opposite pairs, (vi) a between-subjects design with randomization of the selection, order and position of experiential qualities on scales, as well as a random selection of a set of plastic demonstrators in a comparative design set-up, (vii) and finally aiming for a balance of 25 to 30 assessments (material x quality) per participant within a total duration of twenty minutes.

To conclude, we hope these guidelines offer a common starting point for design researchers to set up experiential characterization studies with consumers and plastic materials so that experiential data can be gathered and shared on a large scale, and relationships with extensive user aspects can be investigated.

9. Conclusions and Future Research

9.1 Reflection on the Research

How can we capture the way consumers and end-users experience materials, i.e. experiential material characterization, and embed it better in product design? This question was the starting point of this thesis, and brought a number of further questions with it along the way. *What is the state of the art of experiential material characterization in product design? How can research on experiential material characterization be improved by means of an appropriate demonstrator form? How can user/consumer aspects be involved more extensively in experiential characterization of materials?* And *How can these insights be integrated in a framework for experiential material characterization?*

What we saw in this thesis was that – despite the growing interest in this research field – several gaps or opportunities could be identified that were drafted as the six needs for further research in Chapter 1. Two of the largest challenges of this thesis, in this respect, were (i) to find an appropriate and physical material representation that could facilitate within-material-class comparisons – of plastics for example – and trigger consumers in multimodal experiential material characterization, and (ii) to include individual self-expressive values in detailed segmentation profiles.

With regard to the detailed sub research questions, we can conclude that we succeeded in the development of the demonstrator form, as well as the relevant consumers segments. However, during and after the research done, many new questions arose (as it should in research). Thus, to fully answer the overall research question, additional studies are still required. This first section of the conclusion chapter reflects upon these considerations.

9.1.1 The Sense in Standardization

In the beginning of this doctoral project, we quickly discovered the great variety in experiential characterization of materials. Both our own attempt to set up small explorative studies with materials and the difficulties to control experimental conditions, and the extensive literature review on other cases on this subject, revealed that there are numerous ways to deal with such methodological choices, and indicated that some level of streamlining these experiments would be valuable. Therefore, we wanted to aim for standardization within this field. Originally, we reasoned if we could pin down or control as many aspects as possible, over time, a large set of experiential material data could be collected. This way, data of different studies could be combined and compared, leading to a 'database', as is custom for technical properties.

However, two considerations arose in this regard. First, to be able to benefit from standardized experiential material characterization including all the elements as proposed in the guidelines of Chapter 8, the initial dataset must be very large. Roughly estimated, over 4000 responses would be required to provide sufficient data for statistical processing (taking into account the four consumer segments, the extensive list of experiential qualities, the number of (plastic) materials, etc.). As physical evaluations of materials is needed, this would still be a time-consuming and costly undertaking.

Second, when reflecting on this objective of standardization at the end of the dissertation, we recognize that this should refer to the standardization of the method rather than the standardization of data. Based on this thesis, collecting self-expressive values of respondents and dividing them in one of the four consumer segments, in combination with using the designed standard abstract form to represent materials in a standardized procedure, would offer a great added value to the field of experiential material characterization, to enable comparison of data from different studies.

In addition, the question remains whether it is actually possible to organize experiential material data in a database? Are there one-to-one relationships that can be included, as there are for technical material properties? How can we enhance the dualist understanding of materials, both from an experiential and a technical perspective?

In the past, various attempts have been made to find interrelationships between technical properties and experiential qualities that are very useful for designers in their materials selection process. In the Properties Relation Sheet, van Kesteren (2008) sums up the links between several experiential qualities, the contributing physical properties and the way designers can tune these perceived qualities. For example, the visual glossiness of a material is determined by the reflection coefficient of the material, the surface roughness, the orientation of pigments and the index of refraction, and can be tuned by surface treatments and external influences such as the light source. The perceived softness of a material depends on the elasticity modulus and the hardness, and can be tuned by geometry, roughness properties and texture properties. All in all, most tuning opportunities lie in the area of geometry and surface treatments, illustrating the great importance of a 'constant' form for experiential studies as well as colour-material-finish considerations (CMF, see further on). In the Expressive-Sensorial Atlas, Rognoli (2010) refers to the associations between warmth perception and thermal capacity and conductivity, between weight perception and material density, etc. Based on the development of a set of design tools for interdisciplinary translation, Wilkes et al. (2016) showed the relation between perceived hardness and elasticity modulus, between perceived warmth and thermal effusivity, and between perceived roughness and actual roughness. Similarly, Piselli et al. (2018) found a positive correlation between perceived glossiness and the physical measurement of glossiness, and propose the integration of user perception in sensory analysis to rationalize CMF decision with quantifiable information.

These interrelationships could represent the bridge between inspirational experiential material qualities and informational technical material properties, in a 'database' that combines both experiential cases and technical datasheets (similar to the Product Material Database of Ansys - formerly CES - Granta Edupack).

9.1.2 The Question of Qualitative versus Quantitative

This dissertation started with the aim of bridging the gap between qualitative experiential qualities and quantitative technical properties with a more quantitative approach to experiential material characterization as well. Although when following the guidelines of Chapter 8, and involving a large number of consumers that evaluates various material demonstrators, one could also reach quantitative data on experiential qualities, this does not mean that this data can be handled the same way as technical material data through standardized tests. Experiential material qualities are still very dependent of multiple contextual factors, so no exact one-to-one relationships can be guaranteed. The obtained data does, however, indicate potential patterns into which qualities are perceived differently or more important by different types of consumers, and must as such be further investigated qualitatively in specific design cases. It can also offer inspiration for the designer in the early phases of the design process to select a set of materials that might be useful when designing a product for a certain target group and/or with an intended quality in mind (such as durable, professional, high quality, etc.).

Moreover, additional qualitative studies leave opportunities to investigate the link between experiential levels, and the why of these relationships, which has not yet been covered in this thesis.

9.1.3 Who Will Give Us the Right Input?

In an ideal scenario, a large number of consumer respondents should be recruited to link the consumer segments with experiential material data by using material demonstrators in experiments. However, this cannot happen overnight, and might not be feasible (nor affordable) in the short term.

Similar to what is done within sensory food science, a high involved panel could be recruited initially, involving consumers that well represent each of the four segments. We can imagine that people who are very 'tactile' in life or profession might be more comfortable than the average consumer in characterizing the experiential qualities of materials, which could also increase the reliability of the obtained data. We think of people such as a wine taster, chocolatier, fashion designer, and so on. It might be relevant to select respondents through a preliminary study that assesses their preference for haptic information, for example by the "Need for Touch" (NFT) scale (Peck & Childers, 2003).

In this respect, we might consider employing design students again, as they are very accessible – which was also shown by the prevalence of students in the studies of the review in Chapter 1 – and can be easily attracted in a materials experience library at campus. Moreover, bachelor students might be less biased yet than master students, but they have already had an initiation of materials science. Nevertheless, it might be more difficult to find design students in each of the four clusters as we assume they represent a more homogenous group instead of a broader consumer population.

All in all, a complementary approach that involves different types of respondents or expertise, is probably most realistic, and could be a powerful methodology for experiential material characterization. In the beginning of setting up an experience library, we could focus on a high involved panel (i.e. trained consumers or design students) for initial data and later on complement this with broader consumer data (i.e. naive respondents). New materials that are added to the library can then be handled by the panel as well, before broader experiments.

9.1.4 The Case of Context

The material demonstrator of Chapter 4 aimed to avoid the effect of context, or at least control these effects. By proposing a standard form for experiential studies, we tried to minimize the effect of product context associations and controlled the effect of form (as form would be a constant). By incorporating the four segments of Chapter 7, we also tried to include the effect of user aspects on a material's meaning. We assume that the obtained experiential data offer insight in the potential qualities that stand out for a particular material and for a particular segment, but when applied in a real design context, these qualities can still be enhanced or undermined (or even completely shifted), which must be further addressed by the designer through qualitative studies or interviews with consumers.

9.1.5 Emerging Materials

Emerging materials or "advanced materials and disruptive technologies, with an emphasis on aesthetic and application novelty" (Pedgley et al., 2021, p. 16) are gaining more importance over the last years, both by designers and design researchers. This thesis focussed on more traditional materials within industrial design and product design, such as plastics, but keeping in mind the rise of alternatives such as recycled plastics and biobased plastics. However, the overall insights can be applied to other new materials such as living materials, mycelium, smart textiles, electroluminescence materials, DIY materials and so on. First of all, when studying these new materials, it is not only interesting to include the designer that will design with and for these materials, but also the consumer they want to reach by means of the segmentation survey and clusters of Chapter 7. The individual self-expressive values of conservation, innovativeness and green self-identity might have an influence on the extent that people would like or accept these materials and the applications thereof. Secondly, such emerging materials definitely need speaking demonstrators to communicate their potential. In order to facilitate the comparison with conventional (plastic) materials, it would be very interesting to employ the same form as that of Chapter 4, though it might not always be feasible as the form was intended for injection moulding.

9.1.6 The Injection Mould

The proposed demonstrator form of Chapter 4 was developed for the purpose of injection moulding a broad number of plastic materials. Therefore, we kept in mind aspects such as a two-part mould, a large draft, decent wall thickness, etc. However, not all plastic materials will match this mould equally well, as some will flow better than others. Although injection moulding usually delivers high quality pieces, in the process of setting the right parameters, failed pieces will occur as well. Albeit interesting for engineers or designers from a practical perspective, in experiential studies, this could possibly give a distorted image of the material's qualities applied in real products. Therefore, it is important that materials for the demonstrator library are selected independently and fairly before inclusion.

9.2 Theoretical Conclusions

9.2.1 Overall Conclusion

In product design, materials can be considered from both a technical and a user-centred experiential perspective. However, we learned that experiential characterization perspective is much more complex to address systematically than technical characterization. This thesis has made a start in making supporting the standardization of the method to retrieve user-centred experiential material qualities. In order to accomplish this, we first showed that consumers are capable of evaluating the potential experiential qualities of materials by means of manipulating an abstract material demonstrator form in a specific experimental set-up. In addition, this thesis showed that based on individual self-expressive values, consumers can be classified in clusters that differ in experiential material preferences. By using material demonstrators, more insights in preferences of cluster segments can be achieved. This can aid designers in selecting appropriate materials for their products aimed at these segments early in the design process.

- **Proposition 1**: This dissertation contributes to the way we can continue materials experience studies and systematically gather experiential material data, by addressing the six defined needs: (i) need for within-material class comparisons, (ii) need for physical material representations, (iii) need for multimodal interaction with stimuli, (iv) need for complementary experimental set-up and methods, (v) need for studying temporality of materials experience, and (vi) need for integration of extensive user aspects for consumer segmentation.
- **Proposition 2**: Within experiential material characterization, the standardization of the method proved to be more important than the actual standardization of the experiential data.
- **Proposition 3**: As no all-encompassing one-to-one relationships between materials and their experiential qualities can be guaranteed, a qualitative approach should supplement the proposed semi-quantitative approach in order to enrich the experiential data with actual context-related insights.
- **Proposition 4**: The added value of the abstract demonstrator is twofold: the form can facilitate the (rather quantitative) characterization of a material's 'inherent' experiential qualities – that can be either enhanced or undermined by designers – as well as the (qualitative) study of the underlying dynamics of materials experience.

9.2.2 Propositions per Research Question

RQ1: What is the state of the art of experiential material characterization in product design?

- **Proposition 1.1**: Abstract physical material representations are defined as a crucial aspect of multimodal material characterization experiments.
    - Such form allows an equal and thus constant presentation of various materials, but is varied in itself, and as such evokes interaction, and allows or facilitates free exploration. This requires an appropriate level of complexity of the form to trigger respondents to empathize with a material sample multimodally.
- **Proposition 1.2**: The integration of extensive user aspects (in terms of individual self-expressive values) is needed to facilitate consumer segmentation within materials experience context.

  - These user aspects are defined as the following individual self-expressive values: personality traits, personal values, environmental concern, green self-identity, consumer innate innovativeness, aesthetic experiences, and materialism.
- **Proposition 1.3**: A gap is defined in longitudinal studies to understand the temporality of materials experience, which requires ethnographic studies that complement in-lab experiments.

RQ2: How can research on experiential material characterization be improved by means of an appropriate demonstrator form?

- **Proposition 2.1**: In order to find a balance between an engaging, interactive and interesting form and reduce influence of context, it was found that: (i) neutrality does not exist, however, things can be more or less neutral than others, and a form might still be neutral enough for material exploration. (ii)Neutrality through simplicity causes too much simplification instead of interactivity to engage consumers in extensive material exploration.
- **Proposition 2.2**: The proposed demonstrator form is a physical and decontextualized expression of a material's experiential qualities, and offers a higher control or independency than with actual products, as well as a higher level multimodal interaction than with standard flat plates.
- **Proposition 2.3**: From a methodological point of view, the successive small experiments showed that consumers were capable to envision the potential experiential qualities and materials experience by means of the abstract form, and imagine the material's application in a real product.

RQ3: How can user/consumer aspects be involved more extensively in experiential characterization of materials?

- **Proposition 3.1**: The individual self-expressive values of consumers influence the preference for certain experiential material qualities, which can guide designers to select the appropriate materials for the intended target group.
- P**roposition 3.2**: Based on a specific set of individual self-expressive values, it is possible to achieve a rich segmentation of consumers in four clusters that significantly prefer different material qualities in everyday products.

RQ4: What does an integrated framework for future experiential material characterization look like?

- **Proposition 4.1**: The proposed methodology offers a common (or standardized) starting point for design researchers to set up experiential characterization studies with consumers and with the proposed demonstrator form, so that relationship between experiential material qualities and consumer segments can be investigated.

9.2.3 Future Research

Based on the gaps detected in the literature review and on the learnings throughout this dissertation, several opportunities for future research can be defined that we have not been able to incorporate yet. To accommodate a cluster analysis for segmentation, and due to some covid-19 restrictions regarding one-to-one interviews with physical samples, we threw it a different tack, and focussed on rather quantitative experiments throughout the dissertation. Therefore, future research ideas involve a more qualitative research approach to improve our insights. Overall, we would want to start with gathering first comparative data on a selection of materials (to initiate an experiential material library), e.g. the most used plastic materials in product design. For each of these materials, we would develop demonstrator forms. In addition, we would develop a structured questionnaire containing a preselection of experiential qualities over the four levels, as well as some more in-depth open questions on the why's and the interrelationships between the qualities (laddering technique). A first exploration could be set up through a stratified convenience sample, where for example hundred students each recruit eight respondents (aiming for two of each consumer cluster) that each evaluate five materials (=100x8x5). This way, it can be validated to what extent the demonstrator actually works for consumers for experiential material characterization or not, whether the form encourages to interact with the materials, and so on.

9.2.3.1 The Performative Level of Experiential Qualities

Once the physical material demonstrators are in place, and ready for use in experiments, the performative level would be one of the first things to explore. As the demonstrator is aimed at a multimodal and free exploration of materials, it should also encourage the participant to perform various actions when interacting with the material. A first pre-study has been done already in the context of a master thesis, during which a "heat map" of the demonstrator was developed, showing the main interaction points spread over the form when performing several actions as suggested in the Ma2E4 toolkit (Camere & Karana, 2018). The next step would be to observe during experiential characterization with the demonstrator forms what type of performative actions are performed spontaneously, and with which materials. Qualitatively asking why the respondent interacts with the material that way, and what other experiential qualities evoked him or her to do so, will offer insight the differences between materials on a performative level. This could also offer inspiration for a designer when designing a product for a material, or a material for a product.

9.2.3.2 Context

Another element to include in these first experiments, would be the influence of contextual factors such as context and product function. In studies 3, 5, and 6 of Chapter 4, we already tried to question respondents about to what extent the demonstrator form appealed to him/her to get an idea of the potential materials experience in a product, and to what extent the material of the form could be envisioned in a real product such as a water kettle. Although we initially expected more difficulties here, participants were able to empathize with such a hypothetical situation by means of the demonstrator form. Thus, further experiments could try to involve different use contexts or product types by means of the proposed demonstrator form by asking participants to envision its material in different products, and evaluating the experiential qualities as such. Of course, this could and should be supplemented with small scale qualitative studies with actual materialized products to verify the outcomes. In addition, it would also be interesting to examine whether all four consumer segments are equally capable of envisioning abstract materials in real products (perhaps innovators can do this more easily?).

9.2.3.3 Colour – Material – Finish (CMF) Decision-making

One of the limitations within this thesis is the fact that material aspects such as colour, finish (or textures), and additives have not yet been included in the experiential characterization framework. To control experimental conditions, throughout the studies we used materials in similar and 'neutral' colours to avoid the effect of material colour, and we used the same manufacturing processes (3D printing) so that surface finish would be the same or inherent to the material itself.

As a designer, when choosing a material and a production technique, this will of course affect the colour and finish of the product's surface, i.e. **Colour-Material-Finish (CMF)** decision-making (Becerra, 2021). Once an appropriate material is selected, the desired colour and finish must be chosen as well. Moreover, when done thoughtfully, colour and finish might even enhance the experiential qualities of a material in a product. In addition, the sustainable perception of a material might be emphasized by manipulating its colour and finish or texture, for example. In addition, the use of material combinations in a product will influence the overall perception of a product as well. We recommend that future research explores these CMF aspects of materials and material combinations as well in the context of materials experience.

For example, in an architectural context, Wastiels et al. (2012a, 2012b, 2013) found a stronger effect of colour compared to roughness on the warmth perception of materials of walls. Also the relationship between colours and emotions has been investigated (Simmons, 2006). Ou et al. (2004) identified three colour-emotion factors (colour activity, colour weight, and colour heat) and developed four culture-independent colour-emotion models, including warm-cool, heavy-light, active-passive, and hard-soft. They also developed a model to predict colour emotions of a pair of colours, based on the colour-appearance attributes of the both colours (Ou et al., 2004). Page et al. (2012) demonstrated the associations between emotions, colours, and colour conventions within particular product categories. Finally, the Antwerp-based Color Navigator (2022) shows the importance of colour identity, neuromarketing and visual nudging. They state to be a "Google Maps for colours", and help companies to select and combine the colours that match with their brand identity, region, and target audience.

Thus, future experiments can include a set of plastic materials in different colours, and study the effect of colour in this context. As the demonstrator form mould does not allow different textures or production techniques, this would require a different research set up and form. However, the effect of post-production decoration, paint or other finishes – that partly or completely hide the actual character of a material – can be investigated.

9.2.3.4 Sustainable Perception of Materials

One of the reasons to focus on plastic materials for the proposed material demonstrator forms, is the opportunity to examine sustainable material perception in the future. For example, virgin plastics can be compared with biobased or recycled plastics, that can be valuable in a circular economy. Indeed, Pedgley, Rognoli, and Karana (2021) state that the lack of knowledge on the technical properties and experiential qualities of biobased plastics and other biobased materials is one of the major challenges.

In combination with the four consumer clusters, future studies can investigate how people differ in terms of sustainable material perception. It can be assumed that, for example, the Green Experience Lovers perceive the experiential qualities of sustainable materials differently compared to the Traditional Curiosity Seekers.

In addition, future studies can look into the experiential qualities that influence a material's sustainable perception. Matte, pastel-coloured and speckled materials are often perceived as more sustainable although this is not always the case, for example when comparing a pure and recyclable virgin plastic with a bamboo fibre composite for a reusable cup. In this regard, a link can be made with research within the research group that investigates the **sustainable perception of reusable alternatives for single-use products**:

The perception that people have of sustainable materials and what they consider sustainable 'looking' or 'feeling' is not always according to reality. Why are so many ecological products made of glass, wood, or stainless steel? Why do so many people think bamboo (fibre) cups are better for the environment than (recycled) PLA cups? Why are matte, pastel-coloured, 'dotted' looks often perceived as the most sustainable among man-made materials?

This is where research on experiential material characterization from a user perspective meets research on sustainability perception of reusable alternatives for single-use products. In the context of the broader research objective of identifying enablers and barriers for the continued usage of reusable alternatives for single-use products, material perception is a key component influencing the purchase decision of potential consumers, thus, co-defining the quality of the product that people eventually end up buying. In turn, this affects the lifespan of the product, which is an important property concerning its continued (long-term) usage. Besides this, the aesthetic qualities of a material, as well as the ease of cleaning, can also define the longevity of use. Finally, the environmental impact during the whole lifecycle of the material should be taken into account when choosing a material for a reusable product in order to be effectively better for the environment.

Technical sustainability characteristics (durability, strength, recyclability, recycled, degradability,...) can be combined with perceptive characteristics (what 'appears' sustainable) to make accurate and effective material choices for reusable products.

- Laure Herweyers -

Furthermore, in the context of **reuse** of product to prolong the lifespan, aspects of **quality and hygiene** must be taken into account as well (especially in times of COVID). This can be partly measured in an objective way from a technical perspective, but it does not mean that when a second-hand product or material is found to be still qualitative and clean, it will also be perceived this way by its potential new users. Therefore, experiential characterization of such products and materials could offer valuable insights for this matter, and could teach us how to positively influence this perception.

9.2.3.5 Temporality of Materials Experience

As already suggested in Chapter 1, the temporality of materials experience is an interesting subject for future research as well. It encompasses longitudinal ethnographic studies that could now be possible by means of the proposed set-up for continuous experiential material characterization. This allows to investigate how materials experience evolves over time, now versus in ten years for example.

In addition, it can also involve different cases of material change (ageing and wear) over time. So far, we have always discussed material as is, without considering the effect of time on materials. Such "traces of use" (Giaccardi et al., 2014) can be considered as a "unique and personal semantic narrative into the objects through material experiences" (Odom & Pierce, 2009, p. 3796). For example, plastics are known to be sensitive to degradation, while woods and leather are often considered to become more beautiful through extensive use. Fisher (2004, p. 30) articulates the following with regard to plastics: "Plastics cease to be pristine, and become evidently worn, in a particular way. They do not patinate; they gather dirt rather than 'charm', and then may elicit particularly strong feelings of disgust".

If future research would explore material change, ageing and wear in the context of materials experience, it could build upon the framework of "interaction of material change and material experience" of Lilley and Bridgens (2021, p. 92) that builds upon previous research and frameworks (Crilly et al., 2004; Karana, Barati, et al., 2015; Karana et al., 2014; Lilley et al., 2016, 2019; Manley et al., 2015). Linking again to (sustainable) perception of materials especially in reuse products, this serves as an interesting pathway for future research that investigates the material perception over time.

An interesting case study that can be set up for this matter, is the following. A small group of pre-selected consumers of each of the four segments can be recruited for a longitudinal study that investigates materials experience of materials in actual products. A specific product category can be chosen, or different types can be selected as was done in the segmentation survey. At the beginning of the study, their first impression and expectations of the product and its materials can be questioned (perhaps even the impression of the product's materials seen from the packaging, to simulate a purchase situation in store). Next, participants can take their product home and actually use it for a longer time in their daily life. By means of qualitative approaches such as diary techniques and interviews, their perception of the experiential qualities can be examined again after certain periods of time (during and after the actual experience). Differences and changes in materials experience over time can then be studies, as well as possible product attachment and emotional bonding.

9.2.3.6 Brands and Materials Experience

In our current consumption society, for each product with its function, a range of product varieties exist from different brands. Moreover, strong brands are often associated with specific materials that they employ in their products and product families. Even when the name of the brand is hidden, people can recognize to which brand a product belongs, for example of Tupperware, Gardena, Apple, Dyson, Koziol, etc. If these companies would launch a product in a material that does not fit in their usual material range, how would this affect the acceptance of the product by the consumer?

As we included twelve brand personality traits (Geuens et al., 2009) to represent a respondent's personality in the cluster analysis in Chapter 6 and Chapter 7, this leaves opportunities to be consistent in future research, and to investigate the link with brand personality. Moreover, it opens opportunities to explore the influence of self-material-congruency, in line with research as that of Higgins (1987). This perspective can be broadened as not only to include actual self-concepts but also ideal and social self-concepts (Sirgy, 1982).

9.3 Designerly Conclusions

9.3.1 Overall Conclusion

As consumers use products not only because of their functional aspects, but also because of their symbolic meaning (Bloch, 1995; Krippendorff & Butter, 1984; Norman, 2004), designers strive to create also solutions for these needs and wants of targeted consumers, taking drivers for individual self-expression from the beginning onwards into of the design process. Appropriate material choice has proven to contribute to this design aim throughout our research (see Chapters 2, 5,6, and 7).

> *"There are things to know, ways of knowing them, and ways of finding about them that are specific to the design area"*(Cross, 1982, p. 223).

This dissertation contributes to the field of design in two ways. First, design researchers are guided in how to set up experiential characterization studies, and which methodological aspects they need to consider. They can build upon the segmentation survey and the four clusters to integrate user aspects, and they can employ the proposed demonstrator form as an abstract and standard representation of materials. Second, designers themselves can benefit in various ways. The addition of material demonstrator forms in different materials to a material library, can help them in physically exploring and comparing materials for their designs, and in experiencing the potential materials experiences first hand. A collection of experiential qualities of materials from previous research or design cases can offer them inspiration, already early in the design process. It can help them explore how an intended target group might react differently on materials in different product categories. It makes them consider what kind of materials might be interesting for aimed market segment, and what these consumers might expect from a product and its materials. This way, when actually designing a product, the materials and its limitations or opportunities can already be taken into account. Thus, evolving through the design process, this inspiration can be linked more and more with information on technical properties of materials (cfr. CES database) and manufacturing techniques. Finally, designers are also encouraged to conduct additional, qualitative studies themselves to verify how consumers experience a set of potential materials envisioned in an actual product and context.

Overall, we aimed at industrial designers of everyday life products; products that are seen, touched, and used throughout the day. Figure 9.1 shows various type of products that might be interesting design cases for that matter, as they might benefit of particular attention to experiential qualities of materials from the perspective of the targeted consumer. For example, products such as **switchgear** (e.g. light gears and sockets) and **door handles** are found in each home environment, are very often touched and triggers the senses, and can be part of the interior and reflect the style and self-expressive values of the resident. Moreover, the look of these products is reasonably free to choose by the designer, provided that a few functional requirements are taken into account.

Other household products are also very useful design cases, for example, bathroom and kitchen products of Brabantia, or the assortment of Tupperware products. They both tend to go beyond functionality and address the aesthetic experience of consumers as well. The same can be said for brands such as Apple, Samsonite, and Renson.

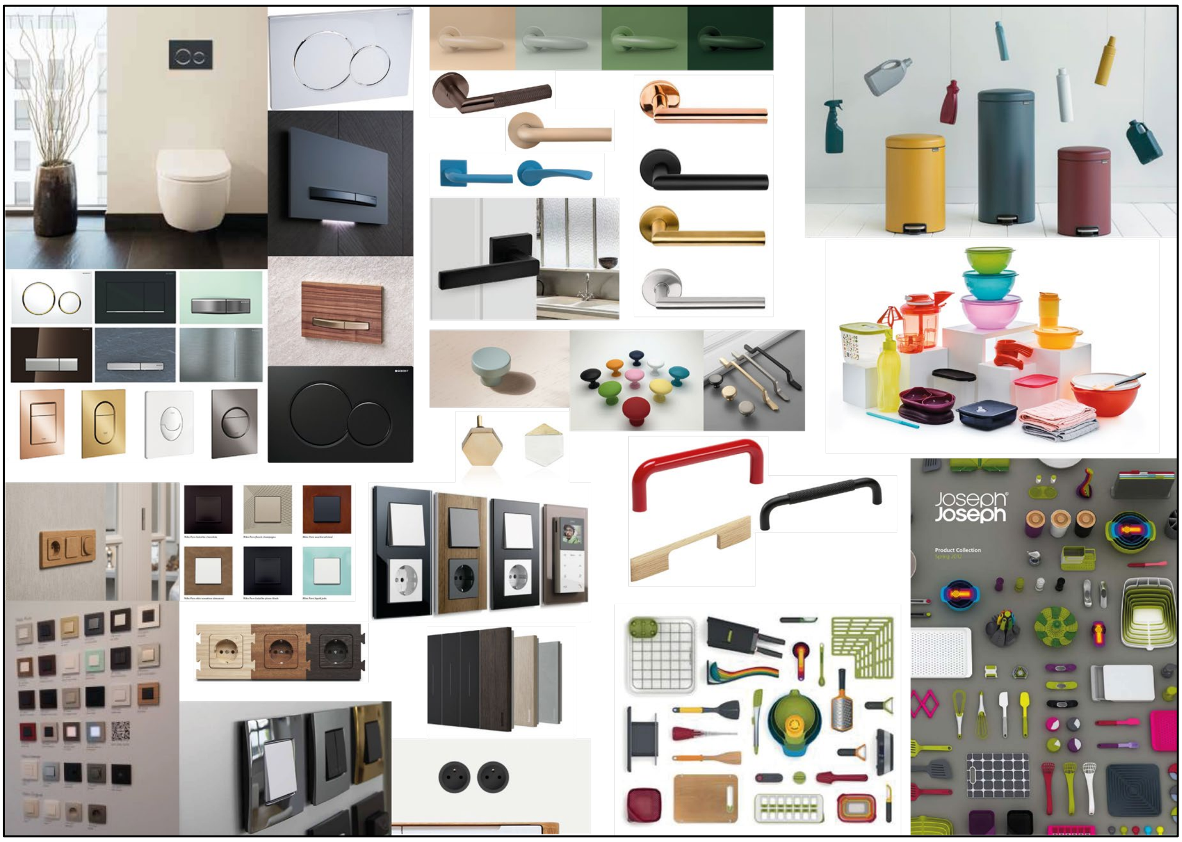


Figure 9.1. Examples of products that are frequently seen, touched or used throughout the day.

9.3.2 *What to Design Next?*

In order to further unravel and validate the potential relationships between the evoked experiential expression by materials and the preference of consumers to use materials for self-expression, we suggest that two additional elements need to be designed, both from the perspective of consumers and the perspective of designers.

First, with the demonstrator form we aimed to attract and engage **consumers** in a multimodal interaction with materials not yet materialized in products. However, we reason that more is needed to facilitate the actual experiential characterization of materials as well. We propose to recruit consumers at a physical, **sensory booth** that is dedicated to the evaluation of specific sensorial attributes and experiential qualities facilitates (following the guidelines of Chapter 8), and that also collects information of extensive user aspects (discussed in Chapter 7).

Second, to help **designers**, experiential data on specific material cases and according to different segments must be collected in a straightforward way, and implemented in a **digital tool** that provides easy access through meaningful filters in a search engine. This way, previous studies and cases can offer inspiration for the designer in different phases of the design process.

9.3.2.1 Sensory Booth for Experiential Material Characterization

Based on the literature review of Chapter 1, the fourth need suggested a complementary experimental set-up and methods that are adjusted to the context of physical material representations and multimodal, free exploration. Therefore, a custom-made experiment table was proposed. Indeed, in order to facilitate experiential material characterization with consumers in an interactive, multi-sensory and fun way, a physical set-up that is dedicated to a set of different sensorial attributes would offer great opportunities to increase consensus on the interpretation of these attributes. In this context, Piselli et al. (2018) proposed a specific training to allow consumer involvement to achieve a higher level of consensus by aligning their perceptions. Ideally, such training might be replaced by a dedicated experimental set-up that imposes a specific - almost standard - way of evaluating each experiential quality.

Currently, experiential material characterization is often done online or on paper, using semantic scales with or without clarifying icons. However, the proposed material demonstrator forms of Chapter 4 might not be sufficient to trigger consumers in an extensive material exploration. Consumer involvement could be increased through tangible manifestation or physical supportive elements that help participants to evaluate the experiential qualities of the material demonstrators. In particular the sensorial attributes can sometimes be open for interpretation, while a more standard manner of evaluation could increase the quality, consistency, and generalizability of the obtained experiential material data.

For example, the sensorial attribute Acoustics may require a dedicated 'soundboard' that guides participants in the same way of evaluating sound. This way, it could be avoided that some tap the form with their fingernails, while others tap it on the table or even tap two forms together, which would lead to different perceptions of acoustics. Another example concerning the attribute of Transparency, could be the use of a dedicated light spot that activates participants to hold the demonstrator form in front of it, to see whether the thinner wall thickness allows light to pass through. Moreover, each sensorial attribute would involve one or more different senses and different actions (cfr. performative level) to adequately explore and score its perception. When combined, an exposition of multiple material exploration booths could be gathered as part of an materials experience lab or material library.

Conclusively, the effect of such sensory booths for experiential material characterization should be measured in future research that compares traditional characterization on paper or online with an active and physical participation. This way, an answer could be formulated to the following research question: *How do physical supportive elements increase consumer participation and quality of experiential (sensorial) material characterization?* Furthermore, this raises addition sub-questions, such as:

- Does the use of such sensory booths lead to a change in material judgement?
- Does the use of such sensory booths lead to more richness in the obtained material data?
- Does the use of such sensory booths lead to a more active material characterization?
- How does it facilitate the observation of performative actions with materials?
- Does it lead to more fun for the consumer participants?
- Does it make the participants more curious?
- Does it lead to more motivation to participate in studying experiential material characterization (e.g. by means of feedback about themselves)?
- To what extent does it lead to greater understandability of the experiential qualities?
- Would participants like to repeat and/or recommend the experiment?

Footnote: In the academic year of 2021-2022, a master student will dedicate her thesis on the development or prototyping of such sensory booth(s), and the investigation of the effect on experiential material characterization by consumers. She will also look into the technology that is needed to tag and automatically identify each material demonstrator form and the scoring of the experiential qualities that is gathered in an experiential material database.

9.3.2.2 Case Based Designer Tool

As reflected upon in the beginning of this conclusion chapter, an experiential database with one-to-one relationships as there exists for technical material properties is not feasible nor desirable. However, during experiential material characterization studies, data will be collected on the experiential qualities of (plastic) materials, as well as on the individual self-expressive values of consumers (and the segment they belong to). These data should be gathered in a case based database, than can be coupled with manufacturing techniques and technical properties in existing databases, e.g. the CES EduPack database (Ashby & Cebon, 2007). In order for such experiential data to be useful for designers throughout the design process, it needs to be translated into a meaningful design tool. As a recommendation, we refer to the search engine of Material District (2019) that is rather focused on innovative semi-finished (sheet) materials for architecture and interior, but employs interesting filters and tags to commence a material search. Similarly, a designer tool could use filters to organize material cases from previous research or projects according to experiential qualities that were found prominent by specific target groups and in specific product contexts. This way, a designer can browse through various inspirational cases that have combined and emphasized specific qualities of materials. Instead of a literal materials selection tool that narrows down until a set of materials that definitely meet your requirements (as does the EduPack software), it should rather be a tool that presents material cases that the designer can explore. The following filters could offer potential for such tool, involving restrictive technical parameters as well as inspirational experiential parameters:

- Material family and class: with a preliminary focus on polymers, although it could and should be extended to other material families such as metals, ceramics, woods, etc.
- Technical material properties: such as low/high E-modulus, low/high tensile strength, etc., but also chemical resistance, UV and weather resistance, and so on. As this concerns objective and numerical properties, it is also possible to use numbered sliders to select a range of desired tensile strength, similar to the way you select a price range when searching on a web shop.
- Possible manufacturing techniques: injection moulding was the starting point within this research, but could be extended to vacuum forming, rotation moulding, etc. for plastics, and of course other techniques for other material families.
- Additional tags: renewable (yes/no), biobased (yes/no), recycled (yes/no), etc.
- Experiential material qualities: sensorial attributes, interpretive characteristics, affective characteristics, and performative actions.
    - For example, for the attribute of glossiness, filters such as glossy, satin, and matte could be included, while for temperature, filters such as cold, medium, and warm could be included.
- Consumer segments (i.e. the four clusters as filters) and/or individual self-expressive values (see Chapter 7)

  - o For example, one could filter on high/low green self-identity, on high/low materialism, and so on.
  - o Additionally, filters such as gender or age categories could of course be included as well.
- – When product aspects would be incorporated later on, the product context or product type could be a filter too (see Chapter 7): informative, affective, habitual and satisfaction products.

Furthermore, the use of such designer tool might differ depending on the following parameters: (i) the moment in the design process, (ii) the type of design process, (iii) the level of experience of the designer, and (iv) any prior knowledge (or bias). In the beginning of a design process, the designer might be looking more for **inspiration** and experiential material qualities, compared to the final stages of the design process when **information** and technical properties gain importance. The further along in the process, the more (technical) filters are likely to be selected, and the fewer materials to choose from. Considering the type of design process, the starting point of a material search can go from a specific manufacturing technique that is particular for a company, or a specific target group of consumers that is already in mind, or a specific product context or product type such as a redesign, or finally, a typical sector such as the medical sector or toys industry that adhere to own ISO standards that can influence the material choices. Also the experience of the designer can influence the use of this tool. A first year design student will enter a material library and accompanying tool differently than a last year student or a professional designer with twenty years of experience. The tool should offer flexibility in the way of searching, and should be **embedded in a physical material library** that triggers all designers to explore potential materials from both an experiential and a technical perspective. Finally, prior knowledge can be both useful and restrictive when entering the materials selection process. For example, a technical bias can help you to select adequate filters, but can also stop you from looking beyond the well-known materials.

All in all, the focus or added value here lies in the incorporation of experiential material qualities that are particularly useful in the beginning of a design process when inspiration is needed and when the target group is usually better known than the required technical properties of the final product/material. When exploring a set of interesting materials, the digital tool should also refer to the physical material library and indicate where to find the accompanying demonstrator forms as well as additional samples or existing products. It should also list the technical properties (datasheet) and potential manufacturing techniques that can be considered for the proposed material, and it could link to similar materials and specific design cases that might be interesting. Two small examples are drawn up below to indicate different reasoning processes in this context:

- *I want to (re)design a vacuum cleaner for the Realistic Go-Getters (consumer cluster 2). I could set the product type at informative products and look for material cases or examples in which the material was perceived as professional, expensive and formal for that product type according to this segment of consumers, and for which the material had a high strength in terms of technical properties. The potential materials that arise, can be inspirational for the ideation and first quick designs so that from early on, the design and form are aligned with the desired material.*
- *I want to design eye glasses (or another affective product type for that matter) in a material that is perceived as durable and elegant by the Green Experience Lovers (consumer cluster 3), or by consumers that specifically express a high green self-identity. By using these filters, a set of material cases will appear that can be inspirational for the designer. In addition, the designer could decide to look up de demonstrator forms of these materials, and use them in a qualitative interview with consumers of the target group to find out which material is preferred for that specific product or*

context, and why. The shown selection of material cases might also indicate related experiential qualities. For example, perhaps most materials that are perceived as durable and elegant, show a matte finish and weak colour intensities? This might make the designer think…

The material cases that are presented based on the filters can offer designers inspiration with regards to the experiential qualities of the used materials, as well as a link to the technical properties of the materials used and the production techniques. Clicking through on specific descriptive tags of such material case, can again sum up other examples that involve materials with a similar E-modulus, or a similar target group, a similar glossy perception, and so on. Of course, the usefulness and interaction with this digital tool should be further explored and modified in future research.

9.3.3 Future Vision

9.3.3.1 Materials Experience Library

From a practical perspective and in order to facilitate data collection through experiential material characterization, a materials experience lab or atelier might be built in the future while setting up an experiential material database. On the new campus of Product Development in Antwerp, a dedicated room will be provided to emerge students and visitors in the world of materials. This accessible and visible location should not only contain a collection material samples and products made through various manufacturing techniques, but also the developed material demonstrator forms in different plastic materials (material library). In addition, the sensory booths might be installed here so that passers-by can participate in experiential material characterization experiments, and receive feedback on the consumer segment they belong to. The digital designer tool should also part of this set-up and could be accessed either on location or from home, and should communicate on the various materials and samples that can be physically found in the material library.

This material library has a double function; it should offer inspiration to designers as well as place for experiential data generation. Designers or design researchers can come and collect a set of interesting materials, and use the sensory booths to attract consumers to participate in more qualitative experiments with these materials. On the other hand, designers can physically browse through a collection of materials in various representations, experience them first hand, and discover what manufacturing techniques are possible and what kind of products can be produced. Each material sample or product should be tagged so that designers can look up inspirational material cases and its emphasized experiential qualities, as well as technical material properties.

Ideally, such Materials Experience library should foster the curiosity of designers, and both encourage and facilitate the search for alternative materials. For example, when exploring a particular material, other materials with similar properties could be highlighted – literally – to attract the designer to move along the library and discover new possibilities. It is the interplay between the digital tool, technical databases, the physical material samples, and the sensory booths that provides variety and creativity.

9.3.3.2 Opportunities of Technology in Experiential Material Characterization

Evolving with new innovations, technological advances can offer potential for implementation in the context of experiential material characterization. Perhaps, it could contribute to the objectivity of measuring experiential qualities, or to the automatization of recording this data.

For example, one of the challenges is how to accurately measure emotions as these are complex, subjective, and comprised of multiple components. **Electroencephalography (EEG)** might be a promising tool in consumer research to measure real-time brain activity and emotions in contrast to self-reporting options. A growing number of non-invasive and low cost devices for biometric measurements are available on the market such as EEG headsets and health bracelets that could offer opportunities within the sensory booths in the material library set-up.

Additionally, the application of **eye-tracking and facial expression analysis** in characterization experiments seems promising and interesting to implement in the sensory booths. Eye-tracking can detect blink frequency, pupil size, point of regard, etc. (López-Gil et al., 2016), and as such indicate what parts of the material received more attention than other parts. As our face is one of the main indicators for emotions, they can be "read" based on subtle alterations in our eyes, brows, lids, nostrils, and lips. Facial expressions are " movements of the numerous muscles supplied by the facial nerve that are attached to and move the facial skin" (Krosschell, 2020), and correlate with emotions such as fear, anger, happiness, surprise, disgust, and sadness. iMotions for example, offers a facial expression analysis technology that is fully automated and computer-based. Based on statistics, face features filmed by a simple camera are translated to metrics, and a classification of these features is done for each emotion. Thus, embedding a camera into the sensory booths could be the next step to include this subconscious level in experiential material characterization, in an attempt to bridge the gap between what consumers say they feel and what consumers actually feel.

Next, Virtual Reality (VR) has potential to be used as a research tool for human-environment interaction, as is already done in architectural research (Kuliga et al., 2015), User Experience (UX) studies (Rebelo et al., 2012), and by Niu et Lo (2020) who investigated material perception in virtual environments. VR might increase controlled laboratory circumstances and could visualize all kind of materials in different demonstrator forms, products and more importantly, concrete usage contexts, without having to actually manufacture them. However, it might still be quite hard to distinguish similar types of plastics and this technology does not yet allow to trigger all senses and experience all experiential levels, as for example, exploring the flexibility or softness of a certain material. Perhaps, the development of haptic gloves (Shor et al., 2018) can enable touch and tactile feedback in virtual reality, and as such, offer potential in experiential material characterization as well.

9.3.3.3 Acceleration of Consumer Segmentation through Visual Personas

Since extensive measurement scales were used in the segmentation survey, subsequent research based on this method might be time-consuming and lead to decreased motivation and attention of respondents, especially when they also need to evaluate the experiential qualities of a set of materials demonstrators. Therefore, we suggest to explore to what extent the segmentation survey could be shortened or even build around visualisation of the crucial segmentation elements (personas) without a reduction in correctly allocating respondents to one of the clusters (e.g. less questions or items, in combination with four visual personas).

Introduced by Cooper (1999), the methodological concept of personas has been well integrated in marketing, consumer behaviour and (user-centred) design processes (Manning, Temkin, & Belanger, 2003; Miaskiewicz & Kozar, 2011; Pruitt & Adlin, 2006). Pruitt and Adlin (2006, p. 11) define personas as "fictitious, specific, concrete representations of target users". People who resemble such an archetype share similar attributes, needs, characteristics and objectives (Cooper, 1999; Pruitt & Adlin, 2006; Salminen, Jung, Chowdhury, Robillos, & Jansen, 2021). As an abstraction of real consumers it provides insight into user behaviour (Pruitt & Grudin, 2003). Moreover, data-driven personas (DDPs) (Aboelmaged & Mouakket, 2020) can enhance and inform decision making and product positioning as they help to relate with targeted users (Bradley, Oliveira, Birrell, & Cain, 2021; Pruitt & Adlin, 2006).

Thus, we express the ambition to develop an efficient and appealing instrument to assign individual consumers to the clusters in follow-up studies or practical applications. Hence, when short on time or when the user segmentation is part of a larger experiential material characterization study, researchers can use visual personas and/or a short questionnaire instead of the full questionnaire, albeit with some loss of allocation accuracy.

9.3.3.4 The Materials Experience Community

Finally, we envision a future in which a worldwide network or community on Materials Experience is actively generating and sharing data. What if such dedicated sensory booths with a collection of demonstrator forms in various materials could be found on different places and campuses (e.g. at TU Delft or Politecnico di Milano), or even travel around. What if consumers of different countries and cultures could be gathered to participate in experiential characterization experiments that all follow this alternative way of standardization. This way, material cases from all over the world can be collected to inspire designers on how to select materials for their experiential qualities as well. I conclude this thesis with reaching out to everyone who read it to build the community together, and collaboratively increase the experiential material knowledge.

REFERENCES

References

Aaker, J. L. (1997). Dimensions of Brand Personality. *Journal of Marketing Research*, *34*(3), 347–357. https://doi.org/10.2139/ssrn.945432

Agost, M.-J., & Vergara, M. (2014). Relationship between meanings, emotions, product preferences and personal values. Application to ceramic tile floorings. *Applied Ergonomics*, *45*(4), 1076–1086. https://doi.org/10.1016/J.APERGO.2014.01.008

Amburgey, J. W., & Thoman, D. B. (2012). Dimensionality of the New Ecological Paradigm: Issues of factor structure and measurement. *Environment and Behavior*, *44*(2), 235–256. https://doi.org/10.1177/0013916511402064

Anderson, M. (2012). New Ecological Paradigm (NEP) Scale. *The Berkshire Encyclopedia of Sustainability*.

Angelini, L., Lalanne, D., van den Hoven, E., Khaled, O. A., & Mugellini, E. (2015). Move, hold and touch: A framework for Tangible gesture interactive systems. *Machines*, *3*(3), 173–207. https://doi.org/10.3390/machines3030173

Arabe, K. C. (2004). *Materials' Central Role in Product Personality*. Thomas Net Industrial New Room (March). https://news.thomasnet.com/imt/2004/03/02/materials_centr

Arnocky, S., Stroink, M., & DeCicco, T. (2007). Self-construal predicts environmental concern, cooperation, and conservation. *Journal of Environmental Psychology*, *27*(4), 255–264. https://doi.org/10.1016/J.JENVP.2007.06.005

Artacho-Ramírez, M. A., Diego-Mas, J. A., & Alcaide-Marzal, J. (2008). Influence of the mode of graphical representation on the perception of product aesthetic and emotional features: An exploratory study. *International Journal of Industrial Ergonomics*, *38*(11–12), 942–952. https://doi.org/10.1016/J.ERGON.2008.02.020

Asbjørn Sörensen, C. (2018). *A Material Framework for Product Design (doctoral dissertation)*.

Ashby, M. (1999). *Materials selection in mechanical design* (Second edi). Butterworth-Heinemann.

Ashby, M., Bréchet, Y. J. M., Cebon, D., & Salvo, L. (2004). Selection strategies for materials and processes. *Materials & Design*, *25*(1), 51–67. https://doi.org/10.1016/S0261-3069(03)00159-6

Ashby, M., & Cebon, D. (2007). *Teaching Engineering Materials: the CES EduPack*.

Ashby, M., & Johnson, K. (2002). *Materials and Design: The Art and Science of Material Selection in Product Design*. Butterworth-Heinemann.

Ashby, M., & Johnson, K. (2010). *Materials and design : the art and science of material selection in product design*. Elsevier/Butterworth-Heinemann.

Ashby, M., & Johnson, K. (2012). *Materials and Design: The Art and Science of Material Selection in Product Design.* Elsevier.

Avkiran, N. K. (1994). Developing an Instrument to Measure Customer Service Quality in Branch Banking. *International Journal of Bank Marketing*, *12*(6), 10–18. https://doi.org/10.1108/02652329410063223

Bahrudin, F. I., & Aurisicchio, M. (2018). 'Is this wallet made of real leaves?': A Study of Sustainable Materials' Emotional Experiences. *DS 91: Proceedings of NordDesign 2018, Linköping, Sweden, 14th - 17th August 2018*.

Bakker, C., & Schuit, C. (2017). *The Long View: Exploring Product Lifetime Extension*.

Balaji, M. S., Raghavan, S., & Jha, S. (2011). Role of tactile and visual inputs in product evaluation: a multisensory perspective. *Asia Pacific Journal of Marketing and Logistics*, *23*(4), 513–530. https://doi.org/10.1108/13555851111165066

Bamberg, S. (2003). How does environmental concern influence specific environmentally related behaviors? A new answer to an old question. *Journal of Environmental Psychology*, *23*(1), 21–32. https://doi.org/10.1016/S0272-4944(02)00078-6

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, *27*(1), 14–25. https://doi.org/10.1016/J.JENVP.2006.12.002

Bang, A. L., Buur, J., Lønne, I. A., & Nimkulrat, N. (2015). Tangible Means: Experiential Knowledge Through Materials: Conference Proceedings. *International Conference 2015 of the Design Research Society Special Interest Group on Experiential Knowledge*.

Barati, B. (2019). *Design touch matters: Bending and stretching the potentials of smart material composites (Dissertation)*. TU Delft.

Barbarossa, C., Beckmann, S. C., De Pelsmacker, P., Moons, I., & Gwozdz, W. (2015). A self-identity based model of electric car adoption intention: a cross-cultural comparative study. *Journal of Environmental Psychology*, *42*(ISSN 0272-4944), 149–160. https://doi.org/http://dx.doi.org/doi:10.1016/J.JENVP.2015.04.001

Barbarossa, C., De Pelsmacker, P., & Moons, I. (2017). Personal Values, Green Self-identity and Electric Car Adoption. *Ecological Economics*, *140*, 190–200. https://doi.org/10.1016/J.ECOLECON.2017.05.015

Beasley, T. M., & Schumacker, R. E. (1995). Multiple Regression Approach to Analyzing Contingency Tables: Post Hoc and Planned Comparison Procedures. *The Journal of Experimental Education*, *64*(1), 79–93. https://doi.org/10.1080/00220973.1995.9943797

Becerra, L. (2021). *The Fundamental Principles of CMF: Design, Colour, Material, Finish*. Frame. https://www.copyrightbookshop.be/shop/the-fundamental-principles-of-cmf-design-colour-material-finish/

Belk, R. W. (1984). Three Scales to Measure Constructs Related to Materialism: Reliability, Validity, and Relationships to Measures of Happiness. *ACR North American Advances*, *NA-11*.

Belk, R. W. (1985). Materialism: Trait Aspects of Living in the Material World. *Journal of Consumer Research*, *12*(3), 265. https://doi.org/10.1086/208515

Belk, R. W. (1988). Possessions and the Extended Self. *Journal of Consumer Research*, *15*(2), 139. https://doi.org/10.1086/209154

Berger, D. (1986). Theory into practice: The FCB grid. *European Research*, *14*, 35–46.

Bergmann Tiest, W. M., & Kappers, A. M. L. (2007). Haptic and visual perception of roughness. *Acta Psychologica*, *124*(2), 177–189. https://doi.org/10.1016/J.ACTPSY.2006.03.002

Berlyne, D. E. (1960). Conflict, arousal, and curiosity. In *Conflict, arousal, and curiosity*. McGraw-Hill Book Company. https://doi.org/10.1037/11164-000

Berson, Alex., Smith, S., & Thearling, Kurt. (2000). *Building data mining applications for CRM*. McGraw-Hill.

Bloch, P. H. (1995). Seeking the Ideal Form: Product Design and Consumer Response. *Journal of Marketing*, *59*(3), 16. https://doi.org/https://doi.org/10.1177/002224299505900302

Brunel, F. F., & Kumar, R. (2007). Design and the Big Five: Linking Product Aesthetics to Product Personality. *ACR North American Advances*, *NA-34*.

Brysbaert, M. (2019). How Many Participants Do We Have to Include in Properly Powered Experiments? A Tutorial of Power Analysis with Reference Tables. *Journal of Cognition*, *2*(1), 1–38. https://doi.org/10.5334/joc.72

Camere, S., & Karana, E. (2017). *Ma2E4 Toolkit*. Materials Experience Lab - Tools & Methods. http://materialsexperiencelab.com/ma2e4-toolkit-experiential-characterization-of-materials/

Camere, S., & Karana, E. (2018). Experiential characterization of materials: Toward a toolkit. *International Conference on Design Research Society (DRS)*. https://doi.org/10.21606/dma.2017.508

Çelen, A., Erdoğan, T., & Taymaz, E. (2005). *Fast Moving Consumer Goods: Competitive Conditions and Policies*.

Cerny, B. A., & Kaiser, H. F. (1977). A study of a measure of sampling adequacy for factor-analytic correlation matrices. *Multivariate Behavioral Research*, *12*(1), 43–47. https://doi.org/10.1207/s15327906mbr1201_3

Cestre, G. (1966). Diffusion et innovativité: définition, modélisation et mesure: *Recherche et Applications En Marketing*, *11*(1), 69–88. https://doi.org/10.1177/076737019601100105

Chang, C.-C., & Wu, J.-C. (2009). The underlying factors dominating categorical perception of product form of mobile phones. *International Journal of Industrial Ergonomics*, *39*(5), 667–680. https://doi.org/10.1016/J.ERGON.2009.02.012

Chang, W., & Wu, T.-Y. (2007). Exploring Types and Characteristics of Product Forms. *International Journal of Design*, *1*(1), 3–14.

Chapman, J. (2021). *Meaningful Stuff : Design that Lasts*. The MIT Press. https://mitpress.mit.edu/books/meaningful-stuff

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior and Organization*, *81*(1), 1–8. https://doi.org/10.1016/j.jebo.2011.08.009

Charters, S. (2006). Aesthetic Products and Aesthetic Consumption: A Review. *Https://Doi.Org/10.1080/10253860600772255*, *9*(3), 235–255. https://doi.org/10.1080/10253860600772255

Chen, H. T., & Lin, Y. T. (2017). A study of the relationships among sensory experience, emotion, and buying behavior in coffeehouse chains. *Service Business 2017 12:3*, *12*(3), 551–573. https://doi.org/10.1007/S11628-017-0354-5

Chen, X., Barnes, C. J., Childs, T. H. C., Henson, B., & Shao, F. (2009). Materials' tactile testing and characterisation for consumer products' affective packaging design. *Materials & Design*, *30*(10), 4299–4310. https://doi.org/10.1016/J.MATDES.2009.04.021

Chen, X., Shao, F., Barnes, C., Childs, T., & Henson, B. (2009). Exploring relationships between touch perception and surface physical properties. *International Journal of Design*, *3*(2), 67–76.

Chen, Y. T., & Chuang, M. C. (2014). The study of tactile feeling and It's expressing vocabulary. *International Journal of Industrial Ergonomics*, *44*(5), 675–684. https://doi.org/10.1016/j.ergon.2014.07.003

Cheong, H. J., & Cheong, Y. (2021). Updating the Foote, Cone & Belding Grid. *Journal of Advertising Research*, *61*(1), 12–29. https://doi.org/10.2501/JAR-2020-014

Chien, C.-W., Lin, C.-L., & Lin, R.-T. (2014). A Study of Rational and Emotional Product Properties. *International Conference on Kansei Engineering and Emotion Research (KEER 2014)*, 517–525.

Child, D. (2006). *The Essentials of Factor Analysis* (3rd ed.). Continuum.

Chiner, M. (1988). Planning of expert systems for materials selection. *Materials and Design*, *9*(4), 195–203. https://doi.org/http://dx.doi.org/10.1016/0261-3069(88)90031-3

Choi, J. (2017). Material selection by the evaluation of diffuse interface of material perception and product personality. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *11*(4), 967–977. https://doi.org/10.1007/s12008-016-0320-9

Cleaver, G. (2018). Ranking and Rank-Rating. In *Descriptive Analysis in Sensory Evaluation* (pp. 447–491). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118991657.ch12

Cleridou, K., & Furnham, A. (2014). Personality Correlates of Aesthetic Preferences for Art, Architecture, and Music. *Http://Dx.Doi.Org/10.2190/EM.32.2.f*, *32*(2), 231–255. https://doi.org/10.2190/EM.32.2.F

Color Navigator. (2022). *Neuromarketing*. About Us | Color Navigator. https://colornavigator.net/about-us/#neuromarketing

Confente, I., Scarpi, D., & Russo, I. (2020). Marketing a new generation of bio-plastics products for a circular economy: The role of green self-identity, self-congruity, and perceived value. *Journal of Business Research*, *112*, 431–439. https://doi.org/10.1016/J.JBUSRES.2019.10.030

Conway, J. M., & Huffcutt, A. I. (2003). *A Review and Evaluation of Exploratory Factor Analysis Practices in Organizational Research*. https://doi.org/10.1177/1094428103251541

Cooper, T. (2016). The Significance of Product Longevity. In *Longer Lasting Products* (pp. 29–62). Routledge. https://doi.org/10.4324/9781315592930-9

Creusen, M. E. H. (1998). *Product appearance and consumer choice (doctoral dissertation)*. TU Delft.

Creusen, M. E. H., & Schoormans, J. P. L. (2005). The Different Roles of Product Appearance in Consumer Choice*. *Journal of Product Innovation Management*, *22*(1), 63–81. https://doi.org/10.1111/j.0737-6782.2005.00103.x

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: Consumer response to the visual domain in product design. *Design Studies*, *25*(6), 547–577. https://doi.org/10.1016/j.destud.2004.03.001

Crilly, N., Moultrie, J., & Clarkson, P. J. (2009). Shaping things: intended consumer response and the other determinants of product form. *Design Studies*, *30*(3), 224–254. https://doi.org/10.1016/j.destud.2008.08.001

Crippa, G., Rognoli, V., & Levi, M. (2012). Materials and emotions: A study on the relations between materials and emotions in industrial products. *8th International Design and Emotion Conference*.

Cross, N. (1982). Designerly ways of knowing. *Design Studies*, *3*(4), 221–227. https://doi.org/10.1016/0142-694X(82)90040-0

Cross, N. (2006). Designerly Ways of Knowing. In *Designerly Ways of Knowing*. Springer London. https://doi.org/10.1007/1-84628-301-9

Cutkosky, M. R. (1989). On Grasp Choice, Grasp Models, and the Design of Hands for Manufacturing Tasks. *IEEE Transactions on Robotics and Automation*, *5*(3), 269–279. https://doi.org/10.1109/70.34763

Dacleu Ndengue, J., Juganaru-Mathieu, M., & Faucheu, J. (2017). Material perception and material identification in product design. *Proceedings of the International Conference on Engineering Design, ICED*, *8*(DS87-8), 429–437.

Datschefski, E. (2001). *The total beauty of sustainable products*. RotoVision.

Dehlholm, C., Brockhoff, P. B., Meinert, L., Aaslyng, M. D., & Bredie, W. L. P. (2012). Rapid descriptive sensory methods – Comparison of Free Multiple Sorting, Partial Napping, Napping, Flash Profiling and conventional profiling. *Food Quality and Preference*, *26*(2), 267–277. https://doi.org/10.1016/j.foodqual.2012.02.012

Dehn, J. (2014). Conception and realization of a sustainable materials library. In E. Karana, O. Pedgley, & V. Rognoli (Eds.), *Materials Experience: Fundamentals of Materials and Design* (pp. 155–168). Butterworth-Heinemann.

Deng, Y. M., & Edwards, K. L. (2007). The role of materials identification and selection in engineering design. *Materials and Design*, *28*(1), 131–139. https://doi.org/10.1016/j.matdes.2005.05.003

Desmet, P. M. A. (2002). *Designing emotions (doctoral dissertation)*. https://studiolab.ide.tudelft.nl/studiolab/desmet/dissertation/

Desmet, P. M. A. (2010). Three Levels of Product Emotion. *International Conference on Kansei Engeineering and Emotion Research (KEER2010)*.

Desmet, P. M. A. (2012). Faces of Product Pleasure: 25 Positive Emotions in Human-Product Interactions. *International Journal of Design*, *6*(2). http://www.ijdesign.org/index.php/IJDesign/article/view/1190

Desmet, P. M. A., & Hekkert, P. (2007). Framework of Product Experience. *International Journal of Design*, *1*(1). http://ijdesign.org/index.php/IJDesign/article/view/66/15

Dibb, S., & Simkin, L. (1996). *The Market Segmentation Workbook: Target Marketing for Marketing Managers*. Routledge.

D'Olivo, P., Curto, B. J. Del, Faucheu, J., Lafon, D., BASSEREAU, J.-F., & Sébastien, L. (2013). Sensory Metrology: When Emotions and Experiences Contribute to Design. *Proceedings of the International Conference on Engineering Design, ICED13 (Vol. 7 DS75-07)*, 507–516.

Doordan, D. D. P. (2003). On Materials. *Design Issues*, *19*(19), 3–8. https://doi.org/10.1162/074793603322545000

Dunlap, R. E. (2008). The new environmental paradigm scale: From marginality to worldwide use. In *Journal of Environmental Education*. https://doi.org/10.3200/JOEE.40.1.3-18

Dunlap, R. E., Liere, K. D. Van, Mertig, A. G., Jones, R. E., Van, K. D., Primen, L., Mertig, A. G., & Jones, R. E. (2000). New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues*, *56*(3), 425–442. https://doi.org/10.1111/0022-4537.00176

Dunlap, R. E., Van, K. D., Primen, L., Mertig, A. G., & Jones, R. E. (2000). Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues*, *56*(3), 425–442.

Ellen MacArthur Foundation, & McKinsey & Company. (2012). *Towards the Circular Economy* (McKinsey & Company, Ed.). Ellen MacArthur Foundation.

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, *7*(3), 93–99. https://doi.org/10.1016/j.afjem.2017.08.001

Essenscia. (2020). *Kerncijfers 2020 (Key Figures 2020)*. https://www.essenscia.be/wp-content/uploads/2021/05/kerncijfers2020-belgium-nl.pdf

Etzi, R., Spence, C., & Gallace, A. (2014). Textures that we like to touch: An experimental study of aesthetic preferences for tactile stimuli. *Consciousness and Cognition*, *29*, 178–188. https://doi.org/10.1016/J.CONCOG.2014.08.011

European Commission. (2015). *Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU Action Plan for the Circular Economy*.

European Commission. (2017). *A European Strategy for Plastics in a Circular Economy*. https://www.europarc.org/wp-content/uploads/2018/01/Eu-plastics-strategy-brochure.pdf

Farag, M. M. (1989). *Selection of Materials and Manufacturing Processes for Engineering Design*. Prentice Hall.

Farag, M. M. (2002). Quantitative methods of materials selection. In M. Kutz (Ed.), *Handbook of materials selection* (pp. 466–488). John Wiley & Sons. https://doi.org/10.1002/9780470172551.ch1

Faucheu, J., Caroli, A., Del Curto, B., & Delafosse, D. (2015). Experimental Setup for Visual and Tactile Evaluation of Materials and Products Through Napping® Procedure. In M. B. Christian Weber, Stephan Husung, Gaetano Cascini, Marco CantaMESsa, Dorian Marjanovic (Ed.), *Proceedings of the 20th International Conference on Engineering Design (ICED 15)* (pp. 129–138).

Fenko, A., Schifferstein, H. N. J., & Hekkert, P. (2010). Looking hot or feeling hot: What determines the product experience of warmth? *Materials & Design*, *31*(3), 1325–1331. https://doi.org/10.1016/j.matdes.2009.09.008

Field, A. (2013). *Discovering Statistics Using IBM SPSS*. Sage.

Fisher, T. H. (2004). What We Touch, Touches Us: Materials, Affects, and Affordances. *Design Issues*, *20*(4), 20–31. https://doi.org/10.1162/0747936042312066

Fleming, R. W. (2014). Visual perception of materials and their properties. *Vision Research*, *94*, 62–75.

Fleming, R. W. (2017). Material Perception. *Annual Review of Vision Science*, *3*(1), 365–388. https://doi.org/10.1146/annurev-vision-102016-061429

Flint, D. J. (2002). Compressing new product success-to-success cycle time deep customer value understanding and idea generation. *Industrial Marketing Management*, *31*(4), 305–315. https://doi.org/10.1016/S0019-8501(01)00165-1

Fokkinga, S. F. (2015). *Design -|+ Negative emotions for positive experiences (doctoral dissertation)*. https://doi.org/10.4233/UUID:F81FBAAB-B3D1-407D-98D4-6775FED2EC81

Fransson, N., & Gärling, T. (1999). Environmental Concern: Conceptual Definitions, Measurement Methods and Research Findings. *Journal of Environmental Psychology*, *19*(4), 369–382. https://doi.org/10.1006/JEVP.1999.0141

Freinkel, S. (2013). Plastic: A Toxic Love Story. *Journal of Social History*, *46*, 811–814.

Fujisaki, W., Tokita, M., & Kariya, K. (2015). Perception of the material properties of wood based on vision, audition, and touch. *Vision Research*, *109*, 185–200. https://doi.org/10.1016/j.visres.2014.11.020

Gatignon, H., & Robertson, T. S. (1991). Innovative decision processes. In *Handbook of consumer behavior*. Prentice-Hall.

Geiser, K., & Gros, X. E. (2001). Materials matter: Toward a sustainable materials policy. *Electronic Green Journal*, *1*(15), 479.

Georgiev, G. V., & Nagai, Y. (2011). A conceptual network analysis of user impressions and meanings of product materials in design. *Materials & Design*, *32*(8–9), 4230–4240. https://doi.org/10.1016/J.MATDES.2011.04.024

Geuens, M., Weijters, B., & de Wulf, K. (2009). A new measure of brand personality. *International Journal of Research in Marketing*, *26*(2), 97–107. https://www.sciencedirect.com/science/article/pii/S0167811609000172

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Giaccardi, E., & Karana, E. (2015). Foundations of Materials Experience. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, 2447–2456. https://doi.org/10.1145/2702123.2702337

Giaccardi, E., Karana, E., Robbins, H., & D'olivo, P. (2014). Growing traces on objects of daily use: A product design perspective for HCI. *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques (DIS)*, 473–482. https://doi.org/10.1145/2598510.2602964

Giboreau, A., Navarro, S., Faye, P., & Dumortier, J. (2001). Sensory evaluation of automotive fabrics: the contribution of categorization tasks and non verbal information to set-up a descriptive method of tactile properties. *Food Quality and Preference*, *12*(5–7), 311–322. https://doi.org/10.1016/S0950-3293(01)00016-7

Glen, S. (2017). *Standardized Residuals in Statistics: What are They?* Statistics How To. http://www.statisticshowto.com/what-is-a-standardized-residuals/

Goldberg, L. R. (1981). Language and individual differences: The search for universals in personality lexicons. In *Review of personality and social psychology* (Vol. 2, Issue 1, pp. 141–165). https://doi.org/10.1037/0022-3514.59.6.1216

González, E. M., Felix, R., Carrete, L., Centeno, E., & Castaño, R. (2015). Green Shades: A Segmentation Approach Based on Ecological Consumer Behavior in an Emerging Economy. *Http://Dx.Doi.Org/10.1080/10696679.2015.1032395*, *23*(3), 287–302. https://doi.org/10.1080/10696679.2015.1032395

Govers. (2004). *Product Personality*. Technical University of Delft.

Grace, D., & O'Cass, A. (2004). Examining service experiences and post-consumption evaluations. *Journal of Services Marketing*, *18*(6), 450–461. https://doi.org/10.1108/08876040410557230

Granta. (2016). *CES EduPack - Products, Materials and Processes database*. http://www.grantadesign.com/education/editions/products.htm

Grunert, S. C., & Juhl, H. J. (1995). Values, environmental attitudes, and buying of organic foods. *Journal of Economic Psychology*, *16*(1), 39–62. https://doi.org/10.1016/0167-4870(94)00034-8

Haase, J., & Wiedmann, K.-P. (2018). The sensory perception item set (SPI): An exploratory effort to develop a holistic scale for sensory marketing. *Psychology & Marketing*, *35*(10), 727–739. https://doi.org/10.1002/mar.21130

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2013). *Multivariate Data Analysis: Pearson New International Edition* (7th ed.). Pearson.

Hair, J. F., Sarstedt, M., & Ringle, C. M. (2019). Rethinking some of the rethinking of partial least squares. *European Journal of Marketing*, *53*(4), 566–584. https://doi.org/10.1108/EJM-10-2018-0665

Halada, K., & Yamamoto, R. (2001). The current status of research and ecomaterials. *MRS Bulletin*, *11*, 871–879.

Hansla, A., Gamble, A., Juliusson, A., & Gärling, T. (2008). The relationships between awareness of consequences, environmental concern, and value orientations. *Journal of Environmental Psychology*, *28*(1), 1–9. https://doi.org/10.1016/J.JENVP.2007.08.004

Hasling, K. M. (2015). *Learning through Materials: Developing materials teaching in the design education*.

Hasling, K. M. (2016). Bridging understandings of materials in sustainable product design education. *Celebration & Contemplation, 10th International Conference on Design & Emotion*, 181–190.

Hassenzahl, M. (2003). The Thing and I: Understanding the Relationship Between User and Product. In M. A. Blythe, K. Overbeeke, A. F. Monk, & P. C. Wright (Eds.), *Funology. Human-Computer Interaction Series* (Vol. 3, pp. 31–42). Springer. https://doi.org/10.1007/1-4020-2967-5_4

Hassenzahl, M. (2010). Experience Design: Technology for All the Right Reasons. In *Synthesis Lectures on Human-Centered Informatics* (Vol. 3, Issue 1). https://doi.org/10.2200/S00261ED1V01Y201003HCI008

Hassenzahl, M. (2013). User Experience and Experience Design. In M. Soegaard & R. F. Dam (Eds.), *The Encyclopedia of Human-Computer Interaction* (2nd ed.). The Interaction Design Foundation. https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/user-experience-and-experience-design

Hekkert, P. (2006). Design Aesthetics: Principles of pleasure in design. *Psychology Sciences*, *48*(2), 157–172. https://psycnet.apa.org/record/2006-10718-006

Hekkert, P., & Leder, H. (2008). Product Aesthetics. In *Product Experience* (pp. 259–285). Elsevier. https://doi.org/10.1016/B978-008045089-6.50013-7

Hirschman, E. C., & Holbrook, M. B. (1982). Hedonic Consumption: Emerging Concepts, Methods and Propositions. *Journal of Marketing*, *46*(3), 92–101. https://doi.org/10.1177/002224298204600314

Hodgson, S. N. B., & Harper, J. F. (2004). EFFECTIVE USE OF MATERIALS IN THE DESIGN PROCESS: MORE THAN A SELECTION PROBLEM. *DS 33: Proceedings of E&PDE 2004,* *the 7th International Conference on Engineering and Product Design Education, Delft, the Netherlands, 02.-03.09.2004*, 593–601.

Hogan, T., Hinrichs, U., & Hornecker, E. (2016). The Elicitation Interview Technique: Capturing People's Experiences of Data Representations. *IEEE Transactions on Visualization and Computer Graphics*, *22*(12), 2579–2593. https://doi.org/10.1109/TVCG.2015.2511718

Høibø, O., Hansen, E., & Nybakk, E. (2015). Building material preferences with a focus on wood in urban housing: Durability and environmental impacts. *Canadian Journal of Forest Research*, *45*(11), 1617–1627. https://doi.org/10.1139/CJFR-2015-0123

Høibø, O., & Nyrud, A. Q. (2010). Consumer perception of wood surfaces: the relationship between stated preferences and visual homogeneity. *Journal of Wood Science*, *56*(4), 276–283. https://doi.org/10.1007/s10086-009-1104-7

Holbrook, M. B. (1980). Some Preliminary Notes on Research in Consumer Esthetics. *NA - Advances in Consumer Research Volume 07*, *07*, 104–108.

Holbrook, M. B., & Hirschman, E. C. (1982). The Experiential Aspects of Consumption: Consumer Fantasies, Feelings, and Fun. *Journal of Consumer Research*, *9*(2), 132. https://doi.org/10.1086/208906

Hong, B.-S. (2006). Analysis of Fashion Magazine Advertising by FCB GRID. *Journal of the Korean Home Economics Association*, *44*(1), 159–168.

Hope, A. D., Jones, M., & Zuo, H. (2012). Sensory perception in materials selection for industrial/product design. *International Journal of Designed Objects*, *6*(3), 17–31. https://doi.org/10.18848/2325-1379/cgp/v06i03/38662

Hosany, S., & Martin, D. (2012). Self-image congruence in consumer behavior. *Journal of Business Research*, *65*(5), 685–691. https://doi.org/10.1016/J.JBUSRES.2011.03.015

Hosey, L. (2012). *The Shape of Green: Aesthetics, Ecology, and Design*. Island Press. https://www.amazon.com/Shape-Green-Aesthetics-Ecology-Design/dp/161091032X

Hsu, S. H., Chuang, M. C., & Chang, C. C. (2000). A semantic differential study of designers' and users' product form perception. *International Journal of Industrial Ergonomics*, *25*(4), 375–391. https://doi.org/10.1016/S0169-8141(99)00026-8

Hubo, S., & Ragaert, K. (2014). Evaluation of post-industrial and post-consumer polyolefinbased polymer waste streams for injection moulding. *6th Polymers & Mould Innovations International Conference*, 201–206.

Hung, W.-K. ;, & Chen, L. (2012). Effects of novelty and its dimensions on aesthetic preference in product design. In *International Journal of Design* (Vol. 6, Issue 2).

Huysman, S., De Schaepmeester, J., Ragaert, K., Dewulf, J., & De Meester, S. (2017). Performance indicators for a circular economy : a case study on post-industrial plastic waste. *RESOURCES CONSERVATION AND RECYCLING*, *120*, 46–54.

Ignatyev, I. A., Thielemans, W., & Vander Beke, B. (2014). Recycling of Polymers: A Review. *ChemSusChem*, *7*(6), 1579–1593. https://doi.org/10.1002/cssc.201300898

Ingold, T. (2007). Materials against materiality. *Archaeological Dialogues*, *14*(1), 1–16. https://doi.org/10.1017/S1380203807002127

Ingold, T. (2012). Toward an Ecology of Materials. *Annual Review of Anthropology*, *41*(1), 427–442. https://doi.org/10.1146/annurev-anthro-081309-145920

Jahan, A., Ismail, M. Y., Sapuan, S. M., & Mustapha, F. (2010). Material screening and choosing methods - A review. *Materials and Design*, *31*(2), 696–705. https://doi.org/10.1016/j.matdes.2009.08.013

Jansen, K., & TU Delft. (2021). *Emerging Materials*. Sustainable Design Engineering - Section Materializing Futures. https://www.tudelft.nl/io/over-io/afdelingen/sustainable-design-engineering/section-materializing-futures/emerging-materials

Jordan, P. W. (1998). Human factors for pleasure in product use. *Applied Ergonomics*, *29*(1), 25–33.

Jordan, P. W. (2002). *Designing pleasurable products: An introduction to the new human factors*.

Kaiser, F. G., Wölfing, S., & Fuhrer, U. (1999). Environmental Attitude and Ecological Behaviour. *Journal of Environmental Psychology*, *19*(1), 1–19. https://doi.org/10.1006/JEVP.1998.0107

Kapkın, E., & Joines, S. (2018). An investigation into the relationship between product form and perceived meanings. *International Journal of Industrial Ergonomics*, *67*, 259–273. https://doi.org/10.1016/J.ERGON.2018.05.009

Karana, E. (2004). *Guidlines for a materials selection source for industrial design activity: A survey on the expectations of Turkish designers*. TU Delft.

Karana, E. (2009). *Meanings of Materials (Doctoral dissertation)*. Delft University of Technology.

Karana, E. (2010). How do Materials Obtain Their Meanings? *METU Journal of Faculty of Architecture*, *27*(2), 271–285. https://doi.org/10.4305/METU.JFA.2010.2.15

Karana, E. (2012). Characterization of 'natural' and 'high-quality' materials to improve perception of bio-plastics. *Journal of Cleaner Production*, *37*, 316–325. https://doi.org/10.1016/j.jclepro.2012.07.034

Karana, E., Barati, B., Rognoli, V., & Zeeuw van der Laan, A. (2015). Material Driven Design (MDD): A Method to Design for Material Experiences. *International Journal of Design*, *9*(2), online. http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/1965

Karana, E., Giaccardi, E., & Rognoli, V. (2017). Materially yours. In J. Chapman (Ed.), *Routledge Handbook of Sustainable Product Design* (1st ed., pp. 206–221). Routledge. https://doi.org/10.4324/9781315693309-18

Karana, E., Giaccardi, E., Stamhuis, N., & Goossensen, J. (2016). The Tuning of Materials. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16*, 619–631. https://doi.org/10.1145/2901790.2901909

Karana, E., & Hekkert, P. (2010). User-Material-Product Interrelationships in Attributing Meanings. *International Journal of Design*, *3*(43–52).

Karana, E., Hekkert, P., & Kandachar, P. (2008a). Material considerations in product design: A survey on crucial material aspects used by product designers. *Materials and Design*, *29*(6), 1081–1089. https://doi.org/10.1016/j.matdes.2007.06.002

Karana, E., Hekkert, P., & Kandachar, P. (2008b). Materials experience: Descriptive categories in material appraisals. *The International Conference on Tools and Methods in Competitive Engineering (TMCE)*, 399–412.

Karana, E., Hekkert, P., & Kandachar, P. (2009a). Assessing material properties on sensorial scales. *2009 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, DETC2009*, *2*, 911–916. https://doi.org/10.1115/DETC2009-86756

Karana, E., Hekkert, P., & Kandachar, P. (2009b). Meanings of materials through sensorial properties and manufacturing processes. *Materials and Design*, *30*(7), 2778–2784. https://doi.org/10.1016/j.matdes.2008.09.028

Karana, E., Hekkert, P., & Kandachar, P. (2010). A tool for meaning driven materials selection. *Materials and Design*, *31*(6), 2932–2941. https://doi.org/10.1016/j.matdes.2009.12.021

Karana, E., & Nijkamp, N. (2014). Fiberness, reflectiveness and roughness in the characterization of natural and high quality materials. *Journal of Cleaner Production*, *68*, 252–260. https://doi.org/10.1016/J.JCLEPRO.2014.01.001

Karana, E., Pedgley, O., & Rognoli, V. (2014). *Materials Experience: Fundamentals of Materials and Design* (Butterworth-Heineman, Ed.; 1st ed.). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/C2012-0-02198-9

Karana, E., Pedgley, O., & Rognoli, V. (2015). On materials experience. *Design Issues*, *31*(3), 16–27. https://doi.org/10.1162/DESI_a_00335

Karana, E., & Rognoli, V. (n.d.). *Materials Experience Lab*. Retrieved April 4, 2019, from http://materialsexperiencelab.com/

Karana, E., & van Kesteren, I. (2006). "Material effects": The role of materials in people's product evaluations. *The 5th International Conference on Design and Emotion*.

Karana, E., van Weelderen, W., & van Woerden, E.-J. (2007). The Effect of Form on Attributing Meanings to Materials. *27th Computers and Information in Engineering Conference*, 471–487. https://doi.org/10.1115/DETC2007-34646

Karapanos, E., Zimmerman, J., Forlizzi, J., & Martens, J.-B. (2009). User experience over time: An Initial Framework. *Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09*, 729. https://doi.org/10.1145/1518701.1518814

Kaul, A., & Rao, V. R. (1995). Research for product positioning and design decisions: An integrative review. *International Journal of Research in Marketing*, *12*(4), 293–320. https://doi.org/10.1016/0167-8116(94)00018-2

Kemp, S. E., Hort, J., & Hollowood, T. (2018). *Descriptive analysis in sensory evaluation* (S. E. Kemp, J. Hort, & T. Hollowood, Eds.). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118991657

Kitsawad, K., & Guinard, J. X. (2014). Combining means-end chain analysis and the Portrait Value Questionnaire to research the influence of personal values on food choice. *Food Quality and Preference*, *35*, 48–58. https://doi.org/10.1016/J.FOODQUAL.2014.01.003

Ko, Y.-C., Lo, C.-H., & Chen, C.-C. (2018). Influence of Personality Traits on Consumer Preferences: The Case of Office Chair Selection by Attractiveness. *Sustainability 2018, Vol. 10, Page 4183*, *10*(11), 4183. https://doi.org/10.3390/SU10114183

Kotler, P. T., & Armstrong, G. (2017). *Principles of Marketing* (17th (global editio…, Issue Marketing 1). Pearson.

Krippendorff, K., & Butter, R. (1984). Product Semantics: Exploring the Symbolic Qualities of Form. *Innovation*, *3*(2), 4–9. http://repository.upenn.edu/asc_papers/40

Krippendorff, K., & Butter, R. (2007). *Semantics: Meanings and Contexts of Artifacts*. http://repository.upenn.edu/asc_papers

Krosschell, K. (2020, March 10). *Facial Expression Analysis: The Complete Pocket Guide*. IMotions. https://imotions.com/blog/facial-expression-analysis/

Krystallis, A., Vassallo, M., & Chryssohoidis, G. (2012). The usefulness of Schwartz's 'Values Theory' in understanding consumer behaviour towards differentiated products. *Journal of Marketing Management*, *28*(11–12), 1438–1463. https://doi.org/10.1080/0267257X.2012.715091

Kuliga, S. F., Thrash, T., Dalton, R. C., & Hölscher, C. (2015). Virtual reality as an empirical research tool — Exploring user experience in a real building and a corresponding virtual model. *Computers, Environment and Urban Systems*, *54*, 363–375. https://doi.org/10.1016/J.COMPENVURBSYS.2015.09.006

Laughlin, Z., Conreen, M., Witchel, H. J., & Miodownik, M. (2011). The use of standard electrode potentials to predict the taste of solid metals. *Food Quality and Preference*, *22*(7), 628–637. https://doi.org/10.1016/j.foodqual.2011.03.012

Ledahudec, J., Pilková, L., & Pokorný, J. (1992). Comparison of structured and unstructured graphical scales for the evaluation of sensory quality. *Food / Nahrung*, *36*(1), 96–98. https://doi.org/http://doi.wiley.com/10.1002/food.19920360116

Lederman, S. J., & Klatzky, R. L. (2009). Haptic perception: A tutorial. In *Attention, Perception, and Psychophysics* (Vol. 71, Issue 7, pp. 1439–1459). Springer. https://doi.org/10.3758/APP.71.7.1439

Lerma Valero, J. R. (2020). Plastics Injection Molding. In *Plastics Injection Molding* (p. 350). Hanser Publications. https://doi.org/10.3139/9781569906903.fm

Levy, Y., & Ellis, T. J. (2006). A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research. *Informing Science Journal*, *9*.

Lilley, D., & Bridgens, B. (2021). Material change: transforming experience. In *Materials Experience 2* (pp. 89–102). Butterworth-Heinemann. https://doi.org/10.1016/B978-0-12-819244-3.00027-2

Lilley, D., Bridgens, B., Davies, A., & Holstov, A. (2019). Ageing (dis)gracefully: Enabling designers to understand material change. *Journal of Cleaner Production*, *220*, 417–430. https://doi.org/10.1016/J.JCLEPRO.2019.01.304

Lilley, D., Smalley, G., Bridgens, B., Wilson, G. T., & Balasundaram, K. (2016). Cosmetic obsolescence? User perceptions of new and artificially aged materials. *Materials & Design*, *101*, 355–365. https://doi.org/10.1016/J.MATDES.2016.04.012

Lindberg, S., Roos, A., Kihlstedt, A., & Lindström, M. (2013). A product semantic study of the influence of the sense of touch on the evaluation of wood-based materials. *Materials & Design (1980-2015)*, *52*, 300–307. https://doi.org/10.1016/J.MATDES.2013.05.069

Lindeman, M., & Verkasalo, M. (2005). Measuring Values With the Short Schwartz's Value Survey. *Journal of Personality Assessment*, *85*(2), 170–178. https://doi.org/10.1207/s15327752jpa8502_09

Ljungberg, L. Y., & Edwards, K. L. (2003). Design, materials selection and marketing of successful products. *Materials & Design*, *24*(7), 519–529. https://doi.org/10.1016/S0261-3069(03)00094-3

López-Gil, J.-M., Virgili-Gomá, J., Gil, R., Guilera, T., Batalla, I., Soler-González, J., & García, R. (2016). Method for Improving EEG Based Emotion Recognition by Combining It with Synchronized Biometric and Eye Tracking Technologies in a Non-invasive and Low Cost Way. *Frontiers in Computational Neuroscience*, *0*(AUG), 85. https://doi.org/10.3389/FNCOM.2016.00085

Ludden, G. D. S., Schifferstein, H. N. J., & Hekkert, P. (2008). Surprise As a Design Strategy. *Design Issues*, *24*(2), 28–38. https://doi.org/https://doi.org/10.1162/desi.2008.24.2.28

Ludden, G. D. S., & van Rompay, T. J. L. (2015). How does it feel? Exploring touch on different levels of product experience. *Journal of Engineering Design*, *26*(4–6), 157–168. https://doi.org/10.1080/09544828.2015.1036011

Maine, E., Probert, D., & Ashby, M. (2005). Investing in new materials: A tool for technology managers. *Technovation*, *25*(1), 15–23. https://doi.org/10.1016/S0166-4972(03)00070-1

Manley, A., Lilley, D., & Hurn, K. (2015). Cosmetic wear and affective responses in digital products: towards an understanding of what types of cosmetic wear cause what types of attitudinal responses from smartphone users. *Proceedings of Product Lifetimes and the Environment (PLATE)*. https://repository.lboro.ac.uk/articles/conference_contribution/Cosmetic_wear_and_affective_responses_in_digital_products_towards_an_understanding_of_what_types_of_cosmetic_wear_cause_what_types_of_attitudinal_responses_from_smartphone_users/9341627/1

Manzini, E. (1986). *The Material of Invention*. Arcadia Edizioni.

Martin, C. L. (1998). Relationship marketing: a high-involvement product attribute approach. *Journal of Product & Brand Management*, *7*(1), 6–26. https://doi.org/10.1108/10610429810209700

Martín, R., Iseringhausen, J., Weinmann, M., & Hullin, M. B. (2015). Multimodal perception of material properties. *Proceedings of the ACM SIGGRAPH Symposium on Applied Perception - SAP '15*, 33–40. https://doi.org/10.1145/2804408.2804420

Masson, M., Delarue, J., Bouillot, S., Sieffermann, J.-M., & Blumenthal, D. (2016). Beyond sensory characteristics, how can we identify subjective dimensions? A comparison of six qualitative methods relative to a case study on coffee cups. *Food Quality and Preference*, *47*, 156–165. https://doi.org/10.1016/J.FOODQUAL.2015.01.003

Material District. (2019). *Materials Archive - MaterialDistrict*. https://materialdistrict.com/material/#moved

McCrae, R. R., & Costa, P. T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology*, *52*(1), 81–90. https://doi.org/10.1037/0022-3514.52.1.81

Midgley, D. F., & Dowling, G. R. (1978). Innovativeness: The Concept and Its Measurement. *Journal of Consumer Research*, *4*(4), 229–242. https://doi.org/10.1086/208701

Miodownik, M. A. (2007). Toward designing new sensoaesthetic materials. *Pure and Applied Chemistry*, *79*(10), 1635–1641. https://doi.org/10.1351/PAC200779101635/MACHINEREADABLECITATION/RIS

Mishra, A. A. (2014). Consumer innovativeness and consumer decision styles: a confirmatory and segmentation analysis. *Http://Dx.Doi.Org/10.1080/09593969.2014.911199*, *25*(1), 35–54. https://doi.org/10.1080/09593969.2014.911199

Moons, I., de Pelsmacker, P., & Barbarossa, C. (2020). Do personality- and self-congruity matter for the willingness to pay more for ecotourism? An empirical study in Flanders, Belgium. *Journal of Cleaner Production*, *272*, 122866. https://doi.org/10.1016/J.JCLEPRO.2020.122866

Morton, C., Anable, J., & Nelson, J. D. (2017). Consumer structure in the emerging market for electric vehicles: Identifying market segments using cluster analysis. *International Journal of Sustainable Transportation*, *11*(6), 443–459. https://doi.org/10.1080/15568318.2016.1266533

Mugge, R. (2011). The effect of a business-like personality on the perceived performance quality of products. *International Journal of Design*, *5*(3), 67–76.

Mugge, R., Govers, P. C. M., & Schoormans, J. P. L. (2009). The development and testing of a product personality scale. *Design Studies*, *30*(3), 287–302. https://doi.org/10.1016/j.destud.2008.10.002

Mugge, R., Schifferstein, H. N. J., & Schoormans, J. P. L. (2005). Product Attachment and Product Lifetime: the Role of Personality Congruity and Fashion. *ACR European Advances*, *E-07*. http://www.acrwebsite.org/volumes/13725/eacr/vol7/E-07

Muller, W. (2001). *Order and meaning in design*. Lemma Publishers.

Myers, J. (1996). *Segmentation and positioning for strategic marketing decisions*. American Marketing Association.

Nicolao, L., Irwin, J. R., & Goodman, J. K. (2009). Happiness for Sale: Do Experiential Purchases Make Consumers Happier than Material Purchases? *Journal of Consumer Research*, *36*(2), 188–198. https://doi.org/10.1086/597049

Niu, M., & Lo, C.-H. (2020). An investigation of material perception in virtual environments. In T. Ahram (Ed.), *Advances in human factors in wearable technologies and game design (AHFE 2019)/Advances in intelligent systems and computing* (Vol. 973, pp. 416–426). Cham: Springer.

Norman, D. (2004). *Emotional Design - Why We Love (or Hate) Everyday Things*. Basic Books. https://motamem.org/upload/Emotional-Design-Why-We-Love-or-Hate-Everyday-Things-Donald-Norman.pdf

Odom, W., & Pierce, J. (2009). Improving with age: Designing enduring interactive products. *Conference on Human Factors in Computing Systems (CHI'09)*, 3793–3798. https://doi.org/10.1145/1520340.1520573

Ordoñez, I., & Rahe, U. (2013). Collaboration between design and waste management: Can it help close the material loop? *Resources, Conservation and Recycling*, *72*, 108–117. https://doi.org/10.1016/J.RESCONREC.2013.01.002

Osburg, V.-S., Strack, M., & Toporowski, W. (2015). Consumer acceptance of Wood-Polymer Composites: a conjoint analytical approach with a focus on innovative and environmentally concerned consumers. *Journal of Cleaner Production*, *110*(January), 180–190. https://doi.org/10.1016/J.JCLEPRO.2015.04.086

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The Measurement of Meaning*. USA: University of Illinois Press.

Ostuzzi, F., Salvia, G., Rognoli, V., & Levi, M. (2011). The value of imperfection in industrial product. *Designing Pleasurable Products and Interfaces, Proceedings.*

O'Sullivan, M. G. (2017). Rapid Sensory Profiling Methods. In *A Handbook for Sensory and Consumer-Driven New Product Development* (pp. 59–82). Woodhead Publishing. https://doi.org/10.1016/b978-0-08-100352-7.00004-x

Ou, L. C., Lou, M. R., Woodcock, A., & Wright, A. (2004). A study of colour emotion and colour preference. Part II: Colour emotions for two-colour combinations. *Color Research & Application*, *29*(4), 292–298. https://doi.org/10.1002/COL.20024

Ou, L.-C., Luo, M. R., Woodcock, A., & Wright, A. (2004). A study of colour emotion and colour preference. Part I: Colour emotions for single colours. *Color Research & Application*, *29*(3), 232–240. https://doi.org/10.1002/col.20010

Overvliet, K. E., Karana, E., & Soto-Faraco, S. (2016). Perception of naturalness in textiles. *Materials & Design*, *90*, 1192–1199. https://doi.org/10.1016/J.MATDES.2015.05.039

Overvliet, K. E., & Soto-Faraco, S. (2011). I can't believe this isn't wood! An investigation in the perception of naturalness. *Acta Psychologica*, *136*(1), 95–111. https://doi.org/10.1016/j.actpsy.2010.10.007

Page, T., Thorsteinsson, G., & Ha, J.-G. (2012). Using Colours to alter Consumer Behaviour and Product Success. *International Journal of Contents*, *8*(1), 69–73. https://doi.org/10.5392/IJOC.2012.8.1.069

Pagès, J., Cadoret, M., & Lê, S. (2010). The Sorted Napping: A New Holistic Approach in Sensory Evaluation. *Journal of Sensory Studies*, *25*(5), 637–658. https://doi.org/10.1111/j.1745-459X.2010.00292.x

Peck, J., & Childers, T. L. (2003). Individual Differences in Haptic Information Processing: The "Need for Touch" Scale. *Journal of Consumer Research*, *30*(3), 430–442. https://doi.org/10.1086/378619/0

Pedgley, O. (2009). Influence of stakeholders on industrial design materials and manufacturing selection. *International Journal of Design*.

Pedgley, O. (2010). Invigorating Industrial Design Materials and Manufacturing Education. *METU*, *27*(2), 339–360.

Pedgley, O. (2014). Materials Selection for Product Experience. In *Materials Experience* (pp. 337–349). Elsevier. https://doi.org/10.1016/B978-0-08-099359-1.00024-2

Pedgley, O., Rognoli, V., & Karana, E. (2016). Materials experience as a foundation for materials and design education. *International Journal of Technology and Design*, *26*(613).

Pedgley, O., Rognoli, V., & Karana, E. (2021). Materials Experience 2. In O. Pedgley, V. Rognoli, & E. Karana (Eds.), *Materials Experience 2*. Butterworth-Heinemann. https://doi.org/10.1016/C2018-0-03833-5

Pense-Lheritier, A.-M., Bacle, I., & Delarue, J. (2021). *Non-Food Sensory Practices* (A.-M. Pense-Lheritier, I. Bacle, & J. Delarue, Eds.; 1st ed.). Woodhead Publishing.

Petiot, J.-F., & Yannou, B. (2004). Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. *International Journal of Industrial Ergonomics*, *33*(6), 507–525. https://doi.org/10.1016/J.ERGON.2003.12.004

Picard, D., Dacremont, C., Valentin, D., & Giboreau, A. (2003). Perceptual dimensions of tactile textures. *Acta Psychologica*, *114*(2), 165–184. https://doi.org/10.1016/J.ACTPSY.2003.08.001

Piselli, A., Basso, M., Simonato, M., Furlanetto, R., Cigada, A., De Nardo, L., & Del Curto, B. (2017). Effect of wear from cleaning operations on sintered ceramic surfaces: Correlation of surface properties data with touch perception and digital image processing. *Wear*, *390–391*, 355–366. https://doi.org/10.1016/J.WEAR.2017.09.003

Piselli, A., Baxter, W., Simonato, M., del Curto, B., & Aurisicchio, M. (2018). Development and evaluation of a methodology to integrate technical and sensorial properties in materials selection. *Materials & Design*, *153*, 259–272. https://doi.org/10.1016/J.MATDES.2018.04.081

Poortinga, W., Steg, L., & Vlek, C. (2004). Values, environmental concern, and environmental behavior: A study into household energy use. *Environment and Behavior*, *36*(1), 70–93. https://doi.org/10.1177/0013916503251466

Punj, G., & Stewart, D. W. (1983). Cluster Analysis in Marketing Research: Review and Suggestions for Application. *Journal of Marketing Research*, *20*(2), 134–148. https://doi.org/10.1177/002224378302000204

Ragaert, K. (2016). Trends in mechanical recycling of thermoplastics. In ed. Gerald Pinter and Gerald Pilz (Ed.), *Kunststoff Kolloquium Leoben* (pp. 159–165).

Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. *WASTE MANAGEMENT*, *69*, 24–58. https://doi.org/10.1016/j.wasman.2017.07.044

Ragaert, K., Hubo, S., Delva, L., Veelaert, L., & Du Bois, E. (2017). Upcycling of contaminated post-industrial polypropylene waste: A design from recycling case study. *Polymer Engineering & Science*, *58*(4). https://doi.org/10.1002/PEN.24764

Raju, P. S. (1980). Optimum Stimulation Level: Its Relationship to Personality, Demographics, and Exploratory Behavior. *Journal of Consumer Research*, *7*(3), 272–282. https://www.jstor.org/stable/2489012?seq=1#metadata_info_tab_contents

Ramalhete, P. S., Senos, A. M. R., & Aguiar, C. (2010). Digital tools for material selection in product design. *Materials & Design*, *31*(5), 2275–2287. https://doi.org/10.1016/j.matdes.2009.12.013

Ranscombe, C., Hicks, B., Mullineux, G., & Singh, B. (2012). Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of brand. *Design Studies*, *33*(4), 319–341. https://doi.org/10.1016/j.destud.2011.06.006

Rao, R., & Davim, J. (2008). A decision-making framework model for material selection using a combined multiple attribute decision-making method. *The International Journal of Advanced Manufacturing …*, *35*(7–8), 751–760. https://doi.org/10.1007/s00170-006-0752-7

Ratchford, B., & Vaughn, R. (1989). On the Relationship Between Motives and Purchase Decisions: Some Empirical Approaches. *ACR North American Advances*, *NA-16*.

Rebelo, F., Noriega, P., Duarte, E., & Soares, M. (2012). Using Virtual Reality to Assess User Experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(6), 964–982. https://doi.org/10.1177/0018720812465006

Reinbach, H. C., Giacalone, D., Ribeiro, L. M., Bredie, W. L. P., & Frøst, M. B. (2014). Comparison of three sensory profiling methods based on consumer perception: CATA, CATA with intensity and Napping®. *Food Quality and Preference*, *32*, 160–166. https://doi.org/10.1016/j.foodqual.2013.02.004

Richins, M. L. (2004). The Material Values Scale: Measurement Properties and Development of a Short Form. *Journal of Consumer Research*, *31*(1), 209–219. https://doi.org/10.1086/383436

Richins, M. L., & Dawson, S. (1990). Measuring Material Values: a Preliminary Report of Scale Development. *ACR North American Advances*, *NA-17*.

Richins, M. L., & Dawson, S. (1992). A Consumer Values Orientation for Materialism and Its Measurement: Scale Development and Validation. *Journal of Consumer Research*, *19*(3). https://doi.org/10.1086/209304

Roccas, S., Sagiv, L., Schwartz, S. H., & Knafo, A. (2002). The Big Five personality factors and personal values. *Personality and Social Psychology Bulletin*, *28*(6), 789–801. https://doi.org/10.1177/0146167202289008

Roehrich, G. (1995). Innovativités hédoniste et sociale: proposition d'une échelle de mesure. *Recherche et Applications En Marketing (French Edition)*, *9*(2), 19–42. https://doi.org/10.1177/076737019400900202

Roehrich, G. (2004). Consumer innovativeness: Concepts and measurements. *Journal of Business Research*, *57*(6), 671–677. https://doi.org/10.1016/S0148-2963(02)00311-9

Rognoli, V. (2004). *The expressive-sensorial characterization of materials for design*. Faculty of Design, Politecnico di Milano.

Rognoli, V. (2010). A Broad Survey on Expressive-Sensorial Characterization of Materials for Design Education. *METU Journal of Faculty of Architecture*, *27*(2), 287–300. https://doi.org/10.4305/METU.JFA.2010.2.16

Rognoli, V., Bianchini, M., Maffei, S., & Karana, E. (2015). DIY materials. *Materials & Design*, *86*, 692–702. https://doi.org/10.1016/j.matdes.2015.07.020

Rognoli, V., & Karana, E. (2014). Towards a New Materials Aesthetic Based on Imperfection and Graceful Ageing. In E. Karana, O. Pedgley, & V. Rognoli (Eds.), *Materials Experience: Fundamentals of Materials and Design* (pp. 145–153). Elsevier.

Rognoli, V., Karana, E., & Pedgley, O. (2011). Natural fibre composites in product design: An investigation into material perception and acceptance. *DPPI'11 - Designing Pleasurable Products and Interfaces, Proceedings*, 1. https://doi.org/10.1145/2347504.2347543

Rognoli, V., & Levi, M. (2004). Emotions in Design through Materials An expressive-sensorial Atlas as a Project Tool for Design of Materials. *A. Kurtgözü (Ed.): Proceedings of 4th International Conference on Design & Emotion*, 1–11.

Rognoli, V., Salvia, G., & Levi, M. (2011). The aesthetic of interaction with materials for design: the bioplastic's identity. *Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces - DPPI '11*, 1. https://doi.org/10.1145/2347504.2347540

Rokeach, M. (1973). *The Nature of Human Values*. New York: Free Press. https://doi.org/10.1093/sw/19.6.758

Rosenberg, M. (1979). *Conceiving the Self*. Basic Books, Inc.

Roth, R., Field, F., & Clark, J. (1994). Materials selection and multi-attribute utility analysis. *Journal of Computer-Aided Materials Design*, *1*(3), 325–342.

Rummel, R. (1970). *Applied Factor Analysis*. Northwestern University Press.

Russell, J. A. (2003). Core Affect and the Psychological Construction of Emotion. *Psychological Review*, *110*(1), 145–172. https://doi.org/10.1037/0033-295X.110.1.145

Saito, Y. (2007). Everyday Aesthetics. In *Everyday Aesthetics*. Oxford University Press. https://doi.org/10.1093/ACPROF:OSO/9780199278350.001.0001

Sakamoto, M., & Watanabe, J. (2017). Exploring Tactile Perceptual Dimensions Using Materials Associated with Sensory Vocabulary. *Frontiers in Psychology*, *8*, 569. https://doi.org/10.3389/fpsyg.2017.00569

Salvia, G., Ostuzzi, F., Rognoli, V., & Levi, M. (2011). The value of imperfection in sustainable design: the emotional tie with perfectible artefacts for longer lifespan. *Sustainability in Design : Now! Challenges and Opportunities Fo Design Research, Education and Practice in the XXI Century, Abstracts*.

Samuels, P. (2017). *Advice on Exploratory Factor Analysis*. ResearchGate.

Sapuan, S. (2001). A knowledge-based system for materials selection in mechanical engineering design. *Materials & Design*, *22*(8), 687–695. https://doi.org/10.1016/S0261-3069(00)00108-4

Sauerwein, M., Karana, E., & Rognoli, V. (2017). Revived Beauty: Research into Aesthetic Appreciation of Materials to Valorise Materials from Waste. *Sustainability*, *9*(4), 529. https://doi.org/10.3390/su9040529

Savic, S., & Huang, J. (2014, June). Research Through Design: What Does it Mean for a Design Artifact to be Developed in the Scientific Context? *Proceedings of the 5th STS Italia Conference : A Matter of Design. Making Society through Science and Technology*.

Scherer, C., Emberger-Klein, A., & Menrad, K. (2018). Segmentation of interested and less interested consumers in sports equipment made of bio-based plastic. *Sustainable Production and Consumption*, *14*, 53–65. https://doi.org/10.1016/J.SPC.2018.01.003

Schifferstein, H. N. J. (2010). From salad to bowl: The role of sensory analysis in product experience research. *Food Quality and Preference*, *21*(8), 1059–1067. https://doi.org/10.1016/J.FOODQUAL.2010.07.007

Schifferstein, H. N. J., & Hekkert, P. (2008). *Product experience* (H. Schifferstein & P. Hekkert, Eds.). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-045089-6.X5001-1

Schifferstein, H. N. J., & Wastiels, L. (2014). Sensing materials: Exploring the building blocks for experiential design. In V. Karana, E., Pedgley, O., Rognoli (Ed.), *Materials experience: Fundamentals of materials and design* (1st ed., pp. 15–26). Butterworth Heinemann. https://doi.org/10.1016/B978-0-08-099359-1.00002-3

Schifferstein, H. N. J., & Zwartkruis-Pelgrim, E. P. H. (2008). Consumer-Product Attachment: Measurement and Design Implications. *International Journal of Design*, *2*(3), 1–14. http://www.ijdesign.org/index.php/IJDesign/article/view/325/218

Schmitt, B., Joško Brakus, J., & Zarantonello, L. (2015). From experiential psychology to consumer experience. *Journal of Consumer Psychology*, *25*(1), 166–171. https://doi.org/10.1016/J.JCPS.2014.09.001

Schultz, W. P. (2001). The structure of environmental concern: Concern for self, other people, and the biosphere. *Journal of Environmental Psychology*, *21*(4), 327–339. https://doi.org/10.1006/JEVP.2001.0227

Schwartz, S. H. (1992). Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries. *Advances in Experimental Social Psychology*, *25*, 1–65. https://doi.org/10.1016/S0065-2601(08)60281-6

Schwartz, S. H. (2012). An Overview of the Schwartz Theory of Basic Values. *Online Readings in Psychology and Culture*, *2*(1). https://doi.org/10.9707/2307-0919.1116

Schwartz, S. H., & Sagiv, L. (1995). Identifying Culture-Specifics in the Content and Structure of Values: *Journal of Cross-Cultural Psychology*, *26*(1), 92–116. https://doi.org/10.1177/0022022195261007

Shor, D., Zaaijer, B., Ahsmann, L., Immerzeel, S., Weetzel, M., Eikelenboom, D., Hartcher-O'Brien, J., & Aschenbrenner, D. (2018). Designing Haptics: Comparing Two Virtual Reality Gloves with Respect to Realism, Performance and Comfort. *International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct 2018)*, 318–323. https://doi.org/10.1109/ISMAR-ADJUNCT.2018.00095

Sidel, J. L., & Stone, H. (1993). The role of sensory evaluation in the food industry. *Food Quality and Preference*, *4*(1–2), 65–73. https://doi.org/10.1016/0950-3293(93)90314-V

Silvennoinen, J. M., Rousi, R., Jokinen, J. P. P., & Perälä, P. M. H. (2015). Apperception as a multisensory process in material experience. *Proceedings of the 19th International Academic Mindtrek Conference on - AcademicMindTrek '15*, 144–151. https://doi.org/10.1145/2818187.2818285

Simmons, D. R. (2006). The association of colours with emotions: A systematic approach. *Journal of Vision*, *6*(6), 251–251. https://doi.org/10.1167/6.6.251

Singh, J., & Ordoñez, I. (2016). Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. *Journal of Cleaner Production*, *134*, 342–353. https://doi.org/10.1016/j.jclepro.2015.12.020

Sirgy, M. J. (1982). Self-Concept in Consumer Behavior: A Critical Review. *Journal of Consumer Research*, *9*(3), 287. https://doi.org/10.1086/208924

Sirgy, M. J. (2015). The Self-Concept in Relation to Product Preference and Purchase Intention. In *Marketing Horizons: A 1980's Perspective* (pp. 350–354). Springer International Publishing. https://doi.org/10.1007/978-3-319-10966-4_94

Sitanshu Sekhar Kar, & A. Ramalingam. (2013). Is 30 the magic number? issues in sample size estimation. *National Journal of Community Medicine*, *4*(1), 175–179.

Snyder, C. R., & Fromkin, H. L. (1980). *Uniqueness, the human pursuit of difference*. Plenum Press.

Sonneveld, M. (2007). *Aesthetics of tactile experiences*. Delft University of Technology.

Soto, C. J., & John, O. P. (2017). Short and extra-short forms of the Big Five Inventory–2: The BFI-2-S and BFI-2-XS. *Journal of Research in Personality*, *68*, 69–81. https://doi.org/10.1016/J.JRP.2017.02.004

Soto, J. J., Cantillo, V., & Arellana, J. (2021). Market segmentation for incentivising sustainable transport policies. *Transportation Research Part D: Transport and Environment*, *99*, 103013. https://doi.org/10.1016/J.TRD.2021.103013

Sparks, P., & Shepherd, R. (1992). Self-Identity and the Theory of Planned Behavior: Assesing the Role of Identification with "Green Consumerism." *Social Psychology Quarterly*, *55*(4), 388. https://doi.org/10.2307/2786955

Steenkamp, J.-B. E. M., Hofstede, F. ter, & Wedel, M. (1999). A Cross-National Investigation into the Individual and National Cultural Antecedents of Consumer Innovativeness: *Journal of Marketing*, *63*(2), 55–69. https://doi.org/10.1177/002224299906300204

Stets, J. E., & Burke, P. J. (2000). Identity theory and social identity theory. *Social Psychology Quarterly*, *63*(3), 224–237. https://doi.org/10.2307/2695870

Stevens, J. P. (2012). *Applied Multivariate Statistics for the Social Sciences*. Routledge.

Stryker, S., & Burke, P. J. (2000). The past, present, and future of an identity theory. *Social Psychology Quarterly*, *63*(4), 284–297. https://doi.org/10.2307/2695840

Tabachnick, B., & Fidell, L. (2007). *Using multivariate statistics* (5th ed.). Pearson/Allyn & Bacon.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. Yale University Press.

Tian, Y., & Lu, D. (2015). The Experimental Research on the Influence of Materialism and the Emotion of Awe on Life Satisfaction and Products Preference. *Open Journal of Social Sciences*, *3*(10), 138–145. https://doi.org/10.4236/JSS.2015.310020

Ulusoy, B., & Nilgün, O. (2017). Understanding responses to materials and colors in interiors. *Color Research & Application*, *42*(2), 261–272. https://doi.org/10.1002/col.22072

van Kesteren, I. (2008). *Selecting materials in product design (doctoral dissertation)* [TU Delft, Delft University of Technology]. https://doi.org/978-90-5155-040-5

van Kesteren, I. (2010). A User-centred Materials Selection Approach for Product Designers. *METU Journal of Faculty of Architecture*, *27*(2), 321–338. https://doi.org/10.4305/METU.JFA.2010.2.18

van Kesteren, I., de Bruijn, S., & Stappers, P. J. (2008). Evaluation of materials selection activities in user-centred design projects. *Journal of Engineering Design*, *19*(5), 417–429. https://doi.org/10.1080/09544820701716248

van Kesteren, I., Kandachar, P., & Stappers, P. J. (2006). Activities in selecting materials by product designers. *Proceedings of the International Conference on Advanced Design and Manufacture*.

van Kesteren, I., Stappers, P. J., & de Bruijn, S. (2007a). Defining User-Interaction Aspects for Materials Selection: Three Tools. *Design Inquiries*, 1–10. http://www.nordes.org/opj/index.php/n13/article/viewFile/173/156

van Kesteren, I., Stappers, P. J., & de Bruijn, S. (2007b). Materials in Products Selection: Tools for Including User Interaction in Materials Selection. *International Journal of Design*, *1*(3), 41–55.

van Kesteren, I., Stappers, P. J., & Kandachar, P. (2005). Representing product personality in relation to materials in a product design problem. *Nordic Design Research Conference*, *0*(1). http://www.nordes.org/opj/index.php/n13/article/view/251

van Rompay, T. J. L., Ad TH Pruyn, Peter Tieke, Pruyn, A. T. H., & Tieke, P. (2009). Symbolic Meaning Integration in Design and its Influence on Product and Brand Evaluation. *International Journal of Design*, *3*(2), 19–26.

Varela, P., & Ares, G. (2012). Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. *Food Research International*, *48*(2), 893–908. https://doi.org/10.1016/j.foodres.2012.06.037

Vaughn, R. (1980). How advertising works: A planning model. *Journal of Advertising Research*, *20*(5), 27–33.

Veelaert, L., Du Bois, E., Herweyers, L., & Moons, I. (2021). Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality. *Sustainable Production, Life Cycle Engineering and Management*, 61–77. https://doi.org/10.1007/978-981-15-6775-9_5

Veelaert, L., Du Bois, E., Hubo, S., van Kets, K., Ragaert, K., Hubo, S., & Du Bois, E. (2017). Design from Recycling. In *EKSIG2017: alive, active, adaptive : International Conference on Experiential Knowledge*. Universiteit Antwerpen. https://doi.org/D/2017/12.293.25

Veelaert, L., Du Bois, E., Moons, I., De Pelsmacker, P., Hubo, S., & Ragaert, K. (2020). The Identity of Recycled Plastics: A Vocabulary of Perception. *Sustainability*, *12*(5), 1953. https://doi.org/10.3390/su12051953

Veelaert, L., Du Bois, E., Moons, I., & Karana, E. (2020). Experiential characterization of materials in product design: A literature review. *Materials & Design*, *190*, 108543. https://doi.org/https://doi.org/10.1016/j.matdes.2020.108543

Veelaert, L., Du Bois, E., Ragaert, K., Hubo, S., & Van Kets, K. (2016). Bridging design and engineering in terms of materials selection. *Proceedings of 7th International Polymers & Moulds Innovations Conference*, 319–326. https://doi.org/978-90-813136-0-5

Veelaert, L., Hubo, S., Ragaert, K., Van Doorsselaer, K., & Du Bois, E. (2017). *Determinator design box & booklets - Design From Recycling*.

Veelaert, L., Moons, I., Coppieters, W., & Du Bois, E. (2018). Exploring the Fit Between Materials' Expressive Values and the Self-expression of the End-User. *20thVeelaert, Lore, Ingrid Moons, Werner Coppieters, and Els Du Bois (2018), "Exploring the Fit Between Materials'*

Expressive Values and the Self-Expression of the End-User," in 20th Congress of the International Ergonomics Association, 2045–66. Congress, 2045–2066.

Veelaert, L., Moons, I., Rohaert, S., & Du Bois, E. (2019). A Neutral Form for Experiential Material Characterisation. *Proceedings of the Design Society: International Conference on Engineering Design*, *1*(1), 1743–1752. https://doi.org/10.1017/dsi.2019.180

Veelaert, L., Moons, I., van Gogh, D., Vleugels, J., & Du Bois, E. (2022). A Physical Demonstrator Form for Experiential Material Characterization. *The International Journal of Designed Objects*, *16*(1), 19–48. https://doi.org/10.18848/2325-1379/CGP/V16I01/19-48

Vergara, M., Mondragón, S., Sancho-Bru, J. L., Company, P., & Agost, M.-J. (2011). Perception of products by progressive multisensory integration. A study on hammers. *Applied Ergonomics*, *42*(5), 652–664. https://doi.org/10.1016/J.APERGO.2010.09.014

Vezzoli, C. (2014). The "Material" Side of Design for Sustainability. In Eds. Karana, E., Pedgley, O., Rognoli, V. (Ed.), *Materials Experience: Fundamentals of Materials and Design* (pp. 105–121). Butterworth Heinemann. https://doi.org/10.1016/B978-0-08-099359-1.00008-4

Vyncke, G., Onnekink, J., Feenstra, T., & Ragaert, K. (2018). Design from Recycling for post-consumer WEEE plastics. *International Conference on Polymers and Moulds Innovations (PMI2018)*, 6.

Wagner, J. (1999). Aesthetic value: Beauty in art and fashion. In M. B. Holbrook (Ed.), *Consumer Value: A framework for analysis and research* (pp. 126–146). Routledge interpretive marketing research.

Walker, S. (1995). The Environment, Product Aesthetics and Surface. *Design Issues*, *11*(3), 15. https://doi.org/10.2307/1511767

Wastiels, L. (2010). *Mapping Material Experience in Architecture: Characterization of material warmth*. www.vubpress.be

Wastiels, L., Schifferstein, H. N. J., Heylighen, A., & Wouters, I. (2012a). Relating material experience to technical parameters: A case study on visual and tactile warmth perception of indoor wall materials. *Building and Environment*, *49*, 359–367. https://doi.org/10.1016/J.BUILDENV.2011.08.009

Wastiels, L., Schifferstein, H. N. J., Heylighen, A., & Wouters, I. (2012b). Red or rough, what makes materials warmer? *Materials & Design*, *42*, 441–449. https://doi.org/10.1016/J.MATDES.2012.06.028

Wastiels, L., Schifferstein, H. N. J., Wouters, I., & Heylighen, A. (2013). Touching materials visually: About the dominance of vision in building material assessment. *International Journal of Design*, *7*(2), 31–41.

Whitmarsh, L., & O'Neill, S. (2010). Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *Journal of Environmental Psychology*, *30*(3), 305–314. https://doi.org/10.1016/J.JENVP.2010.01.003

Wilkes, S., Wongsriruksa, S., Howes, P., Gamester, R., Witchel, H., Conreen, M., Laughlin, Z., & Miodownik, M. (2016). Design tools for interdisciplinary translation of material experiences. *Materials & Design*, *90*, 1228–1237. https://doi.org/10.1016/j.matdes.2015.04.013

Wilson Vanvoorhis, C. R., & Morgan, B. L. (2007). Understanding Power and Rules of Thumb for Determining Sample Sizes. In *Tutorials in Quantitative Methods for Psychology* (Vol. 3, Issue 2).

Yanagisawa, H., & Takatsuji, K. (2015). Effects of visual expectation on perceived tactile perception: An evaluation method of surface texture with expectation effect. *International Journal of Design*, *9*(1), 39–51.

Zarandi, M. H. F., Mansour, S., Hosseinijou, S. A., & Avazbeigi, M. (2011). A material selection methodology and expert system for sustainable product design. *International Journal of Advanced Manufacturing Technology*, *57*(9–12), 885–903. https://doi.org/10.1007/s00170-011-3362-y

Zarco, T. H. (2014). The Influence of Materialism on Consumer Preferences: A Conjoint Analysis Approach. *Philippine Management Review*, *21*(0), 39–52.

Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010). An analysis and critique of research through design: Towards a formalization of a research approach. *DIS 2010 - Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 310–319. https://doi.org/10.1145/1858171.1858228

Zuo, H. (2003). *Sensory interaction with materials in product design (doctoral dissertation)*.

Zuo, H. (2010). Zuo, H. (2010). The Selection of Materials to Match Human Sensory Adaptation and Aesthetic Expectation in Industrial Design. METU Journal of Faculty of Architecture, 27(2), 301–319. https://doi.org/10.4305/METU.JFA.2010.2.17The Selection of Materials to M. *METU Journal of Faculty of Architecture*, *27*(2), 301–319. https://doi.org/10.4305/METU.JFA.2010.2.17

Zuo, H., Hope, T., & Jones, M. (2013). Tactile Aesthetics of Materials and Design. In Butterworth-Heineman (Ed.), *Materials Experience: Fundamentals of Materials and Design* (1st ed., pp. 27–37). Elsevier. https://doi.org/10.1016/B978-0-08-099359-1.00003-5

Zuo, H., Jones, M., Castle, P., & Hope, T. (2001). An investigation into the sensory properties of materials. *The Second International Conference on Affective Human Factors Design*.

Zuo, H., Jones, M., Hope, T., & Jones, R. (2016). Sensory Perception of Material Texture in Consumer Products. *The Design Journal*, *19*(3), 405–427. https://doi.org/10.1080/14606925.2016.1149318

Curriculum Vitae

About the author

Lore Veelaert was born on the 28th of August in Antwerp, Belgium. She commenced her bachelor degree in 2010 at the Product Development department of the Artesis University College. In 2013, Lore completed her bachelor studies magna cum laude, and participated in the European Project Semester. She progressed onto her master studies in 2013 at the Product Development department of the University of Antwerp. In 2015, Lore completed her master studies magna cum laude with a design research project. After graduation, she started as a research assistant at the same department within the ecoteam and – in addition to several small projects – she worked for two years on the TETRA research project "Design From Recycling", which she concluded with the development of the "Determinator Box" and accompanying booklets on how to design with recycled plastics. Next, she commenced her doctoral research in 2015 at the Faculty of Design Sciences of the University of Antwerp, supervised by professors from both the Marketing and Product Development departments. Over the years, Lore has been involved as a teacher assistant in several bachelor and master courses such as Sustainable Design, Product & Production, Market Research, Applied Research Techniques, Design for Sustainability, etc. Finally, she is a member of the Faculty Education Committee of the Faculty of Design Sciences (FOWC), the Faculty Research Committee of the Faculty of Design Sciences (FOZC), and the Faculty Council of the Faculty of Design Sciences (FROW).

Education

PhD Fellow (2015-2022) – University of Antwerp – Faculty of Design Sciences – Research Group of Product Development

Master of Product Development (2013-2015) – Magna cum Laude – University of Antwerp - Faculty of Design Sciences – Product Development

Bachelor of Product Development (2010-2013) – Artesis University College – Product Development

Publications in International Journals with Peer Review

A1

Veelaert, L., Du Bois, E., De Pelsmacker, P., Moons, I. (submitted). The Effect of Consumer Segmentation and Product Types on Experiential Material Preferences. *Journal of Design Research*.

Veelaert, L., Moons, I., van Gogh, D., Vleugels, J., & Du Bois, E. (2022). A Physical Demonstrator Form for Experiential Material Characterization. *The International Journal of Designed Objects*, 16(1), 19–48. https://doi.org/10.18848/2325-1379/CGP/V16I01/19-48

Vanhooydonck, A., Van Goethem, S., Van Loon, J., Vandormael, R., Vleugels, J., Peeters, T., Smedts, S., Stokhuijzen, D., Van Camp, M., Veelaert, L., Verlinden, J., Verwulgen, S., Watts, R.T. (2021). Case study into the successful emergency production and certification of a filtering facepiece respirator for Belgian hospitals during the COVID-19 pandemic. *Journal of Manufacturing Systems*, 60, 876–892. https://doi.org/10.1016/J.JMSY.2021.03.016

Van Loon, J., Veelaert, L., Van Goethem, S., Watts, R., Verwulgen, S., Verlinden, J. C., & Du Bois, E. (2021). Reuse of filtering facepiece respirators in the COVID-19 era. *Sustainability*, 13(2). https://doi.org/10.3390/su13020797

Veelaert, L., Du Bois, E., Moons, I., & Karana, E. (2020). Experiential characterization of materials in product design: A literature review. *Materials and Design*, 190. https://doi.org/10.1016/j.matdes.2020.108543

Veelaert, L., Du Bois, E., Moons, I., De Pelsmacker, P., Hubo, S., & Ragaert, K. (2020). The Identity of Recycled Plastics: A Vocabulary of Perception. *Sustainability*, 12(5), 1953. https://doi.org/10.3390/su12051953

H1

Veelaert, L., Du Bois, E., Herweyers, L., & Moons, I. (2021). Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality. *Sustainable Production, Life Cycle Engineering and Management*, 61–77. https://doi.org/10.1007/978-981-15-6775-9_5

Publications in Conference Proceedings

P1

Veelaert, L., Moons, I., & Du Bois, E. (2021). Formulating Guidelines for the Systematic Set-up of Experiential Material Characterization Studies: A Case of Plastic Demonstrators. *Proceedings of the Design Society 1 (ICED 2021)*, 1, 1587–1596. https://doi.org/10.1017/PDS.2021.420

Du Bois, E., Veelaert, L., Tormans, E., & Moons, I. (2021). How Should Plastic Recyclates Look Like to be Perceived as Sustainable: A First Exploration. *Proceedings of the Design Society 1 (ICED 2021)*, 1, 1765–1774. https://doi.org/10.1017/PDS.2021.438

Veelaert, L., Moons, I., Rohaert, S., & Du Bois, E. (2019). A Neutral Form for Experiential Material Characterization. *Proceedings of the Design Society: International Conference on Engineering Design (ICED 2019)*, 1(1), 1743–1752. https://doi.org/10.1017/dsi.2019.180

Du Bois, E., Van Gogh, D., Veelaert, L., & Van Doorsselaer, K. (2019). Design Against the Plastic Soup - The Effect of Small Product Designs in Sustainable Design Education. *Proceedings of the Design*

Society: International Conference on Engineering Design (ICED 2019), 1(1), 3201–3210. https://doi.org/10.1017/DSI.2019.327

Veelaert, L., Moons, I., Coppieters, W., & Du Bois, E. (2018). Exploring the Fit Between Materials' Expressive Values and the Self-expression of the End-User. *Proceedings of 20th Congress of the International Ergonomics Association*, 2045–66. Congress, 2045–2066.

P2

Du Bois, E., Veelaert, L., Vermeersch, B., Zelck, S., & Van Gogh, D. (2019). Fun for life : designerly opportunities for lifetime extension in toys. *4th PLATE Conference – Product Lifetimes and the Environment*, 219–226. https://doi.org/10.14279/DEPOSITONCE-9253

P3

Veelaert, L., Du Bois, E., & De Pelsmacker, P. (2020). Front-end Marketing for Recycled Plastics: The Role of Experiential Material Evaluation. *Proceedings of the European Marketing Academy, 49th,* (59072). Budapest.

Non-written Output

Veelaert, L., Du Bois E., Moons, I., Van Gogh, D., Vleugels, J. (2021). Kunststof Demonstrator vorm (en spuitgietmal) = Plastic Demonstrator Form (and injection mould). Non-Written Output Toolkit, https://hdl.handle.net/10067/1830430151162165141.

Oral Presentations at International Congresses

Veelaert, L., Moons, I., & Du Bois, E. (2021). Formulating Guidelines for the Systematic Set-up of Experiential Material Characterization Studies: A Case of Plastic Demonstrators. *Oral presentation at the International Conference on Engineering Design*, Gothenburg, Sweden (Online).

Veelaert, L., Du Bois, E., Herweyers, L., & Moons, I. (2019). Consumer's Perception of Plastics in Everyday Products in Relation to Their Personality. *Oral presentation at the 11th International Symposium on Environmentally Conscious Design and Inverse Manufacturing (Going Green – EcoDesign 2019)*, Yokohama, Japan.

Veelaert, L., Moons, I., Rohaert, S., & Du Bois, E. (2019). A Neutral Form for Experiential Material Characterization. *Oral presentation at the International Conference on Engineering Design (ICED 2019)*, Delft, the Netherlands.

Veelaert, L., Moons, I., Coppieters, W., & Du Bois, E. (2018). Exploring the Fit Between Materials' Expressive Values and the Self-expression of the End-User. *Oral presentation at the 20th Congress of the International Ergonomics Association*, Florence, Italy.

Master Thesis Supervision (Co-promotor)

Ineke De Hondt (2021-2022): Interactive set-up for experiential characterization experiments with consumers.

Emiel Tormans (2018-2019): Sustainable perception of the consumer in the use of recyclates.

Summary in Dutch

Druk je materiële zelf uit: Ervaringsgerichte karakterisatie van materialen in productontwikkeling

Hoe ervaren consumenten de materialen in producten om zich heen, en hoe kunnen we deze belevingsaspecten capteren in informatie voor ontwerpers? Deze vraag was het beginpunt van dit proefschrift. De voorbije vier jaar zijn we nagegaan hoe we de materiaalbeleving van verschillende soorten consumenten kunnen onderzoeken, zodat ontwerpers en marketeers kunnen inzetten op ervaringsgerichte kwaliteiten van materialen voor de beoogde doelgroep van een te ontwerpen product.

We leven momenteel in een wereld met een overlaad aan producten en varianten op de markt. Dus kunnen we ons afvragen hoe een consument in hemelsnaam kiest welk product hij of zij effectief aankoopt. Om veeleisende consumenten tevreden te stellen, moeten producten voldoen aan zowel functionele eisen als hedonistische behoeftes. Allereerst moet een product dus goed, veilig en eenvoudig werken. Daarnaast moet een product ook het leven van de gebruiker verbeteren, voldoening en plezier geven. We interageren met materialen via producten, en het is via onze zintuigen dat we materialen ervaren. Zonder materialen geen product; materialen vormen dus de visuele en tactiele interface met de wereld om ons heen.

Aangezien productontwikkeling een gebruikersgerichte discipline is, dienen materialen niet op zichzelf bestudeerd te worden, maar ligt de focus op mensen en hun relatie met materialen. Centraal in dit onderzoek stond het verkennen van ervaringsgerichte karakterisatie van materialen, waarbij zowel de fysieke weergave van materialen als de segmentatie van verschillende types consumenten geïntegreerd werden.

Het proefschrift bestaat uit vier delen: (i) ervaringsgerichte karakterisatie in productontwikkeling, (ii) materiaal demonstratievorm, (iii) consumentensegmentatie, en (iv) theoretische en ontwerpgerichte conclusies. Het eerste deel biedt inzicht in de wereld van ervaringsgerichte karakterisatie studies en de methodologische uitdagingen die betrokken zijn bij het bestuderen van materiaalbeleving. Het onthult zes noden voor toekomstig onderzoek. Het tweede deel richt zich op een van deze noden en onderzoekt de geschikte fysieke representatie van materialen voor dergelijke studies. Het derde deel richt zich op de noodzaak om uitgebreide gebruikersaspecten op te nemen en onderzoekt hoe consumenten geclusterd kunnen worden in betekenisvolle segmenten die verschillen op vlak van zelf-expressieve waarden, en op vlak van voorkeuren voor ervaringsgerichte kwaliteiten van materialen in verschillende soorten producten. Het vierde en laatste deel bevat een conclusie over het opzetten van experimenten om ervaringsgerichte kwaliteiten van materialen te onderzoeken, gebaseerd op eerdere bevindingen, evenals een reflectie over het uitgevoerde onderzoek, theoretische conclusies en ontwerpconclusies, en suggesties voor toekomstig onderzoek.

DEEL 1: ervaringsgerichte karakterisatie in productontwikkeling

In hoofdstuk 1 wordt de huidige stand van zaken op het vlak van ervaringsgerichte karakterisatie van producten en materialen uiteengezet. Op basis van 64 studies wordt een overzicht gegeven van verschillende methodologische aspecten zoals variabelen, stimuli, interactiemodaliteiten, experimentele opzet, methodes, en respondenten. Er worden twee belangrijke hiaten gedefinieerd die de fundering vormen voor DEEL 2 en DEEL 3, namelijk een fysieke representatie van materialen in een abstracte vorm voor multimodale karakterisatie van materialen, en een integratie van uitgebreide gebruikersaspecten voor consumentsegmentatie.

Hoofdstuk 2 bespreekt een specifieke casus waarbij ervaringsgerichte kwaliteiten van drie gerecycleerde kunststoffen geëvalueerd worden door materiaalingenieurs en ontwerpers.

DEEL 2: materiaal demonstratievorm

Hoofdstuk 3 betreft een eerste exploratie in de zoektocht naar een geschikte, standaardvorm dat consumenten betrekt in een multimodale interactie met het materiaal waarbij zowel de invloed van product en context geminimaliseerd worden. Vier neutrale vormen worden voorgesteld, maar er blijkt nood aan meer interactiviteit en complexiteit voor een meer diepgaande materiaalexploratie.

Daarom herneemt hoofdstuk 4 deze zoektocht en stelt het een abstracte demonstratievorm voor die geschikter is voor de ervaringsgerichte karakterisatie van materialen door consumenten, in vergelijking met een standaard plat plaatje dat vaak gebruikt wordt. Deze vorm stelt consumenten in staat zich in te leven in de mogelijke materiaalbeleving en applicatie in een echt product.

DEEL 3: consumentensegmentatie

In hoofdstuk 5 en hoofdstuk 6 wordt het potentieel van zelf-expressieve waarden en persoonlijkheidskenmerken onderzocht als parameters die effect hebben op de perceptie en expressie van materialen.

Hoofdstuk 7 bouwt hierop voort en betrekt naast persoonlijke waarden en persoonlijkheidskenmerken, ook milieubezorgdheid, groene identiteit, innovativiteit, esthetische beleving, en materialisme. Op basis van deze set van individuele zelf-expressieve waarden worden er vier clusters van consumenten gevormd die elk verschillende ervaringsgerichte kwaliteiten van materialen prefereren voor vier verschillende producttypes. Er wordt geconcludeerd dat deze vier segmenten een geschikte basis vormen voor het opnemen van uitgebreide gebruikersaspecten in toekomstig onderzoek op vlak van ervaringsgerichte karakterisatie van materialen.

DEEL 4: theoretische en ontwerpgerichte conclusies

Nu de twee belangrijkste noden van hoofdstuk 1 vervuld zijn, brengt hoofdstuk 8 de bevindingen samen in een set richtlijnen voor de experimentele opzet en diens parameters in het specifieke geval van de kunststof demonstratievorm die door consumenten geëvalueerd wordt. Deze richtlijnen beschrijven een reeks methodologische keuzes als eerste stap naar meer gestroomlijnde ervaringsgerichte materiaal karakterisaties in de toekomst om zo een database van verschillende kunststoffen op te bouwen. Tot slot reflecteert hoofdstuk 9 over de bevindingen van dit proefschrift, en bevat het een theoretische en ontwerpgerichte conclusie. Zo worden er per onderzoeksvraag en over het geheel enkele proposities geformuleerd, alsook opportuniteiten voor toekomstig onderzoek.

Acknowledgments

Twelve years ago I arrived at the campus of Product Development to start a great adventure, full of pleasure and hard work, but for only five years… right? I owe thanks to my parents to draw my attention to this course of study that would be just perfect for me – a perfect blend of creativity and science – and/or "that looked already so much fun when we studied architecture in our old days". Arriving as a creative craft child, little did I know that my greatest interest would turn out to be in subjects such as materials science and production techniques, for which all credits go to Karine Van Doorsselaer, one of the most enthusiastic professors who inspired so many students with her basket full of material samples and (failed) products that were given around to experience first-hand. After a master thesis that organically grew more and more into a design research than a traditional product design, I did not hesitate to take on the opportunity to 'stick around' at Product Development on the TETRA project 'Design from Recycling', during which I discovered the wonderful world of materials experience, and met so many inspiring colleagues (some of which now friends), without whom it would not have been possible to finally start – and finish – this doctoral project.

Four years later – as well as 861* papers later (**according to my Mendeley database*), and a total of 2219* respondents later, that participated over the course of 4 years' worth of experiments (**subject to counting errors and excluding experiments that did not make it to this dissertation*) – this book forms the output of this adventure that I could not have done alone.

First of all, I want to express my gratitude to prof. dr. Els Du Bois and prof. dr. Ingrid Moons, the best team of supervisors I could hope for – something that might be even more important than the thesis' subject, as many PhD graduates will probably confirm. Thank you **Els**, for welcoming me with open arms as your first PhD student, for your all-time enthusiasm, and for your clear support in setting up design research, drawing up the best diagrams and shorten too lang manuscripts (again and again). Also, thank you for letting me witness your growing ecoteam and your dedication to your own line of research. Thank you **Ingrid**, for your expertise from the perspective of consumers, psychology and marketing, and your inexhaustible stock of research techniques. Thank you for teaching me how to set up small (and not so small) experiments, for your thorough feedback during every step on the way, and for always being the perfect 'average consumer'. Above all, I thank you both for our shared appetite, for food and treats, but also for research and having fun while doing it.

Patrick De Pelsmacker, thank you for all the things you have taught me, not least in the field of statistics. I cannot say it doesn't hold any more secrets for me, but at least a little less. Thank you for all your valuable feedback over the years, sometimes so quickly that I couldn't follow myself. I believe you have coached me in how to write an article, how to report your results in an adequate way, and how to separate the wheat from the chaff.

Members of my **doctoral committee and jury**, Elvin Karana, Kim Ragaert and Cees de Bondt, thank you for four effort to read my thesis, your thorough feedback, and fruitful discussions.

Ivo Dewit, thank you for your infinite energy and guidance when I was still a student, and for encouraging me and my fellow group members to take our 'Grand.C' project to the next level and even submit our work for a design conference. I will never forget my first conference and our boat in Amsterdam. You taught me how to network like a pro and make the best experience out of it. You also taught me to always check the travel distance between accommodation and conference location (driving distance is not the same as walking distance, Ivo, luckily my morning mood didn't mind a good long and refreshing walk). Over the years, you have always offered a listening ear, have spread your infectious enthusiasm through everything you do, and you always believed in me.

Next, I want to thank my precious colleagues of the one and only '3.07' office. **Jochen Vleugels**, thanks for always being there for me (and all other colleagues and students for that matter). No question or frustration was too small, and I was always allowed to disturb you. I can't begin to sum up how much you have helped me with all kinds of practical issues throughout the years; from 3D printing to Excel, from SPSS to coding and prototyping. I am not exaggerating when I say that none of the papers of this dissertation would have been the same without your help. Thank you for our talks during many walks (part of which in a wheelchair during my pregnancy bed rest, for which thanks again). Thank you, **Marieke Van Camp, Shiram Mukunthan**, **Thomas Peeters**, and **Muriel De Boeck**, the other original warriors of 3.07, as well as **Laure Herweyers**, our youngest warrior, for all the help, feedback, friendship, memes and coffees – many coffees – over the years. Nothing of this experience would have been the same without this amazing group of colleagues and fellow 'sufferers'. Of course, I cannot forget all the other **PO colleagues** within our growing department. All of you contributed to the unique atmosphere at product development, and were always in for a pleasant coffee chat in the kitchen. Furthermore, I would like to thank all the **students** that have in some way contributed to this thesis, going from participation in experiments and workshops, to their assistance in conducting various experiments and recruiting respondents.

Additionally, I want to thank my friends that have supported me over the years and who were always available for the necessary relaxation and putting things in perspective. A special thanks goes to my group of study friends of PO: thank you, **Lore, Lara, Ella, Eline, Sanita**, and especially **Lana** and **Lorens** for proofreading my chapters, and to my group of high school friends: thank you **Lith, Lisa, Annelies, Nona, Elien**, and especially **Leonie** and **Eline**.

Of course I cannot forget my **family** that always have been supportive. In particular, thank you **mum** and **dad**, and my sister **Nele**, for always being ready to help, for making sure I balance work and life, and for being test subjects for many experiments, even when you didn't understand a thing (yet). Thank you **Gert** and **Ilse**, for always being curious about my research and my progress. Thank you **Greet** and **Ludo**, for helping out throughout the years, from groceries to oven dishes and childcare. I want to thank my **grandparents** for their support and for being so proud, down here or from above.

Ben, my support and my rock; as cliche as it sounds, as true as it is for over thirteen years. Thank you for supporting me through this journey, and always keep an eye on work-life balance. We are both not that good at it for ourselves, but all the better for each other. I thank you for our endless, useful – and not so useful – discussions about engineering, materials, society, energy, grocery lists, what to eat for dinner, and so on. Thank you for being the best teammate, who takes over when needed, especially over the past year. Thank you for being an Excel geek with me, and sharing our fascination for formulas and macros. To each his own, right?

While waiting for the visioned material library at our new campus, I have already started well with my collection of material samples that I gathered at home – I'm sorry Ben – in preparation for our renovation first, and now our building project; the perfect excuse! After all, it is so important to look at price, practical, technical, and of course aesthetical considerations, so I have read somewhere… Anyway, I can't wait to see what the future has in store for us.

Finally, I would also like to thank **Mil**, the loudest, cutest, most exhausting, sweetest and awakest baby. Not for his help during the last hard stretch – on the contrary – but to teach me to be productive and efficient on little time and even less sleep. I can only hope this will come in handy later on as well. Furthermore, becoming a mom, gave me a whole new perspective on my own work. We were sure that we would only allow beautiful toys, preferably in wood or pastel colours of course, that would fit perfectly with us and our interior, and not necessarily what a baby finds attractive and entertaining How long would we keep this up? (**This is a rhetorical questions that is not to be answered*.) Surely, other purchase considerations came into play too…

To continue along the same line, reusable cloth diapers are actually a very interesting product in reflection of this dissertation. I could never imagine that even for this kind of product, so many variations could be found on the market, making it overwhelming to choose from. It proved how important it is to experience and touch these diapers first-hand, and try them out about before actually buying a whole set. In addition to *price* considerations (after all, you want to end up cheaper than with disposable diapers), *functional* needs come in play: foremost, a diaper must obviously fulfil its function and absorb properly – the last thing you want are leaks. It must also be easy to put on and close, and be comfortable for the baby. Although most people ambitiously start with cloth diapers from a *sustainable* conviction, such diapers need to be durable and long lasting on their own as well. However, quickly realized that marketing wise, it is very smart – and tempting – to put so many beautiful and fun prints on the market; something for everyone's *style*. The trick is of course not to fall (too deeply) into this trap as a consumer. To conclude, I feel that cloth diapers are soft, warm, dense and colourful (*sensorial*), they are cosy, nostalgic, trendy and natural (*interpretive*). For me, they are pleasant, fascinating and lovable (*affective*). And lastly, they invite me to rub them against each other to become even softer, and they offer such an easy grip of a baby's bottom (*performative*). I am very well aware that for others, the opposite might be true.

Oh, and last but not least, my special thanks goes out to all reviewers no. 2 out there… you know who you are.