The beauty of Unity-in-Variety
Studies on the multisensory aesthetic appreciation of product designs

Post, Ruben

DOI
10.4233/uuid:e13e0924-8f35-430d-8ed0-6b552bc26439

Publication date
2016

Document Version
Final published version

Citation (APA)
Post, R. (2016). *The beauty of Unity-in-Variety: Studies on the multisensory aesthetic appreciation of product designs*. [Dissertation (TU Delft), Delft University of Technology]. https://doi.org/10.4233/uuid:e13e0924-8f35-430d-8ed0-6b552bc26439

THE BEAUTY OF UNITY-IN-VARIETY

STUDIES ON THE MULTISENSORY AESTHETIC APPRECIATION OF PRODUCT DESIGNS

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof. ir. K.C.A.M. Luyben;
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op donderdag 20 oktober 2016 om 12:30 uur

door

RUBEN ARNOLD GERARD POST

Master of Science in Brain and Cognitive Neuroscience,
Universiteit van Amsterdam, Nederland
geboren te Hengelo, Nederland

This dissertation has been approved by the promotor:
Prof.dr. P.P.M. Hekkert

Composition of the doctoral committee:

Rector Magnificus	chairman
Prof.dr. P.P.M. Hekkert	Delft University of Technology

Independent members:

Prof.dr. M. Bordegoni	Politecnico di Milano
Prof.dr. H. Leder	University of Vienna
Prof.dr. J.E. Oberdorf	Delft University of Technology
Prof.dr. R. Reber	University of Oslo
Prof.dr. H. de Ridder	Delft University of Technology

Other members:

Dr. J. Blijlevens	Royal Melbourne Institute of Technology University

RUBEN ARNOLD GERARD POST
The beauty of Unity-in-Variety: Studies on the multisensory aesthetic
appreciation of product designs

ISBN/EAN: 978-94-028-0354-9

Cover design by Simon Jimenez J. ··· www.simonjj.com

Er is geen kant te kiezen
Ze maken ons wat wijs
Ze praten over zwart en wit
Maar wijsheid is vaak grijs
-
(Excerpt from: Het midden – Stef Bos)

Glossary

Aesthetic
… Referring to sensory perception and understanding

Aesthetic appreciation
… The pleasure attained from disinterested sensory processing

Aesthetic principle (in relation to design)
… Those laws governing how a design's tangible and intangible facets impact aesthetic appreciation

Complexity (in relation to design)
… The difficulty (as opposed to simplicity) of making perceptual sense of a design

Element (in relation to design)
… Part or component of a design consisting of a combination of properties

Factor (in relation to design)
… Those dimensions known to influence the arrangement of a design such as, but not limited to, symmetry, balance and continuity

Property (in relation to design)
… The most basic identifiable feature that can be perceived in a product; such as a line, shape, colour, texture, weight or hardness

Unity
… The perception of the whole, of coherence and order between properties and elements

Unity-in-Variety
… An optimal balance of both unity and variety that leads to the highest aesthetic appreciation

Variety
… The impression of diversity that arises from the number and intensity of differences between properties and elements

Project UMA

While this work can be read on its own, the framework that it builds upon and helps to develop is part of project UMA. UMA stands for Unified Model of Aesthetics and is a framework, developed by Paul Hekkert (Delft University of Technology, The Netherlands), which aims to explain the aesthetic appreciation on all levels of the product experience. The project combines experts from the field of design, cognitive psychology, sociology, cognitive neuroscience, philosophy and the arts to identify the principles that govern our aesthetic responses. In doing so, it generates empirical knowledge that can both aid the science of aesthetics as well as guide designers in their daily practice.

www.project-uma.com

This research was supported by the MAGWVICI grant number 453-10-004 from The Netherlands Organization for Scientific Research (NWO) awarded to Paul Hekkert.

This thesis is structured according to several chapters that have been published in, or submitted to, scientific journals and which demarcate sections of our main research questions. As a result, there is a certain degree of repetition and overlap between different chapters.

[1] The opposite of aesthetic is an-aesthetic (without sense perception). Which is exactly the case

Introduction

I cannot give you any example of a thorough aesthetic pleasure more intensely real than a pleasure of this kind—the pleasure which arises in one's mind when a whole mass of different structures run into one harmony as the expression of a central law.

-

Aldous Huxley, on the principle of 'Unity-in-Variety' (1904)

Imagine being in a luxury car showroom, ready for a test drive. A car key is handed to you; its blend of soft rubber, textured plastic, and cool metal invites to be touched. You notice its finely integrated controls, all pleasantly positioned underneath your fingertips, while you open the door of the car and sit down in the driver's seat. Your gaze falls upon the dashboard, gracefully following the line of the steering wheel; although its instrument cluster is packed with information, the dials are spaced such that each one can be easily discerned. Next, your eyes are drawn to the symmetrically ordered buttons on the centre console. It has the same tone, finish and colour scheme of the dashboard that sits flush with the rest of the interior. 'Gosh, this is beautiful,' you think, and you cannot wait to take it for a spin.

Products have the capacity to evoke a sense of beauty in us. Whether marvelling over a new car, admiring the interface of our next generation smartphone or wielding a perfectly balanced kitchen knife, we can appreciate perceiving their *design*: 'The arrangement of the features of an artefact as produced from following a plan' ("Design," 1997). However, most of us are rarely aware what exactly it is that makes a certain product aesthetically appealing. And probably, we would only claim having an aesthetic experience with some of our most favourite products. Yet, even reading this dissertation is an aesthetic experience because you can feel appreciation from simply perceiving it through your senses. You might not have consciously experienced any beauty, but as S

o o n as I s t *ar* T pla ying around wIth *thE* font and spacing you are probably quick to

admit I should return to my normal layout and text design, also for aesthetic reasons…!

This simple example hopefully illustrates that the organization of text elements, which are the different letters and words on this page, not only influences the text's readability, but also our appreciation of it (or, if poorly done, the lack of appreciation). In a similar fashion we can (fail to) appreciate the arrangement of shapes and colours of any other design, be it buttons and components of a car interior, icons on a desktop, or books on a bookshelf (Figure 1). While these examples come from very different product categories, they have in common that we can appreciate the way the various elements of the design are organized and structured to form a coherent and unified whole. It is this idea, that our aesthetic appreciation relies on perceiving '*unity in variety*', that is the focus of this dissertation. Through multiple empirical studies directed at the visual and tactile sensory modality, we aim to extend our understanding of this ancient aesthetic principle. For this aim to have a clear start, it is necessary that we describe the point of departure more explicitly by defining 'aesthetic appreciation'.

FIGURE 1. WE AESTHETICALLY APPRECIATE PERCEIVING ORDER IN OUR ENVIRONMENT BECAUSE IT MAKES IT EASIER FOR US TO UNDERSTAND WHAT WE PERCEIVE.

Aesthetic appreciation

Although aesthetic appreciation, or the experience of beauty, is a universal human experience (Pinker, 2003), the term requires a brief explanation as the word *aesthetic* can have at least ten different meanings (Koren, 2010).

The origin of the word aesthetics can be traced back to the Greek *aisthētikos*, referring to sense perception.[1] It was in the 18th century that this meaning transformed when Alexander Baumgarten took an interest in making a distinction between 'good' and 'bad' art. He claimed aesthetics not only means to perceive, but also to judge and understand through the senses (Baumgarten, 1758/1961). He argued that this judgement arises from our feelings of immediate pleasure or displeasure, thereby adding an affective component to the experience of sensory perception. An aesthetic experience can therefore be positive, leading to appreciation and judging something as beautiful, or negative, leading to boredom and consequently judging something as ugly.[2] Baumgarten further argued that the science of aesthetics should focus on identifying principles of beauty, a suggestion that we closely follow in this dissertation. Shortly after, Kant (1790/2001) adapted Baumgarten's view of aesthetics and added to it that the subjective aesthetic appreciation one feels is 'disinterested'. It is disinterested, because we can experience pleasure from perceiving a beautiful product for its own sake, without being aware of it having any purpose. Just like the font used in this work, we can appreciate its design without being aware of its benefits to our understanding of the text. As a consequence of classifying the aesthetic experience as disinterested, the aesthetic experience in itself is not an emotion, as a certain goal or concern needs to be attained or violated for an emotion to occur (Hekkert, 2006). Nonetheless, an aesthetic experience can surely result in an emotion, as we feel joy, satisfaction and fascination from perceiving beauty (Desmet and Hekkert, 2007).

---

[1] The opposite of aesthetic is an-aesthetic (without sense perception). Which is exactly the case when patients are anaesthetized for surgery.

[2] It is worth quickly noting that based on these two extremes aesthetic experiences can also be neutral. Most of the time, such as while reading your average text page, we are not aware of experiencing aesthetic (dis)pleasure from perceiving the words themself because it simply does not pass over our threshold of awareness (Berlyne, 1971).

Summarized, this work follows the aforementioned line of reasoning and defines aesthetic appreciation as *the pleasure attained from disinterested sensory processing of a stimulus*. We have opted to use 'appreciation' because of its multi-faceted meaning which encapsulates 'the action of estimating qualities or things', 'recognizing and appraising high value', as well as referring to 'the perception and recognition of delicate impressions' ("Appreciation," 1997).

The value of knowing how to create beautiful designs

In line with our definition, we argue that aesthetic appreciation is the result of how our senses perceive and therefore process the world around us. As a result, we can aesthetically appreciate many things or situations and through all our senses, such as tasting a well-balanced dish, hearing a marvellous musical composition, smelling an elegant perfume, handling a professional camera, or seeing a beautiful painting. While we can certainly aesthetically appreciate many aspects nature has to offer as well (e.g. sceneries or animals), the focus of this dissertation is on product design. Nonetheless, the field of design is not limited to industrial products alone and our research thereby also informs areas where design uses natural elements, or applies natural products, such as in landscape design or gastronomy.

The significance of beauty is something we are experientially aware of through the feelings of pleasure and joy that it evokes. Perhaps less well known is that more aesthetically appreciated designs also tend to increase a product's usefulness, usability and performance (Moshagen et al., 2009; Mugge and Schoormans, 2012; Tractinsky et al., 2000; Tuch, Roth, et al., 2012; Van der Heijden, 2003). Beautiful designs can even increase our capacity to learn and process new information (Grabinger, 1993; Pomales-García et al., 2005), partially because its experience motivates us (Zain et al., 2008). The positive impact of aesthetics is even taken into account for hospital designs, where it has been shown to reduce patient stress and argued to speed up recovery (Leather et al., 2003; Ulrich et al., 1993). Given this diversity of positive effects and the abundance of objects around us, there is great value in knowing how beautiful products can be designed.

Knowledge about factors that influence the aesthetic qualities of a design is often encapsulated in aesthetic principles. They describe how a product's tangible and intangible aspects influence the user's appreciation, informing the designer about the impact of their choices and allowing them to have more control over the final product experience (Lidwell et al., 2010). Additionally, such principles allow making rational design decisions, which can be verbalized, thereby helping the designer communicate their choices to stakeholders. The design literature offers a variety of aesthetic (design) principles, one of them being the principle under study: Unity-in-Variety (Hekkert, 2006; Lauer and Pentak, 2012; Lidwell et al., 2010).

The aesthetic principle under study

Throughout centuries of Western and Eastern philosophy runs the idea that beauty resides in the mergence, or harmony, between seemingly contradictory qualities (Kahn, 1981; Nishida et al., 1992; Plotinus, 1969). The combination of strength and technique in a skilful dancer, the sight of a rainbow when sunlight passes through rain, or those works of art that blend impossible shapes and materials into one whole; uniting differences generates in us a sense of beauty and admiration. The idea that beauty can be found in the harmony of seemingly contradictory qualities is prominently captured by the principle of Unity-in-Variety (UiV), at times also referred to as 'uniformity in multiplicity' or 'unity in diversity' or 'order in chaos' (Berlyne, 1971; Cupchik and Winston, 1992).

Fechner (1876) was one of the first not only to elaborately discuss UiV as a principle explaining aesthetic appreciation, but also to pose certain predictions and restrictions about its psychological mechanisms. He stated that aesthetic appreciation of an object requires that we sense coherence and unity within the variety of aspects and attitudes towards it. He went on to assert that the inherent conflicting relationship between both unity and variety implies that there is an optimal balance where aesthetic appreciation is maximized. To clarify this, we briefly discuss both dimensions more closely.

In design, *variety* refers to the sense of diversity in a product and mostly depends on the number of, and degree of differences between, parts of a design. Any design is a collection of separate parts (e.g. buttons, dials, displays or structural components), which can be considered its elements. Each element itself also consists of certain properties, such as its shape, size, colour or texture. Together, these properties and elements define all of the product's perceivable aspects and generate a sense of variety due to the dissimilarity in any of these aspects (Graves, 1951). After all, it is the dissimilarity between elements that allows us to perceive them as being different in the first place. For example, the letters on this page differ in colour from their background to create what is called figure-ground segregation. Similarly for designed products, adding colour creates more variety as the number of identifiable differences increase (Figure 2).[1] Strictly speaking, any difference between elements and properties implies variety, and this difference simultaneously makes it possible for us to distinguish one thing from another. However, only variety leads to chaos and confusion, as we fail to make sense of how different elements and properties of a design relate to each other. It is the way in which the various properties and elements are organized and structured that gives the design its *unity*.

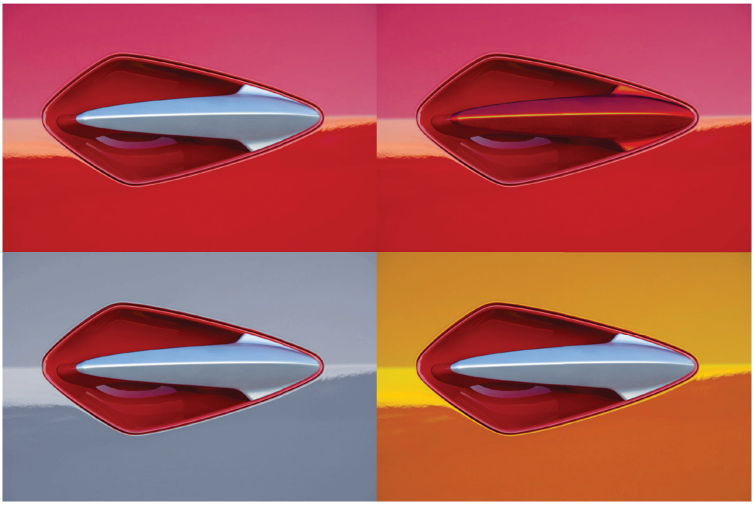


FIGURE 2. MIMICKING THE COLOUR IN THE CAR DOOR HANDLE REDUCES VARIETY, WHEREAS REPLICATING THE COLOUR ON THE CAR DOOR, OR INTRODUCING A NEW COLOUR, CREATES A STRONGER SENSE OF VARIETY.

Unity refers to perceiving order and coherence between the different elements that, if all is well considered, generates a sense of perceiving the whole as pleasantly organized. Our brain continuously attempts—and it must be said, with amazing success—to create a unified experience of our environment by organizing and detecting

[1] Rarely do design factors solely affect unity or variety, as we will discuss shortly. Colour (contrast) can for example also be used to increase unity, as differences become easier to detect (Ramachandran and Hirstein, 1999).

patterns in our perception (Lacey and Sathian, 2014; Palmer and Rock, 1994). Detecting order, coherence and structure in the images we see, the sounds we hear, or the objects we touch, facilitates this process of unification. By carefully positioning elements, choosing similarities between properties, and grouping together aspects that belong to each other, a designer can tap into our brain's natural organization mechanisms and increase a design's unity. As a result, a highly unified product is easy to grasp because its design matches well with our capacity to perceive its different perceptual features. Hence, its various elements and properties are experienced as unified.

The principle of UiV firstly assumes that both unity and variety positively influence an aesthetic experience. The appreciation of variety can be explained by our natural tendency to crave for stimulation and interest, fittingly labelled 'infovore' behaviour (Biederman and Vessel, 2006). The presence of variety signals this potential of learning new relationships and it is thought that our brain has accordingly evolved to appreciate its perception (Berlyne, 1966; Hekkert and Leder, 2008). As such, we derive pleasure from perceiving, for example, the diversity of plants and trees in a botanic garden, the mixture in colours of a pleated shirt or the various components of a car's taillight; they all offer our eyes something to explore visually and challenge our faculties (Figure 3). Without variety, we quickly become bored, as there is simply nothing to evoke our interest. However, having only variety leads to confusion, as we cannot see any order, structure or coherence and fail to understand perceptually what we perceive. For perceptual understanding to occur and for these impressions of variety to be processed efficiently, there needs to be unity binding the individual aspects together. Returning to the examples in Figure 1 and 2, seeing how the different computer icons, car controls or books are organized generates perceptual knowledge through our senses. Unity is so vital for our ability to integrate and recognize parts as belonging to each other that its perception is accordingly also thought to bring pleasure to the perceiver (Biederman and Vessel, 2006; Ramachandran and Hirstein, 1999). Consequently, we appreciate the presence of both unity and variety.

FIGURE 3. THE TAILLIGHT'S VARIETY IN SHAPE AND ORIENTATION CATCHES OUR EYE AS WE TRY TO GRASP ITS DESIGN.

Like many other creative fields, design is of course aware of the importance and value of creating a structured, ordered and unified design, and the design literature is therefore filled with examples of how to create unity (Graves, 1951; Lauer and Pentak, 2012). To name only a few examples; a designer can create unity through the correct use of repetition in colour or shape, positioning of elements to create balance and symmetry, or simply by removing differences (Figure 2).

We have introduced the dimensions of unity and variety separately; they are however intrinsically related to each other by the basic elements of design that bind them. It is apparent that adding additional and different elements to a design raises variety, but as a consequence this will generally decrease unity as it becomes more difficult to maintain order between those elements. Likewise, creating symmetry increases unity while simultaneously decreasing variety, because symmetry decreases difference between sides. Hence, unity and variety are partial opposites. As a result of this negative relationship and simultaneous contribution to aesthetic appreciation, UiV entails that beauty resides in optimally balancing unity and variety (Figure 4; Fechner, 1876).

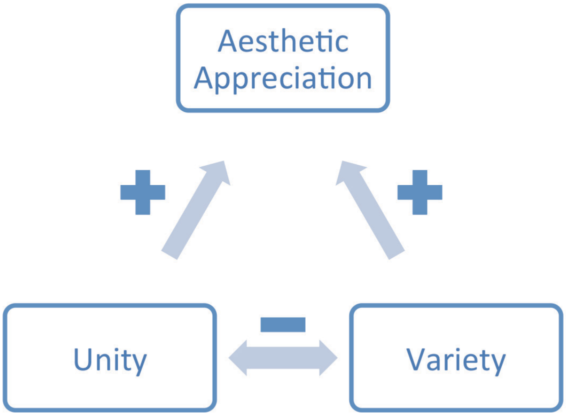


FIGURE 4. UNITY AND VARIETY ARE THOUGHT TO SUPPRESS EACH OTHER'S POSITIVE EFFECT ON AESTHETIC APPRECIATION DUE TO THEIR INHERENT NEGATIVE CORRELATION.

The idea that aesthetic appreciation is highest when unity and variety are optimally combined bears a close resemblance to the prevailing notion in the domain of aesthetics that people prefer a medium degree of complexity (Berlyne, 1971). Although part of the reasons why we prefer moderate complexity is similar to why we prefer a balance between unity and variety (i.e. leading to efficient processing of novel information), there are important differences between both. Firstly, they differ semantically. The opposite of unity is disunity and the opposite of variety is similarity, whereas the opposite of complexity is simplicity (Beardsley, 1958). Secondly, UiV comprises two dimensions that interact, whereas complexity is one-dimensional. As a result, at least conceptually, two products with the same degree of complexity may be rated different in unity and variety (e.g. medium complexity can be achieved by combining moderate unity and variety, or by combining high unity and high variety). We more elaborately relate the outcomes of our research to the existing body of knowledge on complexity in the discussion chapter of this dissertation.

Despite its long history as a requirement for beautiful experiences (e.g. Kant, 1790/2001; Plotinus, 1969), the few empirical studies referring to this principle only propose UiV as an explanation for their findings, did not investigate the principle in relation to everyday objects, and found mixed results (we discuss these studies in Chapter 2; Berlyne, 1972; Berlyne and Boudewijns, 1971; Birkhoff, 1933; Cupchik, 1996; Leeuwenberg and Van der Helm, 1991; Nasar, 1987). Furthermore, research on aesthetic appreciation, and the dimensions determining it, has predominantly focussed on the visual sense (Schifferstein and Hekkert, 2008; Spence and Gallace, 2011). Yet other senses play their part in extracting meaningful information out of the environment as we can feel how different elements are grouped together (Overvliet et al., 2012), hear the unity in musical compositions (Tan and Spackman, 2005), and taste the consistency between various flavours (Giacalone et al., 2014). Hence, little scientific knowledge exists on whether the aforementioned theoretical understanding of UiV actually leads to the highest aesthetic appreciation in different senses, and it is unclear if and how designers could apply this principle to create beautiful product experiences. Lastly, the underlying reasons for why we might appreciate a certain balance between unity and variety lack empirical support. This dissertation aims to fill these gaps by reporting on several studies investigating the aesthetic principle of UiV in the visual and tactile sensory modality of product designs.

This thesis

This work investigates the principle of UiV in the area of product design and in the visual and tactile sensory modality through multiple empirical studies. Product designs were chosen as stimuli because their ubiquitous nature and range of shapes and materials assure that the principle is thoroughly studied with ecologically valid and simultaneously diverse artefacts. Next to this, the natural methodology of designing allows for creating variations of realistic stimuli while maintaining high control over the factors that are influenced. The principle was investigated for vision and touch because these are the two dominant sensory modalities when it comes to pleasant and unpleasant product experiences (Fenko et al., 2010).

By researching this principle, this work aims to achieve three main goals: (1) investigate how unity and variety together determine aesthetic appreciation, (2) identify factors that influence unity and variety, (3) and in doing so, generate a theoretical understanding of why and how we aesthetically appreciate UiV that informs scientific theory and design practice.

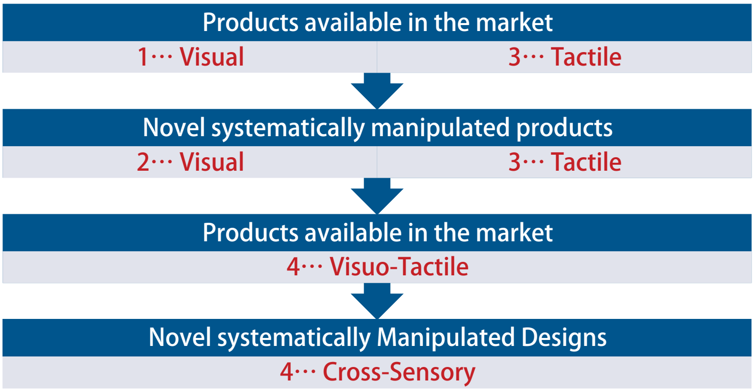


FIGURE 4. ORDER OF THE MAIN STUDIES AND THEIR RESPECTIVE CHAPTERS.

We first separately investigate the aesthetic principle of UiV in the visual and tactile sensory modalities, and then continue to determine its influence in visual-tactile aesthetic experience (Figure 4). Investigations in both sensory modalities start with assessing a range of designs from different product categories to examine whether the principle applies to product designs in general. This is followed by experimentally controlled studies in which we systematically manipulate design factors thought to underlie unity and variety. Next to this, we aim to investigate how individual differences in the evolved motivational states of safety and accomplishment seeking drive the preference for unity and variety (Hekkert, 2014). In doing so, we intend to find support for our theory why we aesthetically appreciate perceiving unity and variety.

The **first** chapter describes the theoretical background for why we aesthetically appreciate unity and variety and shows that both are intuitive concepts that people can judge reliably. It presents multiple quantitative studies that demonstrate how unity and variety relate to each other and to aesthetic appreciation of a range of products from a diversity of product categories. Furthermore, it explains whether individual differences in motivational drives, design expertise and perceived complexity of product categories, influences the appreciation of unity and variety.

The **second** chapter continues research on UiV in the visual modality, but aims to find stronger support for our earlier findings by creating new stimuli that are systematically and independently manipulated on unity and variety. By using web pages as stimuli manipulated through several design factors, we attempt to replicate previous results, extend the principle's applicability to the field of HCI and show how unity and variety can be intentionally influenced.

The **third** chapter describes a first study on UiV performed in the tactile modality. Based on the idea that the psychological mechanisms underlying UiV function similarly in vision and touch, we studied whether the principle can explain aesthetic appreciation of a range of product designs readily found within the market which are only perceived by touch. We extend the findings on tactile aesthetics by using a similar research methodology to chapter three; unity and variety are systematically manipulated through different material and shape changes by creating 3-D printed stimuli and validated in a pre-test. The effects of these manipulations on aesthetic appreciation are assessed in a separate experiment to illustrate how tactile aesthetic appreciation arises and can be influenced.

In the **fourth** chapter we describe research on the multisensory experience of UiV in a study using products available in the market. Besides investigating whether visual and tactile UiV uniquely contribute to the visual-tactile aesthetic experience, the influence of motivational drives on the appreciation of visual and tactile unity and variety is assessed. In an epilogue to this chapter we put forward a cross-sensory UiV hypothesis and briefly presents explorative research in this direction. We summarize important insights from these studies, suggest how different design factors affect unity and variety in vision and touch simultaneously, and give recommendations for future studies.

The **fifth** chapter describes a qualitative study exploring whether the principle can be extended from explaining aesthetic appreciation of products to the aesthetic appreciation of more conceptual designs such as product-service systems.

The **sixth** chapter summarizes all of the findings and discusses the theoretical and practical implications as well as future research directions.

1 Visual Unity-in-Variety

Thus, the brain rewards progress toward organizing the perceptual field into a meaningful configuration. Although ultimately comprehending an object is undoubtedly pleasant, progress toward doing so is equally enjoyable. That is, the process of discovering clues concerning the meaning of an object is rewarded at all levels of stimulus processing.

-

Thomas Armstrong & Brian Detweiler-Bedell, in 'Beauty as an Emotion' (2008)

This chapter presents two consecutive papers that were previously published:

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2016). 'To preserve unity while almost allowing for chaos': Testing the aesthetic principle of unity-in-variety in product design. Acta Psychologica, 163, 142-152

&

Post, R., Blijlevens, J., & Hekkert, P. (2013a). *The influence of unity-in-variety on aesthetic appreciation of car interiors.* Paper presented at the IASDR 2013: Proceedings of the 5th International Congress of International Association of Societies of Design Research" Consilience and Innovation in Design", Tokyo, Japan, 26-30 August 2013.

In many domains of human creativity, varying from art (Cupchik and Gebotys, 1988) and music (Fechner, 1876) to poetry (Lipps, 1903) and architecture (Nasar, 1987), UiV is considered an important factor in explaining aesthetic appreciation. In its broadest sense, the principle states that in order for humans to find pleasure in their interaction with objects, they need to sense a form of unity and coherence in the various parts and approaches towards it (Fechner, 1876).

We set out to study the principle of UiV in the domain of product designs. While other aesthetic principles (cf. e.g., Most Advanced Yet Acceptable; Hekkert et al., 2003) that focus on the effects of typicality and novelty on aesthetic appreciation have been researched thoroughly in the past (Blijlevens et al., 2012; Goode et al., 2013; Hung and Chen, 2012), little empirical research exists on the joint effect of unity and variety on aesthetic pleasure for human artefacts.

In this paper we argue that unity and variety, while being partial opposites, simultaneously contribute to aesthetic appreciation of product designs. We conducted three studies to empirically assess whether there exists such a preferred balance between unity and variety, and further explore how perceived visual complexity and individual differences in motivational drives may influence this combined effect of unity and variety on aesthetic appreciation.

1.1 Unity-in-Variety

The discussion of the relevance of unity and variety in explaining aesthetic appreciation can be traced back almost two millennia (Plotinus, 1969). The principle has since been examined within the context of different fields, most notably general psychology (Eysenck, 1942; Langfeld, 1920), philosophy (Berlyne, 1971; Fechner, 1876; Hutcheson, 1729), the arts (Cupchik et al., 1996), music (Tan and Spackman, 2005) and information theory (Attneave, 1959). The divergence in terminology resulting from such diverse investigations requires us to clearly state the principle as we understand it. We define the principle of UiV as: the maximisation of both unity and variety, in order to achieve a balance that offers the greatest aesthetic appreciation. The term *aesthetic appreciation* refers to pleasure attained from the sensory processing of a stimulus ‘for its own sake’ (Dutton, 2009; Hekkert, 2014). Because the individual concepts of unity and variety can be differently applied across several domains, we briefly discuss both concepts in relation to visual perception and product design aesthetics.

Variety refers to the number and intensity of perceived differences between perceptual properties and elements (Berlyne, 1972). Properties such as colour, line, orientation, size and texture can be regarded as easily identifiable, basic aspects in the perception of products (Graves, 1951). In the case of the car (see Figure 5), such basic properties together create our impression of an element like a car door handle. The other elements of the car, like body panels, windows or wheels, also consist of a variety of these properties. Any differences between property combinations and combinations of elements serve to generate a perceived impression of variety within the car. Increasing the number of elements, or the number of combined property differences among elements, will lead to more variety (Fechner, 1876; Lauer and Pentak, 2012). A car whose door handle is different in colour from the door that it is connected to will be perceived as more varied than one whose handle is similar in colour to the door. Without enough variety in objects, they are perceived as monotonous, leading to boredom and loss of interest (Berlyne, 1971; Bexton et al., 1954; Roehm and Roehm Jr, 2010).

FIGURE 5. BMW M5 (2012), COPYRIGHT BY BMW AG.

Humans actively avoid boredom by searching for variety. This search for variety is ingrained behaviour, as we have a natural tendency to explore and acquire new information (Berlyne, 1966). It is likely that the perception of variety has become pleasurable because it bears the prospect of learning (Berlyne, 1971; Biederman and Vessel, 2006; Hekkert, 2014). We therefore appreciate variety in simple figures (Berlyne et al., 1968; Berlyne, 1970; Eisenman, 1966), art (Cupchik and Gebotys, 1988; Cupchik and Gebotys, 1990), music (Tan et al., 2006), gardens (Lindemann-Matthies and Marty, 2013) and packaging (Kahn, 1995). However, too much variety will permit chaos to trouble our senses, resulting in confusion and lack of understanding. Therefore, variety will only be appreciated if our senses can somehow organize these elements into a comprehensive or unified whole.

Because the number of functional properties and features in products are generally high by default, there is hardly ever a need to increase the variety in designs. Instead, efforts are directed towards organizing components in a structured manner, thereby increasing the design's unity.

Unity is the perception of a whole, and of an order and coherence between properties and elements (Berlyne, 1971; Veryzer and Hutchinson, 1998). Because the world around us is inherently chaotic, our brain continuously seeks to organize and structure incoming sensory information. By grouping visual properties (e.g. lines and colours) into coherent elements, we build an organized mental image of our surroundings. Gestalt psychologists' attempts to discover how perception arises out of such grouping and self-organization of properties and elements led to the laws of perceptual grouping (Kellett, 1939; Köhler, 1929; Wagemans, Elder, et al., 2012; Wertheimer, 1938). Examples of Gestalt laws such as proximity, similarity, and continuity experientially reveal how certain properties of elements can influence their perceptual grouping. The design field was eager to integrate these Gestalt laws as tools to enhance unity (Arnheim, 1954; Lauer and Pentak, 2012; Lidwell et al., 2010). For example, the repetition of similar elements, e.g., using the same handle on the driver's door and the rear passenger door, groups those elements together, thereby supporting our perceptual organisation of the whole car (Figure 5). The car door handles in the figure also follow 'a line' that runs from headlight to taillight; this form of continuity can guide and facilitate our perception. By applying these grouping principles to the elements that make up a product like a car, its overall feeling of unity can be enhanced.

The ability to see unity in an inherently chaotic world helps humans comprehend their surroundings, and has been regarded as supporting apperception, fluent processing, and perceptual organization (Armstrong and Detweiler-Bedell, 2008; Brighouse, 1939; Otis, 1918; Palmer and Rock, 1994). Being able to group elements together and detect unifying properties generates a sense of pleasure. Ramachandran and Hirstein (1999) use the well-known 'Dalmatian dog' example (Figure 6) to explain this: An image of a dog is initially seen as a random pattern of black and white spots. As soon as the viewer discovers that certain spots can be perceptually grouped together to form a Dalmatian, the result is a pleasurable 'aha' sensation. Naturally, the pleasure attained from the perception of unity also extends to other types of stimuli, such as product designs. Evidence for such a universal relationship comes from the domains of websites (Moshagen and Thielsch, 2010), product line drawings (Veryzer and Hutchinson, 1998), art (Cupchik and Gebotys, 1988), music (Tan et al., 2006), and a variety of visual patterns (Berlyne and Boudewijns, 1971; Leeuwenberg and Van der Helm, 1991; Nadal et al., 2010).

FIGURE 6. PLEASURE CAN BE FELT WHEN THE SEEMINGLY RANDOM SPOTS ARE PERCEPTUALLY UNIFIED AND A DALMATIAN DOG IS DISCOVERED [ORIGINAL PHOTOGRAPH ATTRIBUTED TO RONALD C JAMES (1965)].

To summarise, both perceived unity and variety positively influence aesthetic appreciation. However, we can intuitively recognize that unity and variety are at least partial opposites. Returning to the car example (Figure 5), the choice of blue for most body panels adds some variety to the design, as the colour is dissimilar to the colour of the rims. It is possible to increase unity by changing the body colour to silver, thereby mimicking the properties of the rims. Yet, this similarity in colour inevitably decreases the overall variety. Hence, unity and variety are interdependent and likely suppress each other's effect on aesthetic appreciation.

The interdependence of unity and variety is conceptualized in the principle of UiV. Empirical studies into the workings of the principle are, to our knowledge, scarce. Those studies explicitly investigating UiV were performed with the use of relatively simple polygonal figures or patterns (Berlyne, 1972; Berlyne and Boudewijns, 1971; Birkhoff, 1933; Boselie and Leeuwenberg, 1985; Eysenck, 1941). These stimuli are often lacking colour or depth and do not represent the visual complexity of real-life objects, preventing generalization of those findings to objects that humans encounter in their daily lives, such as product designs. More complex stimuli were used by Cupchik and Gebotys (1988). Artists rated forty paintings of different artistic quality on the items: simple-complex, warm-cold, idealized-representational, dynamic-static, original-banal, poorly integrated-well integrated (in theme, colour and design), and unsuccessful-successful. Factor analysis revealed two factors to account for respectively 40% and 24% of variance in ratings. Items making up the first factor consisted of successful, complex, well integrated, dynamic and original. Complexity resembles the degree to which something is perceived as varied, whereas integration (of theme, colour and design) closely resembles unity (Nadal et al., 2010). Since both concepts were also paired with how successful paintings were judged, the authors argued that ratings of aesthetic quality are dependent on the presence of UiV. Lastly, Nasar (1987) studied the influence of coherence and complexity on the perceived quality of urban retail scenes. Nine scale models of city streets were manipulated in their degree of complexity and coherence (low, moderate, high). Complexity was manipulated by changing the amount of variation among signs in terms of physical location, shape, colour, direction and lettering style, and shows resemblance to our definition of variety. Coherence was manipulated through contrast by increasing the size of signs and their lettering, as well as varying letter colour and material in relation to the background. Participants then evaluated nine colour photographs of the retail scenes on pleasantness by imagining in which scenes they would prefer to walk, shop and linger. Moderately complex and highly coherent signscapes were regarded to be most pleasant. However, in a later study the positive effect of complexity disappeared when the simulated scenes were replaced by photographs of real signscapes (Nasar and Hong, 1999).

While these studies bear relevance to the principle of UiV, the results are mixed and do not provide a clear understanding of the exact workings of the principle in explaining aesthetic appreciation. We aim to fill this gap by performing three studies that empirically investigate the relationship between unity, variety and aesthetic appreciation of product designs. In the first study, stimuli from two product categories are used to show the general working mechanism of the principle. The second study functions to replicate and extend findings to other product categories, and investigates individual differences in motivational drives that may influence the preference for unity and variety. In the third study we explore two additional product categories and take into account differences in perceived complexity.

1.2 Study 1

The principle of UiV has a similar structure to the MAYA principle (Most Advanced, Yet Acceptable) in that it also predicts a joint effect on aesthetic appreciation between two seemingly opposing forces, (Hekkert et al., 2003). The MAYA principle states that both novelty and typicality positively influence aesthetic appreciation of product designs; however, because both are partially each other's opposite a trade-off takes place that results in an optimum balance. We argue that a similar trade-off can be found between unity and variety, explaining their joint effect on aesthetic appreciation. The first study therefore aimed to test the following two predictions: firstly, we hypothesise that unity and variety are negatively correlated; and secondly, we predict that both unity and variety positively influence aesthetic appreciation.

1.2.1 Method

1.2.1.1 Participants

Dutch-speaking participants were approached at a Dutch university to fill in an online questionnaire on product evaluations. Participants were randomly assigned to one of two conditions, rating either espresso machines or lamps. In the espresso machine condition, 33 participants completed the questionnaire (mean age = 22.9, SD = 4.2, 25 women) and 36 participants completed the questionnaire in the lamp condition (mean age = 22.4, SD = 3.4, 24 women). All participants received €5 financial compensation after completing the questionnaire.

1.2.1.2 Stimuli

We chose a wide variety of stimuli available in the market to assure that all levels of unity and variety were represented in the stimulus sets as much as possible. The stimuli sets consisted of 12 lamps and 12 espresso machines. These product categories were chosen as they demonstrate a comparatively high degree of freedom in terms of designed properties (e.g. shape, colour, and material), but few differences in functionality (for examples of stimuli see Figure 7). Detailed (≥250k pixels, 72 PPI) colour images in either front or perspective view of each product were used. Photo editing software was used to remove brand logos, and generate an even background.

FIGURE 7. LEFT: ARCHIMOON K LAMP BY PHILIPPE STARCK (2004), COPYRIGHT IMAGE BY FLOS S.P.A. RIGHT: OLYMPIA MAXIMATIC (2011), COPYRIGHT BY OLYMPIA EXPRESS.

1.2.1.3 Pre-test

Because the principle depends on subjective impressions of unity and variety, we performed a pre-test with a subset of the espresso machines to determine whether participants are able to reliably judge unity and variety of product images. Participants were given explicit instructions about unity and variety in both text and illustration[1]. These instructions included statements about the concepts, as well as an example of a product design from a different category than used as stimuli (a photo camera) with an explanation of four aspects that made the product either unified or varied. Participants then rated 10 espresso machines on how unified and varied they perceived them to be (5 point scale, 1: very low, 5: very high). High intraclass correlation coefficients of unity

[1] 'Unity is achieved when all elements in a product seem to belong to each other. These elements help make the product look visually organized, coherent and ordered. The product will therefore look like a whole. Variety depends on the number of, and differences between, elements. Variety will therefore make a product look diverse.' These textual instructions were accompanied by a picture of a photo camera that included four unifying and variegating examples based on Gestalt principles. For unity these were: good form, similarity in colour, similarity in shape and repetition. For variety these were: dissimilarity in colour, asymmetry in shape, non-parallelism and contrast in textures.

(ICC(2,19) = .87) and variety (ICC(2,19) = .92) indicated that participants are able to reliably assess both concepts for photographs of products.

1.2.2 Procedure

two stimulus presentation orders) of an online Dutch questionnaire were created. No order effects were found for the influence of unity and variety on aesthetic appreciation. Participants performed one practise trial, after which all products were displayed on the screen, allowing the participants to familiarize themselves with each one. Participants then rated all twelve products along 7-point scales measuring unity, variety and aesthetic appreciation in two rounds. The first round of questions consisted of four filler items[1] and four items measuring aesthetic appreciation (1: *fully disagree*, to 7: *fully agree*): 'visually, this is a beautiful product', 'visually, this is an attractive product', 'this product is pleasing to see', and 'I like to look at this product'. In the second round, participants rated the same twelve products via three items measuring unity, three items measuring variety and six filler items[2]. Participants rated unity through the items 'little unity – a lot of unity', 'little coherence – a lot of coherence', and 'does not appear to be a whole – appears to be a whole'. Variety was rated using the items 'little variety – a lot of variety', 'little diversity – a lot of diversity', and 'consists of few differing elements – consists of many differing elements'.

Principal component factor analysis with Varimax rotation, including all items belonging to aesthetic appreciation, unity and variety, identified three factors explaining 83% of the total variance (eigenvalues > 1.0). All aesthetic appreciation items loaded highly on the first factor (all loadings > .93). The second factor was comprised of the three variety items (all loadings > .84), while the third factor included all unity items (all loadings > .79). This clearly indicated that despite the inherent interdependence between unity and variety, they were seen as different from each other, and different from aesthetic appreciation. The items corresponding to a factor were averaged, and

[1] 'The usage of this product will frustrate me', 'I dare to trust this product completely to function without problems', 'I will know how to operate the product right away' and 'It will take a lot of effort to use the product'.

[2] 'This is a good example of a [product category]','This is a typical [product category]','This product is original' and 'This product is a new example of a [product category]'.

reliability was calculated using Cronbach's alpha for aesthetic appreciation (Cronbach's $\alpha = .97$), unity (Cronbach's $\alpha = .87$) and variety (Cronbach's $\alpha = .84$).

Furthermore, to explore the test-retest reliability of the unity and variety concepts, we compared the scores on the espresso machines from the pre-test with those from the main test. Intraclass correlations on the standardized composite scores revealed very high agreement on these factors (unity ICC(2,2) = .97, variety ICC(2,2) = .98). We can therefore conclude that there is a high degree of consensus between participants on these concepts, and that participants' understanding of the concepts with explicit examples and explanations of the construct is similar to when these are absent.

1.2.3 Results

Pearson correlations and linear mixed model analyses were performed to investigate how unity and variety relate to each other, and how they together relate to aesthetic appreciation. The analyses in all studies were performed on the non-aggregated data, as data aggregation can lead to inflation of correlation and effect sizes (Clark and Avery, 1976).

In accordance with our first hypothesis, Pearson correlations showed that unity and variety correlated negatively with each other for both product categories ($r_{espresso} = -.50$, $p < .001$; $r_{lamp} = -.22$, $p < .001$). Supporting our second hypothesis, unity correlated positively with aesthetic appreciation ($r_{espresso} = .19$, $p < .001$; $r_{lamp} = .26$, $p < .001$), while variety also correlated positively with aesthetic appreciation ($r_{espresso} = .17$, $p < .001$; $r_{lamp} = .26$, $p < .001$). The negative correlation between unity and variety could however indicate that the correlation between unity and aesthetic appreciation was suppressed by the effect of variety, and vice versa. Partial correlations confirmed these expectations as controlling for each other's influence increased the correlations with aesthetic appreciation of unity ($r_{espresso} = .33$, $p < .001$; $r_{lamp} = .34$, $p < .001$) and variety ($r_{espresso} = .31$, $p < .001$; $r_{lamp} = .33$, $p < .001$).

In order to accurately assess the degrees to which unity and variety together influence aesthetic appreciation, ratings from both product categories were analysed using linear mixed models. Linear mixed models take systematic variability of participants and stimuli into account by modelling these dependencies as random effects, allowing for more accurate estimation of the factors of interest and permitting generalizing to the entire population (Baayen et al., 2008; Judd et al., 2012). We performed linear mixed model analyses with by-participant and by-stimuli crossed random intercepts, allowing for baseline differences in unity and variety scores (Carson and Beeson, 2013). To determine whether unity and variety influence aesthetic appreciation similarly for both product categories, we compared a model with and without the product category factor and its interaction terms. Unity and variety were mean centred and added as independent variables in Model 1, and then together with the product category factor and their interaction terms, as fixed effects independent variables predicting aesthetic appreciation in Model 2. We performed a chi-square likelihood ratio test on the AIC's, obtained by Maximum Likelihood estimation, to determine whether the models significantly differed in fit. Results showed that the model including the product category interaction terms (all interactions $p > .05$) did not fit the data better than the first model (χ^2 (3) = 4.14, $p > .05$). This indicates that the effect of unity and variety on aesthetic appreciation was not influenced by product category. We therefore report the results of the first model that included unity and variety as predictors for aesthetic appreciation of both product categories. As hypothesized, both unity, $F(1, 812.30) = 80.26$, $p < .001$ (β = .34, SE = .038, $p < .001$), and variety, $F(1, 605.75) = 67.97$, $p < .001$ (β = .33, SE = .040, $p < .001$), significantly and positively predicted aesthetic appreciation. Moreover, unity and variety positively predicted aesthetic appreciation to a similar degree as can be seen by comparing the β-values (.34 and .33).

1.2.4 Discussion

The results supported both our hypotheses. First, unity and variety are negatively correlated, implying a trade-off between unity and variety in which a further increase of one will result in a decrease of the other. Secondly, both unity and variety have a positive effect on aesthetic appreciation, especially when the counteracting effect of the other variable is statistically controlled for. We can conclude that the highest aesthetic appreciation is achieved when unity and variety are simultaneously maximized.

In this study, unity and variety showed to be equally important in explaining the aesthetic appreciation of lamps and espresso machines. However, this might not always, or necessarily, be the case. It seems plausible that, under certain conditions, one variable dominates our aesthetic response over the other variable. In Study 2, we investigate whether we can shift the relative importance of unity and variety in explaining aesthetic appreciation in two different ways: first by assessing the relationship between unity and variety and aesthetic pleasure across two inherently more complex product categories than those used in Study 1; and, second, by examining the influence of individual differences in motivational drive.

1.3 Study 2

The visual design of a product is in many ways determined by functional requirements that are characteristic of the product category to which it belongs (Bloch, 1995). Lamps and espresso machines are, functionally speaking, relatively simple and one-dimensional, and the designer therefore has considerable freedom of form. Some products, however, have to fulfil various functional, ergonomic and technical requirements simultaneously, placing significant restrictions on the designer's freedom to experiment with the object's visual appearance (Norman, 2013). In Study 2, we introduce two such products, motorcycles and car interiors, for two reasons: to put our initial hypotheses to a second test, and to assess the generalizability of the UiV principle for more complex products than used in Study 1.

Our second goal in Study 2 was to assess whether the preferred balance of unity and variety could be shifted in favour of one or the other as a result of individual differences in motivational drive. Hekkert (2014) recently introduced a Unified Model of Aesthetics that states that our aesthetic preferences depend upon a continuous battle between two evolutionary, and complementary, motivational drives. One drive motivates humans to seek accomplishment through exploration and learning, while another drive motivates humans to seek safety, and approach objects and situations that are familiar, easy to process, and offer security. Hence, humans seek both safety and accomplishment (Shah et al., 1998). According to Hekkert's model, the trade-off between the needs for safety and accomplishment could form an underlying explanation for the UiV principle demonstrated in Study 1. Whereas unity facilitates perceptual understanding, and can thereby fulfil a need for safety, perceiving variety bears the prospect of mastering new information, thereby fulfilling a need for accomplishment. If Hekkert's explanation is correct, the preferred balance between unity and variety could shift as a result of the impetus towards safety or accomplishment. For people who are generally driven towards safety, the relative balance should shift towards unity, whereas for people who seek accomplishment this balance shifts towards variety. This does not imply that accomplishment seekers do not appreciate unity, as unity is still required to make perceptual sense; however, its relative weight decreases. The same can be said about safety seekers, who, despite their increased need for unity, would still appreciate variety.

A way to assess these individual differences in motivational drives is by measuring people's regulatory focus. Regulatory Focus Theory argues that self-regulation is achieved through a *promotion focus* and *prevention focus* (Higgins, 1997). Promotion seekers are concerned with growth, advancement and accomplishment, while prevention seekers have as a goal to protect and seek safety. Support for the idea that such needs can indeed influence the hedonic appreciation of product designs was found by Hassenzahl et al. (2008). The authors primed people's regulatory focus, and found that the people with a promotion focus rated hedonic designs as more appealing than the people with a prevention focus. Where individuals diverge in terms of their needs for safety and accomplishment ought to therefore play a role in determining the aesthetic appreciation of products. In sum, we hypothesise that accomplishment seekers will appreciate variety more than safety seekers, and safety seekers will appreciate unity more than accomplishment seekers.

1.3.1 Method

1.3.1.1 Participants

Male members of a Dutch consumer panel, whose ages ranged from 18 to 65 and who had completed at least secondary-level vocational education, were approached to fill in an online questionnaire about either car interiors or motorcycles. Only male participants were chosen, as we believe that their assumed degree of affinity with such products assures higher response rates and more engagement in the research. A total of 178 participants completed the questionnaire. Of those participants, four were removed from analyses (3 from the motorcycle category, 1 from the car interiors) due to clear, consecutive high or low scores across all items (e.g., all '7's or all '1's). The car interior condition consisted of 89 participants (mean age = 48.1, SD = 13.7) and the motorcycle condition of 85 participants (mean age = 50.1, SD = 13.1). Compensation for completion of the questionnaire was €2.50.

1.3.1.2 Stimuli

The two stimulus categories included 12 detailed colour photographs (≥250k pixels, 72 PPI) of either modern car interiors, or motorcycles (for examples of stimuli see Figure 8). Car interiors and motorcycles were chosen as they differ from espresso machines and lamps in several aspects, such as functional performance, ergonomics and production constraints. Stimulus selection was carried out in a similar manner to Study 1. The car interiors had been captured from the driver's perspective. Although no images of the full car exterior were used, both designers and users treat car interiors as products on their own (Norman, 2013). The motorcycle images were either in perspective or side view. Photo editing software was used to remove brand logos and generate an even background.

FIGURE 8. LEFT: BMW 1 SERIES COUPÉ (2007), COPYRIGHT BY BMW AG. RIGHT: WUNDERLICH K 1200 R, COPYRIGHT BY WUNDERLICH.

1.3.2 Procedure

two stimuli presentation orders) and no order effects were found. Participants rated all 12 products on items measuring aesthetic appreciation, unity, and variety along 7-point scales (1: fully disagree, to 7: fully agree). The procedure was similar to Study 1, except that we decided to align our items with recent research that had set out to identify and validate, amongst other determinants of aesthetic pleasure, items measuring unity and variety (Blijlevens et al., 2014a). As a result, we revised one unity item and one variety item. The unity item ‘this product looks like a whole’ was replaced with ‘this product is orderly’, to emphasize the use of repetition and structure in designs. The variety item ‘this product looks diverse’ was replaced with the item ‘this product is rich in elements’, to emphasize the number of elements used in designs. Unity was therefore measured using the items: ‘this product looks unified’, ‘this product is orderly’ and ‘this product is coherent’ (Cronbach’s $\alpha = .90$). Variety was measured using the items: ‘this product conveys variety’, ‘this product is rich in elements’ and ‘this product is made of different parts’ (Cronbach’s $\alpha = .70$). All aesthetic appreciation items were the same as those from Study 1 (Cronbach’s $\alpha = .97$). While the reliability of the variety item was lower than in Study 1, we are confident that the items accurately measure the concept as shown by the validation study.

In addition, Chronic Regulatory Focus was evaluated with Dutch proverbs measuring prevention (Cronbach’s $\alpha = .73$) and promotion focus (Cronbach’s $\alpha = .79$). This regulatory focus measure was developed by Van Stekelenburg and Klandermans (2003) and correlates highly with that of Lockwood et al. (2002) and has been successfully applied in several other studies (e.g. Schokker et al., 2010). Difference scores were calculated to create one regulatory focus value by subtracting prevention seeking scores from promotion seeking scores.

1.3.3 Results

Similar to Study 1, Pearson correlations showed that unity and variety were significantly and negatively correlated with each other for both product categories ($r_{car} = -.16$, $p < .001$; $r_{motor} = -.10$, $p < .001$). Also in line with Study 1, unity significantly and positively correlated with aesthetic appreciation ($r_{car} = .64$, $p < .001$; $r_{motor} = .45$, $p < .001$), and variety did so as well ($r_{car} = .10$, $p < .001$; $r_{motor} = .17$, $p < .001$). Partial correlations were calculated and correlations with aesthetic appreciation increased for both unity ($r_{car} = .67$, $p < .001$; $r_{motor} = .48$, $p < .001$) and variety ($r_{car} = .27$, $p < .001$; $r_{motor} = .25$, $p < .001$), indicating that unity and variety supress each other’s effect on aesthetic appreciation.

For both product categories, the correlations between unity and aesthetic appreciation were stronger than those for variety, and thus differed from the balance found in Study 1 where both variables had a similar impact. We therefore performed separate linear mixed model analyses for the car interiors and motorcycles to compare the unity and variety coefficients with those for the espresso machines and lamps from Study 1. Applying the same mixed effects model as in the previous study, unity and variety were added as fixed effects predicting aesthetic appreciation. For the car interiors, unity, $F(1, 971.58) = 390.82$, $p < .001$ ($\beta = .54$, SE = .027, $p < .001$), and variety, $F(1, 1062.84) = 65.26$, $p < .001$ ($\beta = .26$, SE = .033, $p < .001$), significantly and positively predicted aesthetic appreciation. A similar relationship was found for the motorcycles where unity, $F(1, 961.25) = 190.57$, $p < .001$ ($\beta = .47$, SE = .034, $p < .001$), and variety, $F(1, 1007.06) = 46.17$, $p < .001$ ($\beta = .29$, SE = .043, $p < .001$), significantly and positively predicted aesthetic appreciation as well. However, the preferred balance between unity and variety clearly shifted from being equal in Study 1, towards a preference for unity over variety in Study 2.

For each product category, an additional linear mixed model analysis with random intercepts for participant and stimuli were performed to investigate the effect of regulatory focus on aesthetic appreciation. Unity, variety and regulatory focus were variety, as fixed effects predicting aesthetic appreciation. For the car interiors, only unity, $F(1, 971.54) = 386.12$, $p < .001$ ($\beta = .54$, SE = .027, $p < .001$), and variety, $F(1, 1056.35) = 62.01$, $p < .001$ ($\beta = .26$, SE = .033, $p < .001$), reached significance, indicating that differences in regulatory focus did not influence the preferred balance between unity and variety. For the motorcycles, unity, $F(1, 955.76) = 185.92$, $p < .001$ ($\beta = .47$, SE = .034, $p < .001$), variety, $F(1, 1056.35) = 62.01$, $p < .001$ ($\beta = .32$, SE = .044, $p < .001$), and unity, $F(1, 979.84) = 5.61$, $p < .05$ ($\beta = -.06$, SE = .024, $p < .05$), reached significance. This significant interaction indicated that the effect of unity on aesthetic appreciation is influenced by regulatory focus. We further interpreted the interaction effect of these two variables by following a probing approach suggested by Preacher et al. (2006), based on Aiken and West (1991). This analysis generates simple slopes for a predictor at three different values of a conditional moderator. As opposed to artificial dichotomization of continuous variables, this approach prevents loss of information by using the output of the previously performed full linear mixed effects model (MacCallum et al., 2002). The choice for the conditional values of the continuous moderator was based on the mean and 1 SD above and below the mean of the moderator as suggested by (Cohen et al., 2003). We calculated the simple slopes of unity regressed on aesthetic appreciation of the three different levels of regulatory focus (Preacher et al., 2004). As we used a difference score wherein prevention-seeking scores were deducted from promotion seeking scores to calculate our regulatory focus variable, participants with low regulatory focus scores are prevention oriented, whereas those with high regulatory focus scores are promotion orientated. The simple slopes of unity regressed on aesthetic appreciation increased when regulatory focus shifted from promotion to prevention seeking (β_{high} = .39, SE = .047, t = 8.51, p < .001; β_{medium} =.47, SE = .034, t = 13.70, p < .001, and β_{low} .54, SE = .044, t = 12.22, p < .001). Congruent with our expectations, this indicated that prevention seekers preferred unity more in motorcycles than promotion seekers.

1.3.4 Discussion

In line with Study 1, unity and variety were found to be partial opposites while both positively influenced aesthetic appreciation of the product designs. As a result, product designs that maximize and balance both unity and variety are aesthetically preferred. However, for both the motorcycle and car interior categories, unity became relatively more important than variety, leading to a different preferred balance compared to Study 1. A greater importance placed on unity is potentially the result of product category dependent aspects. While there are many aspects that differ between the motorcycles and car interiors, and the lamps and espresso machines from Study 1, what might explain this variance is a differing degree of visual complexity. Products like motorcycles contain on average many more functional components (e.g. instruments, controls, panels) than lamps or espresso machines and, as a result, automatically exhibit more variety than espresso machines and lamps. As a result, visually more complex designs may lead to more importance being attributed to unity to facilitate perceptual understanding of the designs. In Study 3 we investigate whether we can provide further evidence for the assumption that product category complexity is responsible for shifting the preferred balance of unity and variety.

The influence of regulatory focus on the preferred balance between unity and variety led to significant results, but only in the motorcycle condition. Prevention seekers preferred more unity than promotion seekers. According to the theoretical model of aesthetics put forth by Hekkert (2014), an increased appreciation of unity is the result of satisfying a need for safety. This need can be regulated by the perception of unity in the motorcycles, as unity facilitates perceptual understanding. Consequently, participants who are more prevention-focused appreciate this unity more than promotion-focused participants. However, we did not find an effect of regulatory focus on unity for the car interiors, and no effect of regulatory focus on variety in either product category. Perhaps chronic regulatory focus has less explanatory power than experimentally manipulating regulatory focus would have, which could be an option for future research.

1.4 Study 3

In two consecutive studies with four different product categories we have shown that both unity and variety, despite being negatively interrelated, positively and significantly affect aesthetic appreciation. However, whereas Study 1 revealed that unity and variety are equally important in explaining aesthetic appreciation of espresso machines and lamps, Study 2 showed that for car interiors and motorcycles, unity is relatively more important. A reason for this shift may be sought in the latter product's increased visual complexity, which is an important product attribute for consumers when judging the appearance of product designs (Blijlevens et al., 2009). Research by Nadal et al. (2010) shows that the number and variety of elements present is a central factor influencing perceived visual complexity. Because designs that consist of many elements, like motorcycles and car interiors, are visually more complex than designs from product categories such as lamps and espresso machines, we could argue that it is more difficult for someone to detect the unifying relationships in complex designs, as there are more properties that require evaluation. However, when one ultimately succeeds in perceiving those unifying relationships, the extra effort required for perceptual understanding results in increased aesthetic appreciation (Biederman and Vessel, 2006; Muth and Carbon, 2013; Ramachandran and Hirstein, 1999). In contrast, the perception of unity in visually simple designs requires relatively little effort, and should lead to decreased importance for unity in explaining aesthetic appreciation. In order to assess whether complexity may explain the shift in preferred balance between unity and variety between product categories, we performed an additional study with product designs from categories low in visual complexity. As in the previous studies, we hypothesise that unity and variety while suppressing each other's effect, positively influence aesthetic appreciation. Additionally, we hypothesise that variety is relatively more important than unity in explaining the aesthetic appreciation of these visually simple product designs.

1.4.1 Method

1.4.1.1 Participants

Undergraduate students at a Dutch university were approached to fill in an online questionnaire about product design evaluations. A total of 66 participants completed the questionnaires. Of those participants, six were removed from analyses (4 for the USB-stick condition, 2 for the table condition) due to clear consecutive scores across all items (e.g., all '1's or '7's), or because they mentioned that they did not understand the questions. The table condition consisted of 31 participants (mean age = 23.2, SD = 3.7, 14 women) and the USB-stick condition of 29 participants (mean age = 23.4, SD = 3.8, 12 women).

1.4.1.2 Stimuli

A pre-test was performed to determine if the product categories (lamps, espresso machines, car interiors and motorcycles) differed in perceived visual complexity, and to evaluate whether two new product categories (USB-sticks and tables) could be used as categories representing low visual complexity. Twenty-four participants ranked text labels of all product categories according to the question: 'How visually complex (difficult to comprehend) are products from the following category: [insert category here]'. All stimuli from the previous studies and the two new categories were printed on separate A3 papers as reference. Based on the study to which the product categories belonged, low (USB-sticks and tables), medium (espresso machines and lamps) and high (car interiors and motorcycles) visually complex groups were created by calculating their median rank scores. Friedman's ANOVA indicated that there was a significant difference in visual complexity rank scores for the three groups, $\chi^2(2) = 46.52$, $p < .001$). As expected, Wilcoxon signed-rank tests with Bonferroni corrections revealed that the low complexity group scored lower than both the medium ($z = -4.27$, $p < .001$) and high group ($z = -4.37$, $p < .001$), and that the medium group also scored lower on complexity than the high group ($z = -4.19$, $p < .001$). USB-sticks and tables were therefore used in this study as stimuli low in visual complexity. Stimuli selection for the USB-sticks and tables was done in a similar manner to the previous studies, resulting in 12 high-detailed images (≥250k pixels, 72 PPI) per product category. The USB-sticks and tables were displayed in perspective or from the side, and an even background was created using photo editing software (for examples of stimuli see Figure 9).

FIGURE 9. LEFT: KINGSTON DTM30, COPYRIGHT BY KINSTON. RIGHT: TAVÌ TABLE (2006) BY ADELE ROTELLA.

1.4.2 Procedure

The same experimental design as that of the previous studies was used (two product two stimuli presentation orders), and no order effects were found. In two rounds, participants rated all 12 products along 7-point scales (1: fully disagree, to 7: fully agree) identical to those used in Study 2. In the first round, the four aesthetic appreciation items (Cronbach's $\alpha = .96$) were listed together with three filler items[1]. In the second round, the three unity (Cronbach's $\alpha = .88$) and three variety items (Cronbach's $\alpha = .76$) were shown. All product images were displayed before the start of each round to let participants familiarize themselves with the stimuli.

1.4.3 Results

Consistent with the previous studies, we found a significant and negative correlation between unity and variety for both product categories ($r_{table} = -.36$, $p < .001$; $r_{USB} = -.30$, $p < .001$). While unity significantly and positively correlated with aesthetic appreciation of both product categories ($r_{table} = .51$, $p < .001$; $r_{USB} = .65$, $p < .001$), variety initially only did so for the tables ($r_{table} = .18$, $p < .001$; $r_{USB} = -.09$, $p > .05$). However, the correlations between both unity ($r_{table} = .63$, $p < .001$; $r_{USB} = .66$, $p < .001$) and variety ($r_{table} = .45$, p

[1] 'This product is a new example of a [product category]', 'This product is original' and 'This is a good example of a [product category]'

< .001; r_{USB} = .14, p < .01) and aesthetic appreciation reached significance when controlling for each other's influence using partial correlations.

To compare the coefficients of this study with the previous two and assess whether the preferred balance had shifted from unity towards variety, the same linear mixed effects model as before was run for each product category. Unity and variety were added as fixed effects predicting aesthetic appreciation and random effects were modelled for participants and stimuli. For the tables, unity, $F(1, 347.99) = 170.83$, $p < .001$ ($\beta = .61$, SE = .046, $p < .001$), and variety, $F(1, 319.37) = 3.82$, $p < .001$ ($\beta = .20$, SE = .052, $p < .001$), significantly and positively predicted aesthetic appreciation. The coefficients however show that the preferred balance did not shift towards variety, as unity was more important. For the USB-sticks, unity also significantly and positively predicted aesthetic appreciation $F(1, 328.68) = 62.55$, $p < .001$ ($\beta = .45$, SE = .056, $p < .001$), whereas variety was only marginally significant, $F(1, 344.65) = 3.20$, $p = .074$ ($\beta = .11$, SE = .061, $p = .074$). The expected balance between unity and variety did therefore not shift towards variety for both simple product designs. Instead, unity was still the dominant factor.

1.4.4 Discussion

For the product category of tables, this study confirmed previous findings that both unity and variety, although suppressing each other's effect, positively influence aesthetic appreciation of product designs. However, while unity did significantly predict aesthetic appreciation of USB-sticks, variety did not. Overall, we expected variety to become more important than unity for these visually simple designs, a prediction that was not confirmed. Instead, unity was again the most important factor influencing aesthetic appreciation of both product categories, and even to a similar degree as for the highly complex designs in Study 2. Visual complexity, therefore, seems not to be the factor explaining the variance in preferred balance between different product categories.

Alternatively, it could be that the appreciation of unity and variety is dependent on each other's presence. Earlier, we reasoned that humans find both unity and variety pleasurable, because unity benefits perceptual understanding, while variety increases the potential to acquire new information (Biederman and Vessel, 2006; Ramachandran and Hirstein, 1999). Hence, aesthetic appreciation is maximized when the presence of variety is counterbalanced with sufficient unity, and vice versa. This interdependence may also imply that if there is a lack of unity, the appreciation of variety will go down as sense making is troubled. Similarly, the appreciation of unity may decrease when there is a lack of variety, as there is little to keep us interested. Differences in the preferred balance between studies may thus depend on the relative presence of unity and variety. To assess this, we performed a meta-analysis on the combined data of all studies by investigating possible interaction effects.

We performed a linear mixed model analysis that included mean centred scores of unity and variety, and their interaction, as fixed effects predicting aesthetic appreciation. Participants and stimuli were added as random effects with random intercepts. Maximum Likelihood estimation was used to determine whether adding the interaction of unity and variety significantly improved the fit, which it did ($\chi^2(1) = 7.55$, $p < .01$). As expected, the model showed unity, $F(1, 3500.86) = 742.65$, $p < .001$ ($\beta = .46$, SE = .017, p < .001), variety, $F(1, 3394.70) = 197.12$, $p < .001$ ($\beta = .28$, SE = .020, p < .001) variety, $F(1, 3629.35) = 9.56$, $p < .001$ ($\beta = .03$, SE = .010, $p < .005$) to significantly predict aesthetic appreciation. This indicated that the effect of unity and variety on aesthetic appreciation is partially dependent on each other's presence. To further interpret the direction of the interaction effect, we used the same interaction probing approach as applied in Study 2 (Cohen et al., 2003; Preacher et al., 2006). We first calculated three simple slopes for variety regressed on aesthetic appreciation with unity acting as the conditional moderator at the mean, and 1 SD above and below the mean (Preacher et al., 2004). The results showed the slope of variety to increase close to 50% between low and high conditional values of unity ($\beta_{low} = .22$, SE = .025, $t = 9.04$, $p < .001$; $\beta_{medium} = .28$, SE = .020, $t = 14.04$, $p < .001$; $\beta_{high} = .32$, SE = .024, $t = 13.28$, $p < .001$). In addition, the slope of unity was found to increase around 20% between low and high conditional values of variety ($\beta_{low} = .42$, SE = .023, $t = 18.48$, $p < .001$; $\beta_{medium} = .46$, SE = .017, $t = 27.25$, $p < .001$; $\beta_{high} = .50$, SE = .020, $t = 25.49$, $p < .001$). These results suggest that the appreciation of unity and variety is partially dependent on the extent to which both are present. Yet, the appreciation of variety is considerably more dependent on the presence of unity than the other way around.

While we initially did not predict a dominance for either of the two variables in determining aesthetic appreciation, some authors have argued that unity is indeed essential for variety to be appreciated (Fechner, 1876; Fry, 1920). The meta-analysis seems to support this to a degree by showing that unity is the stronger factor (β_{unity} = .46 vs. $\beta_{variety}$ = .28) and that its presence plays an important role in determining the appreciation of variety. When we take this knowledge into account and observe the preferred unity and variety balance for the six product categories, we find a possible explanation for their differences. The relative levels of unity and variety present *within* the stimulus sets differ somewhat between studies. As the meta-analysis and literature suggests, such differences may influence the relative importance of both variables. Careful inspection of the means for unity and variety in each of the studies seems to confirm this idea: the espresso machines (mean difference unity-variety = .96) and lamps (mean difference unity-variety = .94), had substantially more unity than variety, while car interiors (mean difference unity-variety = .02), motorcycles (mean difference unity-variety = -.17) and USB-sticks (mean difference unity-variety = 0.20) had approximately equal levels of unity and variety. The first two product categories are the ones for which unity and variety were equally important in explaining aesthetic appreciation, while for the latter three product categories unity was considerably more important than variety in explaining aesthetic appreciation. These means thus support the idea that ample unity in product designs facilitates the appreciation of variety. The product category of tables seems to be a slight exception, as unity was preferred over variety, despite more unity being present (mean difference unity-variety = .61). This could indicate the presence of additional moderating factors that influence the effect of UiV on aesthetic appreciation. For example, the MAYA principle argues that products are aesthetically preferred when they show a balance in typicality and novelty (Hekkert et al., 2003). Tables are simple product categories where high degrees of variety may be considered atypical, thereby suppressing the appreciation of variety, even if those tables are still highly unified. The same explanation can account for not finding a significant effect of variety for USB-sticks. Such simple products are not expected to contain many different elements and therefore do not allow for variety to be appreciated as much.

1.5 General discussion

The principle of UiV has long been thought to explain part of the experience of beauty or aesthetic appreciation, which is shared among humans (Fechner, 1876; Plotinus, 1969). However, empirical proof for the joint influence of unity and variety on visual aesthetic appreciation was still lacking. In discussing its origin and examining the principle across three studies, we hope to have clarified its significance for the aesthetic appreciation of product designs. The main finding of our research is that, although unity and variety are partial opposites and therefore suppress each other's effect on aesthetic appreciation, both positively affect aesthetic appreciation of a range of product categories. This implies that there is a balance between unity and variety that is aesthetically preferred. As a result, product designs that adhere to this balance are regarded as the most beautiful (Figure 10). We additionally explored how product category variation and individual differences in motivational drives affect the combined relationships of unity and variety on aesthetic appreciation.

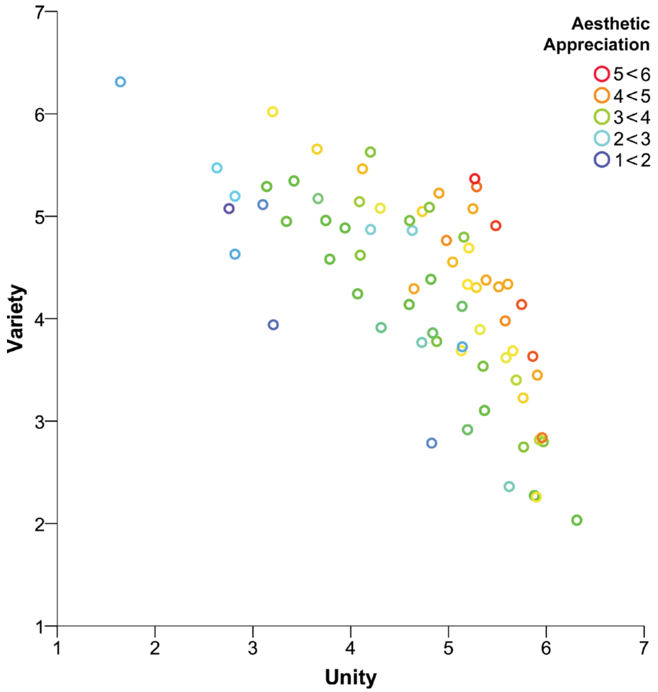


FIGURE 10. PLOTTED MEAN RATINGS FOR ALL 72 PRODUCTS SHOWING AESTHETIC APPRECIATION (IN COLOUR) TO INCREASE FOR HIGHER COMBINATIONS OF UNITY AND VARIETY.

As for the influence of motivational state on the preferred levels of unity and variety, we found that prevention seekers prefer unity to a larger extent than promotion seekers. However, we only found this for motorcycles. This raises the question whether there are differences between both product categories that could have influenced the effect of people's regulatory focus on their preference for unity. Research by Hassenzahl et al. (2008) provides a possible explanation by showing that the effects of regulatory focus on appreciation is larger for a product with hedonic attributes than one with pragmatic attributes. Even though both car interiors and motorcycles are more pragmatic overall (compared to espresso machines and lamps), the motorcycles were presented in full and therefore probably evaluated more on their hedonic qualities than the car interiors, for which mainly the functional parts (i.e. controls and dials) of the interior were visible. Another explanation is statistical: Results show that unity was rated two to three times more important than variety in relation to aesthetic appreciation. The limited variance explained by variety may have mitigated any potential influence on regulatory focus. In order to investigate whether the relationship between motivational drives and the appreciation of UiV can be extended beyond the product category of motorcycles it is advisable to include validated priming paradigms in future studies (Lockwood et al., 2002; Wan et al., 2009).

We found that there is an optimum balance between unity and variety that is aesthetically preferred in all product categories. While for some product categories, this balance implied an equal amount of importance placed on unity and variety to explain aesthetic appreciation, in other categories, unity was relatively more important than variety. As perceived visual complexity of the product categories could not explain these shifts, a meta-analysis of all the products was performed, providing an alternative explanation: We like to perceive as much variety as possible, but for this variety to be enjoyed we need to see the unity in this variety; whereas unity is always liked, the appreciation of variety highly depends on the presence of (sufficient) unity. This asymmetry between unity and variety in predicting aesthetic preference is perfectly captured by the wording of the principle: it is 'unity-*in*-variety' after all.

As stated earlier, we did not find visual complexity of product categories to be a moderator of the preferred UiV balance. Although complexity and the concepts of unity and variety are generally considered different factors influencing aesthetic appreciation (Beardsley, 1958; Berlyne, 1971), they do share similarities through the underlying design dimensions that influence them (e.g. symmetry, number of elements). It is important to further disentangle these concepts to better understand and control for each other's influence. Research by Nadal et al. (2010) gives direction to this disentanglement as they showed how visual complexity can be largely related to the diversity and number of elements that can be perceived, and the way in which these elements are organized. From this, it seems likely that unity would correlate negatively with complexity as increasing organization lowers complexity. Variety would, on the other hand, be expected to correlate positively with complexity, as the number and diversity of elements increase. Future research could take into account how design dimensions underlying both UiV and complexity influence each other, as has for example been done in the domain of consumer research (Townsend and Kahn, 2014).

While our research focused on unity and variety as determinants of aesthetic appreciation, other design factors, such as typicality and novelty, influence a product's appreciation as well (Hekkert et al., 2003). As suggested earlier, the relatively small importance of variety in predicting aesthetic appreciation of USB-sticks and tables might be dependent on typicality or novelty. Typical USB-sticks and tables are relatively simple in their design and therefore considered highly unified. Large deviations from this, in the form of high variety, may prevent the product from being aesthetically appreciated as it has become too atypical or novel. Future studies could investigate the combined effect of these and related design principles to further explore possible interactions.

Although we used verbal ratings of unity and variety as measures of these constructs, a body of literature suggests that these are based on visual principles such as symmetry, simplicity, and contrast (Bell et al., 1991; Chang et al., 2002; Graham, 2008; Moshagen and Thielsch, 2010). That this relationship does not lead to perfect agreement between respondents is most probably due to individual differences in expertise with certain product categories and sensitivity for ordering principles. After all, it takes a sensitive eye to register the sometimes subtle Gestalt principles that are responsible for enhancing unity (Hekkert, 2006). As we have shown the general workings of the UiV principle, our work enables systematically exploring how underlying dimensions, such as the Gestalt principles, determine the preferred balance between unity and variety. While previous studies have done so with line figures of products (Veryzer and Hutchinson, 1998), more realistic stimuli such as websites are especially well suited for systematic manipulations of design factors due their controllable use of layout and colour (Altaboli and Lin, 2012; Bauerly and Liu, 2008). Investigating how dimensions such as symmetry or contrast influence unity and variety with these types of stimuli could thereby further open the black box of how our aesthetic preferences are formed.

1.6 Conclusion

Over three studies, we confirmed that UiV is a principle that explains a trade-off between unity and variety which is achieved by optimizing both at the same time. When such a balance is attained, aesthetic appreciation is maximized. The results of our research not only offer empirical evidence for the validity of this principle in explaining aesthetic appreciation, it also further specifies its working mechanism. We have demonstrated that the relationship between unity and variety is asymmetrical: the appreciation of variety is highly dependent on the presence of unity, whereas unity can be appreciated for its own sake. This finding has several theoretical and practical implications.

Unity-in-variety is a holistic principle that conceptually combines several compositional dimensions (e.g. symmetry, balance, closure, colour) into a coherent overarching theory (Kim, 2006). It thereby offers a way to simultaneously take into account the influence of many of these design dimensions on the aesthetic appreciation of human artefacts. Thinking about such dimensions in terms of balancing unity and variety can therefore aid in the development of comprehensive models of aesthetic appreciation that propose an early stage of analysis during which perceptual grouping and organizing mechanisms are crucial (Bullot and Reber, 2013; Chatterjee, 2004; Hekkert, 2014; Leder et al., 2004).

While we focussed on visual perception in product designs, we argue that the principle also applies to other fields of study, and other sensory modalities. Both unity and variety are concepts studied in the aesthetics of art (Cupchik et al., 1996), architecture (Nasar, 1994) and musicology (Cohen, 1990), but to our knowledge, their interdependent relationship in explaining aesthetic appreciation has not been empirically researched in those fields. Furthermore, it has recently been argued that the

Gestalt laws also apply to tactile perception (Gallace and Spence, 2011b). Accordingly, the importance of these grouping laws in explaining visual UiV makes linking the principle with the tactile modality an interesting possibility. Since UiV can be regarded as a general psychological mechanism, it will be interesting to see whether it shows similar effects on aesthetic appreciation across sensory modalities (see Hekkert, 2014).

Finally, our evidence demonstrating the workings of UiV can inform designers' concepts for more beautiful products. Previous research has shown that designers value the principle of UiV similarly to laymen when rating the same products (Post et al., 2013a).[1] This finding, combined with the consistent results found with the diverse range of products used in this study, provides guidelines on how the principle should be applied. In the words of the late Frans Boselie (1996): 'preserve unity while almost allowing for chaos'.

---

[1] Hekkert et al. (2003), while researching the comparable MAYA principle (see section 2.2 for the similarities between UiV and MAYA), found that experts perceive different cars as being novel or typical, but both variables were equally important in explaining aesthetic preferences for laymen and experts. Based on their research and our reasoning that all persons appreciate perceiving unity and variety, we predicted that the UiV principle also holds for experts. In this study we investigated the principle of UiV for automotive design students performing an identical study with car interiors as the laypersons in Study 2 of this chapter. Results revealed that unity and variety negatively correlated (r = -.15, p < .01), while unity (β = .68, p < .001), and variety (β = .10, p < .05), both significantly contributed to aesthetic appreciation when analysed using a linear regression ($F(2, 321)$ = 134.9, p < .001; explaining 46% of the variance on aesthetic appreciation scores). We thereby replicated previous findings that aesthetic appreciation is highest when unity and variety are optimally combined. However, we also found the preferred balance to shift towards unity for design experts compared to laymen [Post-hoc analysis reveals unity to be significantly more appreciated for designers (z= 3.63, p < .001; whereas variety is appreciated less (z = -2.13, p < .05); calculated using the method suggested by Paternoster et al. (1998)]. This can be explained by the specific education that these designers received. Because of their explicit and implicit training in unifying principles they attribute more importance to unifying aspects and accordingly appreciate its perception more as well. Especially for car interiors, which contain numerous buttons, dials and other components that need to be structured into a coherent design. As a result, while designers appreciate unity more than laymen and therefore prefer different designs, they still appreciate perceiving UiV and the principle therefore still holds for design experts.

2 Visual Unity-in-Variety systematically manipulated

Whether it is the Parthenon or a modern skyscraper, a building is subject to gravitation and stands or falls according to whether or not the physical stresses have been correctly calculated.
The same principle applies to the visual arts, for aesthetic structure is also subject to natural forces that are as potent as gravity. The artist builds with line, shape, and color. It is upon the integration of these elements that the success of any composition depends.

-

Maitland E. Graves in 'The Art and Color of Design' (1951)

This chapter has been accepted for publication as: Post, R.A.G., Nguyen, T.T.H., & Hekkert, P. Unity in variety in website aesthetics: A systematic inquiry.

It has been well established that aesthetic appreciation plays an important role in determining a product's success by contributing to a wide range of positive effects (Bloch, 1995; Creusen and Schoormans, 2005). Within the domain of HCI, aesthetic appreciation has been shown to contribute to user satisfaction (Cyr, 2008), usefulness (Van der Heijden, 2003), usability (Tractinsky et al., 2000; Tuch, Roth, et al., 2012), performance (Moshagen et al., 2009) and a variety of other aspects (For an extensive overview, we recommend readers to read Moshagen and Thielsch, 2010).

Given these beneficial effects, many studies have attempted to identify what design factors determine aesthetic appreciation of (digital) interfaces such as web sites. These studies can roughly be divided in three categories. Firstly, those focusing on basic visual design factors such as symmetry, number of elements and colourfulness (e.g. Bauerly and Liu, 2006; Bauerly and Liu, 2008; Bonnardel et al., 2011; Cyr et al., 2010; Ngo et al., 2002). Secondly, studies that investigate more subjective or psychological dimensions, such as the degree of simplicity or complexity (Moshagen and Thielsch, 2010), order (Schenkman and Jönsson, 2000), (proto)typicality (Tuch, Presslaber, et al., 2012) and novelty (Tuch, Presslaber, et al., 2012). And thirdly, those studies combining both to show how basic visual design factors relate to the subjective perception that gives rise to aesthetic appreciation (e.g. Altaboli and Lin, 2011; Deng and Poole, 2012; Seckler et al., 2015). The added benefit of this latter approach lies in a more holistic explanation of the aesthetic experience, while also giving valuable insights on how to purposefully and methodologically influence it.

An aesthetic principle that also has the potential to explain aesthetic appreciation in a holistic manner, and that has hitherto not been studied within HCI, is that of Unity-in-Variety (UiV). The principle holds that, in order to experience aesthetic pleasure in our interaction with objects, we need to perceive unity in the variety of its parts (Fechner, 1876; Hekkert, 2006; Hutcheson, 1729). The most basic visual properties of almost any object are its colour, shape and texture. Together these form identifiable elements, ranging from structural components to the icons of an interface, which are generally perceived as being parts of a whole impression—the perception of the entire product or scene. It is the way in which these basic design properties and elements are related and organized from which the experience of both unity and variety emerges (Graves, 1951; Lauer and Pentak, 2012).

Humans actively seek variety in the world around them because it stimulates the senses and raises interest through offering novel sensations (Berlyne, 1971). This appetite for information and resulting appreciation of variety is thought to have evolved over time, as its perception bears the prospect of learning and thereby aided in coping with our environment (Biederman and Vessel, 2006; Hekkert, 2014). Variety, as used in design, can be referred to as the number and intensity of perceived differences between perceptual properties (e.g., colour, line, texture) and elements (the identifiable parts resulting from the way properties are organized)(Berlyne, 1958; Graves, 1951; Post et al., 2016). Structural and functional requirements of a design often dictate the presence of a certain degree of variety (Norman, 2013). However, solely perceiving variety leads to overstimulation, disrupting our ability to make perceptual sense (Cropper and Evans, 1968). Hence, for variety to be enjoyed, we need to perceive the unity within it.

Unity refers to the sensation of perceiving the whole and the order or coherence in sensory information (Berlyne, 1971). It facilitates perceptual processing and is thought to generate a feeling of fluency (Armstrong and Detweiler-Bedell, 2008; Reber et al., 2004). As such, unity aids in efficiently processing sensory information and its resulting pleasure is thought to originate from the evolutionary benefits this brought (Biederman and Vessel, 2006). An absence of unity troubles understanding as we fail to 'make sense of' what we see. When unity is perceived however, the *variety* of elements and properties are considered organized, allowing the appreciation of both the variety that stimulates our senses and the unity which enables its effective processing (Parker, 1976). It is this pleasure resulting from sensory understanding that partially determines our aesthetic appreciation of man-made artefacts to this day (Hekkert, 2014).

Since the perception of unity and variety originates from the same sources (i.e. the basic properties and elements of a design), they highly intercorrelate. One can intuitively recognize that increasing variety, for example through increasing the number of parts in a design, will generally decrease unity as it becomes more difficult to maintain coherence, and vice versa. In other words, unity and variety counteract each other. As a result of being partial opposites, yet mutually contributing to aesthetic appreciation, it has been theorized that the most beautiful forms of art and design are those that successfully combine high degrees of unity and variety at the same time, hence Unity-in-Variety (Berlyne, 1971; Hekkert, 2006).

Previous studies confirm that unity and variety together explain aesthetic appreciation of simple figures (Berlyne and Boudewijns, 1971) and art (Cupchik and Gebotys, 1988). More recently, it was found that, despite unity and variety suppressing each other's effect, ratings of both unity and variety positively relate to aesthetic appreciation of tangible product designs (Post et al., 2016). A trade-off between unity and variety was demonstrated resulting in an optimal balance where aesthetic appreciation is maximized. However, this last study only statistically demonstrated the independent effects of both dimensions.

The present study aims to experimentally investigate the principle of UiV in the domain of HCI. We seek to find support for the claim that unity and variety are separate dimensions that both positively influence aesthetic appreciation and that, given their suppressing effect, there exists an optimal balance where aesthetic appreciation is highest. To assess the influence of each dimension on aesthetic appreciation, we systematically and independently manipulated unity and variety in the same sets of web pages. Our research consists of two parts. The first study describes the development and validation of different sets of web pages to examine whether it is possible to systematically and independently manipulate unity and variety. The second study assesses the influence of variations in unity and variety on the aesthetic appreciation of these web pages. In doing so, we strengthen support for the relevance of the principle, extend its applicability to the domain of HCI and show how unity and variety can be intentionally influenced.

2.1 Study 1

We argue that unity and variety are not opposites on a single dimension, but two distinct dimensions positively influencing aesthetic appreciation. However, unity and variety are intrinsically connected by the basic elements of design that affect both dimensions. This inherent relationship makes it difficult to separate their influence. For example, lowering the number of elements in a design to create more order and increase unity will inadvertently also decrease variety. To show that both can indeed be considered separate dimensions uniquely contributing to aesthetic appreciation, it is essential to manipulate them independently. In order to find suitable means to systematically and independently manipulate unity and variety in web pages as realistically as possible, we identified potential design factors in the HCI and aesthetics literature and discuss them in the next two sections.

2.1.1 Factors influencing variety

Several studies use variety and complexity almost interchangeably as they share common ground and largely overlap (Berlyne, 1960). For example, Nadal et al. (2010) showed visual complexity of artworks to be mainly explained by the number and variety of elements within them. We therefore included studies investigating complexity in this overview if their operationalization was similar to our definition of variety.

Early studies on the perception of line figures showed increases in the number of elements, and consequently the *dissimilarity between elements*, to heighten variety (Berlyne and Boudewijns, 1971; Birkhoff, 1933). In the domain of HCI, Nadkarni and Gupta (2007) showed how subjective impressions of dissimilarity in websites contribute to perceived and objective levels of visual complexity. Further experimental support comes from a study performed by Deng and Poole (2012) who found increasing number of elements in web pages (the links, text and graphics) to positively influence complexity ratings. More evidence for the importance of this design factor comes from Reinecke et al. (2013), who showed their computational model to accurately predict visual complexity ratings of participants, based on the number of text groups, image areas and content areas of web pages. Similar research was performed by Michailidou et al. (2008), also showing the number of links, images and words to positively relate to visual complexity.

Diversity in colour, or *colourfulness*, is another design factor considered to influence variety and refers to the number and distribution of colours in terms of their hue, saturation and brightness (Graves, 1951). Colourfulness contributes to variety by increasing differences between elements, offering visual richness and stimulation of our senses (Hall and Hanna, 2004; Nasar, 1987; O'Connor, 2013; Oostendorp and Berlyne, 1978). Although colourfulness can therefore be associated with dissimilarity in elements, both have been identified as separate facets of visual aesthetics and are often measured separately (Moshagen and Thielsch, 2010; Nadkarni and Gupta, 2007). Empirical support for the importance of colourfulness in influencing variety comes from a study by Reinecke et al. (2013). Using a computational modelling approach, the authors found subjective scores of colourfulness to increase with complexity ratings of web pages. A similar modelling approach was used by Miniukovich and De Angeli (2014) who found colour variability to explain part of the variance in visual complexity of graphical user interfaces. Lastly, a study on signscape preferences found colour variation to increase perceived variety as well (Nasar, 1987).

2.1.2 Factors influencing unity

The Gestalt laws of perceptual grouping are common means to achieve unity and are widely known and used in HCI and design in general (Chang et al., 2002; Graham, 2008; Lidwell et al., 2010; Preece et al., 1994). Experimental support for their importance comes from Bell et al. (1991) who studied how well different styles of furniture fit together as a combination of good Gestalts. Their research showed good Gestalts to positively attribute to the aesthetic appreciation of the furniture, and that this relationship was mediated by perceived levels of unity. However, they did not isolate single Gestalt laws (e.g. similarity, symmetry or proximity), making it unclear which ones are most effective in manipulating unity, which is a requisite for our research in order to test the UiV principle. Ngo et al. (2002) did isolate Gestalt laws by developing an aesthetic formula for unity in visual screen design based on *similarity in size* and *proximity*. This formula was tested in another study, and further confirmed by Altaboli and Lin (2012), that showed unity to be one of the stronger dimensions explaining aesthetic appreciation of visual screen designs (Ngo and Byrne, 2001). Similarly, Veryzer and Hutchinson (1998) used line drawings of products manipulated in shape similarity to investigate the influence of unity on aesthetic appreciation. Another Gestalt law considered to influence unity is that of s*ymmetry*, as it facilitates perceptual understanding by reducing redundancy in information, leading to more fluent processing (Garner, 2014; Locher and Nodine, 1989; Reber et al., 2004). In applied terms, it gives structure and creates visual balance to help organize an image (Locher et al., 1998; Wilson and Chatterjee, 2005). Seckler et al. (2015) systematically and objectively manipulated symmetry in web pages, along with other design factors, by centring the layout and creating similarity in background colours. The authors found increasing symmetry to positively influence Gestalt impressions of figural goodness, which is synonymous with unity (Moshagen and Thielsch, 2010).

Although symmetry, similarity and proximity are relevant factors to consider when manipulating unity, candidate design factors need not be restricted to Gestalt laws. *Contrast* is a design factor that can operate in different ways to enhance unity (Graham, 2008). One way is in decreasing differences between elements and their surrounding, as was shown by Nasar (1987). The author lowered contrast in letter sizing, colour and shape of signscapes, which increased perceived coherence. Increasing contrast can however also enhance unity by facilitating detection of differences, a form of figure-ground contrast that leads to increased readability (Hall and Hanna, 2004; Hekkert, 2006; Wagemans, Elder, et al., 2012). Contrast was used in this way by Deng and Poole (2012) to create web pages high in perceived order. Lowering contrast can thus be used to make elements look more similar, whereas higher contrast emphasizes differences between elements that vary.

While there are many more design factors potentially able to influence unity and variety (Graham, 2008; Kim, 2006; Lauer and Pentak, 2012; Lidwell et al., 2010), those described above have been relatively well investigated in the scientific literature and were therefore used for the systematic design of web pages in our study.

2.1.3 Stimulus development

Based on the previously discussed literature, the design factors s*ymmetry* and *contrast* were chosen to manipulate unity while *colourfulness* and *dissimilarity in elements* were chosen to manipulate variety in web pages. Because the influence of design factors on aesthetic appreciation of web pages also depends on their realism, a trained designer was used for the development of the stimuli. The designer created four sets of nine web pages (3 levels of unity manipulations x 3 levels of variety manipulations) using Adobe Photoshop and Illustrator. To better generalize our findings and account for possible effects of website type on aesthetic appreciation (such as reported by De Angeli et al., 2006; Schenkman and Jönsson, 2000; van Schaik and Ling, 2009), two of these four sets were created in a commercial style (insurance theme) and the other two in a communicative style (festival theme) (Lee and Koubek, 2010).

For each style, one set was created by using the factors of *symmetry* (for unity) and *colourfulness* (for variety), and another one was created set by using *contrast* (for unity) and *dissimilarity in elements* (for variety). These combinations of factors were chosen as their implementation in the web pages was thought to isolate the unity and variety manipulations as much as possible. For example, changes in layout symmetry can be achieved without affecting the colour of the elements and vice versa (Jusczyk et al., 1999; Seckler et al., 2015). Similarly, changing the contrast of elements can be done without influencing the shape of such elements.

2.1.3.1 Symmetry X Colourfulness

Websites are often designed with hierarchical clusters or sections that identify individual elements such as menus, text fields, links, images or icons. Unity was therefore manipulated in a commercial and communicative set by disrupting vertical and horizontal symmetry through changing the position of clusters and the position of elements within those clusters. This resulted in low, medium and high levels of symmetry (Symmetry-1, Symmetry-2, and Symmetry-3, respectively). Variety was manipulated in both sets of web pages by changing the number of colours. When more colours were added to a web page, brightness and saturation were kept close to constant, as these are known to influence people's preferences as well (Lindgaard et al., 2011; Palmer and Schloss, 2010). In our low variety web pages (Colourfulness-1) only one colour was present besides the basic grey-scales. For medium (Colourfulness-2) to high variety (Colourfulness-3), additional colours were added and applied to more elements of the pages (Figure 11a and 11b).

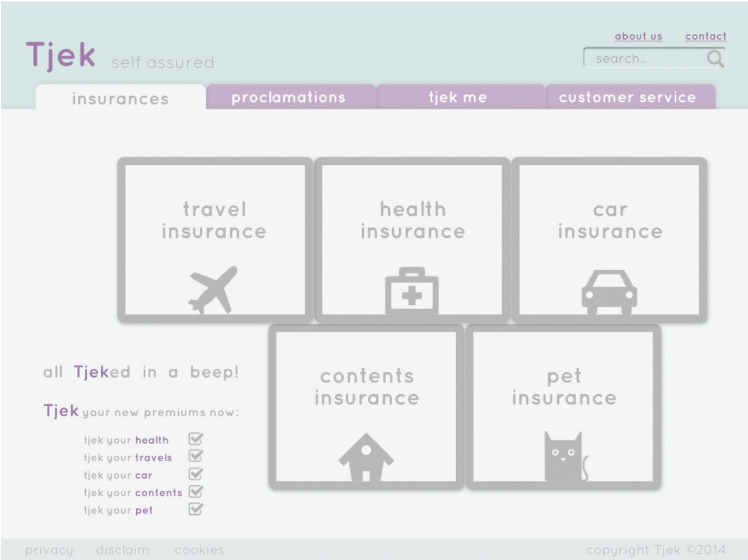
2.1.3.2 Contrast X Dissimilarity in elements

For a second communicative and commercial set of web pages, unity and variety were manipulated through contrast and dissimilarity in elements. For increasing levels of unity, more contrast was created between elements by increasing differences in luminance between foreground and background. This creates differences in contrast ratios (Fukuzumi et al., 1998). For example, the contrast ratio between the white background and black clusters in the commercial pages differed from 1.5:1 for low unity (Contrast-1), to 2:1 for medium (Contrast-2) and 9:1 for high unity (Contrast-3), as calculated using the HSV colour space (Hughes et al., 2013). Variety was manipulated through dissimilarity in elements by using different fonts and icon styles (e.g. regular vs. bold). For pages low in variety, dissimilarity in font type and icon styles was small (Dissimilarity-1), whereas the addition of new fonts and icon styles heightened dissimilarity for the medium (Dissimilarity-2) and high variety pages (Dissimilarity-3) (Figure 12a and 12b).

FIGURE 11A. TWO OF THE NINE STIMULI FROM THE COMMUNICATIVE SET: (ABOVE) SYMMETRY-1 X COLOURFULNESS-1 (BELOW) SYMMETRY-3 X COLOURFULNESS-3

FIGURE 11B. TWO OF THE NINE STIMULI FROM THE COMMERCIAL SET: (ABOVE) SYMMETRY-1 X COLOURFULNESS-1 (BELOW) SYMMETRY-3 X COLOURFULNESS-3

FIGURE 12A. TWO OF THE NINE STIMULI FROM THE COMMUNICATIVE SET: (ABOVE) CONTRAST-1 X DISSIMILARITY-1 (BELOW) CONTRAST-3 X DISSIMILARITY-3



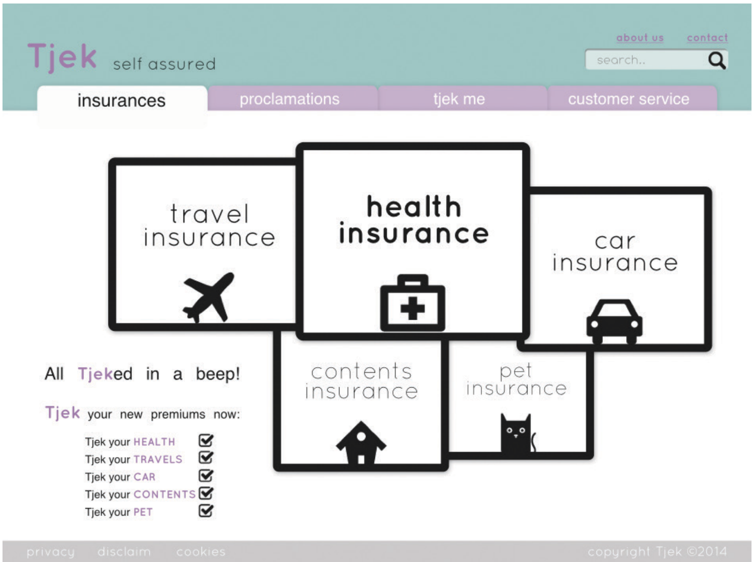


FIGURE 12B. TWO OF THE NINE STIMULI FROM THE COMMERCIAL SET: (ABOVE) CONTRAST-1 X DISSIMILARITY-1 (BELOW) CONTRAST-3 X DISSIMILARITY-3

2.1.4 Test 1: Assessing unity & variety manipulations

We performed a first study to investigate whether the chosen manipulations resulted in independent manipulations of unity and variety in the directions we expected. We hypothesized that for both styles, increasing symmetry or contrast heightens unity ratings and not variety ratings. And secondly, for both styles, increasing colourfulness and dissimilarity in elements heightens variety ratings and not unity ratings.

2.1.4.1 Participants

Visitors of two Dutch university libraries, all having completed secondary education, were approached to voluntarily participate in an online questionnaire. Of the participants who completed the questionnaire, 10 were removed due to consecutive scoring (i.e. rating '5' on all items), leaving a total of 85 participants (mean age = 24.9; SD = 4.9; 43 women).

2.1.4.2 Procedure

The four sets of web pages were administered in a between-subjects design. Groups of 20 to 25 participants were randomly assigned to one of four sets of nine web pages (presented in 948x710 resolution at 96DPI). They were informed that they would rate nine different versions of a web page on their visual appearance. At the start, all versions of the web page were shown in random order for a timed five seconds each to let participants briefly familiarize themselves with the web pages. Participants then filled in an online questionnaire and rated all nine pages, one at a time, on three items measuring unity, three items measuring variety, and two filler items (7-point scale, 1: strongly disagree; 7: strongly agree).[1] The unity and variety items were validated earlier by Blijlevens et al. (2014b) and also used to determine the workings of the UiV principle for different product categories (Post et al., 2016). For unity, these items were: 'This is a unified design', 'This is an orderly design', 'This is a coherent design'. For variety, these items were: 'This design is made of different parts', 'This design is rich in elements' and 'This design conveys variety'. All items and stimuli presentation orders were fully randomized and unity (Cronbach's α, all sets > .86) and variety (Cronbach's α, all sets > .73) items were averaged for further analyses.

[1] Filler items were: 'This is a typical homepage design' and 'This is a novel homepage design'.

2.1.5 Results

We now describe the four sets separately. After visual inspections of graphs of the ratings, we determined whether further statistical testing of our hypotheses was meaningful. The four sets are now discussed two by two, depending on the type of manipulation.

2.1.5.1 Contrast X Dissimilarity in elements

2.1.5.1.1 Communicative Set

Plotted mean unity and variety ratings revealed that unity and variety were both influenced by the degree of *contrast*, resulting in a strong linear relationship for the communicative set (Figure 13 and Table 1). The mutual positive effects of contrast on unity and variety can be explained by its ability to help discriminate elements in perception. Increasing contrast facilitates perceptual understanding and legibility because the structure and organization of the web pages becomes easier to perceive (O'Connor, 2013). On the other hand, the differences between elements in the website are also emphasized, lowering similarity and increasing variety. While the effect of contrast on unity was strong and in the intended direction, it did not independently influence unity as it also had a strong effect on variety. Furthermore, it dominated the effect of *dissimilarity in elements* that showed to have no influence on either unity or variety.

2.1.5.1.2 Commercial Set

Similar effects of *contrast* were found for the commercial set, as both unity and variety ratings increased with higher contrast (Figure 14 and Table 1). *Dissimilarity in elements* did increase variety ratings in this set, possibly because the effect of contrast was less salient. However, unity ratings simultaneously decreased with stronger dissimilarity in elements. While the altered fonts and icon styles created dissimilarity between them and heightens variety, they at the same reduced coherence of the overall web page to such a degree that unity diminished. The finding that dissimilarity in elements had relatively little influence on variety in the communicative set can be explained by the observation that this set contained more text and clusters than the commercial set, making the dissimilarity manipulations less apparent.

Although the manipulations did not result in independent effects on unity and variety, this was not entirely unexpected as impressions of unity and variety arise from shared properties of design. However, due to these strong simultaneous effects of contrast and dissimilarity on unity and variety, their appropriateness for independent manipulations becomes questionable.

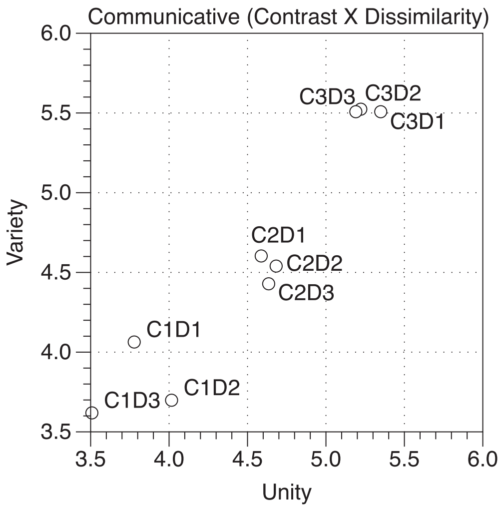


FIGURE 13. PLOTTED MEAN UNITY AND VARIETY RATINGS OF THE COMMUNICATIVE WEB PAGES MANIPULATED IN THREE LEVELS THROUGH RESPECTIVELY CONTRAST AND DISSIMILARITY IN ELEMENTS.

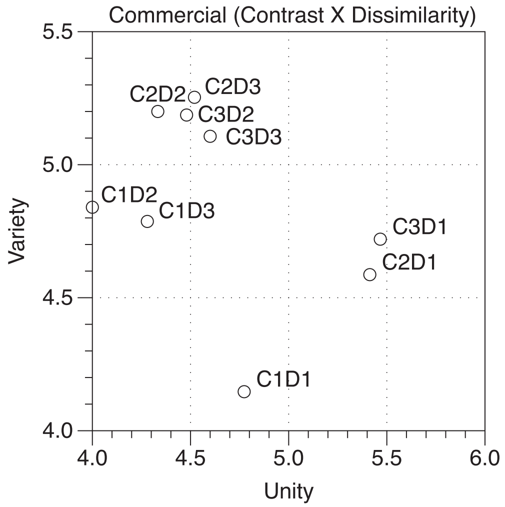


FIGURE 14. PLOTTED MEAN UNITY AND VARIETY RATINGS OF THE COMMERCIAL WEB PAGES MANIPULATED IN THREE LEVELS THROUGH RESPECTIVELY CONTRAST AND DISSIMILARITY IN ELEMENTS.

TABLE 1. MEAN AND STANDARD ERROR OF UNITY AND VARIETY RATINGS AVERAGED PER MANIPULATED LEVEL OF CONTRAST AND DISSIMILARITY IN ELEMENTS FOR BOTH SETS OF WEB PAGES.

	Communicative		Commercial	
	Unity M (SE)	Variety M (SE)	Unity M (SE)	Variety M (SE)
Contrast-1	3.8 (.15)	3.8 (.15)	4.4 (.17)	4.6 (.15)
Contrast-2	4.6 (.12)	4.5 (.12)	4.7 (.14)	5.0 (.14)
Contrast-3	5.3 (.12)	5.5 (.08)	4.9 (.15)	5.1 (.13)
Dissimilarity-1	4.6 (.16)	4.7 (.15)	5.2 (.13)	4.5 (.15)
Dissimilarity-2	4.6 (.13)	4.6 (.15)	4.3 (.17)	5.1 (.14)
Dissimilarity-3	4.5 (.16)	4.5 (.17)	4.5 (.15)	5.1 (.14)

2.1.5.2 Symmetry X Colourfulness

2.1.5.2.1 Communicative Set

Visual inspection of the plotted mean unity and variety ratings in the communicative set showed clear differences in the intended directions (Figure 15 and Table 2). Higher symmetry increased unity ratings, while variety ratings stayed the same. At the same time, adding colour steadily increased variety ratings, while keeping unity constant. Closer inspection showed that unity and variety ratings per web page stayed within their respective manipulation level. This meant that for unity ratings, all web pages designed to be low in unity (Symmetry-1) received lower mean unity ratings than web pages with medium symmetry (Symmetry-2), while mean unity ratings for medium symmetry pages were lower than for high symmetry (Symmetry-3). The same applied to the variety ratings when looking at the colour manipulations (for mean variety ratings, all Colourfulness-1 < Colourfulness-2, and all Colourfulness-2 < Colourfulness-3). Given this positive first inspection, we performed additional statistical analyses to accurately assess independence of the manipulations.

To statistically test whether unity and variety were independently manipulated through symmetry and colourfulness, we performed a series of linear mixed-effects analyses with REML estimation. Linear mixed model analyses are a relatively new and flexible approach to analysing repeated-measures designs. Distinct advantages are that it is robust against violations of homoscedasticity and sphericity, it can take sampling hierarchy into account, it can handle incomplete data and it has higher power in hypothesis testing than repeated-measures ANOVA (Quené and Van den Bergh, 2004). The analyses were performed by adding the three manipulated levels of symmetry and colourfulness as two factors predicting either unity or variety ratings. The model included fixed-effects for symmetry and colourfulness. Random intercepts were included for subjects to account for baseline differences in unity and variety ratings, which increases the sensitivity of the test (Barr et al., 2013).

Results of the first model revealed that symmetry significantly predicted unity ratings ($F_{(2, 132)} = 20.14$, $p < .001$), while colourfulness did not ($F_{(2, 132)} = 2.00$, $p = .14$). Bonferroni corrected pairwise comparisons of the different levels of symmetry revealed that level 3 symmetry was rated significantly higher in unity than level 2 ($p = .003$) and level 1 ($p < .001$), and symmetry level 2 was also rated higher in unity than level 1 ($p = .010$).

The second model showed that colourfulness significantly predicted variety ratings ($F_{(2, 132)} = 22.40$, $p < .001$), whereas symmetry did not ($F_{(2, 132)} = .604$, $p = .55$). Bonferroni corrected pairwise comparisons of the different levels of colourfulness revealed that level 3 colourfulness was rated significantly higher in variety than level 2 ($p = .003$) and level 1 ($p < .001$), and colourfulness level 2 was also rated higher in variety than level 1 (p = .003). Based on the analyses, we can conclude that for the communicative set, symmetry independently and positively influenced unity, while colourfulness independently and positively influenced variety.

2.1.5.2.2 Commercial Set

In line with our expectations, the commercial set showed symmetry to generally increase mean unity ratings (Figure 16 and Table 2). However, the mean unity rating for symmetry level 2 was slightly higher than for level 3. At the same time, symmetry did not affect variety ratings, indicating that symmetry generally had the intended isolated effect. Similar results were found for colourfulness. High colourfulness increased variety ratings, while unity ratings stayed stable. Overall, this set thus showed unity and variety manipulations to have an effect in the directions we intended, except for a lack in unity differences between level 2 and level 3 symmetry (respectively, 5.2 – 5.1). We therefore decided to adjust the commercial set and validate it in a second test.

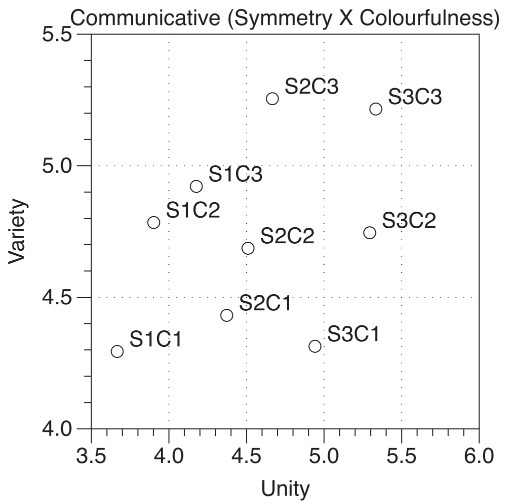


FIGURE 15. PLOTTED MEAN UNITY AND VARIETY RATINGS OF THE COMMUNICATIVE WEB PAGES MANIPULATED IN THREE LEVELS THROUGH RESPECTIVELY SYMMETRY AND COLOURFULNESS.

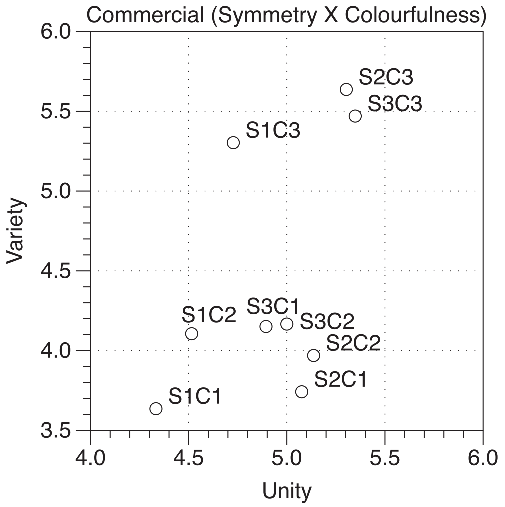


FIGURE 16. PLOTTED MEAN UNITY AND VARIETY RATINGS OF THE COMMERCIAL WEB PAGES MANIPULATED IN THREE LEVELS THROUGH RESPECTIVELY SYMMETRY AND COLOURFULNESS.

TABLE 2. MEAN AND STANDARD ERROR OF UNITY AND VARIETY RATINGS AVERAGED PER MANIPULATED LEVEL OF SYMMETRY AND COLOURFULNESS FOR BOTH WEB PAGES.

	Communicative		Commercial	
	Unity M (SE)	Variety M (SE)	Unity M (SE)	Variety M (SE)
Symmetry-1	3.9 (.20)	4.7 (.14)	4.5 (.15)	4.4 (.18)
Symmetry-2	4.5 (.16)	4.8 (.15)	5.2 (.12)	4.5 (.17)
Symmetry-3	5.2 (.16)	4.8 (.16)	5.1 (.14)	4.6 (.16)
Colourfulness-1	4.4 (.21)	4.3 (.16)	4.8 (.15)	3.8 (.16)
Colourfulness-2	4.6 (.19)	4.7 (.14)	4.9 (.14)	4.1 (.15)
Colourfulness-3	4.7 (.17)	5.1 (.13)	5.1 (.13)	5.5 (.12)

2.1.6 TEST 2

We performed a second study using a redesigned set of the commercial web pages to assess the improved manipulations. Identical to the previously validated communicative set of web pages, we hypothesized that increases in symmetry heighten unity ratings and not variety ratings. And secondly, increasing colourfulness heightens variety ratings and not unity ratings.

2.1.6.1 Participants

Visitors of a Dutch university library, all having completed secondary education, were approached to participate in an online questionnaire. Twenty-three participants completed the questionnaire and two were removed for clear consecutive scoring on all items (e.g., all 5's). The remaining participants were used for further analyses (mean age = 30.8, SD = 4.0, 10 women).

2.1.6.2 Stimuli

The unity ratings of the level 2 and level 3 symmetry pages of the commercial set largely overlapped (Table 2). We therefore removed the level 2 symmetry pages. To complete the set and create a larger spread in ratings than before, we designed three new pages lower in symmetry by distorting horizontal and vertical symmetry of elements more strongly (Figure 17).

2.1.6.3 Procedure

The procedure of this study was identical to the previous test. The unity and variety items were averaged for further analyses (Cronbach's $\alpha_{unity} = .95$; Cronbach's $\alpha_{variety} = .77$).

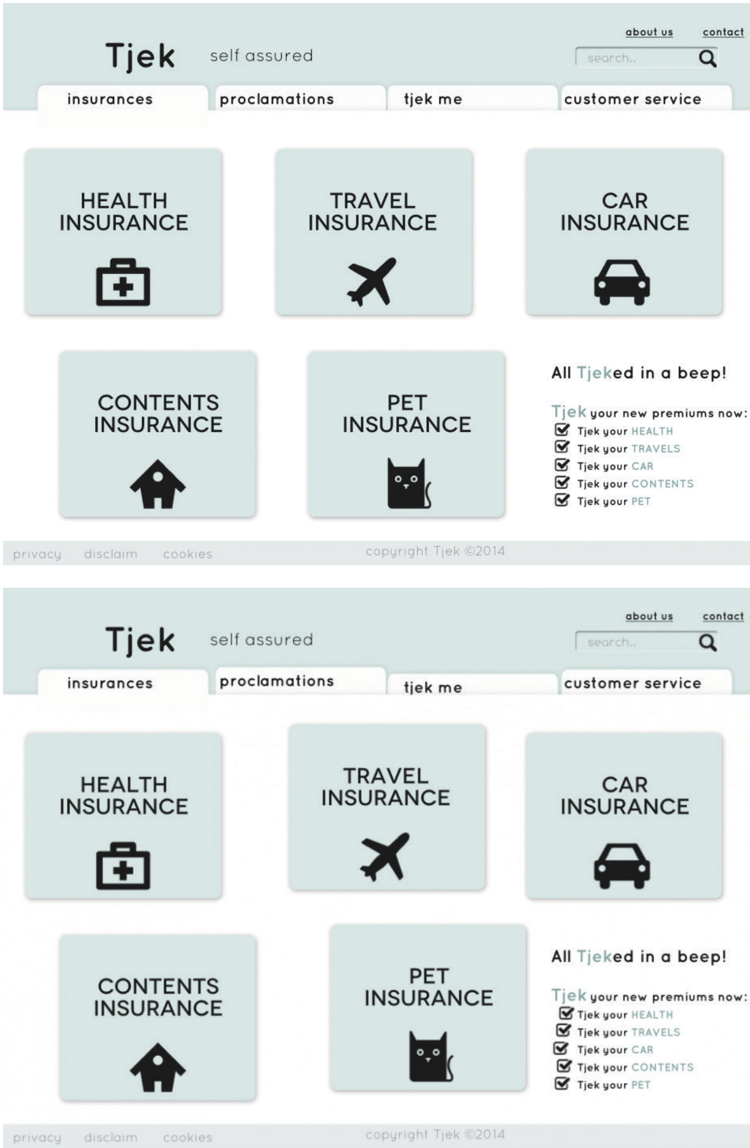


FIGURE 17. COMPARISON OF THE ORIGINAL (ABOVE) AND REDESIGNED (BELOW) SYMMETRY-1 X COLOURFULNESS-1 WEB PAGES.

2.1.7 Results

Visual inspection of the redesigned commercial set showed a clear distinction in unity and variety ratings as a result of changes to the symmetry and number of colours (Figure 18). Higher symmetry primarily resulted in increasing unity ratings, whereas more colours mainly increased variety ratings. Furthermore, mean unity and variety ratings for each web page stayed within the intended manipulation level (Table 3; e.g. for unity ratings, all Symmetry-1 < Symmetry-2, and all Symmetry-2 < Symmetry-3. For variety ratings, all Colourfulness-1 < Colourfulness-2, and all Colourfulness-2 < Colourfulness-3). We performed two linear mixed model analyses, identical to those in the previous pre-test, to statistically assess the effects of our manipulations.

For the first model, symmetry significantly predicted unity ratings ($F_{(2, 164)}$ = 46.27, $p < .001$), while colour did not ($F_{(2, 164)}$ = .40, $p = .67$). Bonferroni corrected pairwise comparisons of the different levels of symmetry revealed that symmetry level 3 was rated significantly higher in unity than level 2 ($p = .005$) and level 1 ($p < .001$), and symmetry level 2 was also rated higher in unity than level 1 ($p < .001$).

For the second model, colourfulness significantly predicted variety ratings ($F_{(2, 164)}$ = 59.64, $p < .001$), while symmetry did not ($F_{(2, 164)}$ = 2.20, $p = .125$). Bonferroni corrected pairwise comparisons of the different levels of colourfulness revealed that colourfulness level 3 was rated significantly higher in variety than level 2 ($p < .001$) and level 1 ($p < .001$), and colourfulness level 2 was also rated higher in variety than level 1 ($p = .003$).

Similar to the communicative set of web pages, symmetry now independently and positively influenced unity, while colourfulness independently and positively influenced variety.

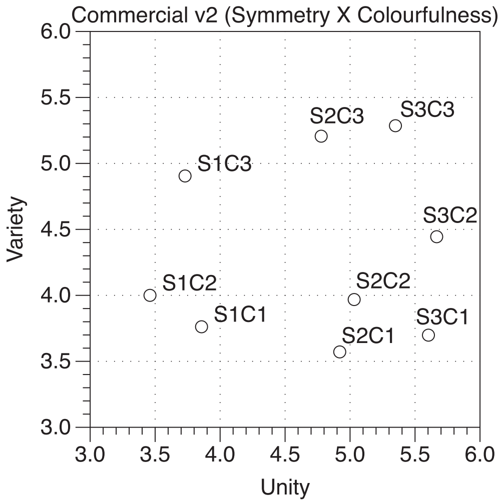


FIGURE 18. PLOTTED UNITY AND VARIETY RATINGS FOR THE REDESIGNED COMMERCIAL SET MANIPULATED IN THREE LEVELS THROUGH RESPECTIVELY SYMMETRY AND COLOURFULNESS.

TABLE 3. MEAN AND STANDARD ERROR OF UNITY AND VARIETY RATINGS AVERAGED PER MANIPULATED LEVEL OF SYMMETRY AND COLOURFULNESS FOR THE REDESIGNED COMMERCIAL SET.

	Unity M (SE)	Variety M (SE)
Symmetry-1	3.7 (.22)	4.2 (.16)
Symmetry-2	4.9 (.16)	4.3 (.18)
Symmetry-3	5.5 (.11)	4.5 (.16)
Colourfulness-1	4.8 (.19)	3.7 (.15)
Colourfulness-2	4.7 (.21)	4.2 (.14)
Colourfulness-3	4.6 (.20)	5.1 (.14)

2.1.8 Discussion

The first study resulted in the development and validation of two sets of web pages, with different content styles, that systematically and independently differ on unity and variety. Unity was manipulated through symmetry, whereas variety was manipulated through colourfulness. The two sets of stimuli allow us to isolate the effects of unity and variety on aesthetic appreciation in the next study.

2.2 Study 2

The principle of UiV entails that unity and variety independently and positively contribute to aesthetic appreciation, and increasing the two ultimately leads to an optimal balance where aesthetic appreciation is highest. We tested these two hypotheses in the upcoming study using the two validated sets of websites from the previous study.

2.2.1 Method

2.2.1.1 Participants

Members of a Dutch consumer panel, all having completed secondary education, were approached to fill in an online questionnaire on the visual appearance of web page designs. A total of 49 participants rated the communicative set and 60 rated the commercial set. Due to consecutive scoring on all items (e.g. all 5's) six participants were removed for the communicative set and three participants were removed for the commercial set. The remaining 43 participants for the communicative set (mean age = 29.5, SD = 4.4, 23 women) and 57 participants for the commercial set (mean age = 31.6, SD = 5.2, 34 women) were used for further analyses.

2.2.1.2 Procedure

The same between-subjects procedure was used as in the previous study with one group rating the web pages in a communicative style, and another group rating the web pages in a commercial style. Participants were asked to rate aesthetic appreciation using three items (7-point scale, 1: strongly disagree; 7: strongly agree): 'This is a beautiful homepage design', 'This is an attractive homepage design' and 'I like the design of this homepage'. The aesthetic appreciation items were averaged for analyses (Cronbach's $\alpha_{communicative} = .92$; $\alpha_{commercial} = .96$). Two additional filler items were included.[1] All items were validated in a cross-cultural study on product design aesthetics by Blijlevens et al. (2014b). We included a question concerning the realism of the web pages at the end of the questionnaire (10-point scale, 1: not realistic at all; 10: very realistic): 'Based on their visual appearance, how realistic did these web pages look to you?' Both sets were deemed sufficiently realistic (Communicative: Mean = 7.7, SD = 1.9; Commercial: Mean = 6.8, SD = 2.0).

2.2.2 Results

2.2.2.1 Separate effects of unity and variety

To test our hypotheses, we performed two linear mixed model analyses per website style. The first analysis aimed to assess whether unity and variety independently and positively influence aesthetic appreciation of web pages of both styles. Linear mixed-effects models using REML estimation were calculated on non-aggregated data. The model included level of unity manipulation and level of variety manipulation as fixed-effect factors predicting aesthetic appreciation, and by-participant random intercepts to allow for baseline differences in unity and variety scores.

2.2.2.1.1 Communicative set

The analysis confirmed our first hypothesis that both unity ($F_{(2, 340)} = 3.780$, $p = .024$) and variety ($F_{(2, 340)} = 21.179$, $p < .001$), significantly and positively predict aesthetic appreciation ratings in the communicative set. The parameter estimates revealed that variety affected mean aesthetic appreciation ratings to a larger degree than unity, as the

[1] Filler items were: 'This is a typical homepage design' and 'This is a novel homepage design'.

estimated mean difference in aesthetic appreciation ratings between low and high manipulations was approximately two times larger for variety than unity (Table 4).

TABLE 4. FIXED-EFFECTS PARAMETER ESTIMATES OF MEAN AESTHETIC APPRECIATION RATINGS FOR MANIPULATED LEVELS OF UNITY AND VARIETY IN THE COMMUNICATIVE SET.

	β	SE	t	*p*
Unity Low	-.25	.09	-2.68	.008
Unity Medium	-.17	.09	-1.86	.063
Unity High	.	.	.	.
Variety Low	-.58	.09	-6.33	< .001
Variety Medium	-.41	.09	-4.49	< .001
Variety High	.	.	.	.

Note: Negative values of the estimates indicate that mean Aesthetic Appreciation of the respective level is lower than the 'High' reference category.

2.2.2.1.2 Commercial set

In line with the previous set, analysis of the commercial set also confirmed our first hypothesis that unity ($F_{(2, 452)}$ = 6.393, p = .002) and variety ($F_{(2, 452)}$ = 73.080 p < .001), significantly and positively predict aesthetic appreciation ratings. Also similar to the communicative set, differences in mean aesthetic appreciation ratings between low and high manipulations were stronger for variety than for unity (Table 5).

TABLE 5. FIXED-EFFECTS PARAMETER ESTIMATES OF MEAN AESTHETIC APPRECIATION RATINGS FOR MANIPULATED LEVELS OF UNITY AND VARIETY IN THE COMMERCIAL SET.

	β	SE	t	*p*
Unity Low	-.40	.11	-3.55	< .001
Unity Medium	-.16	.11	-1.39	.165
Unity High	.	.	.	.
Variety Low	-1.32	.11	-11.76	< .001
Variety Medium	-.93	.11	-8.31	< .001
Variety High	.	.	.	.

Note: Negative values of the estimates indicate that mean Aesthetic Appreciation of the respective level is lower than the 'High' reference category

These findings thus confirmed that unity and variety independently and positively influence aesthetic appreciation of both sets of web pages. Finding support for this does however not automatically imply that web pages combining both are aesthetically preferred. For example, it is possible that some web pages were mainly appreciated for their unity and not for their variety, whereas other pages were appreciated for their variety and not for their unity. To confirm our second hypothesis that it is the combination of unity and variety that leads to the highest aesthetic appreciation, it is necessary to combine both effects.

2.2.2.2 Combined effects of unity and variety

We grouped together web pages with comparable combined unity and variety levels based on Study 1 (e.g., Symmetry-1/Colourfulness-2 and Symmetry-2/Colourfulness-1) to create a variable with five levels representing web pages with increasing unity and variety (Table 6).

TABLE 6. CODING OF THE COMBINED LEVELS OF UNITY AND VARIETY ACCORDING TO PRE-TESTED WEB PAGES.

High Variety	3	4	5
Medium Variety	2	3	4
Low Variety	1	2	3
	Low Unity	Medium Unity	High Unity

A second linear mixed-effects analysis was performed for each style of web pages to determine whether web pages combining increasing levels of unity and variety are aesthetically appreciated the most. A model was built with combined levels of unity and variety as a fixed-effects factor predicting aesthetic appreciation and random intercepts for the subjects.

2.2.2.2.1 Communicative Set

In line with our prediction, the resulting analysis for the communicative set showed that the combined effects of unity and variety significantly predicted aesthetic appreciation ($F_{(4, 340)} = 10.663$, $p < .001$). Estimates of the parameter coefficients revealed that mean aesthetic appreciation increased for higher combinations of unity and variety, and that the highest level of combined unity and variety was significantly higher than any of the lower combinations (Table 7).

TABLE 7. FIXED-EFFECTS PARAMETER ESTIMATES OF THE MEAN AESTHETIC APPRECIATION RATINGS FOR THE COMBINED UNITY AND VARIETY LEVELS IN THE COMMUNICATIVE SET.

	β	SE	t	*p*
UiV Level-1	-.83	.16	-5.09	< .001
UiV Level-2	-.77	.14	-5.54	< .001
UiV Level-3	-.45	.13	-3.44	.001
UiV Level-4	-.35	.14	-2.49	.013
UiV Level-5	.	.	.	.

2.2.2.2.2 Commercial set

Identical to the previous results, combined levels of unity and variety for the commercial set significantly predicted aesthetic appreciation ($F_{(4, 452)} = 28.361$, $p < .001$). Inspection of the parameter estimates showed similar results to the previous set of web pages. Mean aesthetic appreciation increased for higher combinations of unity and variety and the highest combination of unity and variety was significantly higher than any other combination (Table 8). For both sets of web pages, the analyses confirmed our second hypothesis that web pages combining unity and variety are aesthetically appreciated the most.

TABLE 8. FIXED-EFFECTS PARAMETER ESTIMATES OF THE MEAN AESTHETIC APPRECIATION RATINGS FOR THE COMBINED UNITY AND VARIETY LEVELS IN THE COMMERCIAL SET.

	β	SE	t	*p*
UiV Level-1	-1.68	.20	-8.35	< .001
UiV Level-2	-1.56	.18	-8.94	< .001
UiV Level-3	-1.02	.17	-6.18	< .001
UiV Level-4	-.67	.18	-3.85	< .001
UiV Level-5	.	.	.	.

2.2.3 Discussion

This study investigated the influence of unity and variety on aesthetic appreciation of web pages with two different content styles. In line with our hypotheses, the results show that for both styles, unity and variety positively influence aesthetic appreciation of web pages and their combination leads to the highest aesthetic appreciation. As a result, web pages that optimize both unity and variety are aesthetically preferred.

Inspection of the relative unity and variety contributions revealed that variety influenced aesthetic appreciation to a larger extent (two to three times) than unity. Variety was manipulated through colour, a highly salient design property (Lindgaard, 2007), whereas unity was manipulated through symmetry. A comprehensive study on web page aesthetics by Moshagen and Thielsch (2010) showed that colourfulness was judged as more important by participants than symmetry. However, a recent study by Douneva et al. (2015) did not find an effect of colourfulness on web interface aesthetics. In line with these authors, we argue that the strength of the manipulations themselves is likely the most important reason underlying their relative contributions. Colour possibly offers a greater range of manipulation than symmetry without resulting in unrealistic stimuli, especially considering that a lack of variety is not necessarily catastrophic for a product's appreciation. However, a lack of unity results in complete disorder and risks preventing appreciation altogether. In line with this, our designer was instructed to prevent breaking symmetry to such a degree that the layout of web pages would become completely unbalanced (Chang et al., 2002). The overall layout of the designs might therefore still have been considered fairly balanced, suppressing the overall effect of unity.

2.3 General discussion and conclusion

This research aimed to assess whether aesthetic appreciation of web pages can be explained by the principle of UiV. Both unity and variety, independently manipulated through respectively *symmetry* and *colourfulness*, positively contributed to aesthetic appreciation of two sets of web pages that differed in content style (communicative versus commercial). As a result, web pages are aesthetically appreciated the most when both unity and variety are increased to reach an optimal balance. Our research demonstrates the importance of UiV in explaining aesthetic appreciation of web pages and shows how our impressions of interface aesthetics arises from the perception of basic factors of visual design. We thereby further strengthen evidence for the UiV principle as a reliable and robust means to study and design beautiful product designs and we extend its applicability to the field of interface design.

Many design factors that have been studied, both in and outside the field of HCI, can be considered as influencing the UiV principle in one way or another (Kim, 2006). Our first studies showed that symmetry, contrast, dissimilarity in elements and colourfulness indeed do so. Symmetry and colourfulness were found to be important means to purposefully and selectively achieve a desired balance between unity and variety and, despite relatively minor changes, were shown to influence aesthetic appreciation to quite a degree (aesthetic appreciation ratings ranged from 3.2 to 5.0 in the commercial set). We thereby show how aesthetic appreciation is dependent on an optimal balance between unity and variety, and demonstrate that the basic building blocks of visual design underlie these two opposing dimensions.

Besides these contributions, our study also adds to the understanding of why we appreciate websites in the first place. The principle of UiV argues that there is an optimal balance in sensory processing that we aesthetically prefer. When potentially new information (variety) can be perceptually processed in a coherent and meaningful way (unity), such an optimal balance is struck. This balance leads to highly efficient processing of information and simultaneously stimulates our senses. From this information processing perspective, the principle can additionally inform us why beautiful interfaces are also more usable (Tractinsky et al., 2000). Web pages conforming to UiV are likely more efficiently processed, making it easier for users to perform tasks through them. Future research could also look into the ability of UiV to explain the usability of HCI systems.

Lastly, our aim was to use stimuli that are realistic and generalize to modern web sites. Therefore, a trained designer was instructed to make the manipulations of unity and variety in newly build web pages similar to those found in modern websites. This approach follows that of a designer's natural methodology, closing the gap between scientific research and design practice. The knowledge generated through this research can therefore be translated more easily into the field of interface design and many other creative domains, giving designers tools through which they can create more beautiful. As a general guideline, beauty resides in balancing opposites in such a way that they can coexist.

2.3.1 Limitations and future directions

In this research we have shown that *symmetry* and *colour* can be used to independently influence the degree of unity and variety in web pages. While we also manipulated unity through *contrast* and variety through *dissimilarity in elements* in pre-tests, both design factors mostly influenced unity and variety simultaneously. Particularly in the commercially styled set, increasing contrast resulted in more unified and at the same time varied web pages. While contrast was therefore not considered a suitable factor for independent manipulations of unity, the test does suggest that it is an important means to maximize unity and variety. Since the principle of UiV holds that optimizing both unity and variety leads to the highest aesthetic appreciation, this design factor warrants further research.

The influence of *dissimilarity in elements* varied between both sets of web pages. In the commercial set its effect was relatively small, as it was mostly the changes in contrast that dominated impressions of unity and variety. In the communicative set, more dissimilarity in elements led to a decrease in unity and an increase of variety at the same time. This does not mean that dissimilarity in elements plays no useful role in influencing unity and variety, only that their effect is more difficult to systematically control. However, future studies could attempt to find alternative ways to implement the changes to the web pages or apply finer changes to the texts and icons.

Besides the UiV principle, there are other design principles that can be studied in parallel. Impressions of unity and variety are directly attributable to the organization of the most basic elements and properties that can be identified in web pages. As such, judging the degree of unity and variety is likely a relatively low-level perceptual process (Veryzer and Hutchinson, 1998). There are however also design principles that may explain aesthetic appreciation through different properties of web pages. Such is, for example, the MAYA principle. It states that product designs maximizing both typicality and novelty are aesthetically preferred (Hekkert et al., 2003). The typicality of a product refers to the degree to which a product is considered comparable with the prototype of its category and has been shown to also positively attribute to the aesthetic appreciation of web pages (Tuch, Presslaber, et al., 2012). Novelty on the other hand, refers to the originality of a design and is another design dimension contributing to the aesthetic appreciation of web pages (Zeng et al., 2009). Their joined influence on web pages has not yet been researched. Additionally, it may be possible to control for more than two design dimensions if they can be separated enough in their effect. UiV and

MAYA may offer such a combination as their impressions arise from different design properties.

Participants in our study viewed web pages for several seconds. Various studies have looked at the viewing time needed to form an aesthetic judgment of websites and have found as little as 50ms to generate consistent results (Lindgaard et al., 2006; Tractinsky et al., 2006). The previous assertion, that judgments of unity and variety are largely based on low-level perceptual processes, could be further investigated in this regard. We would expect unity and variety ratings to be reliably assessed with short viewing times. However, because a website is likely to lose some of its interest after a while, the relative contribution of variety would be expected to increase over time.

Lastly, we studied the influence of unity and variety for web pages in which no interaction with the page itself was possible. Miniukovich and Angeli (2015) recently studied the influence of diversity on aesthetic appreciation using live graphical user interfaces. The authors found visual diversity to positively contribute to website quality, as measured by its aesthetic properties. As the authors noted, interactive websites have higher ecological validity than static web pages and it would be therefore be relevant to investigate if UiV sustains as an aesthetic principle in more dynamic settings. While controlling possible confounding factors becomes more problematic in highly interactive systems, the successful identification of design principles coupled with skilled interaction designers can further progress this quickly growing field of interest.

3 Tactile Unity-in-Variety systematically manipulated

You mean by understanding that you can talk about it in the way that
you have a habit of talking, putting it in other words. But I mean by
understanding enjoyment.
If you enjoy it, you understand it.
-
Gertrude Stein, from an interview on her work as an artist (1934)

This chapter has been submitted for publication as: Post, R.A.G., Blijlevens, J., Saakes, D., & Hekkert, P. Unity-in-Variety as an aesthetic principle accounting for the tactile appreciation of artefacts.

There is something enjoyable about playing around with a key in your pocket. You explore its material, its shape and position of parts, and the way in which all of this is organized into a single object. Although you could take the key out of your pocket and just look at it, there is pleasure in discovering the properties by touch alone. Hence, we argue that tactile aesthetic appreciation of artefacts results from perceiving how a variety of shape and material properties is organized to form a unified coherent whole: tactile aesthetic appreciation is maximized when there is an optimum balance between the tactile experience of the seemingly opposing dimensions of unity and variety.

The tactile modality is adept at recognizing objects by touch alone (Klatzky et al., 1985). Active hand exploration enables shape and material identification, as well as temperature, weight and hardness estimation, which are difficult or impossible to directly assess using other senses (Lederman and Klatzky, 2009). The ability to actively extract such information helps people to form a unitary perception of objects in our environment and facilitates perceptual understanding (Gibson, 1962).

From an evolutionary perspective, the importance of perceptual understanding for our development and survival cannot be overstated. The ability to group and separate objects in our perception helps to identify threats or opportunities in the environment, and the brain has therefore evolved to generate pleasurable sensations from recognizing aspects that facilitate perceptual understanding (Johnston, 2003; Ramachandran and Hirstein, 1999). Although the environmental threats and benefits that have helped shape these brain mechanisms are different from those in present times (e.g. detecting a camouflaged dangerous animal while reaching for ripe fruit hidden under bushes), the resultant mechanisms are deeply rooted in our brain and still generate pleasure from perceptual understanding to this day (Biederman and Vessel, 2006). This pleasure is the origin of our aesthetic appreciation of artefacts (Hekkert, 2014).

A well-recognized aesthetic principle explaining aesthetic appreciation from the perspective of perceptual understanding is Unity-in-Variety (UiV). This principle states that people appreciate the perception of variety if it is ordered and structured such that they experience it as a unified whole (Fechner, 1876). The perception of variety is enjoyable because it challenges our perceptual capacities and offers the prospect of learning information and potentially discovering new relationships (Berlyne, 1971).

However, for this information to be successfully apprehended, and to aid discovering new relationships in the presented information, it needs to be ordered and structured to facilitate fluent processing and allow the perceptual challenge to be successfully met (Armstrong and Detweiler-Bedell, 2008; Reber et al., 2004). Such unification is facilitated by the Gestalt laws of perceptual grouping (Wagemans, Feldman, et al., 2012). Empirical evidence for the workings of UiV comes from studies by Post et al. (2016); these show that a combination of unity and variety—despite being partial opposites—positively contributes to the visual aesthetic appreciation of a wide range of artefacts.

Unity-in-Variety is one of several aesthetic principles studied for visual aesthetics; a modality that is relatively well understood (Berlyne, 1971; Hekkert, 2006; Leder et al., 2004). However, touch is the second most important sensory modality for pleasurable experiences with products, and which even becomes the dominant one during usage (Fenko et al., 2010). In response, previous research has identified roughness (also shown to be the inverse of smoothness) and hardness as factors influencing pleasurable tactile experiences (Ekman et al., 1965; Essick et al., 1999; Hilsenrat and Reiner, 2011; Verrillo et al., 1999). These studies have generally been performed with simple objects or materials (e.g. sandpaper, cloth, brushes) using passive touch (i.e. sandpaper rubbed against someone's skin rather than exploring the object freely). While such individual features undoubtedly play a role in forming our aesthetic evaluations, there is still much to be learned in how we use active touch to integrate multiple features into the whole impression of an object (Gallace and Spence, 2011a; Sonneveld and Schifferstein, 2008). We believe UiV can offer such an understanding, and we argue that the principle's workings are based on mechanisms of holistic perceptual understanding that are similar to those in the visual modality.

There is substantial evidence for shared perceptual organization mechanisms and neural substrates between vision and touch, and possibly the other senses (Gallace and Spence, 2008; Lacey and Sathian, 2014). While a detailed description is outside the scope of this paper, amodal probabilistic inference processes are considered as a possible mechanism explaining how our brain perceptually groups elements within and between the senses (Fiser, 2009). Very simply put, a probabilistic inference process is a statistical model explaining how elements are linked together into single units as a result of their likelihood of co-occurrence. Evidence for our ability to unify visual shapes, sounds and tactile patterns in terms of probabilistic inference processes suggests that these unitization mechanisms are shared between the senses (Conway and Christiansen, 2005). Such unitization processes are thought to already occur in infants and are argued to help form sensitivity for the Gestalt laws (Bhatt and Quinn, 2011; Wagemans, Feldman, et al., 2012). In light of this, it is timely that many of the Gestalt laws have recently been suggested as grouping elements in tactile perception as well (Gallace and Spence, 2011b). Based on these commonalities between vision and touch, and the importance of Gestalt laws in creating unity within variety as shown in the visual modality, we claim that UiV can also explain tactile aesthetic appreciation.

This research is the first to empirically investigate the principle of UiV for the tactile modality. In the first of two studies using designed products, we aim to find general support for the hypothesis that despite tactile unity and variety being negatively correlated because they are partially each other's perceptual opposites, together they positively attribute to tactile aesthetic appreciation. In the second study, we aim to replicate our findings and strengthen our claims by running an experiment using 3-D printed stimuli, closely resembling everyday objects, which are systematically manipulated in tactile unity and variety using Gestalt principles of tactile grouping.

3.1 Study 1

3.1.1 Method

3.1.1.1 Participants

We performed an a priori power analysis that determined that a sample size of 25 participants gives a power of approximately 80% to detect a large effect ($f^2 \approx 0.35$)[1] for an $\alpha_{\text{one-tailed}}$ of .05 (Faul et al., 2007). Thirty international students from a Dutch university were accordingly invited to voluntarily participate in the study as part of a course. They were informed that they would rate nine products on their tactile appearance. Four participants of the invited 30 did not attend the experiment. Responses from the

[1] Previous studies have shown large effect sizes for unity and variety in explaining visual aesthetic appreciation (Post et al., 2016).

remaining 26 participants (Mean age = 21.5, SD = 1.4, 6 females) were recorded over the course of one week, generating 234 data points.

3.1.1.2 Stimuli

Tactile exploration of a surface is done in a combination of six to eight actions (Lederman and Klatzky, 2009). By using a variety of hand movements, properties such as texture, hardness, elasticity, thermal conductance, weight, and global and exact form can be identified. Car key remotes ('remotes' from now on) were used, as all these tactile properties could be perceived in the stimuli, allowing for a complete assessment of unity and variety. For example, their size allows for fully enclosing the product with one hand, making it possible to assess the global form. The presence of buttons and component spacing requires identification of the exact form. The weight of remotes is in a range where participants can make reliable comparisons between stimuli (17–59 grams). Furthermore, a variety of materials are commonly used in remotes (e.g. plastic, rubber, metal), thereby taking into account differences in material properties such as texture, hardness and heat conductance.

Two design experts were instructed to reduce a set of twenty remotes to nine while retaining as much spread as possible on the tactile aspects of unity and variety (Figure 19). All remotes were duplicates of originals and came from the same supplier (WVO Trading BV, Nunspeet, Netherlands). Because no electronics were present in the duplicates, weights were glued on the inside to increase rigidity and realism. Buttons on the remotes were also glued into a fixed position to prevent a possible interaction experience itself having an effect on the tactile aesthetic appreciation ratings.

FIGURE 19. EXAMPLE OF TWO STIMULI USED IN THE STUDY.

3.1.1.3 Procedure

In a laboratory setting, participants were seated in front of a table with nine adjacent trays, each containing one remote. A large cloth was suspended in the air so as to prevent participants from seeing the remotes, yet enabling them to tactually explore the remotes without the cloth touching their hands. Participants were informed that they were to rate remotes where the functionality had been disabled. Instructions explicitly specified rating the tactile appearance of the products and not the expected functionalities or the differences in the physical quality of their construction. An initial familiarization round allowed participants to tactually explore all the remotes before the ratings round started. Participants rated all nine remotes on 7-point Likert scales (1: fully disagree, to 7: fully agree) measuring tactile unity, tactile variety and tactile aesthetic appreciation. The items were adaptations (to pertain to the experience of touch) of those used in research by Post et al. (2016), which measured the same factors in the visual modality. Unity was measured using the items: '*This design feels unified*', '*This design feels orderly*' and '*This design feels coherent*' (Cronbach's α = .84). Variety was measured using the items: '*This design conveys variety*', '*This design is made of different parts*' and '*This design is rich in elements*' (Cronbach's α = .68). Aesthetic appreciation was measured using the items: '*This product is attractive to touch*', '*This product is pleasing to touch*' and '*I like touching this product*' (Cronbach's α = .92). Both the item order and stimuli order were fully randomized. Participants rated remotes using a paper-and-pencil questionnaire after exploring each individual remote. They were free to use either one or two hands when feeling the remotes and had unlimited time to complete the task.

3.1.2 Results

All subsequent data analyses were performed on non-aggregated and standardized data. As expected, unity and variety negatively correlated with each other ($r = -.39$, $p < .001$), indicating that unified remotes were generally perceived as less varied, and vice versa. We ran linear mixed-model analyses (SPSS version 22) to determine how unity and variety together predict tactile aesthetic appreciation ratings. Unity and variety were entered as fixed-effect covariates predicting aesthetic appreciation with by-participants and by-stimuli crossed random intercepts. Exit interviews with the participants revealed that they regarded differences in weight as important in judging aesthetic appreciation. We therefore compared a model with and without weight (measured in grams), which was added as a covariate, and then performed a chi-square likelihood ratio test on the AICs—obtained by the maximum likelihood estimation—to determine whether the models significantly differed in fit. The model with weight showed a better fit with the data than the model without weight (χ^2 (1) = 4.56, $p < .05$). In line with our expectations, both unity ($\beta = .64$, $t = 11.37$, $p < .001$, 95% CI = [.53, .76]), and variety ($\beta = .14$, $t = 2.40$, $p < .05$, 95% CI = [.03, .26]), significantly and positively predicted tactile aesthetic appreciation. Weight was also found to positively predict aesthetic appreciation ($\beta = .16$, $t = 3.02$, $p < .01$, 95% CI = [.06, .27]).

3.2 Discussion

This study is the first to show that the principle of UiV also accounts for aesthetic appreciation in the tactile modality. Similar to the visual modality, tactile unity and variety both positively influence aesthetic appreciation. Furthermore, because unity and variety are partial opposites, there is an optimum balance between unity and variety that leads to the highest aesthetic appreciation (Figure 20).

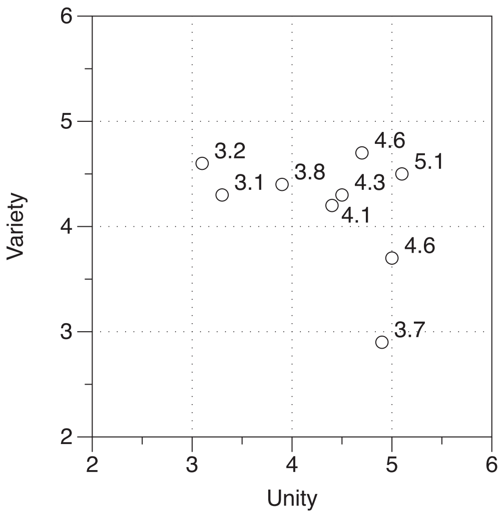


FIGURE 20. MEAN AESTHETIC APPRECIATION RATINGS OF REMOTES IN RELATION TO THEIR AVERAGE UNITY AND VARIETY RATINGS. OPTIMIZING BOTH UNITY AND VARIETY LEADS TO THE HIGHEST AESTHETIC APPRECIATION.

The finding that tactile unity is more important than tactile variety was also seen in the visual modality (Post et al., 2016), and can be explained accordingly. A lack of variety merely results in boredom, but does not impede perceptual processing. Contrastingly, a lack of unity constrains perceptual processing, inhibiting sense-making altogether. As a result, unity can be appreciated without much variety; but for variety to be appreciated, unity needs to be present.

The next study aims to replicate and, in a more controlled way, investigate our current findings by systematically manipulating tactile unity and variety.

3.3 Study 2

As discussed earlier, there are underlying mechanisms of perceptual understanding shared between vision and touch, such as the Gestalt laws of grouping, that may inform the perception of both visual and tactile UiV (Gallace and Spence, 2011b). Gestalt laws (such as similarity, continuity and emergence) have been shown to determine the way we tactually group shapes, materials and lines (Chang et al., 2007a, 2007b; Heller and Brackett, 2003). To more accurately investigate the principle of UiV, we developed 3-D printed versions of new remotes that were systematically manipulated in unity and variety along these Gestalt laws. Besides increasing control over the variable of interest, careful systematic manipulations keep other factors constant (such as brand association, the degree of typicality or novelty and weight), which are known to play a role in forming affective responses to products (Hekkert et al., 2003; Page and Herr, 2002). To maximally separate the influence of our manipulations on unity and variety, the manipulations were applied to either form or material respectively; two properties that we theoretically expected to have the least effect on the other variable. We describe the development of the remotes more elaborately in our pre-test, which aimed to determine the success of our tactile unity and variety manipulations.

3.3.1 Pre-test

3.3.1.1 Method

3.3.1.1.1 Participants

Twenty-nine international students (Mean age = 23.8, SD = 1.6, 6 females) from a Dutch university responded to an online call for participation. Participants were informed that they would judge products by touch. They received 10 euros for 45 minutes. All participants were included for further analyses.

3.3.1.1.2 Stimuli development

For the design of our systematically manipulated stimuli we stayed with the product category of remotes. The common use of different materials, shapes and textures in remotes allows for manipulating these properties without creating ecologically unusual designs.

The new stimuli were manufactured using state-of-the-art 3-D printers (Object 500 Connex3 by Stratasys, Ltd. for printing in plastic and rubber; Shapeways, Inc. for printing in metal). Modern 3-D printers enable the creation of highly detailed (600–1600 dpi), accurate (20–85 microns), customizable and affordable stimuli. The ability to print in a wide range of materials (e.g. polymers, rubbers, ceramics, metals and alloys), which can be finished in different ways (brushed, polished, dyed or coated with velvet), increases their resemblance to products available on the market.

In line with our efforts to create realistic stimuli, and through multiple phases of sketching and prototyping, a professional designer developed a modular remote assembly comprising thirteen exchangeable components (Figure 21). The modular nature of the remotes allowed for high customizability and control over our manipulations.

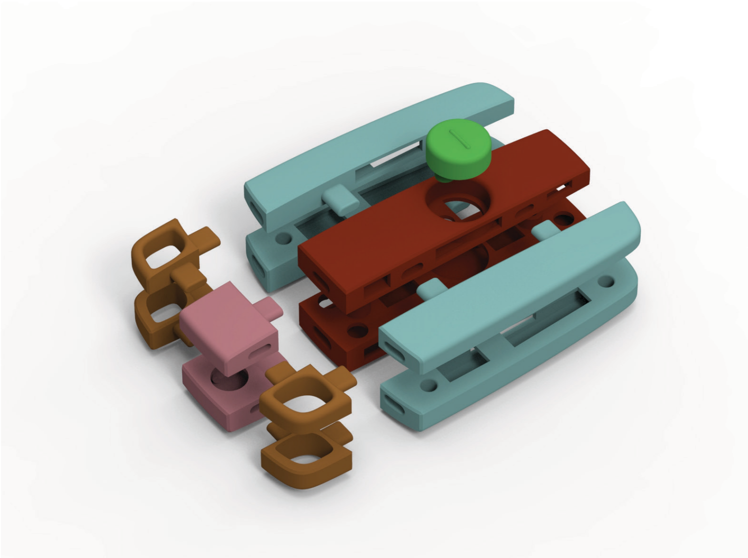


FIGURE 21. RENDER OF THE MODULAR REMOTE ASSEMBLY.

Based on the earlier discussed literature on tactile Gestalt laws, unity was manipulated in form along *continuity* and *emergence*, and applied to minimize the influence on other Gestalt laws (e.g. symmetry and proximity). The Gestalt law of continuity implies that elements are grouped together if they are interpreted as continuing in line or form. Continuity in form was manipulated by designing three versions of the remote's keychain hole (Figure 22). In the most unified component, the keychain hole was identical in thickness to the rest of the remote and its contour followed the line of its surrounding parts. In the medium-unified component, the keychain hole still followed the contour on the horizontal plane, but continuity was lowered in the vertical plane by decreasing the thickness compared to the rest of the remote. In the least unified component, continuity was lowered even more by breaking the contour on the horizontal plane. The second unity manipulation was the emergence of the button. The Gestalt law of emergence implies that parts are separated if they differ from their background. In the most unified version, the button height was the same as the rest of the remote's body. In the medium and least unified versions, the button protruded deeper, thereby making it stand out more from its surroundings.

Variety was manipulated through *(dis)similarity* in component material by using one, two or three different materials (plastic, rubber and metal). Tactile sensations of materials include hardness, elasticity, plasticity and temperature, as well as the surface properties of textures and patterns (Okamoto, Nagano, & Yamada, 2012; Sonneveld & Schifferstein, 2008). The three materials chosen all differ in three of these properties. Printed metal is a good conductor, and therefore considered cold at room temperature, and is hard and smooth if polished. Plastic is less of a heat conductor, and therefore feels slightly warmer than metal, and is lower in hardness and smoothness. Finally, rubber is relatively warm, elastic and sticky or rough (Ashby and Johnson, 2013).

Increasing the number of materials from one to two, then two to three, should increase the number and intensity of differences felt within a remote in a systematic way. All components of the low-variety remotes were therefore printed in plastic. Medium-variety remotes incorporated rubber printed components in the middle (Figure 23) with the rest remaining in plastic. High-variety remotes consisted of polished-metal printed components on the outside, while the top-middle was rubber and the bottom-middle plastic.

FIGURE 22. DIFFERENT VERSIONS OF THE KEYCHAIN MANIPULATED IN UNITY THROUGH CONTINUITY OF FORM (LOW TO HIGH UNITY).

FIGURE 23. OVERVIEW OF ALL NINE 3-D PRINTED REMOTES SYSTEMATICALLY MANIPULATED IN UNITY ON THE X-AXIS (THROUGH EMERGENCE OF THE BUTTON AND CONTINUITY OF FORM) AND VARIETY ON THE Y-AXIS (THROUGH SIMILARITY IN MATERIALS).

As our previous study indicated that weight influenced the aesthetic appreciation of the remotes, we controlled for this by adding small pieces of metal inside the models until all remotes weighed equal (71 grams).

Our design of the manipulations and highly accurate manufacturing assured that the construction of all remotes was of identical quality. The result was a set of nine realistic stimuli (three levels of unity X three levels of variety) that systematically varied in form through the Gestalt laws of continuity and emergence and in the number of materials through (dis)similarity (Figure 23).

3.3.1.1.3 Procedure

The pre-test started with a familiarization round, followed by forced choice paired-comparisons where all remotes were compared on tactile unity or variety in two separate rounds. Paired-comparisons were used to maximize judgement accuracy resulting in 36 comparisons for unity and 36 comparisons for variety. Participants were seated in a laboratory setting in front of a table with a black cloth suspended in the air to block their view. They were allowed to have both hands underneath the curtain to inspect the remotes. In the familiarization round, all nine remotes were presented simultaneously for participants to briefly explore all remotes tactually (1–2 minutes depending on the participant's feedback). They were informed it was important to take their time to carefully explore the remotes. To encourage complete and accurate assessments, they were explicitly told that they were allowed to use their nails to scratch across surfaces or press on materials.

After familiarization, and for all possible combinations of the remotes, participants were informed to select which of the two presented pairs had the highest tactile unity in one round ('*The product feels ordered, unified, coherent and like a whole*'), and which of the two presented pairs were highest on tactile variety in the other round ('*The product is made of different parts, it is varied and rich in elements*'). For each given pair, participants were instructed to hold one remote in each hand to simultaneously compare them. Depending on the unity or variety round (randomized starting order for both), participants indicated for each comparison (by raising their hand) which of the two remotes was highest in either unity or variety. Their responses were recorded by the experimenter. The order of the 36 remote combinations and the hand in which the remotes were given (left versus right) were also fully randomized (no left-handed participants participated in the experiment).

3.3.1.2 Results

We calculated the frequencies of how often a remote was chosen as more unified or more varied, and compared these with the three levels of our unity and variety manipulations. In line with the intended direction, visual inspection of the frequencies revealed unity frequencies to increase for stronger unity manipulations, whereas unity frequencies remained stable for variety manipulations (Figure 24). Also in line with the intended direction, variety frequencies increased for stronger variety manipulations, although there was a tendency for variety frequencies to decrease for stronger unity manipulations.

To statistically assess the relationship between our manipulations and the dependent unity and variety frequencies, we performed chi-square tests on the unity and variety 3 × 2 contingency tables (3 levels of manipulations X more unified/varied). In line with the intended unity manipulation, results showed a significant association between unity frequencies and manipulated unity levels ($\chi^2_{(2)} = 490.36$, $p < .001$; $\eta^2 = .24$). Unity frequencies were also associated with manipulated variety levels, but to a much smaller degree ($\chi^2_{(2)} = 7.69$, $p < .05$; $\eta^2 = .004$). In line with the intended variety manipulations, variety frequencies were significantly associated with manipulated variety levels ($\chi^2_{(2)} = 261.81$, $p < .001$; $\eta^2 = .12$). Variety frequencies were also significantly associated with unity manipulations, but to a lesser degree ($\chi^2_{(2)} = 87.86$, $p < .001$; $\eta^2 = .04$).

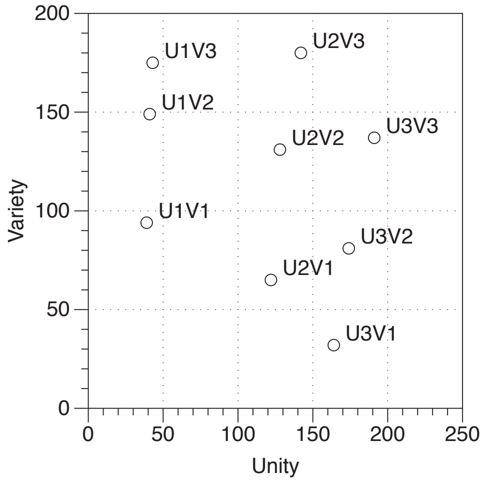


FIGURE 24. PLOTTED UNITY AND VARIETY FREQUENCIES FOR THE RESPECTIVE MANIPULATED LEVELS OF THE REMOTES.

We attempted to manipulate unity and variety as independently as possible, since we argue that they are not opposites of a single dimension, but two distinct dimensions both uniquely contributing to aesthetic appreciation. However, unity and variety are inherently linked by the (material) properties from which they originate. This presents itself in a negative correlation between both dimensions that was found in the first tactile study and in research on visual unity and variety (Post et al., 2016). This inherent relationship prevents completely disentangling their effects; nevertheless, our manipulations mainly influenced the intended dimensions and in the correct direction. Furthermore, the properties chosen to manipulate either unity or variety differed objectively by separating material and form characteristics. We therefore consider unity and variety as successfully manipulated and continued to use these stimuli in the main study.

3.3.2 Main test

The main test aimed to assess how manipulated tactile unity and variety separately and jointly influence aesthetic appreciation. Similar to the first study, we hypothesize that unity and variety both positively influence aesthetic appreciation and, secondly, that there is an optimum balance between unity and variety when aesthetic appreciation is highest.

3.3.2.1 Method

3.3.2.1.1 Participants

We calculated the required minimum sample size to find a large effect ($f \approx 0.40$), based on the results of Study one, with a power of 80% (Faul et al., 2007). Approximately 26 participants were required, assuming the strongest nonsphericity correction of 0.125 given the nine measurements, a correlation among repeated measurements of 0.3 and $\alpha_{\text{one-tailed}}$ set to .05. Thirty-two international students from a Dutch university participated in the experiment (Mean age = 24.0, SD = 2.7, 8 females), of which none had participated in the previous studies, and were paid 8 euros for 30 minutes. All data was collected in one week and all participants were included in further analyses.

3.3.2.1.2 Stimuli

Stimuli were the same as those used in the pre-test.

3.3.2.1.3 Procedure

The identical experimental laboratory setup was used as in the pre-test. Participants were informed that they were going to evaluate nine concept versions of a remote by touch alone. After the same familiarization round as in the pre-test, participants were given one remote at a time, in random order, and asked to verbally rate the remotes on the three aesthetic appreciation items used in the first study using 7-point Likert scales (Cronbach's α = .92). They were instructed to explore remotes for at least forty seconds to allow sufficient time to detect details and to standardize time between stimuli and participants.

Perceived roughness of materials has been shown to negatively relate with preference ratings (e.g. Ekman et al., 1965). The use of different materials prevents us from physically keeping this aspect constant between remotes. To statistically control for it, we included the item '*The material of this car key remote feels rough*' (7-point Likert scale). Because we aimed to create credible stimuli for external validity purposes, the exit questionnaire included the following question: '*How realistic were these car key remotes to feel/touch?*' Participants rated the remotes as sufficiently realistic (Mean = 4.9, SD = 1.1, on a scale 1–7).

3.3.3 Results

All subsequent data analyses were performed on non-aggregated and standardized data. A linear mixed-model analysis with REML estimation was performed to test our first hypothesis that tactile unity and variety separately influence aesthetic appreciation. Levels of manipulated unity and variety were entered together with perceived roughness of the material as fixed-effects predicting aesthetic appreciation with by-participants random intercepts.

In line with our first study, unity (β = .21, t = 3.88, p < .001, 95% CI = [.10, .31]) and variety (β = .21, t = 3.62, p < .001, 95% CI = [.10, .32]) significantly and positively predicted aesthetic appreciation. Despite significant differences in the roughness ratings of the remotes—as assessed in a separate ANOVA, $F(8, 279) = 11.34$, p < .001—material roughness did not significantly influence aesthetic appreciation (β = -.09, t = 1.37, p = .173, 95% CI = [-.21, .04]).

Increasing levels of unity and variety were shown to positively predict tactile aesthetic appreciation ratings. However, this does not automatically imply that remotes optimally combining both are aesthetically appreciated the most. It is conceptually possible that some remotes are solely appreciated because of their unity, while others for their variety.

To assess our second hypothesis, that combining unity and variety leads to an optimum balance when aesthetic appreciation is highest, we performed a second linear mixed-model analysis. The nine versions of remotes were entered as a fixed-effect factor with by-participants random intercepts predicting aesthetic appreciation. The results revealed remote U3V3 to be rated significantly higher in aesthetic appreciation than all the other remotes except U2V3 (Table 9).

TABLE 9. COMPARISONS OF THE MEAN AESTHETIC APPRECIATION RATINGS FOR EACH REMOTE.

	Mean Aesthetic Appreciation	Lower 95% CI	Upper 95% CI
U1V1	3.59**	3.04	4.14
U2V1	4.17*	3.62	4.73
U3V1	4.13*	3.58	4.68
U1V2	3.20**	2.68	3.77
U2V2	4.10*	3.55	4.65
U3V2	3.95*	3.40	4.51
U1V3	4.11*	3.57	4.66
U2V3	5.19	4.64	5.75
U3V3[a]	4.85	.	.

[a]*Remote maximizing unity and variety as the reference category;* $*p < .05$; $**p < .001$.

3.4 General discussion and conclusion

In our two studies, we empirically investigated the principle of UiV in the tactile modality. The studies revealed that tactile unity and variety both positively influence aesthetic appreciation and that, due to their inherent negative relationship, combining unity and variety leads to an optimum balance where aesthetic appreciation is highest.

By using 3-D printed stimuli developed by a professionally trained designer, we demonstrated that Gestalt laws can be applied to systematically manipulate *tactile unity* through changes in continuity and emergence of form, and *tactile variety* through (dis)similarity in materials. Our research thereby also informs theoretical models of tactile perception by showing how the organization of tangible low-level features relates to more global aspects (e.g. symmetry and coherence) and their subsequent aesthetic evaluation (Carbon and Jakesch, 2013).

UiV is grounded in the idea that an optimum balance between unity and variety is preferred because it leads to highly efficient processing of sensory information (Berlyne, 1971). In the second study, we found that the remote maximizing both unity and variety received higher aesthetic appreciation scores than all keys except that with medium unity and high variety. The fact that the high-unity remote was not appreciated more than the medium one could point to a ceiling effect. At the medium level, there was already enough unity to guide perceptual understanding of the remote, thereby limiting the appreciation of additional unity. Hence, the optimal unity and variety balance for these artefacts likely resides somewhere between these two remotes.

The finding that UiV also applies to the tactile modality, and that Gestalt laws of perceptual grouping underlie it, supports the idea that mechanisms facilitating perceptual understanding are likely shared between vision and touch. From this, it seems very plausible that other Gestalt laws, such as proximity or closure, can also be used to influence tactile UiV. Furthermore, the Gestalt laws also apply to other sensory modalities, such as audition (Bregman, 1994). Structural components of music like repetition, closure and contrast have been shown to influence people's judgments of musical unity (Tan and Spackman, 2005). We could therefore predict that, because of the shared underlying mechanisms of perceptual understanding, UiV also applies to the auditory modality. Various studies and qualitative analyses of musical excerpts indeed show unity and variety as important dimensions of music appreciation (Ball, 2010).

Lastly, besides expanding scientific understanding, there is also practical value for many creative domains in knowing how we tactually explore and appreciate the world around us. The intimacy of the tactile sense compared to (for example) vision can generate unique and lasting experiences—even more so for those who cannot rely on their sight any more (Candlin, 2003). Given our numerous interactions with artefacts, the knowledge about how they can be made more aesthetically pleasing can have a widespread and positive influence on our daily lives.

4 Visual-tactile and cross-sensory Unity-in-Variety

Surely it becomes more convenient, more simple to deal with sensory systems when one comprehends that they operate in ways that are at least somewhat uniform. A single psychophysical law, applicable to many senses, is more powerful, more elegant, more beautiful, than 5, 6, 8, or 12 individual laws.

Lawrence Marks, in 'The the unity of the senses' (1978)

In the previous chapters we have seen that visual and tactile UiV can each explain aesthetic appreciation of a variety of product designs. So far we have studied both sensory modalities separately because of the complex nature of multisensory experiences (Marks, 1978). In doing so we attempted to untangle the senses as much as possible and create a basis that then allowed for investigating multisensory aesthetic experiences. Additionally, some products are solely or mostly experienced through one sense, making results from the previous studies already highly applicable to domains such as interface design or printed media. However, most of our daily experiences with products call upon multiple senses (Crilly et al., 2004; Desmet and Hekkert, 2007; Schifferstein and Spence, 2008). For example, approaching a product in a store firstly involves perceiving it visually, after which we may want to hold the product thereby making the aesthetic experience visual-tactile in nature. It is however unclear whether the UiV principle holds for both modalities in a visual-tactile aesthetic experience. Although multisensory product experiences can also involve other modalities, we focus on the visual-tactile experience because these two modalities are the most important for (un)pleasurable product experiences (Fenko et al., 2010). Studying UiV for visual-tactile product experiences increases the applicability and generalizability of the principle and creates a more holistic understanding of how the different senses influence daily aesthetic experiences with products. Awareness of how this principle applies to multisensory product experiences is especially valuable to designers, as the combination of visual and tactile information heightens aesthetic appreciation and leads to improved consumer attitudes and purchase intentions over single sensory experiences (Balaji et al., 2011; Jansson-Boyd and Marlow, 2007). We therefore investigated how visual and tactile unity and variety together relate to the visual-tactile aesthetic appreciation of products.

4.1 Comparing vision and touch

4.1.1 Similarities between vision and touch

While we have previously shown the relevance of UiV in separately explaining visual and tactile aesthetic appreciation, the question remains whether both instances of UiV uniquely contribute to aesthetic appreciation when a product is appraised with the two senses simultaneously. In the previous chapter we argued that impressions of unity and variety are dependent on how a variety of shape and material properties and elements are organized into a unified whole. The degree of overlap and unique contribution of visual and tactile UiV therefore relies on how similar (or different) vision and touch process shape and material information. To inform our research question 'how visual and tactile unity and variety contribute to visual-tactile aesthetic appreciation', we describe literature that discusses the similarities and differences between vision and touch in terms of processing these object properties.

The search to identify the similarities and differences between vision and touch has a long history and is notoriously difficult (Marks, 1978). This is largely due to the conflicting nature of how one unified experience arises out of perceiving through different senses (e.g. the impression we get from holding and looking at a pen feels as one experience, not as a tactile sensation distinct from its visual sensation). While the science of the senses has generally studied the senses in isolation, such a strict distinction is not straightforward, as it has simultaneously been claimed that all our senses have evolved from one primitive sense and are therefore difficult to separate (Marks, 1978; Spence, 2011). Indeed, there is some merit in that view, as touch is first to develop in the infant and tactile exploration in early life is argued to help inform and shape visual processing (Fitzgerald and Gibson, 1984; Gregory, 1967). On the other hand, visual inspection creates many expectations as to the subsequent tactile experience (Ludden et al., 2009; Marks, 1978). Hence, many similarities between vision and touch exist.

The similarities between vision and touch exist on multiple levels that can at least be distinguished in terms of (1) how each modality extracts and processes information, (2) which psychological mechanisms are involved, and (3) the brain regions in which this processing occurs. At the core of these similarities lies the role of the senses in informing us about our environment. Our senses are the gateways through which our brain receives input from outside the body. In registering objects around us, touch and vision process correlated information (e.g. shape, size, material and texture) to form a unified perception of the world: the notion of sensory equivalence (Gibson, 1962; Gibson, 1966; Lindauer et al., 1986; Marks, 1978). That processing of correlated information leads to commonalities in sensory judgments is therefore not very surprising. For example, Owen and Brown (1970) showed that the ability to discriminate shapes by their number of sides was similar in touch and vision, suggesting that the same underlying processes are involved in both sensory modalities. Additional support for the notion of sensory equivalence comes from the same authors who showed high intercorrelations of judgments of form-complexity information between vision and touch (Brown and Owen, 1970). Besides equivalence in extracting object shape information, there is also evidence showing that material information (e.g. texture and hardness) is similarly judged in vision and touch. Yoshida (1968) used multidimensional-scaling techniques to show that vision and touch perform almost identical in judging type and degree of differences between 50 material samples. Additional evidence comes from research combining both shape and texture perception that showed a shared perceptual space between both senses for relatively simple abstract shapes (Cooke et al., 2007), and for more complex organic shapes (Gaißert et al., 2010). Hence, vision and touch seem to highly correlate in the information extracted and processed of an object's material and shape properties.

Besides the similarities in vision and touch in detecting object properties, and judging them accordingly, there are also shared psychological mechanisms between the senses when it comes to organizing this information. There is compelling evidence that multiple Gestalt principles of grouping known to work in vision also apply to touch (Gallace and Spence, 2011b). This strongly suggests not only commonalities in the processing of an object's properties, but also in the way these properties are processed by the brain, and consequently experienced by the perceiver. The finding that statistical learning mechanisms likely underlie the forming and processing of Gestalt laws, and that these mechanisms are modality independent, can even link these psychological mechanisms to parallels at the neural level (Bhatt and Quinn, 2011; Wagemans, Elder, et al., 2012). In relation to the brain, similarities can also be found in common brain regions involved in sensory processing. A review of brain imaging studies by Lacey and Sathian (2014) suggests that there are multiple shared brain regions and mechanisms of perceptual processing in terms of shape, object recognition and categorization.

4.1.2 Differences between vision and touch

The previous summary of research shows clear similarities in the information processing, psychological mechanisms and brain regions involved in tactile and visual perception.

Nonetheless, it is experientially evident that there are differences between visual and tactile perception. Firstly, the senses differ in what they can extract from the environment. While vision is unique in its ability to detect colour, touch is able to directly infer object properties such as its temperature (through heat conductance), weight, and hardness, whereas vision can only do so inferentially (Lederman and Klatzky, 2009). As a consequence of generally needing pressure to inspect shapes and materials, touch is a proximal sense, while vision's ability to capture kinetic energy makes it a distal one and capable of more quickly and accurately assessing a large object's global shape. Furthermore, the spatial resolution of the tactile sense is much more coarse than that of vision (Johnson and Phillips, 1981). As a combined result, texture perception in terms of roughness and smoothness is experienced differently through touch or vision (Björkman, 1967).

The ability to extract different object properties through different senses has clear evolutionary advantages, as the senses can contribute to each other to perceptually comprehend the environment allowing the organism to better cope with potential threats and benefits in it (Marks, 1978). Evidence for such a complimentary role of the senses comes from Whitaker et al. (2008) and (Heller and Schiff, 2013), who reviewed literature describing visual, tactile and visual-tactile texture and shape perception tasks. For example, studies showed differences in texture discrimination performance for both senses, yet judgements of textures were more accurate in bimodal compared to unimodal situations (e.g. Ballesteros et al., 2005; Tiest and Kappers, 2007). Whitaker et al. (2008) therefore conclude, in line with a series of experiments by Lederman et al. (1986), that while the different physiology of vision and touch affects how texture information is extracted, judgment of textures through vision and touch is done in an independent but complementary way. Further support for the complementary role of the senses comes from statistical modelling approaches that suggest that the brain optimally integrates information from both vision and touch to increase discrimination performance of shape perception (Ernst and Banks, 2002). These studies thus reconcile the similarities and differences between vision and touch by showing that, although both share ways in which information of the environment is processed, the differences in their ability to extract information leads to unique and complementary contributions from both senses.

4.1.3 Visual-tactile aesthetic appreciation

The previous overview illustrates that, despite processing a large degree of similar information, differences in the ability to extract information may result in unique contributions to object perception and consequently its judgement. Since we argue that aesthetic appreciation arises from sensory processing, it follows that visual-tactile aesthetic appreciation should abide to this as well. This is in line with studies by Lindauer et al. (1986) in which they found high correlations between visual-tactile perception and aesthetic judgments of ceramic vessels. The authors conclude that the input between vision and touch is more similar than different, and thus in line with a sensory equivalence position, yet the differences in the way vision and touch initially extract information can compliment each other.

Based on the aforementioned studies, certain similarities and differences between touch and vision can also be expected for the perception of unity and variety. The ability to extract common information of object properties through both vision and touch implies that both senses process correlated input. As we saw in the previous chapters, both tactile and visual Gestalt laws of grouping shape unity and variety impressions and thereby influence both tactile and visual aesthetic appreciation. As a result, two shapes identical in form will likely be perceptually grouped together in both modalities through the Gestalt laws and therefore aid perceptual understanding and heighten unity (Chang et al., 2007a; Gallace and Spence, 2011b; Post et al., Submitted; Chapter 3). Similarly for variety, two shapes with different orientations will be perceived as varied both in vision and touch. This extraction of similar object properties and the identical role of Gestalt principles in processing these properties imply that there is probably a high degree of overlap in the impression of unity and variety between vision and touch. Yet, there are also clear differences between the senses in the ability to detect product properties such as hardness, texture or colour that may lead to unique contributions of both senses to unity and variety impressions. This is especially apparent in product surprise where, for example, vision gives the impression that a cup is made of metal, whereas touching the cup informs the user that it is actually made of rubber

(Ludden et al., 2012). Since a product is therefore capable of generating different impressions through vision and touch—differences that may have been deliberately embodied in the object—an object may elicit unity and variety impressions that differ between the senses. As a result of generating different unity and variety impressions for vision and touch, both can be expected to at least partially contribute in unique ways to visual-tactile aesthetic appreciation.

We argue that visual-tactile aesthetic appreciation results from combining both visual and tactile unity and variety impressions. However, because the visual sense can inform the tactile sense of product properties—and vice versa—this leads to expectations that prevent modality specific ratings (Tiest and Kappers, 2007; Yanagisawa and Takatsuji, 2015). The tendency to look away, or close our eyes, when attempting to concentrate on touch, taste or sound exemplifies this difficulty of focusing on a single sense. To help participants arrive at accurate modality specific ratings some researchers apply a split-modality approach in investigating the unique contribution of each sense to product experiences (Schifferstein and Cleiren, 2005). That this indeed helps participants to concentrate on the modality specific object properties we are interested in is reflected by a study from Burns et al. (1995). The authors demonstrated that the description of fabrics perceived through touch primarily led to terms related to basic object properties such as texture, fibre content, weight and fabric characteristic, whereas when touch was combined with vision the descriptions related more to end use and fabric name. We therefore follow a split-modality approach for assessment of visual and tactile unity and variety, which are after all perceived through different senses, while maintaining a combined visual-tactile aesthetic appreciation evaluation that resembles our aesthetic judgements in real life.

To form our hypothesis on how tactile and visual unity and variety relate to visual-tactile aesthetic appreciation, we reviewed and discussed a body of literature on the similarities and differences between both senses. The literature suggests that, despite large similarities in the information processed and the way in which it is incorporated, there are differences in the ability of the senses to extract this information. These differences inform the senses in partially separate ways, and therefore have the potential to generate distinct unity and variety impressions. We therefore hypothesize that visual and tactile unity and variety, despite partially overlapping, also contribute in unique ways to visual-tactile aesthetic appreciation. Additionally, we hypothesize that these unique contributions of unity and variety in each sensory modality still follow the principle of UiV: despite their negative correlation, unity and variety both positively contribute to aesthetic appreciation.

4.1.4 Regulatory focus

In the first chapter we argued that the need for perceiving an optimum balance between unity and variety is driven by two evolved underlying motivational states. These drives are a need for safety and accomplishment (Hekkert, 2014; Shah et al., 1998). We argued that people's need for both safety and accomplishment generates the preferred balance between unity and variety in the visual modality. People have an inherent need for accomplishment seeking because it promotes learning. Variety satisfies this need because it indicates the presence of novel information and the potential of discovering how elements and properties perceptually relate to each other. On the other hand, people have a need for safety and security, a need fulfilled by unity because it facilitates perceptual understanding and quickly comprehending what is perceived, thereby reducing uncertainty (Berlyne, 1971). In line with this, we found in Chapter 1 that for the visual modality the preferred UiV balance shifted towards unity for safety seekers compared to accomplishment seekers. On the same theoretical grounds as in vision, a similar relationship between safety and accomplishment seeking could hold for the tactile modality. There is some empirical evidence to suggest that tactile impressions of unity and variety may be influenced by safety or accomplishment motivation, as Alcántara-Alcover et al. (2014) found that people semantically relate uniform feeling objects in their environment with safety. From this, we argue that the same mechanisms of safety versus accomplishment seeking may therefore apply to the tactile modality and thereby influence the degree to which unity and variety are preferred. As indicated and employed in the first chapter, a way to measure safety and accomplishment is through assessing regulatory focus (Higgins et al., 1997). We therefore included a regulatory focus measure in this study to assess if differences in regulatory focus underlie the relative importance of the UiV contributions. We hypothesize that stronger safety seeking, compared to accomplishment seeking, shifts the preferred balance between unity and variety towards unity in both sensory modalities.

4.1.5 Method

4.1.5.1 Participants

Sixty-seven international students (64% Asian, 36% European) from a Dutch university (Mean age = 25.6, SD = 2.4, 22 females) were recruited through social media. They were asked to give feedback on their perception of products. Participants received 10 Euros in compensation for 45 minutes of testing. All participants were included for data analyses, generating 804 data points.

4.1.5.2 Stimuli

PET bottles (±500ml) from the existing market were chosen as stimuli as they varied in shape and texture, while keeping the overall dimensions similar (Figure 25). Furthermore, because of their simple designs, shape could be reliably assessed by touching them, which can be difficult for more complex objects as touch has a lower spatial resolution than vision (Johnson and Phillips, 1981). Four design experts participated in a pre-test and were instructed to reduce a selection of bottles down to twelve while maintaining a spread in visual and tactile unity and variety. Bottles marketed in different cultures (e.g. Asia, Europe and America) were included to arrive at an internationally representative sample. We excluded bottles with exceptionally recognizable shapes (e.g. Coca-Cola), deviations from the neutral grey transparent plastic, or exceedingly thick or thin plastic. All labels were removed and all bottle caps were painted white to minimize the influence of colour differences on our variables of interest. All bottles were completely filled with water to minimize differences in weight and to create similar structural strength (some bottles were relatively easy to compress when empty).

FIGURE 25. AN OVERVIEW OF ALL THE STIMULI USED IN THE STUDY.

4.1.5.3 Procedure

In a laboratory setting, participants were seated at a table and informed that they were to rate twelve bottles on several visual and tactile items in three rounds. Participants rated visual and tactile unity and variety in a sequential order in the first two rounds: either first rating visual unity and variety for all twelve bottles in round one, and in the second round tactile unity and variety, or the other way around. Because vision informs touch and vice-versa, the order of visual and tactile unity and variety rounds were counterbalanced. This was followed by a regulatory focus questionnaire, which not only served our purposes for testing how it affects the relationship between unity and variety on visual-tactile aesthetic appreciation, but also served as a distraction task before a third round was introduced in which aesthetic appreciation was measured.

In the visual round, participants were not allowed to touch the stimuli, while in the tactile round participants were not allowed to see the stimuli. For the third round, in which aesthetic appreciation was assessed, participants were allowed to both see and touch the stimuli. This was intended to help participants focus as much as possible on either touch or vision, thereby acquiring the most accurate ratings for each modality. For evaluations of unity and variety in the visual round, a single bottle was presented on a black turntable (to allow all sides to be viewed without touching the bottle) while instructing participants not to touch the bottle (Figure 26). For evaluations of unity and variety in the tactile round, a black curtain was suspended in the air and the bottle placed on a table so that participants could feel the bottle given to them by the experimenter without seeing it (Figure 26). Participants were allowed to use both hands to evaluate one bottle at a time and gave their verbal response to the questionnaire items posed by the experimenter. The visual and tactile unity and variety items, as well as the visual-tactile aesthetic appreciation items were adaptations of those used in previous studies on UiV (Post et al., 2016). The items were phrased in such a way that the same items could be applied to the visual and tactile modality. For unity, this was: '*The bottle is ordered, coherent and unified*', while variety was measured using the item: '*The bottle is varied, rich in elements and made of different parts*' (7-point Likert scales, 1:

Fully Disagree – 7: Fully Agree). Two filler items were included to disguise scale purpose.[1] After the round of visual and tactile unity and variety evaluations, regulatory focus was measured using a paper and pencil questionnaire (Higgins et al., 2001).[2] This questionnaire consists of 11 items that measure promotion (Cronbach's α = .62) and prevention (Cronbach's α = .72) orientation using questions such as: '*Do you often do well at different things that you try?*' (promotion), and: '*Not being careful enough has gotten me into trouble at times.*' (prevention). The regulatory focus questionnaire also functioned as a distractor task before the aesthetic appreciation round started to minimize the previous rounds to influence the aesthetic appreciation ratings. Lastly, participants rated visual-tactile aesthetic appreciation of the bottles based on its visual and tactile characteristics using the item: '*The bottle is pleasing to perceive and I like perceiving it. With 'perceiving' we mean both to see and to touch.*', on 7-point Likert scales.

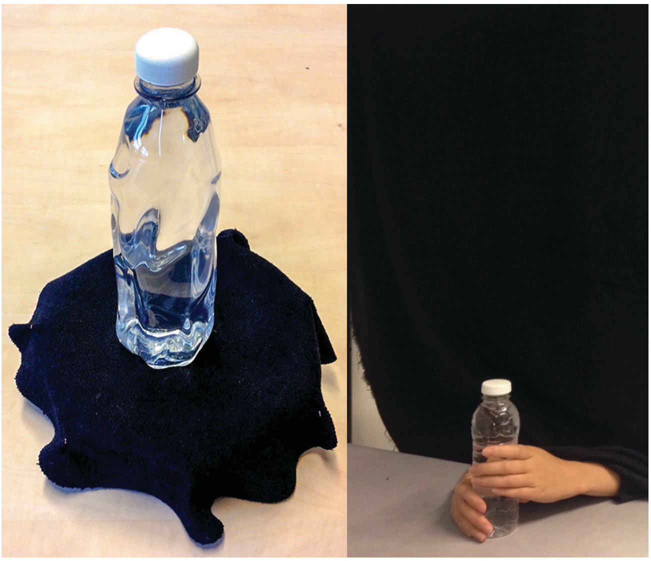


FIGURE 26. PRESENTATION OF THE STIMULI FOR UNITY AND VARIETY RATINGS IN THE VISUAL ROUND (LEFT) AND IN THE TACTILE ROUND (RIGHT).

[1] 'The design of this bottle is original, it is a novel design.'; 'The design of this bottle is standard, typical and common.'

[2] This regulatory focus questionnaire differed from the one in chapter 1, as we needed to use an English version for the international participant sample. Both are however validated questionnaires to measure regulatory focus.

4.1.6 Results

All subsequent data analyses were performed on non-aggregated and standardized data of responses from all the sixty-seven participants. No effects for stimuli or visual/tactile presentation order on aesthetic appreciation were found.

Pearson correlations between unity and variety within each sensory modality revealed that, similar to findings in previous studies, unity and variety were negatively correlated ($r_{tactile}$ = -.19, p < .001; r_{visual} = -.20, p < .001). More unified bottles were therefore generally considered less varied, and vice versa. As can be expected, strong correlations were found for unity and variety between sensory modalities (r_{unity} = .56, p < .001; $r_{variety}$ = .58, p < .001), indicating the intercorrelated nature of visual-tactile perception.

We ran multiple linear mixed model analyses to first investigate the influence of tactile and visual unity and variety on aesthetic appreciation. We first assessed tactile and visual unity and variety separately to replicate previous findings and test our hypothesis that unity and variety both positively relate to aesthetic appreciation within their respective sensory modality. We then assessed whether combining visual and tactile unity and variety leads to unique contributions of each variable to aesthetic appreciation. The unity and variety variables were entered as fixed effects predicting aesthetic appreciation and random intercepts for participants and stimuli were included allowing for baseline differences in ratings (REML estimation was used, unless stated otherwise). The results are presented in Table 10 and show that for the tactile modality (Model 1a), both unity and variety significantly predicted aesthetic appreciation. Similarly for the visual modality (Model 1b), unity and variety significantly predicted aesthetic appreciation. This confirmed our first hypotheses that, in line with earlier findings, despite being negatively correlated, unity and variety both positively influence aesthetic appreciation.

To assess our hypothesis that tactile and visual unity and variety together uniquely contribute to aesthetic appreciation, we compared two models with mono-sensory unity and variety with a model combining vision and touch using a chi-square likelihood ratio test on each model's AIC (obtained by Maximum Likelihood estimation). A highly significant difference between both models indicated a better fit for the model that included both tactile and visual UiV (Model 1a with Model 2: χ^2 (2) = 68, p < .001; Model 1b with Model 2: χ^2 (2) = 27, p < .001). This model (Model 2) revealed that tactile unity and tactile variety, as well as visual unity and visual variety significantly predicted aesthetic appreciation. The model also revealed decreases for all coefficient magnitudes ($Tactile_{unity}$ = -43%, $Tactile_{variety}$ = -28%, $Visual_{unity}$ = -22%, $Visual_{variety}$ = -29%). Combined with the strong correlations of unity and variety between the senses, this could indicate that their influence on aesthetic appreciation partially overlaps. To test this, we compared each coefficient from the visual-tactile model (Model 2) with their respective coefficients in the mono-sensory models (Model 1a and 1b) using the method suggested by Paternoster et al. (1998). This revealed significant decreases in the tactile and visual unity coefficients (z = 2.79, $p_{one\text{-}tailed}$ < .005, z = 1.75, $p_{one\text{-}tailed}$ < .05, respectively). It can be concluded that, despite partial overlap between the senses, visual and tactile UiV still uniquely contribute to aesthetic appreciation.

TABLE 10. ESTIMATES OF FIXED EFFECTS FOR TACTILE, VISUAL, AND VISUAL-TACTILE UNITY AND VARIETY

		β	t	p	95% CI [low, high]
Model 1a					
	Tactile: Unity	.35	9.99	< .001	[.28, .42]
	Tactile: Variety	.11	2.91	< .005	[.04, .19]
Model 1b					
	Visual: Unity	.42	12.16	< .001	[.35, .48]
	Visual: Variety	.14	3.84	< .001	[.07, .21]
Model 2					
	Tactile: Unity	.20	5.40	< .001	[.13, .28]
	Tactile: Variety	.08	2.09	< .05	[.00, .16]
	Visual: Unity	.33	8.63	< .001	[.25, .40]
	Visual: Variety	.10	2.50	< .05	[.02, .18]

4.1.6.1 Regulatory focus

Apart from investigating how the different sensory impressions of unity and variety relate to the visual-tactile aesthetic experience, we were also interested in determining how safety and accomplishment needs affect the preferred balance within each sensory modality. We therefore performed a linear mixed model analysis for each modality. A single regulatory focus variable was calculated by subtracting prevention seeking scores from promotion seeking (Post et al., 2016). Higher values indicated strong promotion seeking, whereas lower values indicated prevention seeking. Unity, variety, regulatory focus and the interaction terms of regulatory focus with unity and variety were added as fixed effects predictors in the model. Baseline differences for participants and stimuli scores were modelled as random effects.

For the tactile modality, unity (β = .35, t = 10.00, p = .004, CI = [.28, .41]), variety (β = .11, t = 2.90, p < .004, CI = [.04, .18]) and unity X regulatory focus (β = -.07, t = -2.02, p < .05, CI = [-.13, .00]) significantly predicted aesthetic appreciation. This indicated that the importance of tactile unity in explaining aesthetic appreciation was dependent on the promotion or prevention orientation of participants. For the visual modality, regulatory focus had no effect as only unity (β = .41, t = 12.03, p < .001, CI = [.35, .48]) and variety (β = .14, t = 3.80, p < .001, CI = [.07, .21]) reached significance. To probe the interaction effect of tactile unity X regulatory focus on aesthetic appreciation, we followed the approached suggested by (Preacher et al., 2004). Simple slopes were calculated for unity regressed on aesthetic appreciation of the mean and 1 SD above and below the mean of the regulatory focus variable. For decreasing levels of the regulatory focus variable, the effect of unity on aesthetic appreciation increased ($\beta_{\text{high-RF}}$ = .28, SE = .048, z = 5.77, p < .001; $\beta_{\text{medium-RF}}$ = .35, SE = .035, z = 10.0, p < .001, and $\beta_{\text{low-RF}}$ = .41, SE = .048, z = 8.74, p < .001). Because lower regulatory focus reflects stronger prevention seeking needs, we can conclude that tactile unity becomes more important for the prevention seekers than for promotion seekers. Summarized, the preferred balance between tactile unity and variety shifts towards unity for prevention seekers compared to promotion seekers, while in the visual modality no such shift was perceived.

4.2 Discussion

This study is the first to show that tactile and visual UiV simultaneously predict aesthetic appreciation of product designs. For both vision and touch, unity and variety, despite being partial opposites, positively influence aesthetic appreciation of PET bottles. These results extend the UiV principle to the multisensory product experience and replicates findings for vision and touch separately. Furthermore, the results revealed that differences in motivational drives influence the preferred balance between unity and variety for the tactile modality.

We found strong intercorrelations of unity and variety across senses, supporting the notion of sensory equivalence and the consensus that vision and touch process similar object information also in terms of how they are aesthetically appreciated (Ernst and Banks, 2002; Gallace and Spence, 2011b; Lindauer et al., 1986; Marks, 1978). Further analyses revealed that in processing correlated information, tactile and visual unity contributions to visual-tactile aesthetic appreciation partially overlap (and they did so between 20-40%). While the coefficients of tactile and visual variety also decreased when analysed together, pointing towards overlap for the appreciation of variety between senses, this change was not significant. That this overlap instead appeared so clearly for unity may be related to the specific object properties that generate tactile and visual unity and variety impressions. As we saw in Chapter 3, the shape of an object is an important property in creating the feeling of perceiving a unified whole. The role of amodal Gestalt laws of grouping in forming unity impressions of an object's shape likely underlies the overlap of tactile and visual unity. On the other hand, an object property such as texture is more likely to be perceived differently (e.g. in terms of roughness) by both senses (Ballesteros et al., 2005), resulting in variety impressions that affect aesthetic appreciation in unique ways. It must however be added that the strong correlations and overlap might also be inflated by the particular product category, as the PET bottles have relatively few properties that could have influenced unity and variety for the separate senses in unique ways. For example, there were few colour and material differences within and between bottles. Yet, despite the similarities of the stimuli in these properties, unity and variety did not perfectly overlap between both modalities. Both dimensions therefore contributed uniquely to the overall aesthetic appreciation of the products. These results indicate that vision and touch share part of their contribution to the aesthetic experience but also compliment each other, confirming the value and need to further study how these senses interact to form the multisensory product experience (Carbon and Jakesch, 2013; Gallace and Spence, 2011a; Spence, 2011; Spence and Gallace, 2011).

Returning to the quote at the beginning of this chapter; in showing a single theory can explain part of the aesthetic experience for multiple senses, UiV is in itself a beautiful design principle (Da Silva et al., 2016).

4.2.1 Regulatory focus

This study also found regulatory focus to affect the degree to which tactile unity influences aesthetic appreciation. Closer inspection of the relative contributions of tactile unity and variety revealed that prevention orientation leads to a stronger appreciation of unity. As a result, the preferred balance between unity and variety shifted towards tactile unity. This can be explained by a stronger need for safety for people with a prevention orientation (Hekkert, 2014). This need manifests itself in appreciating unity because it reduces uncertainty and increases perceptual understanding (Berlyne, 1971). To our knowledge, this is the first time that motivational drives have been shown to influence tactile aesthetic perception.

While a previous study found regulatory focus to affect the importance of unity in the visual modality (Post et al., 2016), this study unexpectedly showed no such effect. It is possible that regulation of safety versus accomplishment needs was achieved entirely through the tactile sense, limiting any effects in vision. A reason as to why can be found when comparing the two senses in regards of their role in detecting potential hazards and opportunities at different spatial distances and locations (Gregory, 1967; Marks, 1978). The sense of touch functions as a way to recognize nearby danger (Ayres and Robbins, 2005; Gallace, 2012; Gregory, 1967). Hence, it is more important for touch to quickly identify and accurately judge objects as failure to do so is potentially much more dangerous than in the more distal visual sense. This more proximal and immediate role of touch is already visible in infant state, where the tactile sense is the first sense to develop and thought to built a basis for understanding the world through the later developed senses (Jansson-Boyd, 2011). Suzuki and Gyoba (2008) give a similar reason for not finding a mere-exposure preference effect for vision, as opposed to touch, when both modalities were tested. Blocking of the participant's sight in the tactile round prevents directly seeing the immediate surroundings, which heightens people's motivational state to avoid negative events and thereby affects the degree to which unity is preferred.

4.2.2 Design relevance

Our findings offer several relevant suggestions when it comes to designing aesthetically appealing products. Although increasing awareness arises for the importance of other sensory modalities, attention for the visual modality likely still dominates the design process (Fenko et al., 2010). Our research however shows that touch plays a significant role as well and should not be ignored in attempting to enrich the aesthetic experience and increase it even further. In order to design for this, the principle of UiV can be applied to shape pleasurable aesthetic experiences in both senses.

Both senses overlap in their ability to detect shape and material properties of objects (Cooke et al., 2007). This overlap might actually be pleasurable, as people prefer congruency between sensory experiences, as this helps them correctly perceive and identify objects (Krishna et al., 2010). Designers can however also use the differences in sensory processing between senses in a positive way. Slight degrees of incongruency between senses might actually be preferred in some situations as it induces a sense of pleasant surprise (Ludden et al., 2009). In this later case, designing different sensations of unity and variety in both senses should raise aesthetic appreciation even further, which could be the topic of research in future studies.

The finding that tactile unity is related to a preference for safety is important to take into account when designing products that need to be touched. Products designed for a user group in which this personality trait is more prone, or in which other factors counterbalance a need for safety, would require higher decrease of tactile unity to achieve the desired aesthetic optimum. Such awareness is specifically important when designing for user groups from various cultures, as they may differ in their dispositional promotion and prevention states (Higgins et al., 2008).

Lastly, the inherent different ways in which touch and vision extract information from the environment may also influence the ability to perceive unity and variety. For example, the global shape of an object becomes difficult to assess by touch if it is very large, whereas vision only requires a glimpse to achieve this. A very large object may therefore be considered less unified in touch than in vision, because uncertainty about the global shape prevents 'seeing' the whole. Another example would be translucent materials. Older iMacs contained translucent backsides, offering a glimpse into the inner technology. This creates a sense of visual variety, but not tactile variety, as we can see numerous hardware components, whereas we can only feel the outer shape of the computer. Designers should be aware of how material choices influence the perception of unity and variety in the different modalities, as they may not always lead to the same experience in both senses (Wastiels et al., 2013).

4.2.3 Limitations and future directions

Although only statistically assessed, the relative contribution of unity and variety to aesthetic appreciation is similar in size for both sensory modalities. However, there was only a limited spread in the tactile and visual dimensions of variety in terms of respectively material and visual properties (i.e. all bottles were entirely plastic and did not have any labels). Because this study did not manipulate these properties, it is difficult to identify how the relative contribution of visual and tactile unity and variety influences aesthetic appreciation of more diverse products. Related to this, we found that unity more strongly predicts aesthetic appreciation than variety in both vision and touch. This is in line with previous research that has used a selection of products available in the market (Post et al., 2014; Post et al., 2016). Unity is more important for the aesthetic experience because without it sense-making is disturbed entirely, whereas a lack of variety merely leads to boredom. However, floor effects may have prevented stronger appreciation of variety as the stimuli had relatively few differences in terms of colour and material. Future studies could use stimuli systematically manipulated on visual and tactile unity and variety to assess the relative contribution of each sensory modality more accurately, as well as testing important design properties to consider for this. As a suggestion, manipulations in colour and 2-D figures are well suited to influence vision without affecting touch, whereas material and texture is more applicable for touch.

Related to the relative contribution of unity and variety in both modalities is the question of sensory dominance. For a long time vision has been considered to completely dominate the perceptual experience (Power, 1980; Rock and Victor, 1964; Spence, 2011; Warren and Rossano, 1991). However, recent findings seem to nuance these claims somewhat as the previous studies on sensory overlap indicate that it might actually be the reliability of an individual sense that weighs its relative importance to multimodal perception (Cooke et al., 2007; Ernst and Banks, 2002). In certain situations, touch has even been shown to dominate vision, as is for example the case for fine surface textures (Guest and Spence, 2003; Heller, 1982). Our finding that tactile and visual UiV simultaneously explain unique aspects of aesthetic appreciation indicates that neither of the senses completely dominates. The magnitude of the coefficients between the senses showed vision to be somewhat more important, which was also reflected by a relatively larger decrease for tactile unity compared to visual unity (-43% versus -22%, respectively), when both senses were combined. While this hints at a slight dominance for vision, future studies could look more closely at the relative contribution of each sensory modality when products from different categories are used.

The finding that UiV applies to both vision and touch simultaneously also raises the question if unity and variety can interact to achieve an optimum balance across the senses. Since aesthetic appreciation arises from balancing unity and variety, products containing high *visual* unity and high *tactile* variety (or *visual* variety and *tactile* unity) may be aesthetically appreciated because a lack of visual variety is compensated for by tactile variety (or the other way round). The current study did however not allow investigating such a cross-sensory UiV hypothesis because there were insufficient stimuli to compare different visual and tactile unity and variety combinations with each other. To accurately test this hypothesis requires systematic and independent manipulations of unity and variety within each sensory modality.

4.3 Explorative epilogue

The possibility of unity and variety interacting across the senses to achieve an optimum balance seems plausible, as it is widely agreed that visual and tactile impressions are integrated to determine overall object perception and perceptual organization (Ernst and Banks, 2002; Marks, 1978; Spence et al., 2007; Warren and Rossano, 1991). For example, information of object properties (such as shape and structure) can be transferred between vision and touch. This 'cross-talk' has even been shown to affect subsequent preferences across vision and touch (Easton et al., 1997; Suzuki and Gyoba, 2008), as well as for vision and audition (Zampini et al., 2003).

The idea of cross-sensory UiV entails that combining high unity and variety *across* the senses (e.g. UvuV or uVUv; for an example, see Figure 27) results in higher aesthetic appreciation than the absence of a unity and variety balance (uVuV, UvUv).[1] In other words: Visual variety can be compensated by tactual unity, or vice versa. Products that are relatively high on both unity and variety *within* one sensory modality would of course still adhere to the principle as studied in the previous chapters (UVuv, uvUV), and these products would at least be equally preferred to cross-sensory UiV. We briefly present some explorative research into this direction to illustrate what studying cross-sensory UiV might entail and suggest how different design factors affect unity and variety in vision and touch simultaneously.

FIGURE 27. CROSS-SENSORY UIV IN THE 'WASTE TABLE FROM SCRAPWOOD' BY PIET HEIN EEK. VISUALLY HIGHLY VARIED THROUGH ITS USE OF DIFFERENT PIECES OF SCRAP WOOD, YET THEIR RANDOM PLACEMENT LOWERS VISUAL UNITY. THE OPPOSITE IS TRUE FOR ITS TACTILE PERCEPTION. THE SIMPLE GEOMETRICAL SHAPE RESULTS IN HIGH TACTILE UNITY, WHILE THE THICK LACQUER SMOOTHENS ANY IRREGULARITIES AND LOWERS TACTILE VARIETY.

Method—The cross-sensory hypothesis can be accurately assessed by comparing aesthetic appreciation ratings of stimuli that are systematically manipulated in unity and variety in both sensory modalities. The 3-D printed remotes from Chapter 3 already systematically differed in tactile unity and variety. We combined these tactile models with renders that were systematically manipulated in visual unity and variety using KeyShot Pro 5 (see Figure 28 for an overview of all possible visual and tactile unity and variety combinations; see Figure 31 for alternative visual unity and variety manipulations

[1] Uppercase letters reflect 'high' levels and lowercase reflect 'low' levels of unity and variety, where the first two letters describe the tactile modality and the latter the visual. UvuV therefore implies: High tactile Unity and low tactile Variety, combined with low visual Unity and high visual Variety.

that we explored). Renders were used instead of manipulating visual unity and variety in the actual tactile models, as this increased control over the visual properties used to manipulate stimuli for both senses. Special care was taken to visually resemble the different material variations (plastic, rubber and metal) used for the *tactile* variety manipulations in the tactile study. Through numerous pre-tests we found that similarity manipulations in labels positively affected visual unity, whereas higher diversity in colours positively influenced visual variety. We selected six visual renders from the pre-tests that were matched with their tactile models to create two cross-sensory UiV combinations (UvuV and uVUv), two mono-sensory UiV combinations (UVuv, uvUV) and two combinations without UiV (uVuV, UvUv; see Figure 28). In the experimental setup, a render with its corresponding tactile model was simultaneously presented to participants while they rated unity, variety, and aesthetic appreciation ratings (Figure 30).

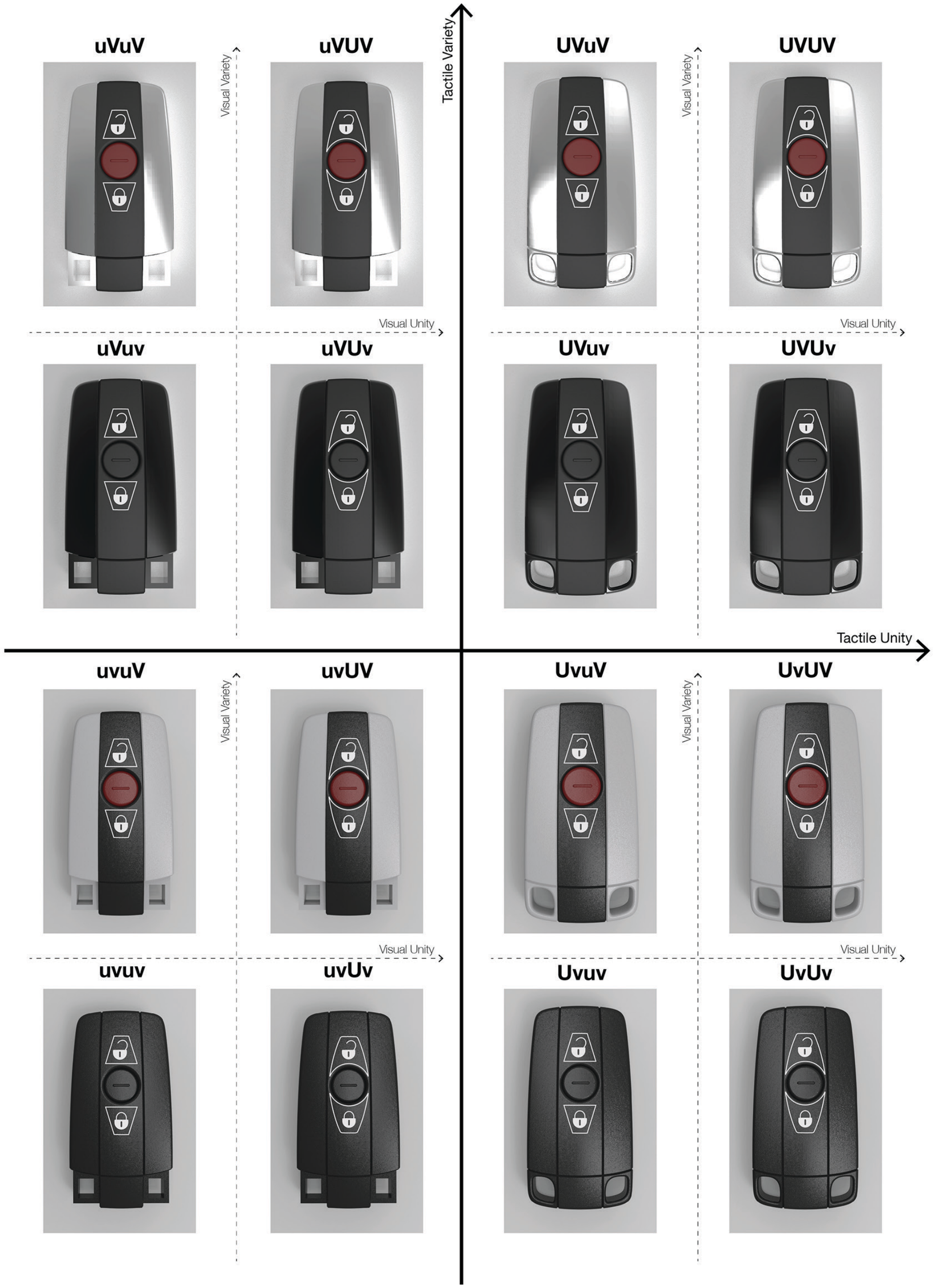


Figure 28. An illustration of all possible combinations of low (lowercase) versus high (uppercase) manipulated levels of tactile (first two letters) and visual (last two letters) unity and variety.

Figure 29. The six renders used in the study. Left column: no UiV balance. Middle column: cross-sensory UiV. Right column: mono-sensory UiV. Tactile unity manipulated through continuity in shape and emergence of the button. Tactile variety manipulated through number of materials (plastic versus plastic, rubber and metal). Visual unity manipulated through dissimilarity in labels. Visual variety manipulated through differences in colour.

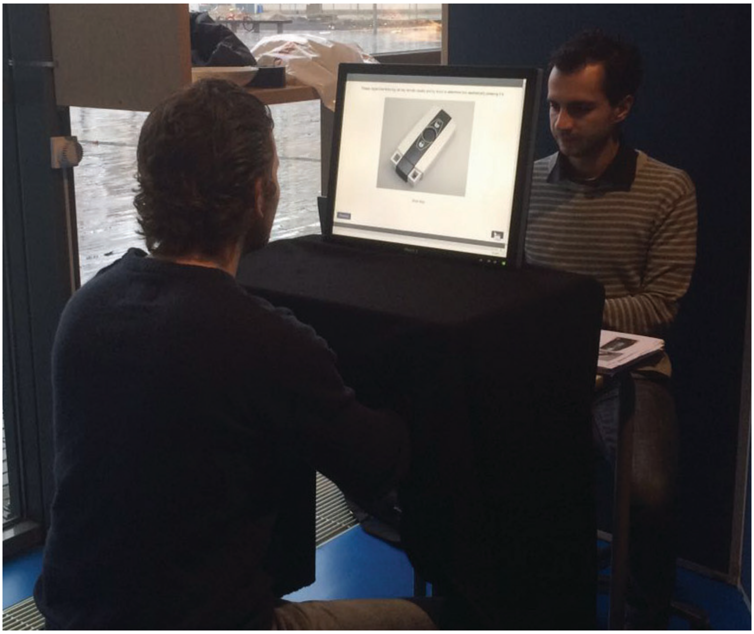


Figure 30. Setup of the exploratory cross-sensory study. Renders of the stimuli were presented visually on a screen, while the physical models used in Chapter 3 were presented hidden from sight.

Results—A manipulation check in the study confirmed earlier pre-tests that visual and tactile unity and variety were rated in the directions we expected; the tactile manipulations in shape and materials affected tactile unity and variety ratings similarly to the pre-test in Chapter 3, whereas the visual manipulations in labels and colour affected visual unity and variety manipulations similarly to the pre-test we just described. However, the final results did not support the hypotheses that cross-sensory UiV (UvuV or uVUv) is appreciated more than when there's an absence of a UiV balance (UvUv or uVuV), nor that mono-sensory UiV (UVuv and uvUV) is preferred over a cross-sensory balance. Instead, we found the tactile manipulations (in shape and material) dominated the effects on aesthetic appreciation.

Discussion—A reason for the dominant effect of touch may have been that the tactile manipulations were simply stronger than the visual manipulations. There was quite some room left to make the visual manipulations of (dis)similarity in labels and diversity in colour more intense than what was used in the final study (Figure 29). Alternatively, the split method of presenting stimuli visually on a display and tactually through physical models may have increased the urge for participants to focus on one modality rather than on both. People generally prefer congruency between the senses. When conflicting information is present, either one modality or the other can dominate (Heller and Schiff, 2013). Although an exit questionnaire indicated that the participants thought the stimuli were realistic, they nonetheless may have perceived differences between the visual and tactile presentations causing them to focus more on the tactile modality.

Suggestions—Despite not confirming our hypotheses, there are several valuable lessons that can be learned from this explorative study.

Firstly, certain object properties and elements are more suitable for unity and variety manipulations between sensory modalities than others. Multiple pre-tests revealed that manipulating the labels of the remotes through the Gestalt law of similarity did not affect tactile ratings. This is rather obvious, because the labels are unperceivable by touch. For the same reason, colourfulness does not affect tactile unity and variety ratings either. Both design factors are therefore highly suitable for visual manipulations. Contrastingly, the tactile unity manipulation in shape impacted both modalities, and even dominated the influence of the visual label manipulations. A product's shape is highly potent in affecting unity, probably because the global shape signals the boundaries of an object and encloses all parts of a product. Shape perception can be achieved through both senses and logically simultaneously affects vision and touch. The effect of the tactile variety manipulation through (dis)similarity in materials is more complicated. Perceiving materials includes sensing its texture (a combination of hardness, roughness and stickiness), heat conductance, colour, glossiness and weight (Karana et al., 2009). As we just discussed, differences in colour naturally only affects vision and the same can be expected for glossiness. Differences in hardness, weight and heat conductance are tactile sensations and will mostly affect tactile variety. It becomes more difficult to predict the degree to which roughness and stickiness independently affect vision and touch because both can perceive them. Nonetheless, variety impressions are expected to increase within both modalities the stronger and more plentiful differences in roughness and stickiness become. It is worth noting that some material properties can be controlled for to more strongly affect only one modality. Differences in hardness can be felt between plastic and rubber. By printing them in the same colour they become visually almost entirely indistinguishable (see for example Figure 23 (Chapter 3) where medium variety remotes were made of black plastic and rubber). A similar effect can be achieved by painting metal to visually mimic these other materials, yet keeping its tactile differences to them largely intact. When intending to selectively influence unity and variety, it's thus important to not only be aware that materials or shapes differ, but especially in which particular properties they differ and whether the senses are able to extract such information.

Secondly, an added consequence of doing multisensory research is that it becomes more difficult to know what the participants are focusing on when stimuli are presented both visually and tactually. It may be that some individuals are more tactually oriented, whereas others focus on vision (Jansson-Boyd and Marlow, 2007). Gathering insights on how the different senses interact can be helped by using different methodological setups, such as comparing uni-modal with bi-modal conditions, or statistically characterizing the relative impact of each sense with weighted average models (Anderson, 1974). Additionally, participants can be directly asked to report on what they are focusing on. This approach may also shed light on the notion of modality appropriateness, which posits that observers rely on the modality that best fits the task at hand (Welch and Warren, 1980). Depending on the type of product, unity may be more easily assessed by vision compared to touch (e.g. for objects which cannot be fully enclosed by hand), while the opposite may be true for variety (e.g. for hidden textures or sensory specific product properties like hardness).

Thirdly, extensive pre-testing is required in this type of cross-sensory research to find manipulations that affect aesthetic appreciation to a comparable degree for each dimension and sensory modality. Because the tactile manipulations dominated the effects on aesthetic appreciation, it became difficult to interpret a possible cross-sensory effect. Precise manipulations become exceedingly difficult the more dimensions are manipulated (four in our case), especially considering their intercorrelations within and across the senses and due to the relatively complex stimuli. These observations indicate that researching cross-sensory UiV is highly complicated and first studying the isolated effects in more simple stimuli is recommended.

FIGURE 31. REMOTES SYSTEMATICALLY MANIPULATED IN VISUAL UNITY THROUGH PROXIMITY (X-AXIS) AND VARIETY THROUGH COLOURFULNESS (Y-AXIS). DECREASING THE DISTANCE BETWEEN ELEMENTS, SUCH AS THE LABELS AND THE BUTTON, INCREASED PROXIMITY WHILE DDING COLOURS TO DIFFERENT BODY PARTS INCREASED COLOURFULNESS.

5 Unity-in-Variety in product-service systems

The attraction, acceptance and satisfaction related to a PSS therefore depend on how its system of products, services, communication and interactions are perceived by the user. We therefore argue it is fundamental to focus on the way in which the different elements of an eco-efficient PSS are perceived. We could talk of a system aesthetic, i.e. an aesthetic as the integrated perceptions of the expression forms of the different elements of the PSS: an aesthetic that therefore integrates in a coordinated way the aesthetics of products, communication, services and interactions.

-

Vezzoli et al., in Product service system design for sustainability (2014)

This chapter has been published as: Post, R. A. G., Da Silva, O., & Hekkert, P. (2015). The beauty in product-service-systems. Paper presented at the IASDR2015 Interplay, Brisbane, Australia.

The benefits of increased design aesthetics are widespread and have been well studied. Beauty has the potential to improve pleasure and satisfaction (Creusen and Snelders, 2002; Cyr et al., 2006), loyalty and overall preference (Schenkman and Jönsson, 2000), and perceived and actual usability (Sonderegger and Sauer, 2010; Tractinsky et al., 2000). Given the importance these factors play in the success of a design, understanding the underlying principles that influence aesthetic appreciation is vital (Bloch, 1995). A number of aesthetic principles of design have already been identified (e.g. Hekkert and Leder, 2008). Such principles are generally studied with tangible products, but not in relation to the intangible services or systems that these products may be part of.

A product-service system (PSS) can be defined as 'an integrated combination of products and services' (Baines et al., 2007). It intends to deliver value in use, and much less in ownership. An example is a car sharing service like Greenwheels. Ownership of the product (a car) remains with the company, whereas users pay for the service to hire a car that is shared among many (Goedkoop, 1999; Meijkamp, 1998). Users register and book a car online or by phone, and they receive a passkey to access a car that is available on fixed locations throughout a city. Such an approach to satisfy users' needs (e.g., transportation) has the benefit of taking the form of a dematerialized service, as the quantity of material artefacts can be reduced by sharing the material product (e.g., the car). As a result, PSSs are often mentioned as one way towards a more sustainable future (Mont, 2002; Vezzoli, 2013). However, for PSSs to be successful, consumers need to be convinced of the value of use, over that of ownership (Baines et al., 2007; Mont, 2002). Hence, increasing the acceptability and satisfaction that a PSS offers is of vital importance.

As aesthetic appeal is known to positively influence the satisfaction and preference for products, increasing a PSS's aesthetics can play a significant role in increasing the overall appreciation of the PSS (Vezzoli et al., 2014). However, to our knowledge, the literature on aesthetic principles of PSSs is minimal to none-existent (search query: "'Product-Service System' Aesthetics'", on Google Scholar, 24-03-2015). The lack of accessibility to aesthetic principles in this domain is illustrated by one study reporting the use of an aesthetic measure ('aesthetic appeal') to assess the multisensory aesthetics of a PSS in the form of a new bus interior and bus transportation service concept (Carreira et al., 2013). There is thus a need for a better understanding of what makes a PSS beautiful to increase user satisfaction and communicate the value of a PSS to users (Vezzoli, 2013). The aim of this paper is to fill this gap in knowledge by showing how two core principles, which have been empirically proven to influence product design aesthetics, can also describe PSSs.

The principle of Unity-in-Variety (UiV) holds that the highest aesthetic appreciation is arrived at when the largest diversity of elements is still experienced as a coherent whole. UiV has traditionally been used to explain aesthetic appreciation in visual domains such as the arts (Cupchik and Gebotys, 1988), but has been shown to apply to product designs as well (Chapter 1; Post et al., 2013b). For products such as car interiors, lamps and espresso machines, it was shown that people aesthetically preferred those designs that combined high variety with high unity. However, the principle not only applies to the visible side of products. Gustav Fechner (1876) was one of the first to write extensively about UiV as essential to aesthetic appreciation. Fechner argued that for humans to find pleasure during the interaction with objects we need to sense a coherence and unity within the various parts and approaches towards it. While Fechner goes on to exemplify how visible properties (e.g. line, shape or colour) of objects relate to sensing unity and variety, he does not limit the principle to these properties alone. Unification of the interactive experience can also exist when the different parts or approaches towards an object generate a sense of joint purpose, idea, or causal connection over time (assuming that there is a functional relationship). Hence, a greater sense of beauty can thus be perceived if not only the immediate sensorial parts of a design, but also the separate actions and purposes, are meaningfully, functionally and temporally connected.

The principle of Maximum-Effect-for-Minimum-Means (MEMM) indicates that the highest degree of aesthetic pleasure is derived from perceiving a purpose being fulfilled in the most efficient way.[1] In design handbooks, this principle is referred to as 'efficiency' (Macnab, 2011), 'economy' (Zelanski and Fisher, 1996) and 'Occam's razor' (Lidwell et al., 2010). These handbooks usually focus on how MEMM can be applied to

[1] Part of this research on UiV has jointly been investigated with the MEMM principle, which is part of the same UMA project (Da Silva et al., 2014, 2016).

the visible properties of products; for instance, in comparing two functionally-equivalent display designs, Lidwell et al. (2010) recommend designers to implement the one with the fewest visual elements. But MEMM does not only apply to visual properties. It also describes the beauty of goal-oriented human performances that are invisible to the human eye; for example, mathematical demonstrations (Hardy, 2012) and logical argumentations (Walsh, 1979). In these cases, efficiency is appreciated in the structure, mechanism or system by which a goal is attained, with the simplest mechanism (e.g., demonstration or argumentation) leading to the highest aesthetic pleasure. Literature in design research further suggests that MEMM is related to the effort people make when interacting with a product, both mentally and physically: '…We like to invest a minimal amount of means, such as effort, resources, brain capacity, to attain the highest possible effect…' (Hekkert, 2006 [p. 163]). A recent conceptual study indicates that MEMM accounts for an evaluation of products that attends to the product's sensory properties, but also to the way the product works and interacts with people (Da Silva et al., 2016). Thus, similarly to UiV, MEMM can be extended to non-sensory properties or aspects of a design.

On the afore-cited theoretical grounds, both UiV and MEMM can be applied to aspects beyond those usually studied in product design aesthetics. We therefore argue that both principles are able to describe the beauty of a PSS as well. In order to assess how, we conducted an explorative, qualitative study.

5.1 Study

5.1.1 Method

The study took the form of an assignment for master students in Industrial Design Engineering from Delft University of Technology. The assignments were part of a course on product experience. The students were asked to reflect upon the principles of UiV and MEMM in relation to a PSS of their choice and were given one week to complete the assignment in written form, supported with illustrations if desired. They were not informed about the way in which the principles might apply to a PSS. They only received the following instructions:

(1) The principle of unity-in-variety states that both unity and variety should be

maximized to achieve the highest level of aesthetic appreciation. (1a) Identify the aspects of the PSS that make it unified and the aspects that make it varied. (1b) How would you increase the unity and/or the variety to maximize the unity-in-variety of your PSS?

(2) The principle of maximum-effect-for-minimum-means implies that efficiency can be aesthetically appreciated. (2a) Evaluate the PSS in terms of efficiency. Is it a minimum means leading to a maximum effect? Justify your answer. (2b) How would you make your PSS more efficient? Specify how you would minimize the means and/or maximize the effect.

Sixty-one assignments were received and submitted to thematic analysis following a theory-driven approach (Braun and Clarke, 2006). Two researchers reviewed the assignments iteratively. Analyst triangulation was used to test for consistency in the interpretation of the assignments and the identification of themes (Patton, 1999). The identification of themes was performed with attention to the participants' explicit remarks and with interest in the relevance of responses to the research question 'How do the principles of UiV and MEMM apply to a PSS?', as opposed to interest in the prevalence of those responses.

The results of the analysis will be presented per principle in the following section. The results will be exemplified with the participants' verbal statements and also, occasionally, with their illustrations. Each quoted statement will be identified (at the end and between brackets) with the participant who made the statement (identified with a number from 1 to 61) and the PSS that the participant was referring to.

5.2 Results

Three recurrent themes were identified in the participants' answers to both parts (1 and 2) of the assignment (no distinction between subparts a and b was made during analysis, and so no distinction will be made when reporting on the results). The three themes were labelled: *sensory properties*, *conceptual understanding*, and *human interaction*. We will now introduce these themes in general terms, and then explain how UiV and MEMM apply to each of them based on the participants' statements.

Sensory properties refers to those aspects of the PSS that can be immediately perceived through any of the senses. In vision, these are properties like colour, shape, material, font and composition. These properties can also apply to other senses such as auditory.

Conceptual understanding entails comprehension of the PSS beyond that of its sensory properties. It involves an understanding of the PSS' function, and of the mechanism by which this function is fulfilled (a mechanism made of physical or non-physical parts).

Human interaction refers to the actions the user has to perform to use the PSS. These actions are as diverse as clicking with a computer mouse or pushing a card into a slot.

5.2.1 UNITY-IN-VARIETY

5.2.1.1 Sensory Properties

Participants found a PSS varied on sensorial properties when differences could be perceived between basic layout aspects of a design such as colour or shape. Whereas a PSS was considered to be unified when similarity, order and coherence was found between such aspects. The following statements from participants illustrate this.

> '*Because Spotify is a music service it showcases album covers designed by others. They used this variety of visual styles in their advantage by ensuring unity with the use of a grid. Certain elements of this grid are consistent among the different screens, others are varied. The Spotify colour scheme also helps in creating visual unity throughout the service.' (Participant 31, Spotify).*

> '*Checking in and out both uses a bleep sound. All the touch points use a bit of pink, mostly due to the OV chip card logo. A lot of machines uses yellow as main colour. However, the shapes of the different machines are different.' (Participant 59, OV-Chip).*

> '*The unity can be found in the same colour red that is always used and in the same way (…). When choosing a user, the square buttons have different colours and can have different icons. However, there is unity in this variety: the icons have a similar style and are placed in the same square boxes. Maximizing Unity-in-Variety between the devices [e.g. smartphone or laptop used to navigate the service], can be done by using the same colours.' (Participant 60, Netflix).*

Similarity and symmetry, which are Gestalt Laws of perceptual grouping well known to unify designs, were generally identified in physical and non-physical interfaces. For instance, in the following statement.

> '*The aspects that makes the Random Reader as a product unified: Similarity: First the buttons on the Random Reader show similarity. The buttons are neatly organized and arranged, this ensures unity. Symmetry: The Random Reader consist of symmetry. The buttons are mirrored along the vertical axis, it makes the design coherent and orderly.*' *(Participant 3, Rabobank Online Banking, Figure 32).*

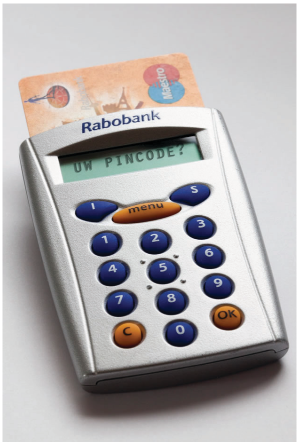


FIGURE 32. RABOBANK RANDOM READER

Especially symmetry and similarity were repeatedly and explicitly mentioned. Similarity was present '*among elements*' (Participant 19, Paper 53); '*in font type*' (Participant 52, Dutch Railroads Travel App); '*in form*' (Participant 33, Google Drive) and '*in colour*' (Participant 13, Blackboard). Symmetry was often related to compositional aspects such as symmetry '*of the frame*' (Participant 14, Spotify); '*of text boxes*' (Participant 33, Magnet.me); and '*in the layout*' (Participant 27, Pinterest).

5.2.1.2 Conceptual understanding

Participants also noticed how different parts of a PSS could be related in a meaningful way. If unified, the various parts of the PSS make clear an underlying structure, relationship or intended use, as the following statements indicate.

> '*The main function of Evernote, collecting and structuring notes, is a good*

example of unity-in-variety. You can have hundreds of notes, with different content (text, photo, scan), lay-out, subject and goal (variety), but you can structure them and make it possible to have an overview (unity). All notes look the same in essence (title, tags, date and content). You can place notes with the same subject in the same folder (unity). But what I think illustrates the aesthetics of Evernote in unity-in-variety is the fact that besides the notebooks you can give your notes tags. By giving each individual note a tag, you have a second layer of structure where you can endlessly create groups and order your notes depending on what you want to use them for.' (Participant 12, Evernote).

As the previous statement suggest, the conceptual understanding of a PSS can be inferred from its sensory properties. Sensory properties help users understand and perceive the unity within a variety of intangible organizations and structures within the PSS. This is more obvious in the following statements.

'*…the different weights and even colours of the texts denote a varied aspect, as they indicate the importance of the text through hierarchy. A title of an album is coloured black, whereas the artist name has uses greyscale, and is also slightly smaller in size.' (Participant 42, Google Play Music).*

'*Different icons for a variety of files: Each format of a file has an unique icon, which makes the format of the file clear in one glance.' (Participant 33, Google Drive).*

'*Different transporters use different colours.' (Participant 59, OV-Chip).*

A statement such as '*The screen in which you can choose your seat looks like the actual cinema hall*' (Participant 36, Pathé App) further suggests that conceptual understanding can be perceived through a visual metaphor, as the metaphor unifies the sensory properties (layout of a cinema) with the intended use of the PSS (buy cinema tickets online).

However, a sense of unity does not necessarily need to directly originate from sensory properties. As mentioned in the following statement, grouping of abstract relationships (such as a music genre) can also be achieved by using conceptual structures like a playlist.

'*Spotify has a big diversity of genres, artists, albums, and songs giving a big variety sense to it, but still the playlist groups songs which have a connection between them. Whether it is the feeling they create, the year they were* *released or many other characteristics. By doing this [grouping through playlists] they generate the feeling of unity.' (Participant 48, Spotify).*

5.2.1.3 Human interaction

For human interactions, unity and variety were perceived as more directly opposing one-another than in the two other themes. Participants regarded differences or irregularities in interaction possibilities, location or manner (e.g. in time, movement or technique), as increasing variety, whereas they regarded similarity in these aspects as unifying. This is indicated by the following statements.

> *'The way to place your OV card is differs for checking in and out at different touch points. Sometimes there is one fast connection and sometimes you have to hold the card for several seconds against the machine. There are also different systems for charging the OV card, sometimes you only have to hold it against a point and sometimes you have to place it in the machine.' (Participant 59, OV-Chip).*

> *'Variety in interaction possibilities (…) and in different ways to send messages (voice, text, photo, video).' (Participant 7, WhatsApp Messenger).*

> *'Operationally the unifying aspect is the action of checking in/out by placing the card in front of a scanner. Varying are the locations of the check-in/out points and whether you check-in/out inside the means of transport (like in the bus) or outside (on the train station).' (Participant 32, OV-Chip).*

> *'The variety comes when we take the Product Service System together. To transfer money you'll not only need the Random Reader but as well the website, your debit card, bank account numbers and a working internet connection. While banking you need to push buttons of the Random Reader but also on the internet, it's really complex and you have to practice a few times before you'll understand it and do it flawless. All this different parts makes it varied.' (Participant 3, Rabobank Online Banking).*

5.2.2 Maximum-Effect-For-Minimum-Means

In answers to the second part of the assignment, the PSS was assumed to be the means to perform a certain function or attain a given effect. The participants generally assumed this effect to be fixed, so in assessing (2a) and increasing (2b) the efficiency of the PSS, they judged and minimized the PSS as a means rather than judged and maximized its function. The themes *sensory properties, conceptual understanding* and *human interaction* thus describe the PSS as a means.

5.2.2.1 Sensory properties

The participants found a PSS efficient when it fulfilled its function with the least possible amount of properties such as colour, text, buttons, icons and columns. Statements such as the following support this idea.

> '*The main page is minimally composed with crucial functions such as a map, route, and music, and start exercise button. For color, it only uses two main colors, white and blue, and exceptionally orange, only for the start button, and it effectively emphasis [emphazises] it.' (Participant 54, Map My Fitness).*

> '*The website uses a lot of white space and very reduced graphics. Every category is explained by one or two sentences. The layout is very minimalistic and I would say that these means are leading [to] the effect of optimal overview and highly understandable data organization.' (Participant 20, Dropbox).*

> '*I think the essence of Evernote can generate a very strong effect, but now the application has too much [many] options and buttons (…) I would make less functions visible at a time. Only the ones you really need. Besides I would use clearer icons and less icons.' (Participant 12, Evernote).*

> '*To achieve 'minimum' means, I would remove some of the icons on the top right corner of the page which are not usually used and keep the most important ones.' (Participant 33, Google Drive).*

> '*The home page is made with lots of columns which make the page very unclear. It is not a minimum means leading to a maximum effect. It is totally the opposite. The page is filled with everything and you will get lost in it.' (Participant 18, Facebook).*

Although less predominantly, non-visual properties were also taken into account in the evaluation of the PSS as a means. For instance, when assessing the feedback provided by the card reader of a transport system, a participant stated: '*Together with the feedback in form of sound, it is tried to communicate whether or not the check-in/check-out was successful (...) A more efficient way to communicate these two variables could be to only use sound*' (Participant 2, OV-Chip). The efficiency of a PSS can thus be described by a wide range of sensory properties, sound included.

5.2.2.2 Conceptual understanding

The participants found a PSS efficient when it managed to fulfil its function through a mechanism comprising the least possible amount of 'parts', such as a card reader and an internet connection. As the following statements reveal, they proposed removing all unnecessary 'parts'. For one participant, this involved replacing several platform-specific internet connections with a single cross-platform one; for another, removing a card reader from a personal banking system.

> *'In terms of means I think lies little room for improvement other than the fact that all players need the same Wi-Fi connection, or have the same operating system when there's no Wi-Fi available in order to enable a Bluetooth connection. A cross-platform Bluetooth connection for example would enhance it in terms of simplifying setting up a game.' (Participant 49, Spaceteam).*

> *'To make the PSS more efficient I would definitely eliminate the Random Reader (…) If you're not at home and you want to transfer money you need this device. But because it's such a little thing which you only use for banking, most of the time you forget it (…) you'll only need your phone and an internet connection to transfer money or to check your balance overview.' (Participant 3, Rabobank Online Banking).*

One participant further argued that applications operated with hand gestures directly made on a touch screen were generally more efficient than those operated with gestures mediated by a computer mouse. For the participant, a mouse is a 'part' a PSS can work without.

> *'The workflow of an app is already more intuitive and efficient than that of a computer with a mouse, since the gestures you make with your hands are directly converted into actions on a touch screen, whereas on a computer a mouse is used to 'interpret' these gestures that are converted into movements with which the functions can be accessed.' (Participant 8, Marktplaats).*

5.2.2.3 Human interaction

The participants found the PSS efficient when it performed its function through an interaction requiring the least possible amount of actions or efforts from people, be these efforts physical or mental. The following statements illustrate this idea.

> *'The effect you seek when using Steam is you want to play or buy games and*

game with other people or your friends. Most of these effects can be achieved with one or two mouse clicks. I think the service delivers high output for minimal effort.' (Participant 6, Steam).

'*An example of something Pinterest does to maximize the effect for minimum efforts is suggesting search terms. When typing a search word in the search bar the result of this search pops up. On the top side of the screen, suggestions for additional search terms pop up. This is something that helps the users to minimize the efforts that he/she needs to put in, to find the optional results.' (Participant 38, Pinterest).*

'*Instagram has put a lot of focus into maximizing its efficiency (…) Within 5 simple actions the user can share a picture with his/her follows (…) filters give the sense that the picture is extensively enhanced for an aesthetic effect, even though it only requires one click.' (Participant 24, Instagram).*

Several statements referred to how efficient it was to reach a given effect with just one or two clicks, a simple tap or swipe. Some examples are: '*With one click statuses can be liked, shared and commented upon*' (Participant 27, Facebook); '*If you like something, you can pin it on your page with just one click*' (Participant 46, Pinterest); '*The amount of functions that are available with the tap of a finger, or two, is incredible*' (Participant 8, Marktplaats); '*You only need two clicks to watch a movie*' (Participant 34, Popcorn Time); '*By a single swipe to the right you, in theory, can find the love of your life*' (Participant 43, Tinder).

While such statements mentioned the manual effort of actions such as clicking, some others clarified that a PSS also requires a cognitive kind of effort from users. For example, in the following one, a participant explained that people are forced to make an effort to understand, i.e., to read and interpret text, when receiving written feedback:

'*Using text as user feedback, in my opinion, is almost never maximum-effect-for-minimum-means, in terms of the effort the user has to make to understand what is communicated.' (Participant 2, OV-Chip).*

In connection to this, another participant suggested transforming written instructions into visual instructions in order to make the PSS more efficient:

'*I would make the Random Reader instructions visual (…) indicating the order of buttons to push. This means it is also directly understandable where to push.' (Participant 25, Rabobank Online Banking).*

Implicit in the last two statements is the idea that a PSS is efficient if it manages to be used intuitively, without conscious cognitive effort. In statements such as the following one, this relationship between efficiency and intuitive interaction became explicit.

> '*In terms of efficiency the interface of the Jawbone UP is very intuitive to use. It utilizes the maximum of the gesture interface of the smartphone to minimize the use of menus and buttons, which creates a very clear and efficient interface.*' *(Participant 40, Jawbone UP 24).*

Although human interaction has been presented as a theme independent of the others, it is crucial to note that none of these aspects are unrelated when it comes to the assessment of a PSS as a means. For instance, the way a bankcard is shaped (sensory property) can affect the way people interact with the overall banking system (human interaction). This example is taken from the following statement, in which a participant suggested changing a card's shape to reduce the mental effort people have to make to properly insert the card in the reader and, consequently, make the overall paying process more efficient.

> '*I [would] make the VISA debit card into an arrow shape. The shape of the card itself indicates which direction you have to insert it, so without checking the direction, people will know how to put it in the chip-card reader at the moment he/she takes out the card. This [would] make the paying process more efficient.*' *(Participant 15, VISA, Figure 33).*

FIGURE 33. SUGGESTED IMPROVEMENT OF VISA CARD.

5.3 Discussion

In this paper, we reported on a qualitative study exploring how the aesthetic principles of UiV and MEMM can apply to PSSs. With this study, we identified three themes that can be interpreted as different levels of user experience: *sensory properties, conceptual understanding* and *human interaction*. We further identified how each of the principles can be applied to each of these levels to enhance aesthetic appreciation of a PSS. A PSS is considered to adhere to the UiV principle if the different sensorial, functional or interactive parts of the PSS are meaningfully related into a unified whole. With regards to MEMM, a PSS is perceived to be a minimum means when it fulfils its function with the least possible amount of sensory properties, the least possible amount of parts, and the least possible amount of actions or efforts from users. Our study thus revealed that UiV and MEMM can be applied to multiple aspects of PSSs. As such, it provides a platform to further develop knowledge into PSS aesthetics, and suggests directions for design practice.

Our findings serve as a tool to identify the aspects of a PSS that can be modified to make the PSS more beautiful and valuable overall. As an illustration, we can think of the car sharing service mentioned in the introduction. This PSS could satisfy the MEMM principle by, for instance, (1) creating an easy-to-grasp interface to rent a car, (2) minimize the number of things needed to utilize it (e.g., only needing a phone to rent and open the car), and (3) having a car in close proximity so it can be quickly and effortlessly accessed. At the same time, the PSS can take into account the UiV principle on the same levels by, for instance, (1) making the rental interface perceptually organized, (2) stocking a variety of cars that can still be identified as belonging to the same service (e.g. through use of similar colours), and (3) create consistency in the way these different cars are operated (e.g. using similar brands of cars). While this example only shows some of the ways designers could make a PSS more aesthetically pleasing, it serves as an illustration of how these two principles, which are usually applied to products, can also be applied in the domain of PSSs.

While our findings provide knowledge of the aesthetics of PSSs, which was previously lacking, there are several topics that could be further investigated. For instance, we have not explored how the different levels interact with one another, nor have we explored how the principles interact with each other on each of these levels. It is possible that, for example, both the conceptual understanding and the human interaction are grounded in the sensory properties of the PSS. Also, the optimization of one of the principles at a certain level could deter the maximization of the other at that same level. It is therefore important to examine these issues to optimally apply the principles to a PSS in order to elicit the most aesthetically pleasing user experience possible. Moreover, principles of design aesthetics other than UiV and MEMM could also be studied to determine their applicability to PSSs. Lastly, the findings we have presented in this paper have been derived from an explorative qualitative study. Experimental and controlled testing of the principles, and the aforementioned issues, could extend or challenge our findings and further develop the aesthetics of PSSs.

6 Concluding discussion

Heraclitus was to propose a different solution; if the universe contains opposites, elements that appear to be incompatible like unity and multiplicity, love and hate, peace and war, calm and movement, harmony between these opposites cannot be realized by annulling one of them, but by leaving both to exist in a state of continuous tension. Harmony is not the absence of but the equilibrium between opposites.

-

Umberto Eco & Alastair McEwen, in 'A history of beauty' (2005)

This research investigated the principle of Unity-in-Variety (UiV) in the domain of product design. Through multiple empirical studies we examined how unity and variety relate to each other and to aesthetic appreciation. We started investigations using high resolution full-colour images of products as stimuli to assess the principle's workings in the visual modality, and continued with a selection of physical products as stimuli in the tactile modality. This was followed by experiments using newly designed systematically manipulated products to replicate and further extend our initial findings. To synthesize findings from separate modalities, we used another set of existing products to study the visual-tactile modality. Additionally, we assessed how underlying design factors (contrast, symmetry, similarity, continuity, colourfulness and emergence) and individual differences (in expertise and motivational drives) influence a preferred balance between unity and variety. The knowledge generated informs how UiV explains aesthetic appreciation, what influences UiV and why we have evolved to aesthetically appreciate perceiving UiV.

In the concluding chapter we briefly summarize the results to our main research goals, elaborate on the findings in more detail, discuss their theoretical and practical implications, and offer a future perspective.

6.1 Results to our research goals

6.1.1 Aim 1: Investigate how UiV relates to aesthetic appreciation

The main aim of this research was to investigate how unity and variety relate to aesthetic appreciation. We found that, despite suppressing each other's effect due to an inherent negative correlation, unity and variety both positively influence aesthetic appreciation in the visual, tactile and visual-tactile product experience (Figure 4, Chapter 1). As a result, we can conclude that an optimum balance exists between these two counteracting forces where aesthetic appreciation is highest. At this optimum balance, increasing unity any further will result in a decrease of variety (or vice versa) and consequently a decrease in aesthetic appreciation (Figure 34). Hence, the principle of UiV can explain a substantial part of the aesthetic appreciation of product designs (15-50% of explained variance of the non-averaged data) and connotes maximizing unity and variety in such a way that they can coexist.

Besides having demonstrated that UiV implies increasing unity and variety until an optimal balance is achieved, for most product categories we found that unity was two to three times more important than variety. Moreover, in Chapter 1 we showed that increasing unity heightens the appreciation of variety to a much larger degree than the other way round. Combining these findings, unity thus appeared to be the dominant dimension of the two and applying the principle implies 'to preserve unity while almost allowing for chaos' (Boselie, 1996).

6.1.2 Aim 2: Identifying factors influencing unity and variety, and their appreciation

Our second main finding provides insights in how various factors underlie unity and variety and their appreciation. Several design factors were shown to determine impressions of unity and variety, while individual differences determined the degree to which they are preferred.

By means of experimental manipulations we demonstrated in Chapter 2 that *symmetry*, *contrast*, *similarity* and *colourfulness* influence impressions of visual unity and variety. Higher symmetry resulted in more unified web pages, whereas increasing colourfulness resulted in more varied web pages, and both did so independently of each other. Furthermore, both manipulated dimensions were demonstrated to independently and positively predict aesthetic appreciation, and maximizing unity and variety led to the highest aesthetic appreciation ratings. Unity and variety were additionally manipulated through respectively contrast and similarity, which influenced unity and variety simultaneously; increasing contrast heightens both impressions of unity and variety, whereas similarity increased unity while lowering variety.

In Chapter 3 we showed that the Gestalt laws of *continuity*, *emergence* and *similarity* underlie tactile unity and variety, and their resulting aesthetic appreciation. Stronger continuity and lower emergence of shape increased felt unity, whereas lower similarity in materials increased felt variety of 3-D printed products. Again, the combination of high unity and variety, as manipulated through the Gestalt laws, was shown to result in the highest aesthetic appreciation.

Next to design factors, we identified how individual differences in motivational drives and expertise can influence the preferred balance between unity and variety.

We revealed that stronger safety needs relative to accomplishment needs increased the appreciation of visual or tactile unity (Chapter 1 and Chapter 4, respectively). As a consequence, the optimum balance between unity and variety shifts towards unity for safety seekers. A similar shift towards a preference for unity occurs for (design) expertise. In Chapter 1 we found that experts give different unity and variety ratings and also appreciate unity to a stronger degree than laymen ratings the same products. Nonetheless, experts still appreciate an optimum balance between unity and variety and the principle therefore maintains.

We additionally investigated whether perceived complexity of product categories could explain shifts in the preferred unity and variety balance between different studies (Chapter 1). We expected variety appreciation to increase for simple product categories because it compensates for the relatively plain products. However, unity remained dominant over variety for simple products. Instead, the preferred UiV balance seemed to be more dependent on the degree of unity and variety that is typical for a specific product category.

Taken together, we show how the optimum balance in unity and variety is at least partially dependent on a combination of objective and subjective aspects. Objective design factors such as symmetry and similarity determine how much unity and variety is present in a design. The degree to which unity and variety are accordingly appreciated relies on the sensitivity of the perceiver, which is at least partially dependent on the individual's expertise, and need for safety and accomplishment seeking.

6.1.3 Aim 3: Develop a comprehensive theoretical understanding of UiV

While the principle of UiV has for many centuries been proposed to explain aesthetic appreciation, few empirical studies examined the joint influence of unity and variety on aesthetic appreciation (Fechner, 1876). By showing that unity and variety are partial opposites together positively influencing aesthetic appreciation we provide evidence that there exists an optimum balance between both where aesthetic appreciation is highest. The findings that led to this conclusion answer some of the long-standing questions concerning the principle and contribute to its theoretical understanding.

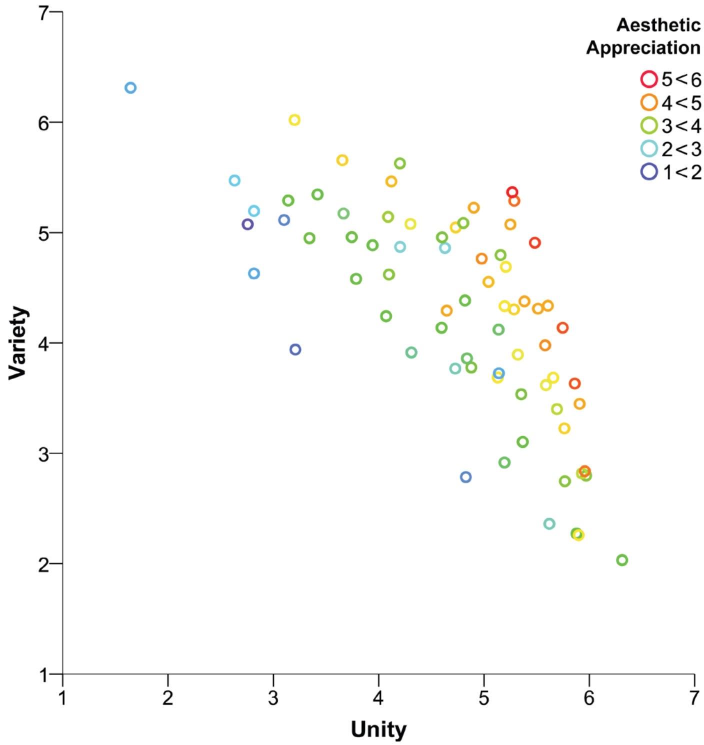


FIGURE 34 (TAKEN FROM CHAPTER 1). PLOTTED MEAN RATINGS FOR 72 PRODUCTS SHOWING AESTHETIC APPRECIATION (IN COLOUR) TO INCREASE FOR HIGHER COMBINATIONS OF UNITY AND VARIETY.

It has generally been accepted that unity and variety are opposites of each other, as can intuitively be recognized (Berlyne, 1971; Leeuwenberg and Van der Helm, 1991). The presence of high variety implies strong and plentiful differences between elements and properties. As a consequence, it becomes more difficult to maintain order and structure between different parts. Products exhibiting high variety will therefore generally be lower in unity, a finding that was confirmed in all our studies (correlations generally varied between -.10 and -.40). However, whether unity and variety are opposites of a single dimension, or two separate dimensions, has been debated (Berlyne, 1971; Birkhoff, 1933; Eysenck, 1942; Moore, 1986). Results from our factor analysis showed that our unity and variety items measure two distinct concepts, findings that were independently confirmed by Blijlevens et al. (2014b). Combined with the consistent weak to moderate negative correlation between both concepts, this indicates that they can be seen as two distinct, but partially opposing dimensions.

The finding that unity and variety are partial opposites has important implications for the working mechanisms of the principle. It implies that there is room for products to maximize the impression of both unity and variety at the same time (Figure 34). Although their partial opposition makes this challenging, it is at this point—where opposition is reconciled—that designs are judged to be the most beautiful. The graph also reveals that combinations of low unity and variety are absent. Such combinations might not even exist, as it is hard to imagine products with very few differences or elements that do not automatically generate a certain degree of unity. Or switching the perspective, a design with low unity is inevitably chaotic and highly diverse.

That a lack of unity results in chaos, which should principally be avoided, also illustrates why unity was generally found to be the dominant factor contributing to aesthetic appreciation (standardized regression weights for unity ranged between .25 and .70, and for variety between .10 and .40). Without unity, the organization between different elements is absent and it becomes more difficult to make sense of what we perceive. Whereas without variety, we might still be able to make sense of what we perceive, but the perceptual challenge is lost and we quickly lose interest. Absence of unity is therefore much more detrimental to aesthetic appreciation than absence of variety. Furthermore, in Chapter 1 we found that increasing unity heightens the appreciation of variety, and to a substantially larger degree than the other way round. Together with the theoretical importance of unity in assuring perceptual understanding, this suggests that unity is the dominant factor and a prerequisite for creating beautiful designs. This is a major theoretical advancement, as it illustrates that the principle is asymmetrical, which has important consequences for how it should be applied, as will be discussed shortly. Nonetheless, the finding that increasing variety can also lead to increased appreciation of unity, and that variety can in certain situations become equally important to unity (Chapter 2 and 3), signifies their mutual dependence and constant balancing dynamic. Appreciation of variety requires the presence of sufficient unity. If variety is increased any further, it becomes necessary to compensate with stronger unity to maintain an optimum balance. Similarly, if unity is overly present, there is room for additional variety and aesthetic appreciation will rise until order and structure is lost.

6.2 Implications for theory

6.2.1 Uniting theories of design aesthetics

By creating a theoretical framework supporting the principle of UiV and through investigating its working mechanisms, we contribute to scientific theory in several ways.

Firstly, our research bridges the fields of evolutionary psychology, perception and design to provide evidence that UiV can explain why and how we aesthetically appreciate product designs. In being exposed to variety, there's potential of discovering and learning new patterns and relationships. Its perception is accordingly appreciated because it fulfils the need to search for novel sensations and stimulate our senses. At the same time, this variety in sensory information needs to be structured and organized in such a way that it matches our perceptual configuration. We experience the variety of sensory impressions as a unified whole when order is perceived between the different properties and elements. The result is that we efficiently process this perceptual information, effectively making sense of what we perceive (Attneave, 1959). The importance of this sense-making process has proven so valuable to the survival of our species that, over time, our brains have evolved to find pleasure in perceiving both unity and variety (Hekkert, 2014). These deeply embedded mechanisms of perceptual pleasure still influence and shape our aesthetic experiences to this day. The pleasures we sense when interacting with products (e.g. solving a puzzle, learning to work with an interface, or sifting through magazines) are the result of challenging our perceptual capacities to process and successfully comprehend the world around us. By linking the principle to evolutionary theory and providing evidence for the influence of underlying motivational drives in its formation, we unite findings from various fields and generate a comprehensive understanding of how and why we appreciate perceiving UiV. The resulting theoretical foundation allows for further studying not only product design aesthetics, but also the appreciation of other objects that can elicit unity and variety experiences, which we will discuss later in this chapter.

Secondly, through systematic manipulations of design factors in realistic stimuli (e.g. Gestalt laws of perceptual grouping, contrast and colourfulness) we show how subjective impressions of unity and variety arise from objective design properties. Practically all design factors are applied through arranging, removing, adding and changing the intensity of lines, shapes and colours, which are the most basic design properties (Graves, 1951; Kim, 2006; Lidwell et al., 2010). By showing that many common design factors underlie unity and variety, the principle integrates their influence into an overarching and holistic theory, and allows for understanding studies into such design factors in terms of optimizing both unity and variety (e.g. Altaboli and Lin, 2012; Chassy et al., 2015; Clement et al., 2013; Creusen et al., 2010; Deng and Poole, 2012; Giese et al., 2013; Joye et al., 2016; Marin and Leder, 2013; Michailidou et al., 2008; Moshagen and Thielsch, 2010; Nadkarni and Gupta, 2007; Reinecke et al., 2013; Roehm and Roehm Jr, 2010; Tuch, Presslaber, et al., 2012; Woods and Boudreau, 1950).

Thirdly, the principle may offer an explanation for the divergent results often found in studies assessing the relationship between complexity and aesthetic appreciation. In his hallmark work, Berlyne (1971) developed the theory of an inverted U-shaped relationship between aesthetic preference and complexity, implying that people generally aesthetically prefer medium complexity. However, later studies presented conflicting results; some researchers found a linear instead of inverted U-shaped relationship, or found low or high degrees of complexity to be preferred (for an elaborate overview of these studies see Nadal (2007)). Nadal et al. (2010) found that complexity in artworks is largely explained by two factors. The first factor refers to the amount of heterogeneity between elements, the variety of colours, the number of elements and their three-dimensional appearance. The second factor refers to the amount of organization and intelligibility of the works of art. These two factors are almost completely analogous to our definitions of variety and unity and also in their relation to beauty ratings. Hence, the earlier findings that medium complexity is aesthetically appreciated can be explained by the principle of UiV. We prefer medium complexity because, similar to an optimum balance between unity and variety, it results in highly efficient processing of diverse perceptual information. Additionally, the principle can give an explanation for why certain studies did not find medium complex stimuli to be preferred. Because unity and variety are two separate but partially opposing dimensions, a skilful artist can combine unity and variety to reach an optimum balance.[1] However, many artefacts will not reach this optimum level and instead will consist of suboptimal combinations of unity and variety that lead to lower aesthetic appreciation, as clearly illustrated by Figure 34. It is possible that studies that did not find medium complexity to be aesthetically preferred included stimuli that had these suboptimal combinations of unity and variety. Future studies could investigate the relationship between UiV and complexity more precisely by disentangling both. For example by showing that stimuli with medium complexity can result in different combinations of unity and variety, whereas stimuli adhering to UiV should still result in medium complexity ratings.

Lastly, the previous points combined with our proposed theoretical account of the principle allows for direct integration with currently accepted models of aesthetic appreciation that rely on perceptual mechanisms of early shape and colour feature integration (Bullot and Reber, 2013; Chatterjee, 2004; Hekkert, 2014; Leder et al., 2004). For example, Leder's model proposes a first level of 'perceptual analyses' of artworks that depend on factors such as contrast, colour, symmetry, grouping and complexity. Factors that are all accounted for by our principle. Similarly, the model of Bullot and Reber includes a level of 'Basic exposure to the work (of art)', in which they refer to various evolved preferences to factors such as symmetry and to the importance of processing fluency (and disfluency), which is intrinsically connected to perceiving order and organization (and disorder and disorganization). Such models would benefit by accommodating the principle of UiV as it simplifies the perceptual level of the models while simultaneously explaining how the different design factors in this level interact.

[1] That it is not easy to achieve such an optimum is reflected by the fact that even some of the most famous designers find it difficult to explain (Maeda, 2006, p. 46): 'Within the same experience, finding the right balance between simplicity and complexity is difficult. Achieving a situation where the differences enhance, instead of cancel out, either's existence is something of a subtle art that I am still unclear about.'

6.2.2 Developing a theory of tactile aesthetic appreciation

Despite the importance of pleasurable tactile experiences, relatively few studies have investigated what influences tactile aesthetic appreciation (Carbon and Jakesch, 2013). Our research demonstrates that the principle and its supporting theoretical framework can be especially informative in studying, understanding and designing for the tactile modality. We revealed that tactile aesthetic experiences are influenced by unity and variety in similar ways to vision. To our knowledge, UiV is the first empirically tested principle of tactile aesthetics. The tactile aesthetic principle states that those designs that combine the highest tactile variety sensations while remaining to feel unified are aesthetically preferred.

Previous studies mostly identified the influence of isolated material properties, such as hardness and texture, on affective responses (Essick et al., 2010). Pleasure received from perceiving those properties have been argued to originate from an innate preference towards soft touch as an indicator of 'motherly' safety (Gallace and Spence, 2011a). Our research adds to the theoretical understanding of tactile aesthetics by supporting the idea that tactile aesthetic appreciation can also result from perceptual understanding of sensorial information itself (Grohmann et al., 2007; Jansson-Boyd and Marlow, 2007). We argued that the mechanisms that process and group different elements in our perceptual systems are likely shared between sensory modalities and should therefore also apply to the tactile modality. Our findings back this theory, as Chapter 3 showed that the Gestalt laws of *emergence*, *continuity* and (dis)*similarity* can be used to influence the degree of tactile unity and variety. We thereby for the first time show the importance of Gestalt laws in determining tactile aesthetic appreciation.

6.2.3 A multisensory perspective

Our research showed that tactile and visual UiV contribute to the multisensory (visual-tactile) aesthetic experience (Chapter 4). Unity and variety were both found to strongly correlate between vision and touch, suggesting that their impressions are largely generated from the same product properties. These strong correlations and comparable ratings in visual and tactile unity and variety are in line with the notion of sensory equivalence, which states that different senses process similar information (Marks, 1978). Nonetheless, while overlap exists for visual and tactile unity and variety impressions, they each also affect the multisensory aesthetic experience in unique ways. This is probably caused by the distinct ways in which different senses extract information about product properties. Differences in heat conductance or softness are not perceived through vision, and materials that differ on this will only be perceived as less varied in touch. On the other hand, properties like colour and reflectivity uniquely influence vision and can add to visual variety without affecting tactile variety. Other properties such as texture roughness or shape outlines can be perceived by both, but may still lead to dissimilar unity and variety impressions because of differences in the resolution of both senses and the ability to detect fine gaps between product parts (Johnson and Phillips, 1981). These modality-specific influences of product properties also make it possible to study cross-sensory UiV, as we explored in Chapter 4. It is theoretically possible that UiV across the senses is appreciated as well because its perception still adheres to an overall optimum UiV balance—some beautiful designs also suggest that this occurs in practice (e.g. Figure 27, Chapter 4). The above highlights the importance of studying the multisensory experience to understand how our senses uniquely and jointly form impressions of unity and variety.

6.3 Implications for practice

6.3.1 Applying the principle

We previously discussed the ability of the principle of UiV to offer a holistic understanding of how the smallest identifiable properties of a design are combined to form the unified experience of the product and its resulting aesthetic appreciation. The principle thereby brings structure to the existing list of design factors known to influence aesthetic appreciation as most of them can be considered as either contributing to unity or to variety (Kim, 2006). Without a need to reduce all design factors to unity and variety, thinking in terms of these two interrelated dimensions helps understand how the use of specific design factors influences the overall impression of UiV. For example, symmetry is often regarded as a necessity to create unity and a determinant for a beautiful design. However, perfect symmetry is not always appreciated, as a product's appreciation depends on the design's overall balance and the emotional response it generates (Hekkert, 2006; Lauer and Pentak, 2012; Locher and

Nagy, 1996). A highly incoherent design is in need for symmetry to create structure and increase comprehensibility. However, a perfectly balanced design might be boring because it offers little variety. As a solution, introducing certain asymmetry to a perfectly balanced design can excite the overall impression of the product (Figure 35). What this example illustrates is the relative ease with which design factors can be understood and verbalized in terms of balancing unity and variety. Doing so can greatly facilitate in communicating and discussing design choices that affect the look and feel of products.

FIGURE 35. EXAMPLES OF PURPOSEFULLY INTRODUCING ASYMMETRY IN PRODUCT DESIGNS TO INCREASE INTEREST.

The application of the principle in design is straightforward in that it functions as a guideline for designers to try and maximize both unity and variety at the same time. In practice this means that designers should focus on creating unity, which is also apparent in the asymmetrical relationship between unity and variety. Variety is often a given because of the various demands and requirements (e.g. ergonomic, functional or regulatory) that need to be adhered to. We do not claim that designers are unaware of the importance to create unity in their designs, as design books are filled with such examples and it has been in a designer's nature to do so (Lauer and Pentak, 2012; Lidwell et al., 2010). We would however like to emphasize that it is the balance between unity and variety that is preferred. Extremely unified products (i.e. those that consequently lack variety) may quickly be considered too boring and interest should be maintained through the presence of variety (Maeda, 2006).

While being clear in what should be aimed for, the UiV principle still offers a high degree of freedom in terms of choosing how such a balance can be achieved. Designers can apply the design factors that we earlier discussed to iteratively design variations of products to reach an optimum balance between unity and variety. While most design factors will contribute to unity and thereby decrease variety, or the other way round, the use of contrast (in colour) seems particularly promising to optimize both simultaneously. Contrast increases variety by making differences between design elements more intense, while simultaneously increasing unity because these differences make it easier for us to perceive the structure of the design (Ramachandran and Hirstein, 1999). This is not a free permit to maximize contrast, as too much (e.g. colour) contrast will eventually break unity as dissimilarities become too large (Lauer and Pentak, 2012; Ramachandran and Hirstein, 1999). Applying a more gradual shift between contrasting elements can alleviate such dissimilarities. The use of gradients (in colour, line, shape, texture) is an excellent way to create unity while maintaining variety. By offering the senses information about the next line, shape, or material gradients guide perception (Figure 36; Graves, 1951).

An important last note is that creating unity does not mean using one design factor over and over. Creating similarity in a design creates order, but solely using similarity between properties will soon lead to a highly repetitive pattern and the appreciation of this unifying factor will go down. While we have studied several design factors in isolation, we did so for methodological reasons. Beautiful designs comprise of various unifying design factors simultaneously to generate a harmonious and balanced whole. It is the designer's duty to pick and choose those design factors that best work together to create Unity-in-Variety.

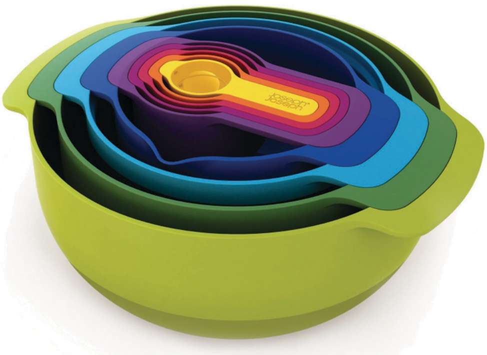


FIGURE 36. THE JOSEPH JOSEPH NEST 9 PLUS BOWL SET USES GRADIENTS IN BOTH COLOUR AND SHAPE TO CREATE A HIGHLY UNIFIED APPEARANCE THAT REMAINS VISUALLY INTERESTING DUE TO ITS VARIETY IN COLOUR.

Designers can consult numerous design books to learn about design factors that create visual unity. Yet for tactile perception of product designs there was little to rely on asides from the designer's own experience and sensitivity, which is undeniably valuable in its own. Although our research is just a first step in understanding how tactile product properties determine aesthetic appreciation, the studies can inform designers in this regard as well. Firstly, our research emphasizes the significance of designing for tactile aesthetic experiences, as visual and tactile unity and variety are comparably important to the aesthetic appreciation of products. Secondly, we showed that the number of differences between material properties greatly influences perceived tactile variety, whereas unity is determined by the way in which materials and product parts are organized and shaped. Research in emerging materials and manufacturing methods has made it possible to use novel materials for the production of products. The use of bio-based materials, shape-shifting polymers or temperature sensitive textiles are just some examples of materials that offer designers exciting and new ways to add tactile variety in products (Figure 37) (Ashby and Johnson, 2013; Karana et al., 2013). Thirdly, in conjunction with the studies on visual-tactile UiV, we revealed that there are large similarities between the visual and tactile unity and variety experiences of products. Changes to product properties will therefore mostly affect both modalities similarly. This coherence between visual and tactile impressions should generally be aimed for, as people tend to prefer congruency between the senses (Krishna et al., 2010). However, in Chapter 4 we showed that visual and tactile UiV, although partially overlapping, still contribute in unique ways to the multisensory experience. The same product properties may elicit different unity and variety impressions between the senses. Vision and touch should therefore be treated separately by designers to arrive at an optimum balance within each sense (Figure 38).

FIGURE 37. MYCELIUM IS AN EXAMPLE OF A BIO-BASED MATERIAL THAT CAN OFFER NOVEL TACTILE SENSATIONS.

FIGURE 38. THE BROSTE ESRUM MUG'S VISUAL CONTRAST IS MOSTLY DUE TO THE COLOUR OF THE MATERIALS. HOWEVER, TACTILE CONTRAST IS ACHIEVED THROUGH COMBINING A SMOOTH POLISHED SURFACE WITH A COARSE TEXTURE.

We have continuously spoken about the need for humans to experience unity and variety and the importance for designers to incorporate this in their design. However, this need is not only passive, as humans actively shape the world around them. We organize our bookshelves according to alphabet, size, or even colour. We create a pleasant working environment by organizing a (computer) desktop and we arrange our furniture until we are satisfied with their positioning (Figure 1, Introduction)—only to change it again once we grow bored with the old setup. In other words, we not only like to perceive unity and variety, we also appreciate creating it. Considering that unity and variety impressions likely change over time, designers can selectively choose to include certain product customizability aimed at letting users create their own optimum level of unity and variety, allowing for renewed aesthetic pleasure.

6.3.2 Individual differences

Because the faculties we use to perceive the world are relatively similar between individuals in how they extract and process information, people generally rate products similarly on unity and variety. This was also reflected in the high intraclass correlation coefficients between participants' ratings of both dimensions. Nevertheless, there are individual differences in perceiving even the most basic object properties like colour and shape (Pickford, 1951; Segall et al., 1966). Bottom-up factors such as the degree of exposure to colour and shape combinations, or top-down factors such as explicit training on design principles, may greatly influence the ability to detect unity (e.g. unification of the dots into a Dalmatian dog in Figure 6 (Chapter 1) can be aided by previous exposure to that image, or by being informed where to look). Variations in unity ratings, and due to their inherent negative relationship also of variety, will largely be caused by people's sensitivity towards detecting unifying factors (Hekkert, 2006). It is therefore not surprising that we found design experts, trained to identify and apply unity principles, to give different unity, variety and aesthetic appreciation ratings compared to laymen rating the same products. Because designers appreciate designs differently compared to the average user—designers tend to prefer more unity—they should be aware that individual differences affect a preferred UiV balance.

Besides expertise, we found individual differences in safety and accomplishment needs to affect the preferred unity and variety balance. Safety seekers tend to appreciate unity more than accomplishment seekers. To use the words of Maeda (2006, p. 60): "There is an important trade-off between being completely lost in the unknown and completely found in the familiar. Too familiar can have the positive aspect of making complete sense, which to some can seem boring; too unknown can have the negative connotations of danger, which to some can seem a thrill. Thus there is a trade-off between being found versus lost. […] Your feeling of youth, state of health, and sense of adventure will dictate your preference for safety versus excitement to find the right balance where you can become 'comfortably lost.'" These individual differences in in safety and accomplishment needs affect the preferred unity and variety balance and could explain why certain products, aimed at a particular group of people, are much more wild colour schemes, exciting shapes, and abundant use of visual elements. For example, all these variegating design elements are very common in the design of products for extreme sports (Figure 39).

FIGURE 39. HIGHLY VARIED PRODUCT DESIGNS MAY BE MORE COMMON IN EXTREME SPORTS BECAUSE THEY ARE AESTHETICALLY PREFERRED BY EXCITEMENT AND THRILL-SEEKERS.

Besides differences between individuals, Chapter 1 revealed that distinct product categories require slightly different degrees of unity and variety to achieve the optimum balance that is aesthetically preferred. Tables and USB-sticks are products in which, due to their generally simple visual design, relatively little variety is present. Adding more variety to these designs may be less acceptable than for products inherently high in variety, such as automotive vehicles. These differences can be explained by people's tendency to compare products with each other to a prototype constructed as an 'average' of that category (Blijlevens et al., 2011; Veryzer and Hutchinson, 1998). People's idea of how unified and varied a prototypical design is may affect their preferred balance. To help designers take this into account, they can generate an overview of existing products to come closest to where the optimum balance within a product category might reside (Figure 40).

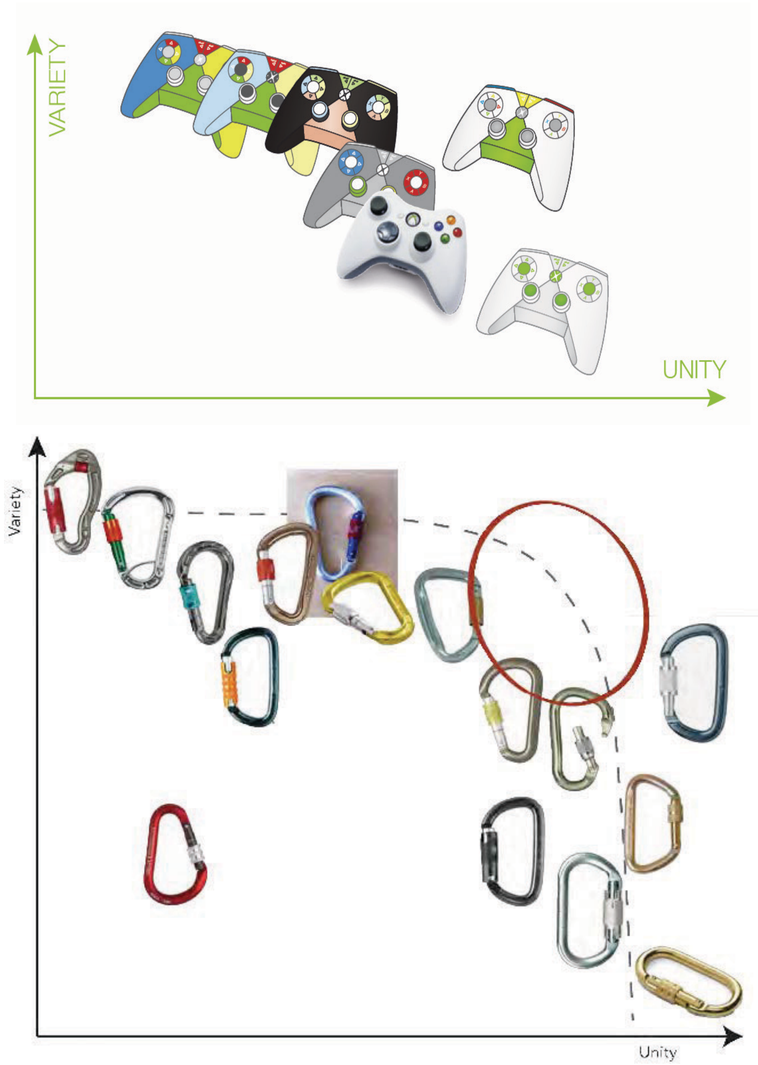


FIGURE 40. EXAMPLES MADE BY STUDENTS TO ILLUSTRATE HOW PRODUCTS CAN BE MAPPED WITHIN THEIR CATEGORY ACCORDING TO THEIR UNITY AND VARIETY BALANCE.

6.3.3 Cultural differences

The location where people grow up has an influence on which colour combinations are used and preferred, as well as how elements are generally organized (Cyr and Trevor - Smith, 2004; Reinecke and Gajos, 2014). Such cultural differences could lead to differences in unity and variety ratings. However, we would expect the principle to hold across cultures, since there is no reason to think that the appreciation of unity and variety itself will differ from culture to culture (Hekkert and Leder, 2008). In fact, many of the organizational and grouping mechanisms can be found in artefacts from all cultures, supporting our argument that the principle applies universally (Hardonk, 1999).

6.4 Future perspective

This research on unity and variety was performed in the domain of design and focussed on the visual and tactile perception of product properties. There are however several reasons to think that the principle can be extended to other domains, senses and cognitive processes. Firstly, the experiences of unity and variety are fundamental and universal in nature because they arise from the way our sensory systems evolved to process information. The mechanisms that underlie object perception and form unity and variety impressions, such as object feature integration, are relatively low-level perceptual processes that are involved in the perception of virtually any stimulus (Marks, 1978). Both concepts are accordingly found in other domains, such as in the perception of gardens and landscapes (Lindemann-Matthies and Marty, 2013; Nohl, 2001), goods and services (Kahn, 1995), architecture (Prak, 1977), and art (Blinderman, 1962; Cupchik and Gebotys, 1988; Parker, 1976). Secondly, our use of stimuli that varied highly in colourfulness, materials, and shape complexity engage our visual and tactile perceptual systems to their fullest and adds to the generalizability of our findings to domains where these combinations of properties are present as well. We would therefore expect highly similar findings for the preference of an optimal balance between unity and variety in the aforementioned domains.

6.4.1 Other sensory modalities

Our research addressed vision and touch because both are considered the two most important modalities for (un)pleasurable product experiences. There is however great value in also studying the principle for the auditory modality, as it is the most important sensory modality after vision and touch for pleasurable product experiences (Fenko et al., 2010). Most people will be familiar with the monotonous beeping of a microwave, offering no variation whatsoever, not even when pressing different buttons. Similarly, many of us awake to a repetitive sounding alarm clock. Instead, products are expected to balance similarities and repetitions in sounds with sufficient auditory variations to be pleasing to the ear—although an alarm clock's function is to wake you, this does not have to be in an unpleasant way. Considering that unity and variety are important concepts in the appreciation of music, and influenced by the Gestalt laws, the principle offers a promising area for further study of music and audition (Ball, 2010; Perrett, 1999; Tan and Spackman, 2005).

Although the similarities between vision and touch are much more apparent than any similarities between either of those and taste, UiV might still contribute to a better understanding of aesthetic appreciation of products such as food and beverages. Delicious taste experiences often involve the combination of different flavours and textures—the latter illustrating even more overlap between senses, as tasting also involves touching. A great example is (makimono) sushi. A combination of vinegared rice, different vegetables, raw seafood and spices give rise to a variety of gustatory sensations, while still being beautifully arranged and bound together to form one roll (Figure 41). Research on flavour perception already demonstrated that flavour complexity influences the aesthetic preferences for different beers (Giacalone et al., 2014). The beauty of the UiV principle itself is that unity and variety seem to be sensory independent concepts, which can be easily translated to other modalities. It would be relatively simple to assess whether the coherent combination of different flavours and textures generates the most aesthetically pleasing taste experiences using the items developed in our work.

FIGURE 41. THE CHARACTERISTIC TECHNIQUE OF CREATING SUSHI LEADS TO UIV IN TASTE AND APPEARANCE.

6.4.2 Beyond the tangible

The focus of our research was on how object properties determine unity and variety. However, the principle need not be limited to purely tangible properties. In Chapter 5 we explored the possibility of extending the principle to analyse and understand the aesthetic appreciation of non-tangible products such as product-service systems. We proposed a theoretical basis for further researching the aesthetics of product-service systems by showing how the principle could relates to their sensory properties, conceptual understanding and physical interaction. A product-service system is considered to adhere to the UiV principle if the different sensorial, functional and interactive parts are meaningfully related into a unified whole.

Others have discussed the UiV principle in relation to higher-level semantic properties as well (Cupchik and Gebotys, 1988; Cupchik and László, 1992; Fechner, 1876; Kreitler and Kreitler, 1972; Nishida et al., 1992). For example, a coherent and meaningful narration depends on creating a unity between the various, sentences, paragraphs and chapters that convey a story (Rosen and Behrens, 1997). In art, Kreitler and Kreitler refer to perceiving unity in a variety of viewpoints and meanings in an artwork. Huxley took a similar perspective on the principle in relation to integrating different scientific theories. Huxley (1904, p. 71) stated: 'I cannot give you any example of a thorough aesthetic pleasure more intensely real than a pleasure of this kind—the pleasure which arises in one's mind when a whole mass of different structures run into one harmony as the expression of a central law.' Extending the principle to such conceptual notions could imply formalizing an aesthetic of ideas, which states that the most beautiful theories are those that integrate and synthesize the highest number and most dissimilar ideas into one unified theory [for an example; see Euler's identity, which unites five fundamental mathematical constants and was rated the most beautiful by mathematicians participating in a study investigating the neural correlates of mathematical beauty (Zeki et al., 2014)].

6.4.3 The temporal aspect

First impressions of a product's shape are made quickly and impact various other product evaluations (Bloch, 1995; Lindgaard et al., 2006). Yet, it would be interesting to study how impressions of unity and variety change over time so to better understand how time-dependent factors like familiarity influence it. As we stated before, it is highly likely that variety will decrease over time, as the relative novelty of such sensations decrease or as previously unknown associations are discovered (Cox and Cox, 2002). One only has to think about learning to understand new interfaces that come with upgrading operating systems, or after purchasing a next generation version of a product, to experience this increase in perceptual understanding during use. Besides investigating unity and variety impressions over time, studying more interactive products, such as fully functional websites, could offer important insights in the aesthetic appreciation of dynamic product experiences.

While we have not investigated how movement relates to unity and variety, Kepes (1967) proposed that movement implies unity through continuity in direction, yet simultaneously implying variety of locations. Hence, movement in itself is a form of UiV over time. How changes in direction or speed relate to unity and variety seems to be a logical first step to investigate dynamic product aesthetics.

6.4.4 Aesthetics and usability

The principle could proof relevant in uncovering the relationship between aesthetics and usability. Multiple studies have demonstrated that beautiful products are at times also seen as more usable (Hamborg et al., 2014; Hassenzahl, 2004; Tractinsky et al., 2000). The rationale that combining unity and variety leads to optimal information processing also applies to product usability. More efficient processing of an interface or product can increase our ability to quickly afford user demands and hence lead to both increases in usability and aesthetic appreciation (Hekkert, 2014).

6.4.5 Objective measures to study UiV

This research developed and validated items that could be used to reliably measure impressions of visual and tactile unity and variety without the need for elaborate explanations of the concepts; simply perceiving objects seems to generate impressions of unity and variety rather intuitively. The research on the principle of UiV can be further assisted with psychophysiological, neural, and time measures to more broadly study how our impression of unity and variety are formed.

Eye movement recording have successfully been used to investigate the aesthetic evaluations of artworks (Hasse and Weber, 2012; Locher, 2014). Experts pay more attention to the relational and compositional elements of an artwork (Nodine et al., 1993). Furthermore, they take a more global as opposed to local processing attitude towards artworks (Zangemeister et al., 1995). Applying this technique to the perception of designs could test the prediction that the increased sensitivity for unity in experts results from increased attention to organizational elements and a more global perception of products.

Studies on website aesthetics have revealed that impressions of visual appeal can already be formed within 50 ms (Lindgaard et al., 2006). Research by Cupchik and Berlyne (1979) suggests that unity in artworks can be reliably judged in 50 ms, whereas variety is slower to be perceived (500-5000 ms). These studies not only show how quickly we can form aesthetic judgements, but also that unity and variety are processed differently. Studying the speed at which people can form impressions of unity and variety could uncover the relationship of the principle of UiV with the notion of processing fluency, which argues that more fluent processing of a stimulus leads to heightened aesthetic appreciation (Reber et al., 1998). It would be expected that more unified and less varied designs are processed faster, and experienced as more fluently processed, than opposite combinations of unity and variety.

On a neural level, models of the brain suggest and support the idea that the brain has evolved to optimally integrate a diversity of information to create a unified perception of the complex world around us (Sporns et al., 2000; Tononi et al., 1998). Given the previously discussed relationship between unity and processing fluency, EEG measure could be applied to relate experiences of unity and variety to neural processing speed (Reber et al., 2004). It would be expected that increasing unity facilitates processing fluency and therefore results in faster or stronger P1 or N1 responses, which are respectively related to initial and discriminative processing of visual stimuli (Vogel and Luck, 2000).

6.4.6 Parts of a whole

The aesthetic experience is undeniably multi-layered and more principles can be identified that work at other levels or moments of the aesthetic experience (Hekkert, 2006). The Unified Model of Aesthetics presents several of these principles that have been empirically investigated. The MAYA principle states that product designs that are novel yet typical at the same time are aesthetically preferred (Hekkert et al., 2003). This principle has some similarities with unity and variety in that novelty and typicality, despite being partial opposites, both positively influence aesthetic appreciation and that their optimal combination is therefore preferred. By combining the UiV and MAYA principle with other aesthetic principles like Maximum Effect for Minimum Means (Da Silva et al., 2016) and 'Autonomous, yet connected' (Blijlevens and Hekkert, 2015), it may be possible to account for a large part of the aesthetic experience of products using relatively few principles that together form one coherent theory.

6.5 Concluding remarks

In researching the principle of UiV our work demonstrates and puts forward a theory of how aesthetic appreciation arises and how it can be influenced. While its realization therefore follows lawful mechanisms, this does not imply that everybody finds the same designs attractive. Beauty is in the eye (and hands) of the beholder, but individual beholders perceive in similar ways. Their eyes and hands appreciate unity in the variety of sensory impressions, which the materials and shapes of products communicate. It is in the designer's skill as an artist and engineer to find the optimal trade-off between these opposing dimensions that can still be perceptually grasped.

Much like the trade-off between unity and variety, external validity and internal validity in scientific research are often in opposition as well. Nonetheless, throughout all studies performed in this work, we have attempted to choose stimuli that are as realistic as possible, while keeping scientific rigor intact, as we believe an optimal balance between these aspects results in the most valuable research findings. The consistent replications of our findings with different participant samples and diverse sets of stimuli greatly contribute to the ecological, internal and external validity of our research.

The recurrent theme in our work is that beauty lies in balancing seemingly opposing forces. However, this is not only a crucial aspect of the UiV principle, or of our methodological approach: resolving conflict by finding new ways of achieving unity within differences is fundamental to human behaviour. To illustrate: The design process itself is one of creating order and structure. After all, the final form of the product is not only determined by the designer's wishes, but especially by the various performance and ergonomic requirements, production and legal restraints, and the way a product is marketed (Bloch, 1995). Bringing together all the requirements pushes companies and designers to their limits in finding ways to integrate these often contradictory demands. In our daily lives, we try to find ways to combine our work drive with our needs for friendship and family, sometimes feeling it is an impossible task, yet leaving us satisfied if we succeed. When we are in conflict with someone, we generally attempt to come to a mutual agreement, which ideally satisfies both parties and unites their different viewpoints. On a collective level, communities strive to realize unity among the diversity of people that inhabit them to create a prosperous, stimulating and lively atmosphere. And in academia, scientists and philosophers attempt to reconcile different discoveries into one coherent theory to somehow, ultimately, grasp the unity of our existence (Nishida et al., 1992). It may be questionable whether all the examples illustrate aesthetic experiences; still, the notion of UiV truly seems to permeate on all levels of human existence. Discovering ways to unify objects, situations, ideas and societies while keeping intact their inherent variety, brings more beauty to life, no matter what its evolved function may be.

References

Alcántara-Alcover, E., Artacho-Ramírez, M. A., Zamora-Álvarez, T., & Martinez, N. (2014). Exploratory study of the influence of the sensory channel in perception of environments. *Journal of Sensory Studies, 29*(4), 258-271. doi: 10.1111/joss.12099

Altaboli, A., & Lin, Y. (2011). Objective and subjective measures of visual aesthetics of website interface design: the two sides of the coin. In J. A. Jacko (Ed.), *Human-Computer Interaction. Design and Development Approaches* (pp. 35-44). Berlin: Springer-Verlag.

Altaboli, A., & Lin, Y. (2012). *Effects of unity of form and symmetry on visual aesthetics of website interface design*. Paper presented at the Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting, HFES 2012, Boston, MA. doi: 10.1177/1071181312561152

Anderson, N. H. (1974). Algebraic models in perception. *Handbook of perception, 2*, 215-298.

Appreciation. (1997) *Oxford English Dictionary*. Oxford, USA: Oxford university press.

Armstrong, T., & Detweiler-Bedell, B. (2008). Beauty as an emotion: The exhilarating prospect of mastering a challenging world. *Review of General Psychology, 12*(4), 305-329. doi: 10.1037/a0012558

Arnheim, R. (1954). Art and visual perception: A psychology of the creative eye: University of California Press.

Ashby, M. F., & Johnson, K. (2013). Materials and design: the art and science of material selection in product design: Butterworth-Heinemann.

Attneave, F. (1959). Applications of information theory to psychology: a summary of basic concepts, methods, and results. Oxford, England: Holt.

Ayres, A. J., & Robbins, J. (2005). Sensory integration and the child: Understanding hidden sensory challenges: Western Psychological Services.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of memory and language, 59*(4), 390-412. doi: 10.1016/j.jml.2007.12.005

Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., . . . Tiwari, A. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221*(10), 1543-1552.

Balaji, M. S., Srividya, R., & Subhash, J. (2011). Role of tactile and visual inputs in product evaluation: a multisensory perspective. *Asia Pacific Journal of Marketing and Logistics, 23*. doi: 10.1108/13555851111165066

Ball, P. (2010). The music instinct: how music works and why we can't do without it: Random House.

Ballesteros, S., Reales, J. M., De León, L. P., & García, B. (2005). *The perception of ecological textures by touch: does the perceptual space change under bimodal visual and haptic exploration?* Paper presented at the Eurohaptics Conference, 2005 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2005. World Haptics 2005. First Joint.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language, 68*(3), 255-278.

Bauerly, M., & Liu, Y. (2006). Computational modeling and experimental investigation of effects of compositional elements on interface and design aesthetics. *International journal of human-computer studies, 64*(8), 670-682.

Bauerly, M., & Liu, Y. (2008). Effects of symmetry and number of compositional elements on interface and design aesthetics. *Intl. Journal of Human–Computer Interaction, 24*(3), 275-287. doi: 10.1080/10447310801920508

Baumgarten, A. G. (1758/1961). *Aesthetica*: Georg Olms Verlag.

Beardsley, M. C. (1958). *Aesthetics: problems in the philosophy of criticism*. New York: Harcourt, Brace.

Bell, S. S., Holbrook, M. B., & Solomon, M. R. (1991). Combining esthetic and social value to explain preferences for product styles with the incorporation of personality and ensemble effects. *Journal of Social Behavior & Personality*.

Berlyne, D., Ogilvie, J., & Parham, L. (1968). The dimensionality of visual complexity, interestingness, and pleasingness. *Canadian Journal of Psychology/Revue canadienne de psychologie, 22*(5), 376-387. doi: 10.1037/h0082777

Berlyne, D. E. (1958). The influence of complexity and novelty in visual figures on orienting responses. *Journal of Experimental Psychology, 55*(3), 289.

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity* (Vol. 331): McGraw-Hill New York.

Berlyne, D. E. (1966). Curiosity and exploration. *Science, 153*(3731), 25-33. doi: 10.1126/science.153.3731.25

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Attention, Perception, & Psychophysics, 8*(5), 279-286. doi: 10.3758/BF03212593

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton-Century-Crofts.

Berlyne, D. E. (1972). Uniformity in variety: extension to three-element visual patterns and to non-verbal measures. *Canadian Journal of Psychology/Revue canadienne de psychologie, 26*(3), 277-291. doi: 10.1037/h0082436

Berlyne, D. E., & Boudewijns, W. J. (1971). Hedonic effects of uniformity in variety. *Canadian Journal of Psychology/Revue canadienne de psychologie, 25*(3), 195-206. doi: 10.1037/h0082381

Bexton, W. H., Heron, W., & Scott, T. H. (1954). Effects of decreased variation in the sensory environment. *Canadian Journal of Psychology/Revue canadienne de psychologie, 8*(2), 70-76. doi: 10.1037/h0083596

Bhatt, R. S., & Quinn, P. C. (2011). How Does Learning Impact Development in Infancy? The Case of Perceptual Organization. *Infancy, 16*(1), 2-38. doi: 10.1111/j.1532-7078.2010.00048.x

Biederman, I., & Vessel, E. (2006). Perceptual Pleasure and the Brain: A novel theory explains why the brain craves information and seeks it through the senses. *American Scientist, 94*(3), 247-253. doi: 10.1511/2006.59.995

Birkhoff, G. D. (1933). *Aesthetic measure*: Harvard University Press Cambridge, MA.

Björkman, M. (1967). Relations between intra-modal and cross-modal matching. *Scandinavian Journal of Psychology, 8*(1), 65-76.

Blijlevens, J., Carbon, C. C., Mugge, R., & Schoormans, J. P. L. (2012). Aesthetic appraisal of product designs: Independent effects of typicality and arousal. *British Journal of Psychology, 103*(1), 44-57. doi: 10.1111/j.2044-8295.2011.02038.x

Blijlevens, J., Creusen, M. E., & Schoormans, J. P. (2009). How consumers perceive product appearance: The identification of three product appearance attributes. *International Journal of Design, 3*(3), 27-35.

Blijlevens, J., Gemser, G., & Mugge, R. (2011). The importance of being 'well-placed': The influence of context on perceived typicality and esthetic appraisal of product appearance. *Acta Psychologica*.

Blijlevens, J., & Hekkert, P. (2015). " *Autonomous, yet connected": A social design principle explaining consumers' aesthetic appreciation of products*. Paper presented at the 2015 Academy of Marketing Conference-The Magic in Marketing.

Blijlevens, J., Thurgood, C., Hekkert, P., Leder, H., & Whitfield, A. (2014a). *The development of a reliable and valid scale to measure aesthetic pleasure in design*. Paper presented at the IAEA, New York, NY, United Stated of America.

Blijlevens, J., Thurgood, C., Hekkert, P., Leder, H., & Whitfield, T. A. (2014b). *The development of a reliable and valid scale to measure aesthetic pleasure in design*. Paper presented at the Proceedings of the 23rd Biennial Congress of the International Association of Empirical Aesthetics, 22-24 augustus 2014, New York, USA.

Blinderman, C. S. (1962). TH Huxley's theory of aesthetics: Unity in diversity. *The Journal of Aesthetics and Art Criticism, 21*(1), 49-55.

Bloch, P. H. (1995). Seeking the ideal form: Product design and consumer response. *The Journal of Marketing, 59*(3), 16-29. doi: 10.2307/1252116

Bonnardel, N., Piolat, A., & Le Bigot, L. (2011). The impact of colour on Website appeal and users' cognitive processes. *Displays, 32*(2), 69-80.

Boselie, F. (1996, 30 Maart 1996). [Waarnemen en waarderen van kunst (Perceiving and appreciating of art). Lecture for 'Het grote nationale smaakdebat'].

Boselie, F., & Leeuwenberg, E. (1985). Birkhoff revisited: Beauty as a function of effect and means. *The American Journal of Psychology, 98*(1), 1-39. doi: 10.2307/1422765

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Bregman, A. S. (1994). Auditory scene analysis: The perceptual organization of sound: MIT press.

Brighouse, G. (1939). A study of aesthetic apperception. *Psychological Monographs: General and Applied, 51*(5), 1-22. doi: 10.1037/h0093474

Brown, D. R., & Owen, D. H. (1970). Visual and tactual form complexity: A psychophysical approach to perceptual equivalence. *Perception & Psychophysics, 7*(4), 225-228.

Bullot, N., & Reber, R. (2013). The artful mind meets art history: toward a psycho-historical framework for the science of art appreciation. *Behavioral and brain sciences, 36*(2), 123-137. doi: 10.1017/S0140525X12000489

Burns, L. D., Brown, D. M., Cameron, B., Chandler, J., Dallas, M. J., & Kaiser, S. B. (1995). Sensory interaction and descriptions of fabric hand. *Perceptual and Motor Skills, 81*(1), 120-122.

Candlin, F. (2003). Blindness, art and exclusion in museums and galleries. *The International Journal of Art & Design, 22*(1), 100-110. doi: 10.1111/1468-5949.00343

Carbon, C.-C., & Jakesch, M. (2013). A model for haptic aesthetic processing and its implications for design. *Proceedings of the IEEE, 101*(9), 2123-2133. doi: 10.1109/JPROC.2012.2219831

Carreira, R., Patrício, L., Jorge, R. N., & Magee, C. L. (2013). Development of an extended Kansei engineering method to incorporate experience requirements in product–service system design. *Journal of Engineering Design, 24*(10), 738-764.

Carson, R. J., & Beeson, C. M. (2013). Crossing language barriers: Using crossed random effects modelling in psycholinguistics research. *Tutorials in Quantitative Methods for Psychology, 9*(1), 25-41.

Chang, D., Dooley, L., & Tuovinen, J. E. (2002). *Gestalt theory in visual screen design: a new look at an old subject*. Paper presented at the Proceedings of the Seventh world conference on computers in education conference on Computers in education: Australian topics.

Chang, D., Nesbitt, K. V., & Wilkins, K. (2007a). *The Gestalt principle of continuation applies to both the haptic and visual grouping of elements*. Paper presented at the EuroHaptics Conference, 2007 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems. World Haptics 2007. Second Joint.

Chang, D., Nesbitt, K. V., & Wilkins, K. (2007b). *The Gestalt principles of similarity and proximity apply to both the haptic and visual grouping of elements*. Paper presented at the Proceedings of the eighth Australasian conference on User interface-Volume 64. doi: 10.1109/whc.2007.113

Chassy, P., Lindell, T. A. E., Jones, J. A., & Paramei, G. V. (2015). A Relationship Between Visual Complexity and Aesthetic Appraisal of Car Front Images: An Eye-Tracker Study. *Perception, 44*(8-9), 1085-1097. doi: 10.1177/0301006615596882

Chatterjee, A. (2004). Prospects for a cognitive neuroscience of visual aesthetics. *Bulletin of Psychology and the Arts, 4*(2), 56-60. doi: 10.1037/e514602010-003

Clark, W. A., & Avery, K. L. (1976). The effects of data aggregation in statistical analysis. *Geographical Analysis, 8*(4), 428-438. doi: 10.1111/j.1538-4632.1976.tb00549.x

Clement, J., Kristensen, T., & Grønhaug, K. (2013). Understanding consumers' in-store visual perception: The influence of package design features on visual attention. *Journal of Retailing and Consumer Services, 20*(2), 234-239. doi: 10.1016/j.jretconser.2013.01.003

Cohen, A. J. (1990). Understanding musical soundtracks. *Empirical Studies of the Arts, 8*(2), 111-124. doi: 10.2190/8Y6G-KTM8-VDX4-UHRW

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (Third Edition ed.). Mahwah, New Jersey: Lawrence Erlbaum Associates. doi: 10.4324/9780203774441

Conway, C. M., & Christiansen, M. H. (2005). Modality-constrained statistical learning of tactile, visual, and auditory sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(1), 24. doi: 10.1037/0278-7393.31.1.24

Cooke, T., Jäkel, F., Wallraven, C., & Bülthoff, H. H. (2007). Multimodal similarity and categorization of novel, three-dimensional objects. *Neuropsychologia, 45*(3), 484-495.

Cox, D., & Cox, A. D. (2002). Beyond first impressions: The effects of repeated exposure on consumer liking of visually complex and simple product designs. *Journal of the Academy of Marketing Science, 30*(2), 119-130.

Creusen, M., & Snelders, D. (2002). Product appearance and consumer pleasure. In W. S. J. Green, P.W. (Ed.), *Pleasure with Products: Beyond Usability* (pp. 69-75). London: Taylor & Francis.

Creusen, M. E., Veryzer, R. W., & Schoormans, J. P. (2010). Product value importance and consumer preference for visual complexity and symmetry. *European Journal of Marketing, 44*(9/10), 1437-1452.

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.

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.

Cropper, A. G., & Evans, S. (1968). Ergonomics and computer display design. *Computer Bulletin, 12*(3), 94-&.

Cupchik, G. C. (1996). Confluence and Divergence in Empirical Aesthetics, Philosophy *Cognitive ecology* (pp. 61-85).

Cupchik, G. C., & Berlyne, D. E. (1979). The perception of collative properties in visual stimuli. *Scandinavian Journal of Psychology, 20*(1), 93-104.

Cupchik, G. C., & Gebotys, R. J. (1988). The search for meaning in art: Interpretive styles and judgments of quality. *Visual Arts Research*, 38-50.

Cupchik, G. C., & Gebotys, R. J. (1990). Interest and pleasure as dimensions of aesthetic response. *Empirical Studies of the Arts, 8*(1), 1-14.

Cupchik, G. C., & László, J. (1992). Emerging visions of the aesthetic process: Psychology, semiology, and philosophy: Cambridge Univ Pr.

Cupchik, G. C., Spiegel, S., & Shereck, L. (1996). Unity in the diversity of aesthetic response. *Visual Arts Research, 22*(1), 1-10.

Cupchik, G. C., & Winston, A. (1992). Reflection and reaction: A dual-process analysis of emotional responses to art. *Art and emotions, 2*, 65-72.

Cyr, D. (2008). Modeling web site design across cultures: relationships to trust, satisfaction, and e-loyalty. *Journal of Management Information Systems, 24*(4), 47-72.

Cyr, D., Head, M., & Ivanov, A. (2006). Design aesthetics leading to m-loyalty in mobile commerce. *Information & Management, 43*(8), 950-963.

Cyr, D., Head, M., & Larios, H. (2010). Colour appeal in website design within and across cultures: A multi-method evaluation. *International journal of human-computer studies, 68*(1), 1-21.

Cyr, D., & Trevor‐Smith, H. (2004). Localization of Web design: An empirical comparison of German, Japanese, and United States Web site characteristics. *Journal of the American society for information science and technology, 55*(13), 1199-1208.

Da Silva, O., Crilly, N., & Hekkert, P. (2014). *Can a Light Switch Be Beautiful? Aesthetic Appreciation of Products as Means.* Paper presented at the K. Niedderer & Y.-K. Lim, Proceedings of the Conference of the Design Research Society.

Da Silva, O., Crilly, N., & Hekkert, P. (2016). Maximum Effect for Minimum Means: The Aesthetics of Efficiency. *Design Issues, 32*(1), 41-51. doi: 10.1162/DESI_a_00363

De Angeli, A., Sutcliffe, A., & Hartmann, J. (2006). *Interaction, usability and aesthetics: what influences users' preferences?* Paper presented at the Proceedings of the 6th conference on Designing Interactive systems.

Deng, L., & Poole, M. S. (2012). Aesthetic design of e-commerce web pages–Webpage Complexity, Order and preference. *Electronic Commerce Research and Applications, 11*(4), 420-440.

Design. (1997) *Oxford English Dictionary*. Oxford, USA: Oxford University Press.

Desmet, P. M., & Hekkert, P. (2007). Framework of product experience. *International Journal of Design, 1*(1), 57-66.

Douneva, M., Haines, R., & Thielsch, M. T. (2015). Effects Of Interface Aesthetics On Team Performance In A Virtual Task.

Dutton, D. (2009). The art instinct: beauty, pleasure, & human evolution. New York: Bloomsbury Press.

Easton, R. D., Greene, A. J., & Srinivas, K. (1997). Transfer between vision and haptics: Memory for 2-D patterns and 3-D objects. *Psychonomic Bulletin & Review, 4*(3), 403-410.

Eco, U., & McEwen, A. (2005). History of beauty.

Eisenman, R. (1966). Pleasing and interesting visual complexity: Support for Berlyne. *Perceptual and Motor Skills, 23*(3), 1167-1170. doi: 10.2466/pms.1966.23.3f.1167

Ekman, G., Hosman, J., & Lindstrom, B. (1965). Roughness, smoothness, and preference: A study of quantitative relations in individual subjects. *Journal of Experimental Psychology, 70*(1), 18. doi: 10.1037/h0021985

Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature, 415*(6870), 429-433.

Essick, G. K., James, A., & McGlone, F. P. (1999). Psychophysical assessment of the affective components of non-painful touch. *Neuroreport, 10*(10), 2083-2087. doi: 10.1097/00001756-199907130-00017

Essick, G. K., McGlone, F., Dancer, C., Fabricant, D., Ragin, Y., Phillips, N., . . . Guest, S. (2010). Quantitative assessment of pleasant touch. *Neuroscience & Biobehavioral Reviews, 34*(2), 192-203. doi: 10.1016/j.neubiorev.2009.02.003

Eysenck, H. J. (1941). The empirical determination of an aesthetic formula. *Psychological review, 48*(1), 83-92. doi: 10.1037/h0062483

Eysenck, H. J. (1942). The experimental study of the'good Gestalt'—a new approach. *Psychological review, 49*(4), 344-364. doi: 10.1037/h0057013

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods, 39*(2), 175-191.

Fechner, G. T. (1876). *Vorschule der aesthetik* (Vol. 1). Leipzig: Breitkopf & Härtel. doi: 10.1017/cbo9781139854580

Fenko, A., Schifferstein, H. N. J., & Hekkert, P. (2010). Shifts in sensory dominance between various stages of user–product interactions. *Applied Ergonomics, 41*(1), 34-40. doi: 10.1016/j.apergo.2009.03.007

Fiser, J. (2009). Perceptual learning and representational learning in humans and animals. *Learning & Behavior, 37*(2), 141-153. doi: 10.3758/LB.37.2.141

Fitzgerald, M., & Gibson, S. (1984). The postnatal physiological and neurochemical development of peripheral sensory C fibres. *Neuroscience, 13*(3), 933-944.

Fry, R. (1920). *Vision and design*. Oxford, England: Chatto & Windus.

Fukuzumi, S. I., Yamazaki, T., Kamijo, K. I., & Hayashi, Y. (1998). Physiological and psychological evaluation for visual display colour readability: a visual evoked potential study and a subjective evaluation study. *Ergonomics, 41*(1), 89-108.

Gaißert, N., Wallraven, C., & Bülthoff, H. H. (2010). Visual and haptic perceptual spaces show high similarity in humans. *Journal of Vision, 10*(11), 2-2. doi: 10.1167/10.11.2

Gallace, A. (2012). Living with touch: Understanding tactile interactions. *The Psychologist, 25*, 3-5.

Gallace, A., & Spence, C. (2008). The cognitive and neural correlates of "tactile consciousness": A multisensory perspective. *Consciousness and cognition, 17*(1), 370-407. doi: 10.1016/j.concog.2007.01.005

Gallace, A., & Spence, C. (2011a). Tactile aesthetics: towards a definition of its characteristics and neural correlates. *Social Semiotics, 21*(4), 569-589. doi: 10.1080/10350330.2011.591998

Gallace, A., & Spence, C. (2011b). To what extent do Gestalt grouping principles influence tactile perception? *Psychological bulletin, 137*(4), 538. doi: 10.1037/a0022335

Garner, W. R. (2014). The processing of information and structure: Psychology Press.

Giacalone, D., Duerlund, M., Bøegh-Petersen, J., Bredie, W. L. P., & Frøst, M. B. (2014). Stimulus collative properties and consumers' flavor preferences. *Appetite, 77*, 20-30. doi: 10.1016/j.appet.2014.02.007

Gibson, J. J. (1962). Observations on active touch. *Psychological review, 69*(6), 477. doi: 10.1037/h0046962

Gibson, J. J. (1966). The senses considered as perceptual systems.

Giese, J. L., Malkewitz, K., Orth, U. R., & Henderson, P. W. (2013). Advancing the aesthetic middle principle: Trade-offs in design attractiveness and strength. *Journal of Business Research*.

Goedkoop, M. J. (1999). *Product service systems, ecological and economic basics*: Ministry of Housing, Spatial Planning and the Environment, Communications Directorate.

Goode, M. R., Dahl, D. W., & Moreau, C. P. (2013). Innovation aesthetics: The relationship between category cues, categorization certainty, and newness perceptions. *Journal of Product Innovation Management, 30*(2), 192-208. doi: 10.1111/j.1540-5885.2012.00995.x

Grabinger, R. S. (1993). Computer screen designs: Viewer judgments. *Educational Technology Research and Development, 41*(2), 35-73.

Graham, L. (2008). Gestalt theory in interactive media design. *Journal of Humanities & Social Sciences, 2*(1).

Graves, M. (1951). *The art of color and design* (2nd ed.). New York: McGraw-Hill Book Company.

Gregory, R. (1967). Origin of eyes and brains. *Nature, 213*(5074), 369-372.

Grohmann, B., Spangenberg, E. R., & Sprott, D. E. (2007). The influence of tactile input on the evaluation of retail product offerings. *Journal of Retailing, 83*(2), 237-245.

Guest, S., & Spence, C. (2003). Tactile dominance in speeded discrimination of textures. *Experimental Brain Research, 150*(2), 201-207.

Hall, R. H., & Hanna, P. (2004). The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention. *Behaviour & Information Technology, 23*(3), 183-195.

Hamborg, K. C., Hülsmann, J., & Kaspar, K. (2014). The interplay between usability and aesthetics: More evidence for the "what is usable is beautiful" notion. *Advances in Human-Computer Interaction, 2014*. doi: 10.1155/2014/946239

Hardonk, M. M. (1999). Cross-cultural universals of aesthetic appreciation in decorative band patterns. Sociale wetenschappen: Nijmegen: 1999.

Hardy, G. H. (2012). *A mathematician's apology*: Cambridge University Press.

Hasse, C., & Weber, R. (2012). Eye movements on facades: The subjective perception of balance in architecture and its link to aesthetic judgment. *Empirical Studies of the Arts, 30*(1), 7-22. doi: 10.2190/EM.30.1.c

Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products. *Human–Computer Interaction, 19*(4), 319-349.

Hassenzahl, M., Schöbel, M., & Trautmann, T. (2008). How motivational orientation influences the evaluation and choice of hedonic and pragmatic interactive products: The role of regulatory focus. *Interacting with Computers, 20*(4), 473-479. doi: 10.1016/j.intcom.2008.05.001

Hekkert, P. (2006). Design aesthetics: Principles of pleasure in design. *Psychology Science, 48*(2), 157-172.

Hekkert, P. (2014). Aesthetic responses to design: A battle of impulses. In T. Smith & P. Tinio (Eds.), *The Cambridge Handbook of the Psychology of Aesthetics and the Arts* (pp. 277-299). Cambridge: Cambridge University Press. doi: 10.1017/cbo9781139207058.015

Hekkert, P., & Leder, H. (2008). Product aesthetics. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 259-286): Elsevier Science.

Hekkert, P., Snelders, D., & van Wieringen, P. C. W. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology, 94*(1), 111-124. doi: 10.1348/000712603762842147

Heller, M. A. (1982). Visual and tactual texture perception: Intersensory cooperation. *Perception & Psychophysics, 31*(4), 339-344.

Heller, M. A., & Brackett, D. D. (2003). Superior haptic perceptual selectivity in late-blind and very-low-vision subjects. *Perception*, 499. doi: 10.1068/p3423

Heller, M. A., & Schiff, W. (2013). *The psychology of touch*: Psychology Press.

Higgins, E., Pierro, A., & Kruglanski, A. (2008). Re-thinking culture and personality: How self-regulatory universals create cross-cultural differences. *Handbook of motivation and cognition within and across cultures*, 102-143.

Higgins, E. T. (1997). Beyond pleasure and pain. *American Psychologist, 52*(12), 1280-1300. doi: 10.1037/0003-066X.52.12.1280

Higgins, E. T., Friedman, R. S., Harlow, R. E., Idson, L. C., Ayduk, O. N., & Taylor, A. (2001). Achievement orientations from subjective histories of success: Promotion pride versus prevention pride. *European Journal of Social Psychology, 31*(1), 3-23.

Higgins, E. T., Shah, J., & Friedman, R. (1997). Emotional responses to goal attainment: strength of regulatory focus as moderator. *Journal of personality and social psychology, 72*(3), 515-525.

Hilsenrat, M., & Reiner, M. (2011). The impact of subliminal haptic perception on the preference discrimination of roughness and compliance. *Brain research bulletin, 85*(5), 267-270. doi: 10.1016/j.brainresbull.2011.03.016

Hughes, J. F., Van Dam, A., Foley, J. D., & Feiner, S. K. (2013). *Computer graphics: principles and practice*: Pearson Education.

Hung, W. K., & Chen, L. L. (2012). Effects of novelty and its dimensions on aesthetic preference in product design. *International Journal of Design, 6*(2), 81-90.

Hutcheson, F. (1729). An inquiry into the original of our ideas of beauty and virtue: in two treatises. Indianapolis: Liberty Fund. doi: 10.1037/11692-000

Huxley, T. H. (1904). *Science and education: essays*: JA Hill and company.

Jansson-Boyd, C., & Marlow, N. (2007). Not only in the eye of the beholder: Tactile information can affect aesthetic evaluation. *Psychology of Aesthetics, Creativity, and the Arts, 1*(3), 170.

Jansson-Boyd, C. V. (2011). Touch matters: exploring the relationship between consumption and tactile interaction. *Social Semiotics, 21*(4), 531-546.

Johnson, K. O., & Phillips, J. R. (1981). Tactile spatial resolution. I. Two-point discrimination, gap detection, grating resolution, and letter recognition. *Journal of neurophysiology, 46*(6), 1177-1192.

Johnston, V. (2003). The origin and function of pleasure. *Cognition & Emotion, 17*(2), 167-179. doi: 10.1080/02699930302290

Joye, Y., Steg, L., Ünal, A. B., & Pals, R. (2016). When complex is easy on the mind: Internal repetition of visual information in complex objects is a source of perceptual fluency. *Journal of Experimental Psychology: Human Perception and Performance, 42*(1), 103-114. doi: 10.1037/xhp0000105

Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: a new and comprehensive solution to a pervasive but largely ignored problem. *Journal of personality and social psychology, 103*(1), 54. doi: 10.1037/a0028347

Jusczyk, P. W., Johnson, S. P., Spelke, E. S., & Kennedy, L. J. (1999). Synchronous change and perception of object unity: Evidence from adults and infants. *Cognition, 71*(3), 257-288.

Kahn, B. E. (1995). Consumer variety-seeking among goods and services: An integrative review. *Journal of Retailing and Consumer Services, 2*(3), 139-148. doi: 10.1016/0969-6989(95)00038-0

Kahn, C. H. (1981). The Art and Thought of Heraclitus: A New Arrangement and Translation of the Fragments with Literary and Philosophical Commentary: Cambridge University Press.

Kant, I. (1790/2001). *Critique of the Power of Judgment* (P. Guyer & E. Matthews, Trans. P. Guyer Ed.): Cambridge Univ Press.

Karana, E., Hekkert, P., & Kandachar, P. (2009). Meanings of materials through sensorial properties and manufacturing processes. *Materials & Design, 30*(7), 2778-2784.

Karana, E., Pedgley, O., & Rognoli, V. (2013). *Materials Experience: fundamentals of materials and design*: Butterworth-Heinemann.

Kellett, K. R. (1939). A Gestalt study of the function of unity in aesthetic perception. *Psychological Monographs: General and Applied, 51*(5), 23-51. doi: 10.1037/h0093475

Kepes, G. (1967). *Language of vision*. Chicago: P. Theobald.

Kim, N. (2006). A history of design theory in art education. *The Journal of Aesthetic Education, 40*(2), 12-28. doi: 10.1353/jae.2006.0015

Klatzky, R. L., Lederman, S. J., & Metzger, V. A. (1985). Identifying objects by touch: An "expert system". *Perception & Psychophysics, 37*(4), 299-302. doi: 10.3758/bf03211351

Köhler, W. (1929). *Gestalt psychology*. New York: Liveright.

Koren, L. (2010). Which" aesthetics" Do You Mean?: Ten Definitions: Imperfect Pub.

Kreitler, H., & Kreitler, S. (1972). *Psychology of the arts*: Duke University Press Durham, NC.

Krishna, A., Elder, R. S., & Caldara, C. (2010). Feminine to smell but masculine to touch? Multisensory congruence and its effect on the aesthetic experience. *Journal of Consumer Psychology, 20*(4), 410-418. doi: 10.1016/j.jcps.2010.06.010

Lacey, S., & Sathian, K. (2014). Visuo-haptic multisensory object recognition, categorization, and representation. *Frontiers in psychology, 5*, 730. doi: 10.3389/fpsyg.2014.00730

Langfeld, H. S. (1920). *The aesthetic attitude*. New York: Harcourt, Brance and Company. doi: 10.1037/10922-000

Lauer, D. A., & Pentak, S. (2012). *Design basics* (8th ed.). Belmont: Wadsworth.

Leather, P., Beale, D., Santos, A., Watts, J., & Lee, L. (2003). Outcomes of environmental appraisal of different hospital waiting areas. *Environment and Behavior, 35*(6), 842-869.

Leder, H., Belke, B., Oeberst, A., & Augustin, D. (2004). A model of aesthetic appreciation and aesthetic judgments. *British Journal of Psychology, 95*(4), 489-508. doi: 10.1348/0007126042369811

Lederman, S., & Klatzky, R. (2009). Haptic perception: A tutorial. *Attention, Perception, & Psychophysics, 71*(7), 1439-1459. doi: 10.3758/APP.71.7.1439

Lederman, S. J., Thorne, G., & Jones, B. (1986). Perception of texture by vision and touch: multidimensionality and intersensory integration. *Journal of Experimental Psychology: Human Perception and Performance, 12*(2), 169.

Lee, S., & Koubek, R. J. (2010). Understanding user preferences based on usability and aesthetics before and after actual use. *Interacting with Computers, 22*(6), 530-543. doi: 10.1016/j.intcom.2010.05.002

Leeuwenberg, E., & Van der Helm, P. (1991). Unity and variety in visual form. *Perception, 20*(5), 595-622. doi: 10.1068/p200595

Lidwell, W., Holden, K., & Butler, J. (2010). Universal principles of design, revised and updated: 125 Ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design. Beverly: Rockport publishers.

Lindauer, M. S., Stergiou, E. A., & Penn, D. L. (1986). Seeing and touching aesthetic objects: I. Judgments. *Bulletin of the Psychonomic Society, 24*(2), 121-124.

Lindemann-Matthies, P., & Marty, T. (2013). Does ecological gardening increase species richness and aesthetic quality of a garden? *Biological Conservation, 159*, 37-44. doi: 10.1016/j.biocon.2012.12.011

Lindgaard, G. (2007). Aesthetics, visual appeal, usability and user satisfaction: What do the user's eyes tell the user's brain. *Australian Journal of Emerging Technologies and Society, 5*(1), 1-14.

Lindgaard, G., Dudek, C., Sen, D., Sumegi, L., & Noonan, P. (2011). An exploration of relations between visual appeal, trustworthiness and perceived usability of homepages. *ACM Transactions on Computer-Human Interaction (TOCHI), 18*(1), 1.

Lindgaard, G., Fernandes, G., Dudek, C., & Brown, J. (2006). Attention web designers: You have 50 milliseconds to make a good first impression! *Behaviour & Information Technology, 25*(2), 115-126.

Lipps, T. (1903). *Grundlegung der Ästhetik*. Hamburg and Leipzig: Leopold Voss.

Locher, P., & Nagy, Y. (1996). Vision spontaneously establishes the percept of pictorial balance. *Empirical Studies of the Arts, 14*(1), 17-31.

Locher, P., & Nodine, C. (1989). The perceptual value of symmetry. *Computers & mathematics with applications, 17*(4), 475-484.

Locher, P. J. (2014). Contemporary Experimental Aesthetics: Procedures and Findings (Vol. 2, pp. 49-80).

Locher, P. J., Stappers, P. J., & Overbeeke, K. (1998). The role of balance as an organizing design principle underlying adults' compositional strategies for creating visual displays. *Acta Psychologica, 99*(2), 141-161. doi: 10.1016/S0001-6918(98)00008-0

Lockwood, P., Jordan, C. H., & Kunda, Z. (2002). Motivation by positive or negative role models: regulatory focus determines who will best inspire us. *Journal of personality and social psychology, 83*(4), 854. doi: 10.1037/0022-3514.83.4.854

Ludden, G. D., Schifferstein, H. N., & Hekkert, P. (2009). Visual-tactual incongruities in products as sources of surprise. *Empirical Studies of the Arts, 27*(1), 61-87.

Ludden, G. D., Schifferstein, H. N., & Hekkert, P. (2012). Beyond surprise: A longitudinal study on the experience of visual-tactual incongruities in products. *International Journal of Design, 6*, 1-23.

MacCallum, R. C., Zhang, S., Preacher, K. J., & Rucker, D. D. (2002). On the practice of dichotomization of quantitative variables. *Psychological methods, 7*(1), 19. doi: 10.1037/1082-989X.7.1.19

Macnab, M. (2011). Design by Nature: Using universal forms and principles in design: New Riders.

Maeda, J. (2006). *The laws of simplicity*: MIT press.

Marin, M. M., & Leder, H. (2013). Examining Complexity across Domains: Relating Subjective and Objective Measures of Affective Environmental Scenes, Paintings and Music. *PLoS ONE, 8*(8). doi: 10.1371/journal.pone.0072412

Marks, L. E. (1978). The unity of the senses: Interrelations among the modalities: Academic Press.

Meijkamp, R. (1998). Changing consumer behaviour through eco - efficient services: an empirical study of car sharing in the Netherlands. *Business Strategy and the Environment, 7*(4), 234-244.

Michailidou, E., Harper, S., & Bechhofer, S. (2008). *Visual complexity and aesthetic perception of web pages.* Paper presented at the Proceedings of the 26th annual ACM international conference on Design of communication.

Miniukovich, A., & Angeli, A. D. (2015). *Visual diversity and user interface quality*. Paper presented at the Proceedings of the 2015 British HCI Conference, Lincoln, Lincolnshire, United Kingdom. doi: 10.1145/2783446.2783580

Miniukovich, A., & De Angeli, A. (2014). *Quantification of interface visual complexity.* Paper presented at the 2014 12th International Working Conference on Advanced Visual Interfaces, AVI 2014, Como. doi: 10.1145/2598153.2598173

Mont, O. K. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production, 10*(3), 237-245.

Moore, K. M. (1986). *Perceptual determinants of aesthetic unity.* University of Maine, Orono.

Moshagen, M., Musch, J., & Göritz, A. S. (2009). A blessing, not a curse: Experimental evidence for beneficial effects of visual aesthetics on performance. *Ergonomics, 52*(10), 1311-1320.

Moshagen, M., & Thielsch, M. T. (2010). Facets of visual aesthetics. *International journal of human-computer studies, 68*(10), 689-709. doi: 10.1016/j.ijhcs.2010.05.006

Mugge, R., & Schoormans, J. P. L. (2012). Product design and apparent usability. The influence of novelty in product appearance. *Applied Ergonomics, 43*(6), 1081-1088. doi: 10.1016/j.apergo.2012.03.009

Muth, C., & Carbon, C. C. (2013). The aesthetic aha: On the pleasure of having insights into Gestalt. *Acta Psychologica, 144*(1), 25-30. doi: 10.1016/j.actpsy.2013.05.001

Nadal, M. (2007). Complexity and aesthetic preference for diverse visual stimuli. *Unpublished doctoral dissertation). Palma: Universitat de les Illes Balears*.

Nadal, M., Munar, E., Marty, G., & Cela-conde, C. J. (2010). Visual complexity and beauty appreciation: Explaining the divergence of results. *Empirical Studies of the Arts, 28*(2), 173-191. doi: 10.2190/EM.28.2.d

Nadkarni, S., & Gupta, R. (2007). A task-based model of perceived website complexity. *Mis Quarterly*, 501-524.

Nasar, J. L. (1987). The effect of sign complexity and coherence on the perceived quality of retail scenes. *Journal of the American Planning Association, 53*(4), 499-509. doi: 10.1080/01944368708977139

Nasar, J. L. (1994). Urban design aesthetics. *Environment and Behavior, 26*(3), 377-778. doi: 10.1177/001391659402600305

Nasar, J. L., & Hong, X. (1999). Visual preferences in urban signscapes. *Environment and Behavior, 31*(5), 671-691. doi: 10.1177/00139169921972290

Ngo, D., & Byrne, J. (2001). Application of an aesthetic evaluation model to data entry screens. *Computers in Human Behavior, 17*(2), 149-185.

Ngo, D. C. L., Teo, L. S., & Byrne, J. G. (2002). Evaluating interface esthetics. *Knowledge and Information Systems, 4*(1), 46-79.

Nishida, K., Abe, M., & Ives, C. (1992). *An inquiry into the good*: Yale University Press.

Nodine, C. F., Locher, P. J., & Krupinski, E. A. (1993). The role of formal art training on perception and aesthetic judgment of art compositions. *Leonardo*, 219-227.

Nohl, W. (2001). Sustainable landscape use and aesthetic perception–preliminary reflections on future landscape aesthetics. *Landscape and Urban Planning, 54*(1–4), 223-237. doi: 10.1016/S0169-2046(01)00138-4

Norman, D. A. (2013). The design of everyday things: Revised and expanded edition. New York: Basic books.

O'Connor, Z. (2013). Colour, contrast and gestalt theories of perception: The impact in contemporary visual communications design. *Color Research & Application*.

Oostendorp, A., & Berlyne, D. (1978). Dimensions in the perception of architecture: I. Identification and interpretation of dimensions of similarity. *Scandinavian Journal of Psychology, 19*(1), 73-82.

Otis, M. (1918). Aesthetic unity: An investigation into the conditions that favor the apperception of a manifold as a unit. *The American Journal of Psychology, 29*(3), 291-315. doi: 10.2307/1414121

Overvliet, K. E., Krampe, R. T., & Wagemans, J. (2012). Perceptual grouping in haptic search: The influence of proximity, similarity, and good continuation. *Journal of Experimental Psychology: Human Perception and Performance, 38*(4), 817.

Owen, D. H., & Brown, D. R. (1970). Visual and tactual form discrimination: Psychophysical comparison within and between modalities. *Perception & Psychophysics, 7*(5), 302-306.

Page, C., & Herr, P. M. (2002). An investigation of the processes by which product design and brand strength interact to determine initial affect and quality judgments. *Journal of Consumer Psychology, 12*(2), 133-147. doi: 10.1207/S15327663JCP1202_06

Palmer, S., & Rock, I. (1994). Rethinking perceptual organization: The role of uniform connectedness. *Psychonomic Bulletin & Review, 1*(1), 29-55. doi: 10.3758/BF03200760

Palmer, S. E., & Schloss, K. B. (2010). *Human preference for individual colors.* Paper presented at the IS&T/SPIE Electronic Imaging.

Parker, D. H. (1976). *The principles of aesthetics*: Greenwood Press.

Paternoster, R., Brame, R., Mazerolle, P., & Piquero, A. (1998). Using the correct statistical test for the equality of regression coefficients. *Criminology, 36*(4), 859-866.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health services research, 34*(5 Pt 2), 1189.

Perrett, R. W. (1999). Musical unity and sentential unity. *British journal of aesthetics, 39*(2), 97-111.

Pickford, R. W. (1951). Individual differences in colour vision.

Pinker, S. (2003). The blank slate: The modern denial of human nature. New York: Penguin Books.

Plotinus. (1969). *The Enneads* (S. MacKenna, Trans.). New York: Faber and Faber.

Pomales-García, C., Liu, Y., & Mendez, D. (2005). *Web-Based Distance Learning Technology: Does Appearance Matter?* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2013a, 26 - 30 August). *The influence of unity-in-variety on aesthetic appreciation of car interiors.* Paper presented at the Consilience and Innovation in Design, Tokyo, Japan.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2013b, March 24-27). *Unity-in-variety in product design aesthetics.* Paper presented at the Tagung experimentell arbeitender Psychologen, Vienna.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2014). *Aesthetic Appreciation of Tactile Unity-in-Variety in Product Designs*. Paper presented at the 23rd Biennial Congress of the International Association of Empirical Aesthetics, New York, United States of America.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2016). 'To preserve unity while almost allowing for chaos': Testing the aesthetic principle of unity-in-variety in product design. *Acta Psychologica, 163*, 142-152. doi: 10.1016/j.actpsy.2015.11.013

Post, R. A. G., Blijlevens, J., Saakes, D., & Hekkert, P. (Submitted).

Power, R. P. (1980). The dominance of touch by vision: Sometimes incomplete. *Perception, 9*(4), 457-466.

Prak, N. L. (1977). *The visual perception of the built environment*: Delft University Press.

Preacher, K. J., Curran, P. J., & Bauer, D. J. (2004). Simple intercepts, simple slopes, and regions of significance in HLM 2-way interactions.

Preacher, K. J., Curran, P. J., & Bauer, D. J. (2006). Computational tools for probing interactions in multiple linear regression, multilevel modeling, and latent curve analysis. *Journal of educational and behavioral statistics, 31*(4), 437-448.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*: Addison-Wesley Longman Ltd.

Quené, H., & Van den Bergh, H. (2004). On multi-level modeling of data from repeated measures designs: A tutorial. *Speech Communication, 43*(1), 103-121.

Ramachandran, V. S., & Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. *Journal of Consciousness Studies, 6*(6-7), 15-51.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364-382. doi: 10.1207/s15327957pspr0804_3

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science, 9*(1), 45-48.

Reinecke, K., & Gajos, K. Z. (2014). *Quantifying visual preferences around the world*, Toronto, ON. doi: 10.1145/2556288.2557052

Reinecke, K., Yeh, T., Miratrix, L., Mardiko, R., Zhao, Y., Liu, J., & Gajos, K. Z. (2013). Predicting users' first impressions of website aesthetics with a quantification of perceived visual complexity and colorfulness, Paris.

Rock, I., & Victor, J. (1964). Vision and touch: An experimentally created conflict between the two senses. *Science, 143*(3606), 594-596.

Roehm, M. L., & Roehm Jr, H. A. (2010). The relationship between packaging uniformity and variety seeking. Psychology and Marketing, 27(12), 1122-1133.

Rosen, L. J., & Behrens, L. (1997). *The Allyn & Bacon Handbook*: ERIC.

Schenkman, B. N., & Jönsson, F. U. (2000). Aesthetics and preferences of web pages. *Behaviour & Information Technology, 19*(5), 367-377.

Schifferstein, H., & Spence, C. (2008). Multisensory Product Experience, Product Experience, H. Schifferstein, P. Hekkert, eds: Elsevier, Amsterdam.

Schifferstein, H. N., & Cleiren, M. (2005). Capturing product experiences: a split-modality approach. *Acta Psychologica, 118*(3), 293-318.

Schifferstein, H. N. J., & Hekkert, P. (2008). Sensory aesthetics in product design. *F. Bacci, & D. Melcher*, 543-569.

Schokker, M. C., Links, T. P., Luttik, M. L., & Hagedoorn, M. (2010). The association between regulatory focus and distress in patients with a chronic disease: The moderating role of partner support. *British Journal of Health Psychology, 15*(1), 63-78.

Seckler, M., Opwis, K., & Tuch, A. N. (2015). Linking objective design factors with subjective aesthetics: An experimental study on how structure and color of websites affect the facets of users' visual aesthetic perception. *Computers in Human Behavior, 49*(0), 375-389. doi: 10.1016/j.chb.2015.02.056

Segall, M. H., Campbell, D. T., & Herskovits, M. J. (1966). *The influence of culture on visual perception*: Bobbs-Merrill Indianapolis.

Shah, J., Higgins, T., & Friedman, R. S. (1998). Performance incentives and means: How regulatory focus influences goal attainment. *Journal of personality and social psychology, 74*(2), 285-293. doi: 10.1037/0022-3514.74.2.285

Sonderegger, A., & Sauer, J. (2010). The influence of design aesthetics in usability testing: Effects on user performance and perceived usability. *Applied Ergonomics, 41*(3), 403-410.

Sonneveld, M. H., & Schifferstein, H. N. J. (2008). The tactual experience of objects. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 41-67). Amsterdam: Elsevier Science Publishers. doi: 10.1016/B978-008045089-6.50005-8

Spence, C. (2011). The multisensory perception of touch. *Art and the Senses*, 85-106.

Spence, C., & Gallace, A. (2011). Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing, 28*(3), 267-308.

Spence, C., Sanabria, D., & Soto-Faraco, S. (2007). Intersensory Gestalten and crossmodal scene perception. *Psychology of beauty and Kansei: New horizons of Gestalt perception*, 519-579.

Sporns, O., Tononi, G., & Edelman, G. M. (2000). Connectivity and complexity: the relationship between neuroanatomy and brain dynamics. *Neural Networks, 13*(8), 909-922.

Stein, G. (1934). https://soundcloud.com/brainpicker/rare-gertrude-stein-interview.

Suzuki, M., & Gyoba, J. (2008). Visual and tactile cross-modal mere exposure effects. *Cognition and Emotion, 22*(1), 147-154.

Tan, S. L., & Spackman, M. P. (2005). Listeners' judgments of the musical unity of structurally altered and intact musical compositions. *Psychology of Music, 33*(2), 133-153. doi: 10.1177/0305735605050648

Tan, S. L., Spackman, M. P., & Peaslee, C. L. (2006). The effects of repeated exposure on liking and judgments of musical unity of intact and patchwork compositions. *Music Perception, 23*(5), 407-421.

Tiest, W. M. B., & Kappers, A. M. (2007). Haptic and visual perception of roughness. *Acta Psychologica, 124*(2), 177-189.

Tononi, G., Edelman, G. M., & Sporns, O. (1998). Complexity and coherency: integrating information in the brain. *Trends in cognitive sciences, 2*(12), 474-484.

Townsend, C., & Kahn, B. E. (2014). The "Visual preference heuristic": The influence of visual versus verbal depiction on assortment processing, perceived variety, and choice overload. *Journal of Consumer Research, 40*(5), 993-1015.

Tractinsky, N., Cokhavi, A., Kirschenbaum, M., & Sharfi, T. (2006). Evaluating the consistency of immediate aesthetic perceptions of web pages. *International Journal of Human Computer Studies, 64*(11), 1071-1083. doi: 10.1016/j.ijhcs.2006.06.009

Tractinsky, N., Katz, A., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers, 13*(2), 127-145.

Tuch, A. N., Presslaber, E. E., Stöcklin, M., Opwis, K., & Bargas-Avila, J. A. (2012). The role of visual complexity and prototypicality regarding first impression of websites: Working towards understanding aesthetic judgments. *International journal of human-computer studies, 70*(11), 794-811. doi: 10.1016/j.ijhcs.2012.06.003

Tuch, A. N., Roth, S. P., HornbæK, K., Opwis, K., & Bargas-Avila, J. A. (2012). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. *Computers in Human Behavior, 28*(5), 1596-1607.

Ulrich, R. S., Lundén, O., & Eltinge, J. (1993). *Effects of exposure to nature and abstract pictures on patients recovering from heart surgery.* Paper presented at the Thirty-third meeting of the Society of Psychophysiological Research, Rottach-Egern, Germany.

Van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in The Netherlands. *Information & Management, 40*(6), 541-549.

van Schaik, P., & Ling, J. (2009). The role of context in perceptions of the aesthetics of web pages over time. *International Journal of Human Computer Studies, 67*(1), 79-89. doi: 10.1016/j.ijhcs.2008.09.012

Van Stekelenburg, J., & Klandermans, B. (2003). Regulatory focus meten met behulp van spreekwoorden (using proverbs to measure regulatory focus). *Groningen: Jaarboek Sociale Psychologie. Social comparison and motivation*.

Verrillo, R. T., Bolanowski, S. J., & McGlone, R. P. (1999). Subjective magnitude of tactile roughness. *Somatosensory & motor research, 16*(4), 352-360. doi: 10.1080/08990229970401

Veryzer, R. W., & Hutchinson, J. W. (1998). The influence of unity and prototypicality on aesthetic responses to new product designs. *Journal of Consumer Research, 24*(4), 374-385.

Vezzoli, C. (2013). System design for sustainability: The challenge of behaviour change. In R. Crocker & S. Ehmann (Eds.), *Motivating Change: Sustainable Design and Behaviour in the Built Environment* (pp. 276-290). doi: 10.4324/9780203482087

Vezzoli, C., Kohtala, C., Srinivasan, A., Xin, L., Fusakul, M., Sateesh, D., & Diehl, J. (2014). *Product-service system design for sustainability*: Greenleaf Publishing.

Vogel, E. K., & Luck, S. J. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology, 37*(02), 190-203.

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization. *Psychological bulletin, 138*(6), 1172-1217. doi: 10.1037/a0029333

Wagemans, J., Feldman, J., Gepshtein, S., Kimchi, R., Pomerantz, J. R., van der Helm, P. A., & van Leeuwen, C. (2012). A century of Gestalt psychology in visual perception: II. Conceptual and theoretical foundations.

Walsh, D. (1979). Occam's razor: A principle of intellectual elegance. *American Philosophical Quarterly*, 241-244.

Wan, E. W., Hong, J., & Sternthal, B. (2009). The effect of regulatory orientation and decision strategy on brand judgments. *Journal of Consumer Research, 35*(6), 1026-1038.

Warren, D., & Rossano, M. (1991). Intermodality relations: Vision and touch. *The psychology of touch*, 119-137.

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.

Welch, R. B., & Warren, D. H. (1980). Immediate perceptual response to intersensory discrepancy. *Psychological bulletin, 88*(3), 638.

Wertheimer, M. (1938). Laws of organization in perceptual forms. *A source book of Gestalt psychology*, 71-88.

Whitaker, T. A., Simões-Franklin, C., & Newell, F. N. (2008). Vision and touch: Independent or integrated systems for the perception of texture? *Brain Research, 1242*, 59-72. doi: 10.1016/j.brainres.2008.05.037

Wilson, A., & Chatterjee, A. (2005). The assessment of preference for balance: Introducing a new test. *Empirical Studies of the Arts, 23*(2), 165-180.

Woods, W. A., & Boudreau, J. C. (1950). Design complexity as a determiner of visual attention among artists and non-artists. *Journal of Applied Psychology, 34*(5), 355.

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.

Yoshida, M. (1968). Dimensions of tactual impressions (1). *Japanese Psychological Research, 10*(3), 123-137.

Zain, J. M., Tey, M., & Soon, G. Y. (2008). *Using Aesthetic Measurement Application (AMA) to Measure Aesthetics of Web Page Interfaces.* Paper presented at the Natural Computation, 2008. ICNC'08. Fourth International Conference on.

Zampini, M., Guest, S., & Spence, C. (2003). The role of auditory cues in modulating the perception of electric toothbrushes. *Journal of dental research, 82*(11), 929-932.

Zangemeister, W., Sherman, K., & Stark, L. (1995). Evidence for a global scanpath strategy in viewing abstract compared with realistic images. *Neuropsychologia, 33*(8), 1009-1025.

Zeki, S., Romaya, J. P., Benincasa, D., & Atiyah, M. F. (2014). The experience of mathematical beauty and its neural correlates. *Front Hum Neurosci, 8*.

Zelanski, P., & Fisher, M. P. (1996). *Design principles and problems*: Harcourt Brace College Publishers.

Zeng, L., Salvendy, G., & Zhang, M. (2009). Factor structure of web site creativity. *Computers in Human Behavior, 25*(2), 568-577. doi: 10.1016/j.chb.2008.12.023

Summary

This thesis embarks from the idea that aesthetic appreciation of product designs is determined by simultaneously perceiving the two partially opposing dimensions of *unity* and *variety*. People actively avoid boredom by searching for variety because it challenges the senses and offers the potential of learning new information. Hence, people browse through thick catalogues, are attracted to colourful bouquets and let their eyes and hands explore a novel car interior. In doing so, these products offer stimulation to the senses. However, too much variety leads to confusion, as people fail to make sense of what they perceive. It is therefore that they appreciate perceiving unity at the same time, as it brings structure to variety; items in a catalogue are precisely ordered, flowers are neatly arranged and components of a car interior are carefully picked and organized. The above idea is captured in an age-old aesthetic principle, aptly named *Unity-in-Variety* (UiV). The principle states that perceiving a balance between the opposing forces of unity and variety is aesthetically preferred. While this principle has been argued to explain aesthetic appreciation for works of art, music and landscapes, little empirical research existed on this principle and, to our knowledge, none for product designs. By performing twelve studies and multiple pilot studies, mostly quantitative in nature, we empirically investigated the principle of UiV to determine whether it can explain how and why we aesthetically appreciate perceiving product designs by vision and touch.

To demonstrate how unity and variety relate to each other and to aesthetic appreciation, we first separately researched the visual and tactile modality using a range of products readily found on the market. We continued with experimental investigations of the principle by systematically manipulating unity and variety in product designs through various design factors (e.g. the Gestalt laws of symmetry and similarity). For the visual modality, these manipulations were performed in newly designed sets of webpages. For the tactile modality, we designed and produced 3-D printed models of car key remotes to systematically manipulate materials and shapes. The investigations within vision and touch were followed by a study combining both senses to assess how unity and variety relate to visual-tactile aesthetic appreciation, and an additional study exploring how unity and variety may interact across the senses. Furthermore, to build a

broader understanding of what influences our appreciation for unity and variety, we investigated individual differences in motivational drives and design expertise. Lastly, we explored the possibility of extending the principle's applicability from individual products to product-service systems.

Our main finding is that unity and variety, despite being negatively correlated, positively influence aesthetic appreciation of product designs. As a result of their partial opposition, there is a trade-off between unity and variety leading to a balance where aesthetic appreciation is highest. Additionally, we found that unity is the dominant factor of the two; its influence is on average twice the size of variety, and its presence is a condition for an appreciation of variety. These results were obtained with a range of products from different product categories and replicated in the visual, tactile and visual-tactile product experience.

Having demonstrated how unity and variety together determine aesthetic appreciation, we investigated how several factors underlie the degree of unity and variety and their respective appreciation. Several commonly used design factors were experimentally shown to influence unity and variety in vision (through *symmetry*, *contrast*, *similarity* and *colourfulness*), and in touch (through *continuity*, *emergence* and *similarity*). Besides these design factors, we identified how individual differences in motivational drives and expertise can influence the preferred balance between unity and variety. Individuals with safety needs preferred visual or tactile unity to individuals with accomplishment needs. As a result, the preferred balance between unity and variety shifts towards unity for safety seekers. A similar shift towards a preference for unity occurred for (design) experts. Experts rate the same products differently on unity and variety compared to laymen, possibly as a result of their explicit and implicit training in applying unifying design factors. Yet, they also appreciate an optimum balance between unity and variety and the principle therefore equally holds for design experts.

The combined results of our studies demonstrate that the UiV principle can consistently explain visual, tactile and visual-tactile aesthetic appreciation for product designs. It does so by showing that aesthetic appreciation is highest when the two partially opposing dimensions of unity and variety are increased until they arrive at an optimum balance. We furthermore demonstrated how various design factors and individual differences underlie this preferred unity and variety balance. In doing so, the principle offers a holistic understanding of how the smallest perceptual properties of a design are combined to form the unified experience of the product and its aesthetic appreciation. The knowledge generated through our research contributes to current theories and models of aesthetic appreciation by explaining how and why people find aesthetic pleasure in perceiving product designs. Furthermore, UiV is possibly the first principle to account for tactile aesthetic appreciation, as we illustrated how the Gestalt laws play an important role in creating tactile unity within the variety of shapes and materials of a physical product. Next to this, our methodological approach demonstrates how novel 3-D printing technologies can aid in accurately studying realistic stimuli. Lastly, the results from our research can act as a guideline for designers and provides a promising basis for researching the principle in other modalities (such as auditory and gustatory), as well as for other domains (such as for product-service systems, architecture and the arts).

Samenvatting

Dit proefschrift start vanuit de gedachte dat esthetische waardering van producten bepaald wordt door het tegelijkertijd waarnemen van de twee schijnbaar tegengestelde dimensies van *eenheid* (unity) en *verscheidenheid* (variety). Mensen voorkomen verveling door op zoek te gaan naar verscheidenheid. Verscheidenheid daagt de zintuigen uit en biedt daardoor de mogelijkheid nieuwe kennis op te doen. Als een gevolg daarvan bladeren mensen door dikke tijdschriften, voelen zij zich aangetrokken tot een kleurrijk boeket en ervaren ze esthetisch genot wanneer zij een nieuw auto interieur aftasten. Teveel verscheidenheid leidt echter tot verwarring omdat mensen moeite hebben te begrijpen wat ze precies waarnemen. Het is daarom noodzakelijk dat tegelijkertijd de eenheid waargenomen wordt die structuur aanbrengt in de verscheidenheid; producten in een tijdschrift zijn nauwkeurig geordend, bloemen in een boeket zijn bedachtzaam geschikt en de onderdelen van een auto interieur zijn zorgvuldig uitgekozen en sluiten naadloos op elkaar aan. Bovenstaand idee wordt omvat door het eeuwenoude principe, toepasselijk genaamd, *Eenheid-in-Verscheidenheid* (Unity-in-Variety), dat stelt dat het waarnemen van een balans tussen de twee tegengestelde dimensies van eenheid en verscheidenheid esthetisch geprefereerd wordt. Hoewel dit principe wordt geacht de esthetische waardering voor kunst, muziek en landschappen te verklaren, bestaat er weinig empirisch onderzoek naar dit principe en, voor zover bij ons bekend is, niets voor producten. Door het uitvoeren van twaalf studies en meerdere pilotstudies, waarvan de meeste kwantitatief van aard, hebben wij het Eenheid-in-Verscheidenheid principe empirisch onderzocht om te bepalen of het kan verklaren hoe en waarom mensen producten esthetisch waarderen met hun visuele en tactiele zintuigen.

Om aan te tonen hoe eenheid en verscheidenheid zich tot elkaar en tot esthetische waardering verhouden onderzochten wij het visuele en tactiele zintuig met een reeks van producten uit de bestaande markt. Dit werd gevolgd door experimentele studies waarin eenheid en verscheidenheid systematisch werden gemanipuleerd in nieuwe producten door middel van verschillende ontwerpfactoren (b.v. de Gestalt wetten van *symmetrie* en *gelijkheid*). Voor het visuele zintuig werden deze manipulaties uitgevoerd door sets van nieuwe webpagina's te ontwerpen. Voor het tastzintuig ontwierpen en produceerden we 3-D geprinte modellen van autosleutels die systematisch gemanipuleerd waren in materiaal en vormgeving. Deze studies, die de visuele en tactiele zintuigen afzonderlijk onderzochten, werden opgevolgd door een studie die beide zintuigen combineerde om vast te stellen hoe eenheid en verscheidenheid zich verhouden tot de visueel-tactiele esthetische waardering, en middels een studie die verkende hoe eenheid en verscheidenheid kunnen interacteren tussen de zintuigen. Daarnaast werd een breder begrip gecreëerd over de aspecten die de waardering van eenheid en verscheidenheid kunnen beïnvloeden door individuele verschillen in motiverende gesteldheid en ontwerpexpertise in acht te nemen. Tenslotte werd verkend of de toepasbaarheid van het principe uitgebreid kon worden van individuele producten naar product-service systemen.

Onze hoofdbevinding is dat eenheid en verscheidenheid, ondanks dat ze negatief correleren, esthetische waardering voor productontwerpen positief beïnvloeden. Door de gedeeltelijke tegenstelling tussen eenheid en verscheidenheid bestaat er een wisselwerking die resulteert in een de balans tussen beiden waar esthetische waardering maximaal is. Daarnaast vonden wij dat eenheid de dominante dimensie is met een invloed die gemiddeld twee keer zo groot is als verscheidenheid, en vonden wij dat de waardering voor verscheidenheid grotendeels afhankelijk is van de aanwezigheid van eenheid. Deze resultaten werden verkregen met een reeks van producten uit verschillende productcategorieën en werden gerepliceerd voor de visuele, tactiele en visueel-tactiele productbeleving.

Na aangetoond te hebben hoe eenheid en verscheidenheid samen esthetische waardering bepalen werd onderzocht hoe diverse factoren de mate van en waardering voor eenheid en verscheidenheid bepalen. Voor verschillende veelgebruikte ontwerpfactoren werd experimenteel aangetoond dat ze visuele en tactiele eenheid en verscheidenheid beïnvloeden (voor visueel d.m.v.: symmetrie, contrast, gelijkheid en kleurigheid; voor tast d.m.v.: continuïteit, verschijning en gelijkheid). Naast deze ontwerpfactoren ontdekten wij hoe individuele verschillen in motiverende gesteldheden en ontwerpexpertise invloed hebben op de geprefereerde balans tussen eenheid en verscheidenheid. In relatie tot het eerste, individuen die veiligheid zoeken prefereren visuele of tactiele eenheid meer dan individuen die zoeken naar vervulling.

Dit heeft als gevolg dat de geprefereerde balans tussen eenheid en verscheidenheid voor mensen die meer zoeken naar veiligheid verschuift richting eenheid. Een vergelijkbare verschuiving werd gevonden bij (ontwerp) experts. Experts beoordelen dezelfde producten anders op eenheid en verscheidenheid in verhouding tot leken, mogelijk als gevolg van hun expliciete en impliciete training in het toepassen van ontwerpfactoren die eenheid verhogen. Echter, ook experts waarderen een balans waar zowel eenheid als verscheidenheid aanwezig is en het principe is daarom ook voor hen toepasbaar.

De gecombineerde resultaten van onze studies laten zien dat het Eenheid-in-Verscheidenheid principe consistent de visuele, tactiele en visueel-tactiele esthetische waardering voor productontwerpen kan verklaren. Dit blijkt uit onze bevinding dat esthetische waardering het hoogste is wanneer de deels tegengestelde dimensies van eenheid en verscheidenheid gemaximaliseerd worden tot er een optimale balans is bereikt. Bovendien laten wij zien hoe verschillende ontwerpfactoren en individuele verschillen onderliggend zijn aan deze geprefereerde eenheid en verscheidenheid balans. Daarmee biedt het principe een holistisch begrip van hoe de kleinst waarneembare perceptuele eigenschappen van een ontwerp gecombineerd worden tot één gehele ervaring van het product en haar esthetische waardering. De kennis die door dit onderzoek ontwikkeld is draagt bij aan hedendaagse theorieën en modellen van esthetische waardering door te verklaren hoe en waarom mensen producten esthetisch waarderen. Bovendien is Eenheid-in-Verscheidenheid mogelijk het eerste principe dat tactiele esthetische waardering kan verklaren, wat blijkt uit de rol die Gestalt wetten spelen bij het creëren van tactiele eenheid binnen een verscheidenheid aan vormen en materialen van een tastbaar product. Daarnaast laat onze methodologische aanpak zien hoe nieuwe 3-D printtechnieken kunnen helpen in het nauwkeurig bestuderen van realistische stimuli. Tenslotte kunnen onze onderzoeksresultaten dienen als richtlijnen voor ontwerpers en biedt het een veelbelovende basis voor onderzoek naar het principe in andere zintuigen (zoals reuk en smaak), net als in andere domeinen (zoals product-service systemen, architectuur en de kunst).

Acknowledgements

While this thesis is the result of many years of my work, it is similarly the result of the people that have helped me in doing so. A few words of gratitude for the immeasurable support I have received.

Firstly, my supervisory team, Paul and Janneke. Paul, thank you for making this whole adventure possible. Your playfulness, positive energy, knowledge and ability to somehow manage it all are things I greatly admire. There's never a dull moment when you're around and you made my journey a beautiful one. Like any good teacher, what you showed and taught me extended well beyond that what the job description officially denounced and I am forever thankful for it. Janneke, thank you for your countless revisions, words of encouragement, and for keeping me under your wings both in Delft and in Ozzie Land. Thank you both for our lively discussions, the usual disagreements and the less common agreements. You challenged and guided me in this journey and I am extremely grateful for how you dealt with this stubborn guy.

My friends and colleagues from the Industrial Design faculty, specifically those in the StudioLab and in the Design Aesthetics department; thank you for the welcoming escapes from work during lunch, coffee (of varying quality) or gaming on the Super Nintendo. In particular, Deger, Nynke and Steven, it was a pleasure working next to you and learning about design, emotions, life, and Japanese potatoes. Jasper, thank you for having faith in my ability to aid in UXAD, allowing me to discover my joy in doing usability research. Aadjan, thank you for creating and maintaining the vibrant, diverse and comfortable environment that is StudioLab. Elmer van Grondelle and Koos Eissen, thank you for letting me have a taste of automotive design. Also a warm thank you to the wonderful ladies from the secretariat, who somehow always knew the right answer to whatever weird question confusing PhD students come up with.

My fellow UMAns:

Nazli, I dearly missed having you around in the Studiolab for the last parts of UMA. But in my memories your beautiful smile, humor and joy for life never left. It makes me happy knowing you'll be on my side during the defense and I hope to continue our lovely lunches, dinners and gossiping for a long time to come.

Michaël, your advice on statistics and help with multiple studies during the last part of my PhD was indispensible, many, many thanks. I look back with great pleasure on our time together, especially during conferences, and I'll miss your wit and our coffee breaks.

Simon, thank you for your all-round help with the studies, your positive attitude and advice on designing. Without it I wouldn't have been able to finish some of the last chapters, let alone create such a beautiful cover. Also, the broken key is forgiven…

Odette, we shared the journey of a PhD, a workspace, a conference paper, and a professor. We shared our thoughts, (dark) humor, music, views on life, and our inquiry into beauty. It's only fitting that we share our defense date (and very MEMM, supposedly). Thank you for bringing so many valuable moments and memories to this journey. I cherish them and our friendship dearly.

Pa en ma, bedankt dat jullie mij in de opvoeding de vrijheid hebben gegund om mijzelf te ontwikkelen tot wie ik wil zijn. Ik denk dat dat één van de meest waardevolle dingen is die je als ouder je kind kunt bieden en ik ben jullie daar bijzonder dankbaar voor. Dank voor alles wat jullie mij gegeven hebben, waar ook dit boek een resultaat van is.

Lot en Marieke, jullie namen geregeld polshoogte om te horen of het allemaal nog goed ging met jullie kleine broertje. En wanneer het soms wat minder ging, dan waren er gelukkig de momenten waarop ik uit kon blazen en weer even kind kon zijn door met jullie prachtige kinderen mee te spelen.

Hennie en Peter, jullie steun, wijsheid en betrokkenheid binnen en buiten mijn promotie om waren mij bijzonder waardevol. Al weet ik dat jullie het met veel liefde deden en zullen blijven doen, ik ben dankbaar voor onze hechte band.

Dr. Thomas, Funda, Sora, Zen, Desiré, Melanie, Sander, Stijn (a.k.a. de Osdorp Posse). Bedankt voor het argwanend toelaten dat ik de muziek bepaal. Bedankt voor het virtueel vieren van Sinterklaas, voor de bijlessen geografie, voor de pogingen me dronken te voeren, en voor talloze andere momenten. Al weet ik dat het niet zo is, jullie vriendschap lijkt soms vanzelfsprekend en dat is wat het zo mooi en waardevol maakt.

Arda en Jeroen, ik bewonder jullie energie, enthousiasme en goedheid. Bedankt dat jullie je passie met ons delen voor eten, drinken, reizen, motorrijden, klimmen en 'nerden' in het algemeen. Jeroen, dat ik mijn leven letterlijk aan je heb toevertrouwd tijdens ontelbare klimsessies, geeft me het volste vertrouwen dat je me ook zult beschermen tijdens de verdediging.

Michiel, bedankt voor de vele uren therapeutisch sleutelen aan motoren en de gesprekken over het leven die daar onvermijdelijk uit volgden. Ik ben blij dat de verhuizing uit onze eerste 'garage' (een lekkende zeecontainer van 6m^2) naar het paleis waarin we het laatste jaar gewerkt hebben niets af heeft gedaan aan deze waardevolle momenten. Ik hoop je eerder vroeger dan later te bezoeken in Lund (of in China?).

Netty, Han en de hele zondagsfamilie; iedereen zou eigenlijk zo'n tweede familie moeten hebben. Bedankt voor de altijd warme ontvangst en gezelligheid, hoe lang we elkaar soms ook niet hebben gezien.

Channah. Liefje. Ik zou kunnen denken dat de schoonheid van onze liefde zit in de eenheid die twee verschillende mensen zo dicht bij elkaar brengt. Ik zou kunnen denken dat die schoonheid in de harmonie van onze contrasterende karakters zit. Ik zou nog veel meer kunnen denken. Maar wanneer ik bij jou ben kan ik eindelijk stoppen met denken en beginnen die schoonheid in onze liefde geheel te ervaren. Met je troostende muziek, culinair talent en liefdevolle woorden breng je mijn gedachten tot rust en mijn geluk tot leven. Bedankt dat je me altijd gesteund hebt, met name in periodes dat dat niet makkelijk was. Bedankt voor al het goeds dat je geeft aan de mensen om je heen en dat ik zo gelukkig mag zijn daar zo dicht bij te staan. Ik hou van je.

About the author

Ruben Post was born on the 13th of April 1986 in Hengelo, The Netherlands. After receiving his VWO diploma at the Waerdenborch (Holten) in 2005, he shortly studied Industrial Design in Twente, but decided to switch to the Institute of Interdisciplinary Studies at the University of Amsterdam. At this institute he completed his Bachelor in Natural and Social Sciences in 2009, followed by a Research Master in Cognitive Neuroscience (Cum Laude) in 2011, with a focus on visual perception and aesthetics. Immediately afterwards, he started his PhD on Product Design Aesthetics, as member of the UMA (Unified Model of Aesthetics) research group, at the Industrial Design Engineering faculty of the Delft University of Technology.

Ruben has presented his work at various international conferences (TEAP, IASDR2013/2015, IAEA2014 and DeSForM2015) and in lectures to Master students at national and international universities.

His interest covers anything related to understanding how the brain builds a meaningful understanding of the world, especially in relation to the artefacts we interact with. This understanding he experientially gains while driving and maintaining various motorcycles.

··· Publications

Post, R. A. G., Berghman, M., & Hekkert, P. (Manuscript In Preparation). The influence of distal versus proximal senses on the multi-sensory appreciation of product designs.

Post, R. A. G., Blijlevens, J., Saakes, D., & Hekkert, P. (Submitted). Unity-in-Variety as an aesthetic principle accounting for the tactile appreciation of artefacts.

Post, R. A. G., Nguyen, T., & Hekkert, P. (Accepted for publication). Unity in Variety in website aesthetics: A systematic inquiry.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2016). 'To preserve unity while almost allowing for chaos': Testing the aesthetic principle of unity-in-variety in product design. Acta Psychologica, 163, 142-152. doi: 10.1016/j.actpsy.2015.11.013

Post, R. A. G., Da Silva, O., & Hekkert, P. (2015). The beauty in product-service-systems. Paper presented at the IASDR2015 Interplay, Brisbane, Australia.

Post, R. A. G., Saakes, D., & Hekkert, P. (2015). A Design Research Methodology using 3D-Printed Modular Designs to Study the Aesthetic Appreciation of Form and Material. Paper presented at the Design and semantics of form and movement conference - Aesthetics of interaction: Dynamic, Multisensory, Wise, Milan, Italy.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2014). Aesthetic Appreciation of Tactile Unity-in-Variety in Product Designs. Paper presented at the 23rd Biennial Congress of the International Association of Empirical Aesthetics, New York, United States of America.

Post, R., Blijlevens, J., & Hekkert, P. (2013a). The influence of unity-in-variety on aesthetic appreciation of car interiors. Paper presented at the IASDR 2013: Proceedings of the 5th International Congress of International Association of Societies of Design Research" Consilience and Innovation in Design", Tokyo, Japan, 26-30 August 2013.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2013b, March 24-27). Unity-in-variety in product design aesthetics. Paper presented at the Tagung experimentell arbeitender Psychologen, Vienna.

Meuwese, J. D., Post, R. A., Scholte, H. S., & Lamme, V. A. (2013). Does perceptual learning require consciousness or attention? Journal of cognitive neuroscience, 25(10), 1579-1596.

van Dijk, A., Klanker, M., van Oorschot, N., Post, R., Hamelink, R., Feenstra, M. G. P., & Denys, D. (2013). Deep brain stimulation affects conditioned and unconditioned anxiety in different brain areas. Transl Psychiatry, 3, e289. doi: 10.1038/tp.2013.56

Post, R. A. G. (2009). Zien met je oren. BLIND, (21). (www.ziedaar.nl)