Aesthetic heuristics for design: cognitive and sociocultural determinants

Abstract

Aesthetic pleasure is derived from sensory perception. This pleasure depends on three aspects: the physical properties of the object, the qualities of the perceiver, and four types of aesthetic determinants. Perceptual determinants and beauty standards have been studied scientifically and many methodological rules known and used by designers for decades, such as balance, good proportion, and Gestalt laws, have also been developed. In contrast, cognitive and socio-cultural determinants lack methods to support the aesthetic design process of designers. The use of heuristics as a method of support to this process could be a means of extending the aesthetic possibilities of the product when limited time and knowledge are available. Through a literature review and an analysis of award-winning products the aesthetic heuristics were identified, extracted, organized, and classified, resulting in a repertoire of 48 aesthetic heuristics of cognitive and socio-cultural determinants which were used in two exploratory studies. The results showed that these heuristics allow new and original ideas to be created in less time than usual and expand the possibilities in the aesthetic design process.

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Heuristics, aesthetic pleasure, design, beauty.

Heurísticos estéticos para el diseño: determinantes cognitivos y socio-culturales

Resumen

El placer estético se obtiene a partir de la percepción sensorial. Este placer depende de tres aspectos: las propiedades físicas del objeto, las cualidades del perceptor y cuatro tipos de determinantes estéticos. Los determinantes perceptuales y estándares de belleza se han estudiado científicamente. Así mismo se han desarrollado muchas de las reglas metodológicas conocidas y usadas por los diseñadores durante décadas; el equilibrio, la buena proporción y las leyes de la Gestalt. Por el contrario, los determinantes cognitivos y socioculturales carecen de métodos que apoyen el proceso de diseño estético de los diseñadores. El uso de los heurísticos como método de apoyo a este proceso, podría ser un medio para ampliar las posibilidades estéticas del producto cuando se dispone de tiempo y conocimientos limitados. Mediante una revisión de la literatura y un análisis de los productos premiados, identificamos, extrajimos, organizamos y clasificamos los heurísticos estéticos, dando como resultado un repertorio de 48 heurísticos estéticos de los determinantes cognitivos y socioculturales. Usamos estos heurísticos en dos estudios exploratorios. Los resultados mostraron que estos heurísticos permiten crear ideas nuevas y originales en menos tiempo de lo habitual y ampliar las posibilidades en el proceso de diseño estético.

Palabras clave:
Heurísticos, placer estético, diseño, belleza.

Introduction

Framework of Aesthetic pleasure

How to make beautiful products? And, why do people feel attracted to them? Product design aesthetics is about the appearance of products, it is about manipulating their form elements such as geometry, color, shape, or material to affect the human senses and generate aesthetic pleasure. This pleasure depends on many aesthetic determinants, which are the variables that designers can manipulate in the design process. According to Hekkert (2008), the application of these determinants in the design process could be "a way to ensure the acceptance and appreciation of the product", that is, generate aesthetic pleasure. This appreciation is given by the agreement to needs for safety and fulfillment (Berghman & Hekkert, 2016) that are manifested in the aesthetic determinants. Likewise, Blijlevens et al. (2014), explain that aesthetic pleasure can be better understood from an interactionist perspective. This perspective includes the interaction between physical properties of the object such as balance, symmetry, color, complexity, etc. (the objectivist perspective), and the qualities of the perceiver as a basis for generating aesthetic pleasure (the subjective perspective: "beauty is in the eyes of the beholder"). Therefore, the interactionist perspective states that "the aesthetic pleasure is the result, of how the receiver and objects relate" (Blijlevens et al., 2014). This latter perspective will be adopted in this study.

Aesthetic determinants have been explained and reviewed in different studies and they can be classified into four groups (Hekkert, 2008; 2015; Crozier, 1994; Berlyne, 1966; Crilly, Moultrie, and Clarkson, 2004; Bloch, 1995; Veryzer, 1993, 1999; Köhler, 1992; Padovan, 1999; Schofield, 1958; Wittkower, 1960; Arnheim, 1974, 1988).

I. The absolute standards of beauty comprise the rules or patterns of a geometric or mathematical nature that have been imposed historically by art, architecture, and philosophy as balance, good proportion, etc. (Padovan, 1999; Scholfield, 1958; Arnheim, 1984; Levison, 2003).

II. Perceptual determinants are those that share the same human biological functional basis, referring to how the shape is perceived and how the visual elements are organized to create a perceptual order in products (Köhler, 1992) (for example Gestalt laws, symmetry, similarity, etc.) (Martindale, 1999; Ramachandran, 1999).

III. Cognitive determinants are based on how people process the information they get from a product (Wilson, Keil, 2009). Knowledge, experience, and recurring information structures are important for these determinants (Hekkert, 2008). Some of these determinants are given by a cognitive process of repeated experience with objects which allows people to categorize them (Whitfield, 1983; Hekkert, 2015; Zajonc, 1968). In addition, psychology says that the appreciation of an object increases if it is presented frequently: the effect of "mere exposure" (Zajonc, 1968). The "familiarity" and "novelty" determinants are also part of this group. Stimuli with such characteristics enable people to discover and learn new things, increasing interest (Bornstein, 1989). The determinants of this group are novelty, unexpectedness, innovation, complexity, a-typicality, originality, typicality, familiarity, prototypicality, identifiability, process fluency, Most Advanced Yet Acceptable (MAYA) and congruency (Hekkert, 2008; 2014).

IV. The socio-cultural determinants, are related to the way people interact with others and the balance between the need to be part of a group and the autonomy of oneself. As a result of human evolution, people like to be part of a group to increase safety and reproductive possibility (Axelrod & Hamilton

1981). At the same time, however, there are needs for autonomy and for objects that represent people uniqueness into the social group to which they belong (Berghman & Hekkert, 2016). The determinants of this group are connectivity, uniqueness, cultural standards and values, and congruency (Hekkert, 2008; 2014).

The groups I-II of determinants have been studied scientifically and experimentally in the field of design. They are also explained in many design textbooks. Moreover, methodological rules have also been developed and used by designers for decades. In contrast, cognitive and socio-cultural groups have been little explored in the field of design. They have been associated more with psychological and sociological domains. Therefore, there is a lack of methods for these determinants that support the aesthetic design process in industrial design (Lidwell, Holden, & Butler, 2010; Norman, 2002; Hannah, 2002; Gatto, Porter, & Selleck, 1978; Quarante, 1994; Samara, 2008; Wolchonok, 2013; Lauer & Pentak, 2011; Wong, 1993; De Sausmarez, 1992; Elam, 2001; Faimon & Weigand, 2004; Luecking, 2002; Bowers, 1999; Zelanski & Fisher, 2007) and in product design engineering (Ulrich & Eppinger 1995; Roozenburg & Eekels 1995; Pahl et al., 2013; Otto & Wood 2000; Cross, 1989). For this reason, the researchers decided to focus this research on the last two groups. However, this lack of methods seems to be present in other design activities as well.

Aesthetics can give companies the opportunity to have products with higher prices, with higher sales, with the promise of an adequate return on investment (Crilly et al., 2004). Some classical studies have shown that if consumers are given two products with similar characteristics in price and function, people will choose the most attractive one (Kottler & Rath 1984; Nussbaum, 1988). It is important to note that aesthetics refers not only to the final external appearance of the product, as a combination of shapes, colors, or materials (Hekkert & Leder, 2008), but also to the cognitive and socio-cultural aspects

involved in generating aesthetic pleasure. These aspects are the central purpose of this research through the study of cognitive and socio-cultural aesthetic determinants in the design process. Therefore, a poor understanding of the needs and aspirations of the customer and user could result in an inadequate aesthetics that could lead to products failing the market (Cooper, 2001; Baxter, 1995). Consequently, it is important to find design methods that support designers by structuring and supporting aesthetics in the design process to achieve high aesthetic pleasure and more attractive products (da Silva et al., 2013).

Heuristics as aesthetic design strategies

Expert designers develop their knowledge through years of experience exposed to many different design problems (Cross, 2004). This experience could be seen as rules. Sometimes, they are not aware of those rules, and they commonly call them intuition. Ramachandran and Hirstein (1999) argue that these rules or principles are a set of heuristics that artists, or designers in this case, use consciously or unconsciously to awaken the visual areas of the brain. On the contrary, non-expert designers have been less exposed to design problems (they are less experienced); and they require some methods to support their design process.

Two strategies were identified to carry out the aesthetic design process. In the first place**, the computer-based strategy** that tries to model aesthetic pleasure and its determinants using computer-based algorithms (Bentley & Corne, 2002; Galanter, 2012; Cadavid et al., 2016). In the second place, **the manual strategy** that is composed of *tacit heuristics* based on the intuition of the designer (that draws on professional experience, academic education, or from evolutionary rooted psychological mechanisms) and *explicit heuristics* articulated and used in a deliberated manner (Cadavid et al., 2016).

Given the complexity and limited application in industrial and product design of the computational strategy, this research is directed at the manual strategy and explicit heuristics used in a deliberate manner. Heuristics could be seen as a resource to support the aesthetic design process, allowing designers to come up with solutions that reasonably approach the best possible answer or optimal solution (Nisbett & Ross, 1982; Yilmaz, 2010) using limited time and knowledge (Gigerenzer, 1999). These could also provide designers with cognitive strategies to "jump" into new spaces of solution, seeing the same elements already known but structured differently, offering new ideas and solutions (Yilmaz, 2010).

Heuristics are commonly called "rules of thumb" (Nisbett et al., 1983). They are useful cognitive tools necessary for making decisions and solve problems that cannot be handled by logic and probability alone (Gigerenzer, 1999). These have been used by different disciplines, including design, where they are considered rules that facilitate the exploration of multiple designs during concept generation (Daly et al., 2012). In addition, heuristics could reduce the time of the conceptualization process and could guide the designer toward discovering more solutions. However, the fact that "heuristics do not guarantee the best solution" (Yilmaz, 2010) cannot be ignored. Thus, the application of heuristics could be seen as a method to expand the aesthetic possibilities of the product and achieve design concepts closer to a positive aesthetic pleasure.

The authors of this research believe that the application of heuristics in design could be used in the aesthetic design process and is not only limited to creative design. (Yilmaz, 2010). Based on this assumption, a literature review was conducted to identify authors and methods to obtain heuristics for the aesthetic design process. Moreover, award-winning products were examined to validate the heuristics found in the literature review.

Research motivation and research questions

As mentioned above, a knowledge gap on the cognitive and sociocultural determinants of aesthetic pleasure was identified, as these determinants are not explicitly present in design textbooks or in the design process. So, the researchers believe that a set of heuristics from these determinants could support the designer's aesthetic design process. Therefore, this article describes exploratory research of the aesthetic design heuristics of the cognitive and sociocultural determinants. The research questions are:

- RQ1: How to identify and extract aesthetic design heuristics from the cognitive and socio-cultural determinants?
- RQ2: How to organize and classify aesthetic heuristics of cognitive and sociocultural determinants in a repertoire?
- RQ3: To what extent would the application of the aesthetic heuristics (organized as a repertoire) in the design process contribute (without ensuring it) to increase the level of aesthetic pleasure in products?

To answer these questions, two methods were developed for the construction of a repertoire of aesthetic heuristics. Additionally, two studies were carried out to measure the effect of using the repertoire of aesthetic heuristics in the design process. The first study was conducted with 13 expert designers who evaluated the repertoire and the second study was conducted with five Product Design Engineering students who used two heuristics in a design task. The development of methods and the exploratory studies are extensively explained in the following sections.

Research method

In this research two methods were developed to extract aesthetic heuristics from a literature review and the analysis of award-winning products. The resulting methods permitted to build up a repertoire of aesthetic heuristics that answer RQ1 and RQ2. The first method was proposed by Yilmaz, (2010) which was developed in three phases. 1. A total of 400 award-winning products were analyzed in the first phase and key features of the products were identified. 2. Then, 200 designs made by an expert designer were analyzed in the second phase. 3. In the third phase, the observation and think-aloud protocol methods to analyze design engineers during their design process were applied. The characteristics found in these three studies were grouped by similarity and compared to each other to find patterns that resulted in 77 heuristics to increase creativity in the design process (Daly et al., 2014, Yilmaz et al., 2014).

The second method was the extraction of visual design heuristics from a quantitative literature review used by Kimball (2013). In this case, the method allows finding principles of visual design by means of a search protocol. A total of 47 texts were examined, including books, textbooks, websites, and scientific articles published between 1904 and 2011.

Extraction of aesthetic heuristics from literature review

The first method to extract aesthetic heuristics is based on a literature review that is explained extensively in Cadavid et al. (2016), *figure 1*.

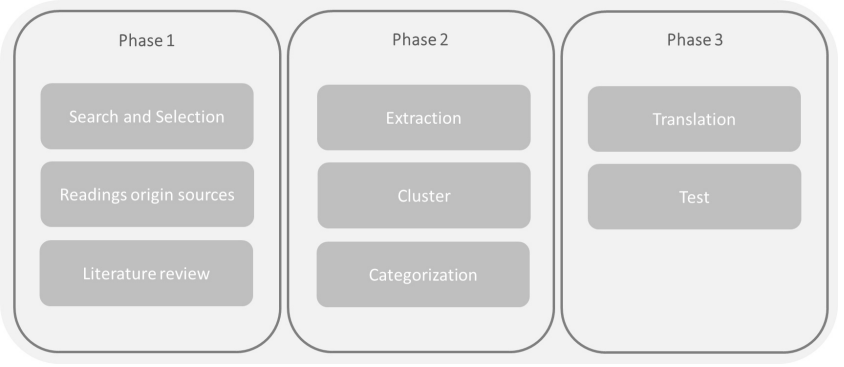


Figure 1: Method for extracting aesthetic design heuristics from a literature review. From Cadavid et al, 2016

The *bounded rationality* approach was used to support the identification, selection, and extraction of the aesthetic heuristics. This approach proposes that inferences about the world can be made with limited time, knowledge, and computational power to make different decisions (Gigerenzer, 1999; Cadavid et al, 2016).

For the extraction of cognitive and sociocultural heuristics from the literature, the following protocol was used. In the first place, a bibliographic search question was defined according to a comprehensive framework on aesthetics and prior knowledge of the aesthetic determinants (Hekkert, 2008, 2015). Secondly, an inclusion criterion was established to identify scientific literature related to the question and the research objective. Thirdly, the minimalist heuristic of bounded *rationality* (Gigerenzer, 1999) was used for the selection process. And finally, the heuristics were extracted and translated into a more understandable language to designers in order to be effectively tested and used in the design process (Cadavid et al., 2016).

Extraction of aesthetic heuristics from award-winning products.

The method applied by Yilmaz (2010) was used for this process of heuristic extraction from award-winning products. However, given the nature of the groups of aesthetic determinants being studied in this research (cognitive and sociocultural), designer intention analysis played an important role in the heuristic construction. Therefore, the inclusion of a content analysis and product semantic analysis methods (Krippendorff, 1984, 1989, 2004) were necessary to build up this method and the heuristics extracted, *Figure 2*.

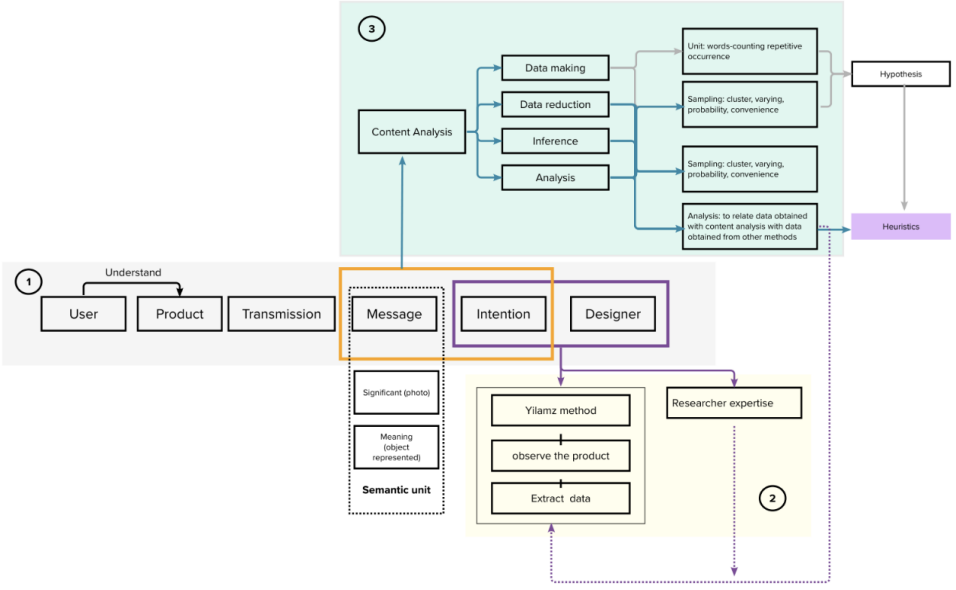


Figure 2: Method for extracting aesthetic heuristics from award-winning products.

For this process, 65 award-winning products from different categories of two renowned design competitions were randomly selected (*Red Dot Design Award* and *A'Design Award and Competition)*. These two were selected because the analysis required that the competitions included different categories and types of products. It is important to notice that the yearbooks of the competition contained the description of the intention of the designer. The aesthetics of the product was part of the evaluation criteria for the competition.

The products were analyzed as follows. 1. An observation was made to identify the most likely aesthetic determinants applied by the designer. 2. Using the content analysis method from the designer's description and the comments of the judges, words related to aesthetics and the formal characteristics of a product such as color, geometry, shape, etc. were selected, highlighted, and grouped. The words related to the designer intention were analyzed in the same way. 3. The words related to aesthetics and the intention of the designer were crossed with a higher frequency. As a result, hypotheses of the possible heuristics used by the designer in the product were developed. These were then compared and validated with the aesthetics determinants recognized in the first stage by observation to build up the final heuristics. This method will be further illustrated in this paper.

Heuristics obtained from these two methods were compared by similarity and summarized by means of a proportional stratified sampling in which, according to the number of heuristics obtained for each aesthetic determinant and their frequency of occurrence, a weight was assigned to a list of heuristics, resulting in a final repertoire of aesthetic heuristics.

The process of organizing and classifying aesthetic heuristics of cognitive and sociocultural determinants in a repertoire.

Using the literature review method, 131 texts were examined, including articles, theses, and books, resulting in 286 extracted aesthetic heuristics. These heuristics were classified into six categories by clustering analysis. Each time a heuristic was extracted, it was grouped with others according to similarity of content. Six categories were obtained. The heuristic,

1. Impacts the shape of the product.
2. Explains the determinant phenomena.
3. Explains the action of the aesthetic determinant involving another determinant.
4. Impacts the shape of the product involving another determinant.
5. Explains the adverse effects of using the determinant.
6. Explains the effect of a determinant on the usability of the product.

Subsequently, the heuristics obtained were translated into a language more understandable to designers. This process is illustrated in the following example:

- **The heuristic extracted uses scientific jargon:** "Design should allow users to maintain their own identity and use the product as means of expressing personality. Design should enhance the value of scarcity by allowing the user to experience the process of the product completion or its historical meaning in addition to the diversity and uniqueness of the form."(Kim & Nam 2014)
- **The main message of the heuristic is recognized and extracted**: *Design should allow users to maintain their own identity and use the product as a means to express their personality.*

- **Some keywords and general ideas from the extracted heuristic were taken to support and specify the construction of the final heuristic:** *identity, personality, singularity, shape*.
- **Finally, the heuristic was translated into a language understandable to product designers:** elements that could be customized by users such as colors, materials, size, shape, or graphics are used to allow them to express their personalities.

Figure 3 shows an example of how the extraction of aesthetic heuristics from award-winning products was carried out. First, by observing the product and knowing the explanation of the determinants, the most likely aesthetic determinants applied by the designer were selected. (MAYA, for example: familiar aspects such the architecture of a kettle and use of novel materials such as the crystals on the lid are combined; familiarity: the shape and architecture of a kettle; and identifiability: the architecture of a kettle). Then, the words related to aesthetics (color, roundness, chromed, etc.) were counted and compared to the intention of the designer: for instance "the kettle was designed for the Chinese market". These two were crossed and analyzed to develop hypotheses of the possible heuristics used by the designer to design the product. Then, they were compared with the aesthetic determinants recognized in the first stage (for example MAYA, familiarity, and identifiability) to construct the final heuristics, for instance to "Preserve the traditional shapes or architecture of the product".

Product's name: K206- Buydeem Technology (Shenzhen) Co.,LTD	Description of the authors	Syntactical Units	# Repetition
 Red dot design Award 2014	The K206 kettle was designed for the Chinese market. In aesthetic terms it is characterized by a combination of simple, classical roundness with contemporary, streamlining details. Particularly eye-catching are the crystals, which sparkle according to the lighting and in combination with the chromed handle and the glossy lid give the appliance an elegant impression.	Chinese	1
		Aesthetic	1
		Combination	2
		Simple	1
		Classical	1
		Roundness	1
		Contemporary	1
		Streamlining	1
		Details	1
		Crystals	2
	Description of jury	Sparkle	1
	This kettle appears not only elegant, but due to the crystals and the use of light, creamy colours it also has a fresh, emotional component.	Chromed	1
		Glossy	1
		Elegant	2
		Impression	1
Aesthetics variables (at first sight)	Hypothesis of designer intentions	Creamy	1
MAYA	The designer decided to combine classical shapes with contemporary characteristics in the Kettle design, to increase the aesthetics of a traditional product.	Colours	1
Familiarity			
Identifiability			
		Words related with the aesthetics	
		Words related with the designer intentions	

Heuristics	
MAYA	Combine typical shapes of the product categoy with new colors and materials.
Atypicality	Use atypical component (piece of the product) for the propduct category.
Familiarity	Conserve a familar architecture for the product category.
	Include familiar shapes of the product category in the new product design.
Identifiability	Use typical shapes of the product category for a easier classification of the product.
Cultural standars and Values	Conserve the traditional shapes or architecture of a product.
Complexity	Use visual asymmetry in the product.
Process fluency	Use physical characteristics such as simple shapes or symetrical forms in order to have a better usability and easy identifiability fluency of a product.

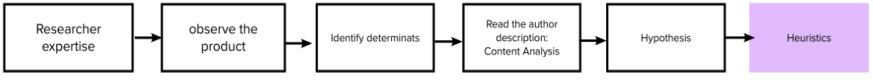


Figure 3 Award-winning product analysis: K206 kettle. Red dot design Award 2014

Finally, a triangulation process was carried out comparing the heuristics extracted from the award-winning products method and heuristics obtained from the literature review method. The result of the triangulation was 213 aesthetic heuristics, from which 116 were part of the category *Heuristics that impact the shape of the product* which was explained above. Since the focus of this research was to know how heuristics could support the designers in the formal design process, only the heuristics that could impact the shape of the product were considered. Although the heuristics of the category "*Heuristics that impact the product shape involving another determinant"* were related to the formal characteristics of the product, they were left aside because they involved two or more determinants in a heuristic. This could have increased the difficulty in interpreting the results of the study.

The 116 heuristics were summarized in a repertoire using proportionate stratified sampling. According to the number of heuristics that each of the 17 aesthetic determinants had (for example the complexity determinant had 11 heuristics) and the frequency of their occurrence (for example, the 11 heuristics of the complexity determinant appear 49 times). Each determinant was assigned a weight in the repertoire. The five heuristics most frequently found in each determinant were included in the repertoire. As a result, 48 aesthetic heuristics were obtained *(Table 1)*. This repertoire contains the most representative aesthetic heuristics of cognitive and sociocultural determinants. These were chosen using a systematic method and ensuring that each heuristic was present in both the literature and the award-winning products. This process is believed to make heuristics highly valuable for aesthetic design because they were used in actual design practice, impacting the aesthetic design process and they are present in the existing determinant literature.

Table 1: Four heuristics from the list of 48 aesthetic heuristics

Novelty
1.Use materials, colors, shapes, or geometries not normally used in the category of the product.
Unexpected
5. Design the product using atypical and unexpected characteristics for the product category such as materials, shapes, textures, sizes, functions or mechanisms.
Complexity
12. Use at least three different colors or more in the same product.
MAYA (Most Advanced Yet Acceptable)
33. Preserve the typical shapes or geometries of the product category and include atypical characteristics such as colors, textures, or materials.

Exploratory studies of the aesthetic heuristics

First study: Aesthetic heuristic and experts

This repertoire was used in two exploratory studies to find out how the use of these heuristics contributes to an increased level of aesthetic pleasure in products in the design process. The first study was conducted with expert designers, to estimate how much the use of aesthetic heuristics in the design process contributes to increasing the aesthetic pleasure obtained from products. The second study was conducted with senior engineering design students to understand how students integrated the heuristics in the design process and how heuristics intervened in the results.

To measure the effectiveness of the use of aesthetic heuristics in the designer's formal design process and answer the **RQ3**, two exploratory studies were

designed. The first study was carried out to evaluate the repertoire of aesthetic heuristics and how it would contribute (without ensuring it) to increasing the level of aesthetic pleasure in products. A second study was designed to evaluate the use of aesthetic heuristics by designers in the design process.

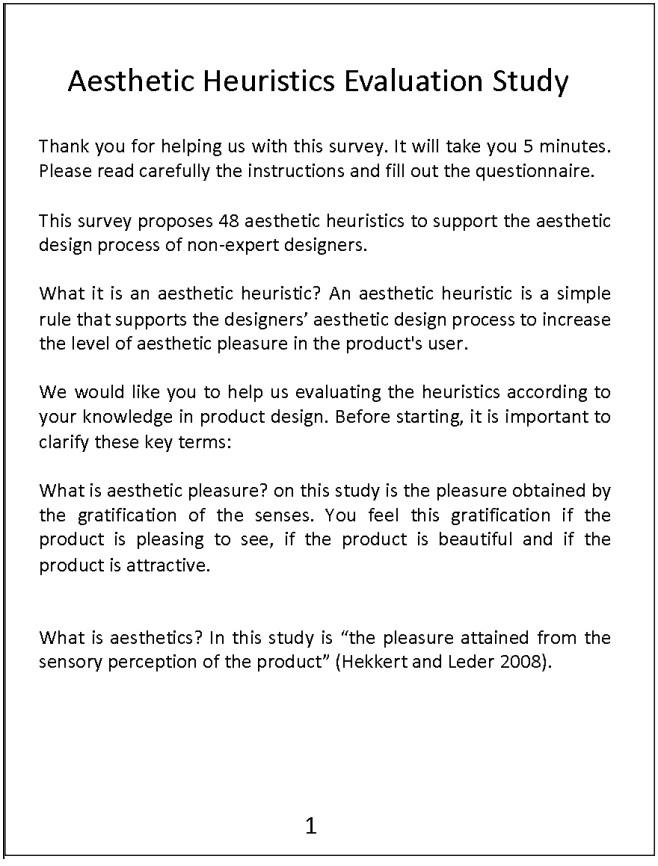
The first study was conducted to find out how the repertoire of 48 aesthetic heuristics proposed answer to **RQ3:** *"To what extent the application of aesthetic heuristics (organized as a repertoire) in the design process would contribute (without ensuring it) to an increase in the level of aesthetic pleasure in products?"* The heuristics were presented in a web questionnaire format (*Figure 4,5,6*) to 13 expert designers with three to ten years of experience, designing in the industry or teaching in universities, *Table 2*.

Table 2: Experts Profile description

# Experts	Years of experience	Profession
2	3-5	Product design engineer
8	6-10	Product design engineer
3	11-20	Industrial designer

The experts were informed about the nature of the study. Key research concepts such as aesthetic pleasure, aesthetic heuristics, and aesthetics, were presented and defined to ensure that they understood the concepts in the same way they were used in this research (*Figure 4*). In addition, an example of how a designer applied heuristics in a product was presented (*Figure 5*). Finally, they were instructed to evaluate each heuristic on a 3-points Likert scale (High, Moderate and Low) to the question: *To what extent would the application of the following aesthetic heuristics contribute in the design process (without ensuring it) to increase the level of aesthetic pleasure in products? (The product is pleasing to*

the eye, this is a beautiful product, and this is an attractive product) (*Figure 6*). As a result of this study, 624 scores were obtained from the 48 heuristics.



Aesthetic Heuristics Evaluation Study

Thank you for helping us with this survey. It will take you 5 minutes. Please read carefully the instructions and fill out the questionnaire.

This survey proposes 48 aesthetic heuristics to support the aesthetic design process of non-expert designers.

What it is an aesthetic heuristic? An aesthetic heuristic is a simple rule that supports the designers' aesthetic design process to increase the level of aesthetic pleasure in the product's user.

We would like you to help us evaluating the heuristics according to your knowledge in product design. Before starting, it is important to clarify these key terms:

What is aesthetic pleasure? on this study is the pleasure obtained by the gratification of the senses. You feel this gratification if the product is pleasing to see, if the product is beautiful and if the product is attractive.

What is aesthetics? In this study is "the pleasure attained from the sensory perception of the product" (Hekkert and Leder 2008).

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Figure 4: The key concepts of the research presented to the experts

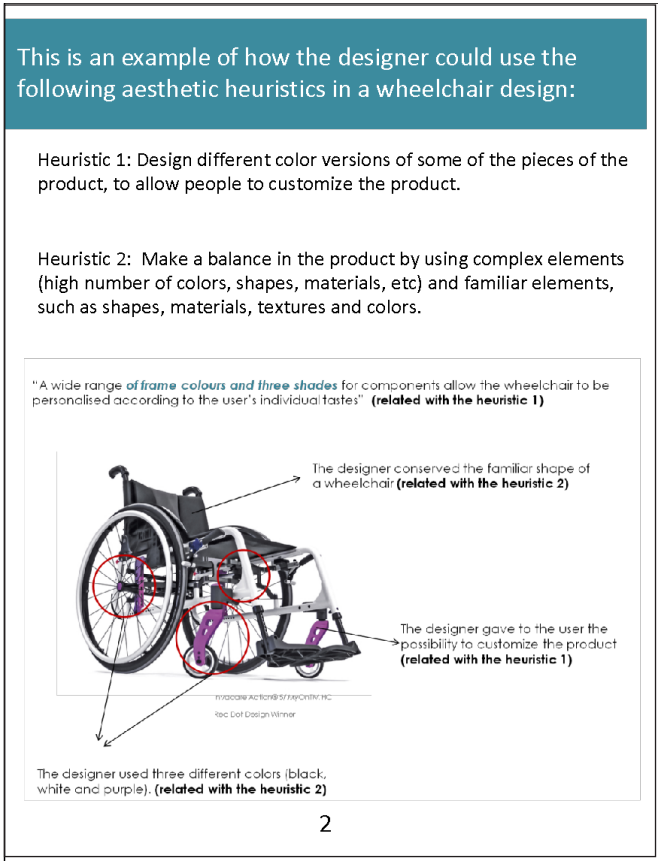


Figure 5 Example of how a designer applied heuristics to a product: The Action 5 / MyOn HC wheelchair. Red Dot Design Award 2014

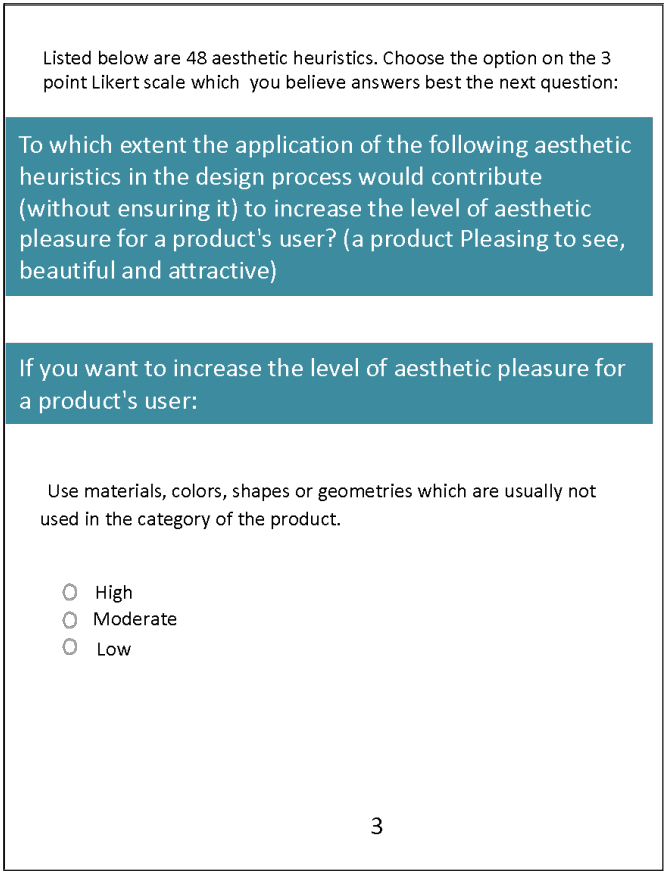


Figure 6: instructions to evaluate the heuristics

After data analysis, overall results show that 48% of the times the evaluators considered that the use of aesthetic heuristics in product design would contribute "moderately" to increase the aesthetic pleasure, followed by "high contribution" with a 31%, and "low contribution" with 22% *(figure 7)*.

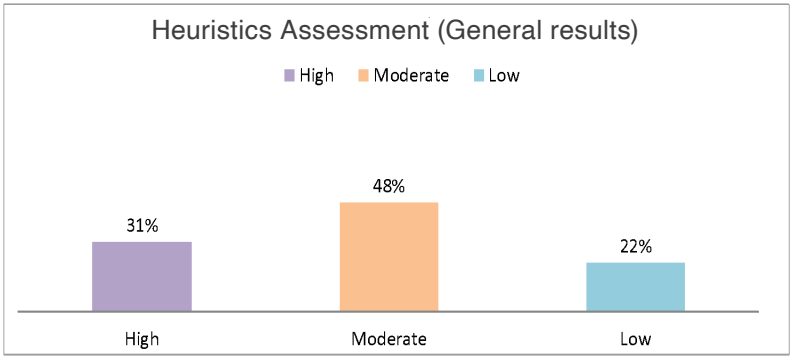


Figure 7 General results: Study of 48 aesthetic heuristics

Subsequently, a second analysis was carried out by heuristic. The aim was to identify whether the results of individual heuristic evaluation might show a trend. For instance, the heuristic "Using cultural traditions as a basis for designing new products" was rated by seven experts as "high contributor" to the aesthetic pleasure, and six of the experts scored it as a "moderate contributor". Given these results, it cannot be ensured that experts think that this heuristic contributes to increasing the aesthetic pleasure at a moderate level, but that the heuristic contributes moderately but with a tendency to be high. It was found that many of the heuristics tended to be high or low. For example, *figure 8 left* shows a tendency to high (heuristic #5), *figure 8 right* (heuristic #12), shows a trend to low. This leads to reclassifying five levels of heuristics according to their scores: high, high/moderate, moderate, low/moderate, and low (table 3).

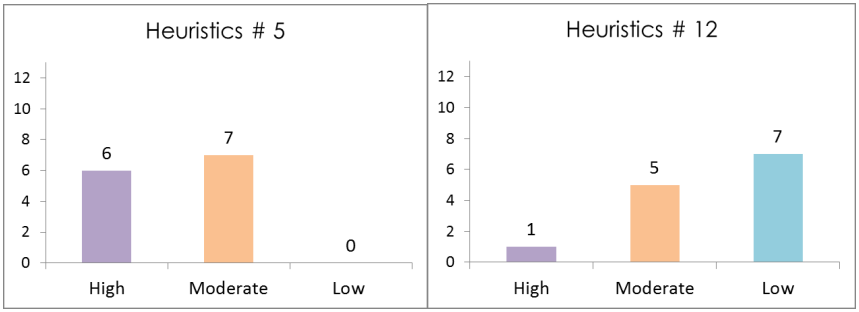


Figure 8: Example of heuristics tendency results

Table 3: Results of heuristic analysis by heuristic

Levels of aesthetic pleasure contribution	Aesthetic heuristic number *(From figure 7)*
High	6,34,27,30
High/Moderate	3,5,7,20,21,33,40,42,44,28,29,31,32,45,46,38
Moderate	1,2,4,8,17,19,22,35,41,43,10,13,25,26,47,36,37
Low/Moderate	18,24,9,11,12,15,48,39
Low	23,14,16

In addition, it was found that some of the heuristics were at low/moderate and low levels that are believed to be counterintuitive to the designers. This probably explains the scores of designers. For example, the complexity determinant heuristic *"Use visual asymmetry in the product"* (*figure 9*) is opposed to the presumably more traditional heuristic "use symmetry". The heuristic "Use at least three different colors or more in the same product" (*figure 10*) goes against the heuristic "Use different colors with moderate differences between them".

K206 kettle
Extracted from: Red Dot Award

Figure 9 Heuristic application example, "Use of visual asymmetry in the product: K206 kettle. Red Dot Design Award 2014

Action 5 / MyOn HC
Extracted from: Red Dot Award

Williamson Tea limited edition Caddies
Extracted from Red Dot Award

Figure 10: *Heuristic application example, "Use at least three different colors or more in the same product": The Action 5 / MyOn HC wheelchair and* Williamson-tea-limited-edition-caddies. *Red Dot Design Award 2014*

The latter examples were not shown to the evaluators (figure 9 and 10). They are illustrative examples of products containing the lower heuristics rates.

For this study, it was also significant to know the inter-evaluators agreement to evaluate the validity of the results. Consequently, Light's kappa was calculated among the 13 evaluators. This statistic allows evaluating the agreement between more than two evaluators on categorical data to be evaluated (Conger, 1980). The result *k= 0.0675* shows a slight agreement between evaluators (Abraira, 2001). Therefore, it was decided to check whether the years of experience could make a difference and affect the way experts rate the heuristics. So, the Light's kappa was calculated again but this time separating the data by years of experience. The values obtained were experts from 3- 5 years: *k*= 0,0554, experts from 6-10 years: *k*=0.0595 and experts from 11-20 years: *k*=0.1268. Although agreements between rates are still small, after a qualitative analysis of the rates heuristic by heuristic, experts with more than 10 years of experience tend to have more agreement between them and rate the heuristic as "high" more than the other two groups of experts, *figure 11*.

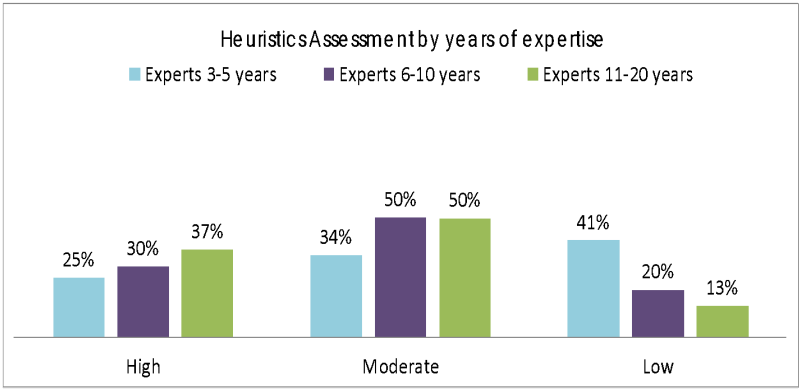


Figure 11: Overall results comparing years of experience

F*igure 11* shows the overall results by comparing years of experience of the evaluators. For instance, experts with more years of experience think that only 13% of the time heuristics have a "low contribution" to the aesthetic pleasure in the products. On the contrary, experts with 3-5 years of experience think that 41% of the time heuristics could have a low contribution to the aesthetic pleasure in products. These results lead to thinking that the more years of experience, the more knowledge about these rules (heuristics) they have. This is probably due to the large number of design situations to which these experts have been exposed compared to the other two groups of experts 3-5 and 6-10 years.

Second Study: The use of aesthetic heuristics by non-expert designers

Design aesthetic heuristics were tested with last semester design engineering students. A set of 81 cards containing the definition of the 28 aesthetic determinants and the heuristic that explain them, and 48 aesthetic heuristics (repertoire) were designed for the test. The heuristics explaining the aesthetic determinants were included based on a preliminary test because the students were not familiar with the "aesthetic design determinant" concept.

The main task of this experiment was to design a novel portfolio for a packaging company, which sought an original, creative, and aesthetic way to present their work to their customers. This design task was chosen because the students feel more engaged in real-life design activities involving business projects and the execution of activities for a real market. Besides, products with these characteristics are little known in the market, which prevent students from having product references to copy, making the task more challenging for them.

Procedure of the experiment

A group of five students was invited to participate in this experiment (three women, two men). They developed this activity as a final project to obtain their university degree (the whole project took four months). Before the experiment started the students had to carry out some design activities to obtain information and insights that were later used in the design process.

Image 1: Group of students participating in the study

In a 120-minute session, participants were asked to design four concepts in four different phases (*Image1)*. The first and third phases were experimental conditions. No information on heuristics was submitted *(table 4)*. Although the students have experience in systematic design (Pahl & Beitz 1988) and product design methodology (Ulrich & Eppinger 1995), they were not asked which methods they used in the experiment to increase the ecological validity

of the experiment. The second and fourth conditions were the conditions of use of heuristics, where two different aesthetic heuristics were presented (*table 4*). For these phases, participants were asked to randomly select two cards explaining the aesthetic determinants. The first card was about the originality determinant. The second was about the unexpected determinant. Students were provided with a booklet containing a description of the activity, a page with the instructions for the card set, and four blank pages to draw concept designs. It was also suggested that "comments be used to explain or highlight something about their concept".

Table 4: Concept generation phases: conditions vs heuristics

Phase 1: *Concept 1*	**Phase 2**: *Concept 2*	**Phase 3:** *Concept 3*	**Phase 4:** *Concept 4*
Control condition *Design task*: Design a novel design concept of a company portfolio package. "Without using Heuristics"	**Heuristic condition** *Design task:* Design a novel design concept for a portfolio package of a company. ***Heuristic used:*** "Use materials with unknown characteristics such as new material but with a familiar appearance, transparent material with hidden characteristics or a material with a visual illusion"	**Control condition** *Design task*: Design a novel design concept for an internal element of a company portfolio. "Without using Heuristics"	**Heuristic condition** *Design task:* Design a novel design concept of an internal element of a company portfolio. ***Using the heuristic:*** "Use characteristics which have never been used in the product category such as shapes, colors, materials or textures"

Evaluation of the study with non-expert designers' case.

At the end of the session with the students, 20 concepts were obtained. These were evaluated by three design experts *(Table 5)* with experience in industry and academia, which allowed a broad perspective in product design.

Table 5: Expert's profile

Expert	**Years of Teaching/ working experience**	**Background**
# 1	**20 years**	Industrial designer with Master studies in Humanities.
#2	**10 years**	Production Engineering, with a Master of science degree in Engineering.
#3	**5 Years**	Product design Engineering with a Master's degree in design and a Master's degree in furniture design.

The experts were informed about the nature of the study. In addition, key concepts of the research were presented to ensure that they were understood in the same way as used in this research (aesthetic pleasure, aesthetic heuristic, and aesthetics). Finally, they were asked to evaluate the aesthetic pleasure of the 20 concepts made by the students, using a 7-points scale: *This product is nice to see, this is a beautiful product, and this is an attractive product* (Blijlevens et al., 2014). In addition to this, they had to score the originality and unexpectedness determinants of the aesthetic pleasure used in the generation of concepts of the study. Seven-point scales were used to rate originality (*This product is original; the design of this product is novel* (Snelders & Hekkert, 1999)), and unexpectedness (*The design has a familiar appearance for this kind of product, the product is surprising* (Ludden et al., 2004; 2012)). The design concepts were presented to the experts in random order to avoid any ordering effect.

A correlation analysis between the scores given by the experts using the aesthetic pleasure indicators (pleasing, beautiful, and attractive) and the aesthetic pleasure determinants, originality and unexpected was carried out. *Figure 12* shows the overall results of the correlations between aesthetic pleasure, originality,

and unexpectedness. *Figure 13* shows the overall results of the correlations aesthetic pleasure-originality and aesthetic pleasure-unexpectedness without using heuristics.

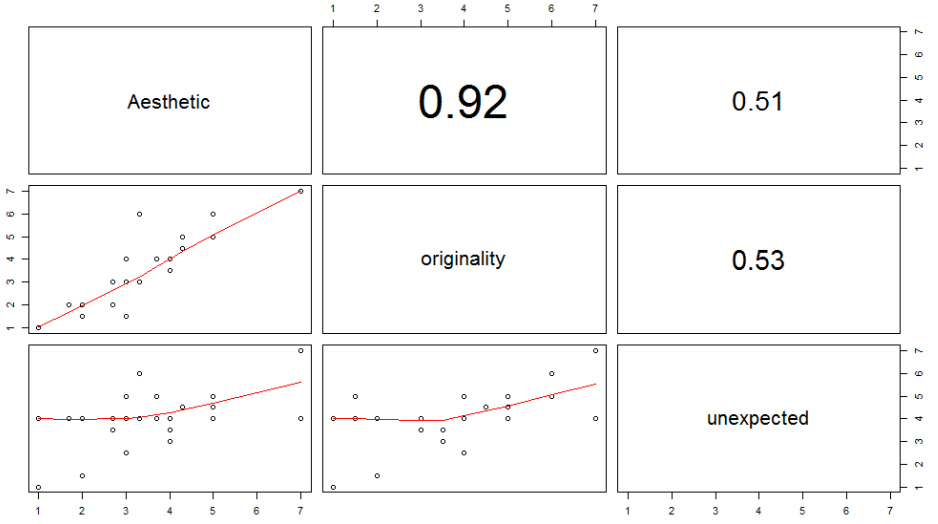


Figure 12: Correlation results with the use of the heuristics

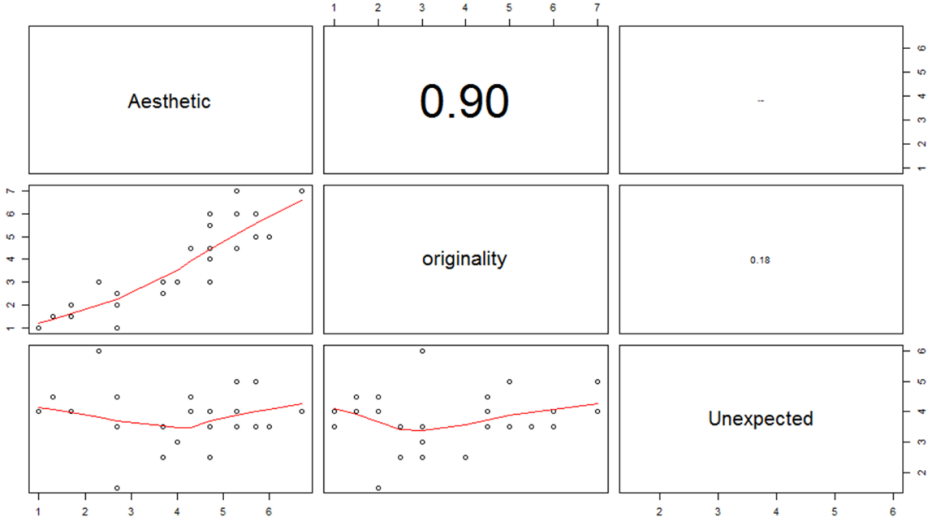


Figure 13: Correlation with originality and unexpected results without using heuristics

These results show a strong correlation in the 20 concepts between aesthetic pleasure and the "originality" evaluations, even in those concepts where heuristics were not used (values between *r*= 0, 7969 and *r*=0, 9976) *tables 6, 7*. This could be because the design task had a low difficulty, resulting in highly original concepts. Nothing can be ensured about the positive effect of the heuristic in this case.

Table 6: Correlation results without heuristics

	Aesthetic pleasure--Unexpected	P-value	Aesthetic pleasure-Originality	P-value
Student 1	0,1155	0,8276	0,9409	0.00513
Student 2	-0,2625	0,6153	0,9680	0.00152
Student 3	0.3966	0,4363	0,941	0.00513
Student 4	-0,0671	0,8995	0,8755	0.0223
Student 5	0,3110	0,5485	0,9922	0,0917

Table 7: Correlation results using heuristics

	Aesthetic pleasure-Unexpected	P-value	Aesthetic pleasure--Originality	P-value
Student 1	0,1653	0,7542	0,9923	0,0892
Student 2	-0,0492	0,9262	0,8718	0,02361
Student 3	0,3404	0,5092	0,7969	0,05769
Student 4	0,0899	0,8655	0,9976	0,000008
Student 5	0,8728	0,0233	0,9504	0,00363

On the contrary, the correlation between Aesthetic Pleasure and the application of "unexpected" heuristic had differences between the concepts designed applying the heuristic and the concepts without applying it, *Table 7*. Students 1, 2, and 3 had a small variation on the correlations within their design concepts using and without using the "unexpected" determinant heuristic. This suggests that there is no difference in using or not using the heuristic *(tables 5, 6)*.

However, students 4 and 5 had a high variation on the correlations between their design concepts: Student 4: r= -0,0671 p= 0,8995 before heuristic use and r= 0,0899 p= 0,8655 after heuristic use. Student 5: r= 0,3110 p= 0,5485 before heuristic use and r= 0,8728 p= 0,0233 after heuristic use. The most noticeable difference was in student 5 (*figure 14)*.

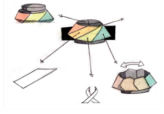
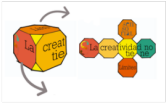
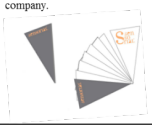
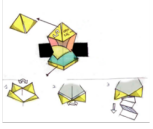
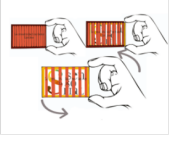
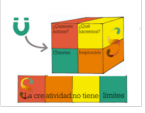
1. Concepts without using heuristics	The spiral shape represents the services offered by the company. This could be used to store office objects on the desk 	A business card. When it comes in contact with water, shows new information about company. 	The package is inspired by one of the letters of the company's name (s) 
2. Concepts without using heuristics	3D puzzle, each piece represents a service offered by the company. 	This is a holographic cube. On each side of the cube are the products designed by the company and the services they offer. 	The design is inspired by a palette of colors, each card contains a service and information of the company. 
3. Concepts using heuristics **Unexpected:** "Use materials with unknown characteristics such as a new material but with a familiar look, transparent material with hidden characteristics or a material with a visual illusion"	Package that use a secret door to generate surprise when it is opened to generate brand awareness 	Business card which shows new information each time it is moved 	The design is based on the matryoshkas dolls, where a larger element contains several smaller elements. The company services are shown in the individual elements 
4. Concepts using heuristics. **Originality:** "Use characteristics which have never been using in the category of the product such as shapes, colors, materials or textures"	Interactive element that uses different combinations at several levels to reveal compartments with the information of the services 	Modular cube. The pieces could be arranged in different ways, allowing to display the services offer by the company and also the possible combinations of them. 	Element which at the contact with one its faces an internal light turns on showing the description of services provided by the company 
	Student 2	**Student 4**	**Student 5**

Figure 14: Students 2-4-5 sketch concepts

The results of students 4 and 5 could be due to the fact that, while all students were educated in the same circumstances, these two students had an emphasis on product management and marketing during their career, not on design conceptualization. They were probably less exposed to design activities than the other three students or may simply require methods or tools to structure their design process (Cross, 2004). Also, Lu (2015) has shown that there are designers with different types of cognition and idea generation. Therefore, these students probably required external methodological tools as a basis for developing new design solutions, which could explain the difference in the results.

Figure 14 includes examples of the design concepts of three of the students: one concept without the use of heuristics and two concepts with the use of heuristics from the unexpected and originality determinants, respectively. Comparing the results between students, students four and five had "simple ideas". Their drawings contain basic geometries and a small number of elements such as colors or shapes, unlike the other three students whose concepts have more complex elements and geometries. This may reflect poor drawing skills and little design experience of students four and five, which is probably an answer to why they obtained those results. Consequently, with this exploratory research, some light has been shed on how students use aesthetic heuristics and how heuristics support the design process of students.

After the conceptual design session, and to understand the experience of students using heuristics, they were asked their opinion on the use of heuristics. They expressed, for instance: "with the use of heuristics, we required more time to think about how to apply what we were reading before we started drawing, but when ideas came to our mind, these were more complete, and we spent less time drawing the final concept".

The time was taken in the session. The results show that when they designed the first two products without using heuristics, they went to the paper directly and drew many concepts changing the idea rapidly, which took them a long time before coming up with a good idea (around 25-30 minutes). Conversely, when heuristics were provided to the students, they needed more time to start drawing (about 10-15 minutes) but when they finally started, the final idea came immediately, and they did not need to draw many ideas to get to the final concept.

These results are consistent with Ahmed et al., (2003) who state that there are differences between novice and experienced engineers. While non-experienced engineers use "trial and error" techniques and multiple iterations to generate solutions, experts do a preliminary evaluation of their multiple solution options before proposing and implementing them. Although the evidence is limited, this suggests that using heuristics might push the students into a different and presumably more expert mode.

Conclusions

This research aimed to find out how to extract aesthetic design heuristics from the cognitive and sociocultural determinants and study their impact on the design process and aesthetic pleasure. As a result, two methods were developed to extract, categorize, and organize the aesthetic heuristics. The heuristics obtained were grouped and compared by similarity resulting in a total of 213 aesthetic heuristics. This research only considered the heuristics from the category *"Heuristics that impact the shape of the product."* These were summarized in a repertoire using a proportionate stratified sample. The result was a repertoire of 48 aesthetic heuristics of the cognitive and socio-cultural determinants, which were validated in two exploratory studies.

The results of the first study show that the more skilled the designer, the more he/she recognizes the value of heuristics in the aesthetic process of design. Moreover, this suggests that heuristics that are less known to designers or those heuristics that are counterintuitive, are actually used in product design but designers are not aware of them. That is how heuristics proposed here could be a novel tool or method to design, not only for non-expert, but also expert designers. These could enrich their design process by increasing the variety and aesthetic possibilities of their products and thus increasing creativity (Shah, Kulkarni & Vargas-Hernandez, 2000) and the aesthetic pleasure of their solutions.

In addition, the results obtained from the kappa results in this first study may be due to the fact that a homogeneous expert's sample was not used. So, it is recommended to use a homogeneous sample for further studies if the goal is to generalize the results.

The second study showed that the use of aesthetic heuristics somehow impacts the generation of ideas which coincided with previous studies on designer's concept idea generation. The impact was most noticeable on students four and five. This may be because these two had less experience in conceptualizing design than the other three students. Evidence suggests that these aesthetic heuristics can be considered as a tool to support the design process directed at non-expert designers.

The number of students used for the experiment and their low drawing skills were the main limitations of the second study. However, performing a real design task added ecological validity to our study.

As a final conclusion, it is important to note that with the use of a single aesthetic heuristic in a single phase of the design process, it cannot be expected

immediate results (increase in aesthetic pleasure). In addition, the experiment forced the students to use only one of the heuristics which is not the natural way to design and could affect the creativity of the students.

The design process was considered as an integrated process, therefore, it was necessary to apply many aesthetic heuristics in the different phases of the conceptual design process until getting to the final product. Despite this, the heuristics were easy to use by the students allowing them to get a good result.

In addition, the determinants used in this research (cognitive and sociocultural) are based on how people process information according to their experience with an object and its cultural characteristics. Although, a reliable scale to measure the aesthetic pleasure in the design concepts was used, there were subjective elements, such as previous experience, that intervened in the results and that were not controlled.

Finally, the card set used for this research was not tested and this could, therefore, have affected the results in some way. For example, products used in the cards as examples of heuristics could bias the ideas of the students, or the product explanation and the designer intention could be misinterpreted by the students. Consequently, a further detailed study of the set of cards and the repertoire is suggested. These could be a useful and valuable knowledge base for developing a rigorous and structured method to be used as support of the intuitive aesthetic design process of designers. In addition, the results of this research provide a knowledge base on cognitive and sociocultural aesthetic determinants that could be used in future studies in this field.

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Figure 5,10: Invacare France Operations SAS, Fondettes, France. (2022, 28 January). Action 5 / MyOn HC [Photography]. https://www.red-dot.org. https://www.red-dot.org/project/action-5-myon-hc-33172

Figure 10: Springetts Brand Design Consultants Ltd, London. (2022, 28 January). Williamson Tea Limited Edition Caddie [Photography]. https://www.red-dot.org. https://www.red-dot.org/project/williamson-tea-limited-edition-caddies-20952

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