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PERCEIVED CHARACTERISTICS OF MATERIALS IN A PRODUCT AESTHETICS CONTEXT

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ABSTRACT

Materials possess a number of objective characteristics, the values of which can be determined experimentally. On the other hand, materials also have a number of subjective characteristics, such as perceived quality, perceived performance, and so on. These perceived features are very important in constructing the product's aesthetics. The paper presents the results of three experiments performed to determine perceived characteristics (quality, performance, durability, modernity, and aesthetics) associated with four classes of materials (metal, plastic, wood, and ceramics). Computer-designed product models were used in the experiments. All products used in the experiment were low-tech. The design was varied on three levels: minimal, elaborate, and exceptional. Differences in perception were found for each level of design. It has been found that the elaborate design improves the perception of the characteristics of the materials, but the exceptional design has a negative influence on the perception. Plastics benefit greatly from the contribution of design, while wood (traditional material) is better perceived in the case of minimal design.

KEYWORDS: materials perception, product aesthetics, perceived quality, perceived performance, perceived durability

1. Introduction

Materials have an important contribution to product aesthetics, given that each material is perceived differently through the senses. Therefore, the choice of materials is an important task for the product designer.

The process of selecting materials is very complex, depending on a number of characteristics of different nature: functional, technological, financial, aesthetic, maintenance, etc. Although these characteristics are often considered separately (which is not correct), their action is synergic. A competent designer should consider and balance these different characteristics in the selection of materials to ensure that the product will not only fulfil its functions but will also have a proper aesthetic appearance, leading to a positive experience for the user.

Today, the designer has at her/his disposal numerous informational resources for the selection of materials, such as textbooks, manuals, databases, the internet, computer applications, examples of good practices, etc. [1]. However, the range of materials available to the designer is very large and constantly growing. It is estimated that there are over 100,000 materials [2]. The selection of materials is increasingly complex and has become a critical component of the design process [3].

The fact that the technical characteristics are easier to determine does not mean that they are more important than the aesthetic characteristics. It does not make sense to define technical characteristics in great detail and ignore other characteristics [3]. Moreover, Gant [4] indicated that materials are vectors through which designers create deep emotional connections between products and their contemplators.

Each material has distinctive characteristics that the designer can exploit as a source of inventiveness, while at the same time other characteristics are constraints. It is a well-known fact that new materials allow and even stimulate designers to create new shapes, colours, and textures and to involve users in new ways of using products. "Form Follows Materials" is the paraphrase of Michael Ashby [5] which emphasizes the strong influence of materials in shaping products.

Products material greatly influences the range of functions, durability, associated costs, perceived quality, user feedback, and user experience. When users interact with products, their senses come into contact with the materials from which these products are made, especially their casings. Users notice the colours of the materials, feel their texture, local deformation, and weight, and hear the sounds that the materials produce when the product is working [6].

Designers use materials as vectors to generate complex sensory experiences when people come in contact with products. In these cases, the materials are used as codes that convey meanings for generating emotions. For example, wood and ceramics are frequently used in Zen-inspired design, considered as a balance between general and detail, simplicity and ease of use [7].

By reducing the complexity of the material selection process to the extreme, the designer is put in a position to take into account the practical needs, but also the meanings that the materials convey. The designer asks questions such as: "Due to the material chosen, will the product express quality, ease of use, convenience, durability?" [8]. It would be beneficial for designers to have a dictionary of meanings for different materials.

An important axiological aspect of the material's meaning is that people use materials in interiors created or designed by themselves to build a strong personal identity. So, the materials convey the cardinal values of the owner [9].

What is known today about the meanings of materials is the result of the process of recording society's general impression, records made by theorists of the field in a relatively subjective manner. Objective approaches based on scientific experiments are rare.

Thus, ceramic is associated with stiffness, coldness, and weight (especially due to its use for festive dinner services) [10]. Ceramic is perceived as a hygienic and abrasion-resistant material. Metals offer strength (perceived, but also real), toughness, but are felt like a cold and distant materials, like most artificial materials. Following the Industrial Revolution, metals became associated with high precision, technological superiority, and economic power [11]. Wood is perhaps the warmest and closest to the human spirit of all existing classes of materials. It is easy to process, and its anisotropy is often used as inspiration by creators. It has a strong association with the notion of craftsmanship.

The most debated class of materials in terms of meanings is indisputably that of plastics. Manzini [12] even argued that there was a "loss of meaning" in the world of materials because of plastic. At the beginning of the twentieth century, plastics were considered symbols of progress and modernism. They successfully replaced traditional materials such as metal, wood, and ceramics. Interwar designers made new shapes with the help of thermosetting materials (bakelite, melamine, etc.), then plastics went through a period of adoration in the sixties of the last century to fall into the position of hated materials, being associated with kitsch, cheapness and, especially pollution.

Katz [13], but also most specialists, justifiably believed that plastic products have organic forms due to a technological condition, namely the requirement for the semi-liquid material to flow into the injection mould. This is the cause of the appearance of so many elongated and rounded products in the creation of designers such as Eero Aarnio, Verner Panton, Joe Colombo, Gino Colombini, etc. Technological conditions obviously also influence the shapes of products made from other classes of materials.

The semantic correlation between materials and forms was also investigated. It has been found that people associate certain materials with certain shapes as a result of their daily experience of using products in which the casing from a certain material has a certain shape [14]. For example, metals are presented in products with flat surfaces and straight edges, and plastics in products with rounded shapes. In fact, technological requirements have imposed these correlations.

Another direction of research was to determine the tactile perception of quality and performance associated with different materials. For example, Dumitrescu [15] studied the correlation between a series of parameters (quality, performance, price, warmth, and aesthetic preference) tactile perception, and different classes of materials, focusing on the class of wood.

From the study of the dedicated literature, it can be observed that there is little research aimed at the correlation between certain classes of materials and the perception of certain characteristics of the products. Such research would be useful to draft a designer's guide to the choice of materials, so that the product would gain certain perceived characteristics such as quality, durability, etc.

2. Method

Following the study and assimilation of the specialised literature, the following research objectives (RO) have emerged:

RO1. Establishment of a hierarchy of the main classes of materials according to a series of significant perceived characteristics.

RO2. Study the influence of design on the perception of the considered characteristics according to the generic classes of materials. The levels of parameter design to be considered were: minimal, elaborate, and exceptional.

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RO3. Study the influence of the mode of display on the perception of the considered characteristics.

For RO2, a number of null hypotheses were also formulated. In order not to take up too much space with repetitive statements, only the generic format of the working hypotheses is indicated below:

H0XY: The perception of the characteristic X for a product made of material Y is the same regardless of the type of design (minimal, elaborate, or exceptional).

In order to perform the experiment, the following classes of materials were chosen:

- wood;
- metal;
- plastic;
- ceramics.

And the following perceived characteristics were taken into account:

- quality;
- performance;
- durability;
- modernity;
- aesthetics.

To avoid the bias of results, it was decided that the products used in the experiment should not be computer, electronic or other high-tech types. Finally, the following product subclasses were chosen: desk lamp; stool; coat hanger; citrus juicer; soap dish; ashtray and sticky note compartment. It was also decided that the structural and functional complexity of the products should be at a reduced level, so the materials would be more important to the observer. In order to obtain the images to be used in the experiment, the products were modelled in Catia software by a student enrolled in a master's programme in computer-aided design. The distinction between the different classes of materials was achieved in terms of colour and texture.

Fig. 1. *Wooden stool – elaborate design*

Three levels of design were chosen: minimal, elaborate, and exceptional. The minimal design referred to the products with a simple and functional look. The elaborate design included products that show a certain refinement of shapes, colours, and textures to improve the appearance. The exceptional design referred to products in which the designer's intervention was radical and changed to some extent the archetypal structure of the product. For products with exceptional design, the sources of inspiration were the creations of famous designers such as Philippe Starck or Stefano Giovannoni. Figures 1-4 show examples of product images.

Fig. 2. *Ceramic sticky notes compartment-exceptional design*

Fig. 3. *Plastic citrus juicer-exceptional design*

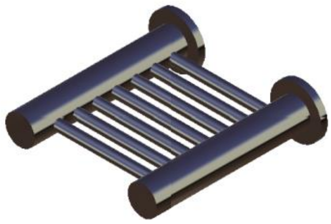

Fig. 4. *Metallic soap dish-minimal design*

It was decided that the participants in the experiment would evaluate the products using an electronic questionnaire in which each product image would be followed by the following instruction: "Please assess the above product against the following characteristics:", followed by the list of five characteristics. The assessment would be performed using 5-point Likert scales.

In order to avoid the fatigue and boredom of the participants, three separate experiments were organised. In Experiment 1, the design levels were minimal and elaborate, and the products used were: a lamp, a stool, and a coat hanger. In Experiment 2, the design levels were minimal and exceptional, and the products used were: a citrus juicer, a soap dish, and an ashtray. Experiment 3 targeted Research Objective 3, and the design levels were minimal and exceptional, and the product used was a sticky note compartment. In this experiment, in the first stage, the products were shown in separate images, and in the second stage, the four products corresponding to the four materials were presented in a single image.

3. Results

3.1. Experiment 1

The experiment was carried out with 203 participants (121 women and 82 men). All participants were students enrolled at a large technical university in Romania. The participants had basic training in product aesthetics. The accuracy of the results was tested using Z-score. No Z-scores were outside the interval [-3; +3], so no data sets were eliminated. The Z-score ranged between -2.81 and 2.50. The reliability of data was tested using Cronbach's alpha coefficient. The calculated value for the whole set of data was $\alpha = 0.972$, a value which stands for very good reliability.

After collecting all the results, the average values were calculated for each material against each perceived characteristic. The results are displayed in Tables 1-4.

Table 1. *Overall mean values for perceived characteristics in Experiment 1*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	3.058	3.034	3.162	3.024	2.807
Metal	3.294	3.132	3.470	3.180	2.999
Wood	3.019	2.943	3.126	2.834	2.703
Ceramic	2.984	2.993	3.245	2.904	2.742

Table 2. *Mean values for perceived characteristics for minimal design in Experiment 1*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	2.926	2.898	3.079	2.646	2.477
Metal	3.200	3.102	3.391	2.957	2.931
Wood	3.020	2.959	3.158	2.620	2.721
Ceramic	2.734	2.885	3.085	2.556	2.511

Table 3. *Mean values for perceived characteristics for elaborate design in Experiment 1*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	3.190	3.169	3.245	3.402	3.136
Metal	3.388	3.163	3.548	3.402	3.067
Wood	3.018	2.928	3.095	3.048	2.685
Ceramic	3.233	3.102	3.406	3.253	2.974

Table 4. *Difference (elaborate – minimal design) between mean values in Experiment 1*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	0.264	0.271	0.166	0.756	0.659
Metal	0.187	0.061	0.158	0.445	0.136
Wood	-0.002	-0.031	-0.062	0.427	-0.036
Ceramic	0.499	0.217	0.320	0.697	0.463

When overall means (Table 1) were considered, the ranking of materials was clear and also uniform for the five characteristics considered: quality, performance, durability, modernity, and aesthetics. The hierarchy was: metal, plastic, ceramic, and wood, with the observation, that the differences were very small (negligible) between the last two materials in the case of quality and performance.

In the case of minimal design (Table 2), there was a change in the hierarchy, respectively the plastic was overtaken by wood and sometimes even ceramics. Even if the differences were small, the change in the hierarchy was significant. When the design did not affect the perception, the hierarchy corresponded to the reality, respectively the wood had superior perceived quality and durability compared to

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plastic. Plastic retained the advantage of perceived modernity, especially since it is a relatively recent material.

When the influence of elaborate design intervened (Table 3), the plastic was favoured especially in terms of aesthetics. It should be noted that design significantly improved the perception of the plastic characteristics.

After making the differences between the mean values of the product characteristics with an elaborate design and those corresponding to minimal design (Table 4), it was found that the elaborate design positively influenced the perception of all characteristics of materials, with one notable exception: wood. So, the elaborate design was unfavourable to wood products, but modernity had to gain; it should not be forgotten that wood is the oldest material used by man and is considered to be the paradigm of traditional material.

Table 5. *Results of T-Test - Paired Two Sample for Means (minimal design-elaborate design)*

***t*(202) = 1.65**		***p* < 0.05**	***Difference is***
Variation of quality for wooden products	-2.71	0.0037	significant
Variation of quality for metallic products	-3.01	0.0014	significant
Variation of quality for plastic products	-4.47	6.3×10^{-6}	significant
Variation of quality for ceramic products	-6,53	2.5×10^{-10}	significant
Variation of performance for wooden products	-1.37	0.08	not significant
Variation of performance for metallic products	-1.48	0.069	not significant
Variation of performance for plastic products	-2.57	0.059	not significant
Variation of performance for ceramic products	-4.66	2.81×10^{-6}	significant
Variation of durability for wooden products	-1.59	0.0056	significant
Variation of durability for metallic products	-2.06	0.021	significant
Variation of durability for plastic products	-3.83	8.31×10^{-5}	significant
Variation of durability for ceramic products	-6.33	7.73×10^{-10}	significant
Variation of modernity for wooden products	-8.65	7.9×10^{-16}	significant
Variation of modernity for metallic products	-7.95	6.18×10^{-14}	significant
Variation of modernity for plastic products	-9.67	9.6×10^{-19}	significant
Variation of modernity for ceramic products	-13.8	1.67×10^{-31}	significant
Variation of aesthetics for wooden products	-3.17	0.0008	significant
Variation of aesthetics for metallic products	-1.59	0.0056	significant
Variation of aesthetics for plastic products	-5.56	4.13×10^{-8}	significant
Variation of aesthetics for ceramic products	-9.29	1.21×10^{-17}	significant

The question was whether there was a true difference between the perception of the product characteristics with a minimal design and those with an elaborate design. It should be kept in mind that 5-point Likert scales were used, and a difference of 0.1 was actually just 2.5%. In such a situation, it is recommended to use a t-test - paired two samples for means. The generic null hypothesis was: H0: The perception of the characteristic X for a product made of material Y is the same regardless of the type of design (minimal or elaborate). (The corollary of this hypothesis was that the difference was insignificant.) In order to reject the hypothesis (and the difference to be significant), the p-value should be < 0.05. Table 5 contains the results of the application of the t-test - paired two samples for means. The difference was significant in the vast majority of cases except for the performance characteristics of wood, metal, and plastic. In other words, the perceived performance of these materials was not influenced by design. People did not expect these materials to work better if people saw them in a higher aesthetic context.

3.2. Experiment 2

Experiment 2 was carried out with 152 participants (93 women and 59 men). All participants were students enrolled at a large technical university in Romania. The participants had basic training in product aesthetics. No participants were involved in Experiment 1. The accuracy of the results was tested using Z-score. No Z-scores were outside the interval [-3; +3], so no data sets were eliminated. The Z-score ranged between -2.18 and 2.51. The reliability of data was tested using Cronbach’s alpha coefficient. The calculated value for the whole set of data was α = 0.98, a value which stands for very good reliability.

After collecting all the results, the average values were calculated for each material against each perceived characteristic. The results are displayed in Tables 6-7. Not all results are presented because some are very similar to those results obtained in Experiment 1.

Table 6. *Mean values for perceived characteristics for exceptional design in Experiment 2*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	2.796	2.776	2.978	2.798	2.526
Metal	2.925	2.857	3.160	2.943	2.643
Wood	2.748	2.708	2.919	2.781	2.412
Ceramic	2.932	2.846	3.107	2.897	2.660

Table 7. *Difference (exceptional – minimal design) between mean values in Experiment 2*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	-0.331	-0.340	-0.235	-0.221	-0.390
Metal	-0.373	-0.355	-0.366	-0.151	-0.384
Wood	-0.274	-0.300	-0.401	-0.072	-0.406
Ceramic	-0.428	-0.421	-0.366	-0.344	-0.577

Table 8. *Results of T-Test - Paired Two Sample for Means (minimal design-exceptional design)*

$t(151) = 1.65$		$p < 0.05$	*Difference is*
Variation of quality for wooden products	4.77	2.15×10^{-6}	significant
Variation of quality for metallic products	6.54	4.33×10^{-10}	significant
Variation of quality for plastic products	5.58	5.18×10^{-8}	significant
Variation of quality for ceramic products	8.16	5.95×10^{-14}	significant
Variation of performance for wooden products	5.42	1.12×10^{-7}	significant
Variation of performance for metallic products	6.15	3.31×10^{-9}	significant
Variation of performance for plastic products	6.25	1.99×10^{-9}	significant
Variation of performance for ceramic products	7.29	8.17×10^{-12}	significant
Variation of durability for wooden products	4.67	3.31×10^{-6}	significant
Variation of durability for metallic products	6.42	8.21×10^{-6}	significant
Variation of durability for plastic products	4.08	3.65×10^{-5}	significant
Variation of durability for ceramic products	6.12	3.83×10^{-9}	significant
Variation of modernity for wooden products	1.05	0.14	not significant
Variation of modernity for metallic products	2.15	0.016	significant
Variation of modernity for plastic products	3.4	0.0004	significant
Variation of modernity for ceramic products	4.96	9.13×10^{-7}	significant
Variation of aesthetics for wooden products	5.38	1.38×10^{-7}	significant
Variation of aesthetics for metallic products	7.5	2.47×10^{-12}	significant
Variation of aesthetics for plastic products	5.82	1.66×10^{-8}	significant
Variation of aesthetics for ceramic products	7.68	9.09×10^{-13}	significant

There were certainly many similarities in the hierarchy of materials obtained in the two experiments. The most remarkable difference was the rise of ceramics in the case of exceptional design, which ended up achieving values very close to the metal or even exceeding it (Table 6).

Surprising were the differences between the means of characteristics; the perception of products with an exceptional design was lower than those associated with products with a minimal design (Table 7). The situation was the same for all characteristics and all materials. It can even be said that the exceptional design acted against the perception of characteristics. A direct conclusion was that when a manufacturing company would rely on the good reputation of the materials used, then the design should be elaborate at most.

As in the case of Experiment 1, the question of the authenticity of the observed differences was raised. The t-test - paired two samples for means was applied again and the null hypothesis was: H0: The perception of the characteristic X for a product made of material Y is the same regardless of the type of design (minimal or exceptional). In order to reject the hypothesis (and the difference to be significant), the p-value < 0.05. Table 8 contains the results of the application of the t-test - paired two samples for means. The difference was significant in the vast majority of cases with only one exception: the modernity of wood products. This was expected because the wood was perceived as a traditional/classic material and no aesthetic trick can change that.

3.3. Experiment 3

The purpose of Experiment 3 was not to reconfirm the results obtained in the first two experiments but to investigate possible differences generated by the mode of display. Is influenced the perception of material characteristics if the products are displayed separately or together?

Experiment 3 was carried out with 211 participants (114 women and 97 men). All participants were students enrolled at a large technical university in Romania. The participants had basic training in product aesthetics. No participants were involved in the previous experiments. The participants assessed the products (sticky notes compartments) presented one per image and after one week the same participants assessed the same products but displayed four on one image (corresponding to the four materials). The accuracy of the results was tested using Z-score. No Z-scores were outside the interval [-3; +3], so no data sets were eliminated. The Z-score ranged between -1.95 and 1.25. The reliability of data was tested using Cronbach's alpha coefficient. The calculated value for the whole set of data was α = 0.958, a value which stands for very good reliability.

Table 9. *Difference (one product per image against all products per image) between mean values*

	Quality	Performance	Durability	Modernity	Aesthetics
Plastic	-0.100	-0.175	-0.100	-0.152	-0.197
Metal	-0.187	-0.197	-0.045	-0.204	-0.299
Wood	-0.088	-0.211	-0.062	-0.190	-0.178
Ceramic	-0.185	-0.211	-0.081	-0.218	-0.415

The differences between mean values are displayed in Table 9. It can be easily observed that in all cases the presentation of all four products together led to a positive assessment. So, in general, it is better to display the products together to improve the quality of assessment.

4. Discussion and Conclusions

From the very beginning, it should be noted that the experiments were well designed and that the participants were positively involved in the run of experiments. No Z-Score data were removed, and Cronbach-alpha values were very high (> 0.958) in all cases.

In the three experiments, there were considered five material characteristics with an important role in public perception: quality, performance, durability, modernity, and aesthetics. Given that the assessment was made from a design perspective, purely technical characteristics such as yield strength, electrical conductivity, etc. were not taken into account, as they were insignificant to the general public.

The generic materials subjected to experiments were chosen from the same perspective of relevance to the general public. Thus, no polymer matrix composite materials were selected, because it would be difficult for the public to distinguish them from ordinary plastics. Glass had also been ignored because it had similar properties to ceramics, except for transparency.

The design was varied on three levels: minimal, elaborate, and exceptional. The minimal level corresponded to products with a simple and functional appearance. The elaborate level corresponded to products that display a certain refinement of shapes, colours, and textures to improve the appearance. Exceptional level corresponded to products in which the designer's action was radical and altered to some extent the archetypal structure of the product.

After the analysis of the results of Experiment 1, a partially unexpected perception hierarchy of materials emerged: 1 - metal; 2 - plastic; 3-4 - wood and ceramics. The surprise was the plastic, which surpassed materials with superior values of intrinsic characteristics. The explanation was that the elaborate design favours plastic.

When the design was at the minimal level, the hierarchy of materials was the natural one, with wood surpassing plastic in the relevant characteristics. But when the level of design was elaborated, all the characteristics of the materials were perceived with superior values for metal, plastic and ceramics. Moreover, plastic, and ceramics values have made a substantial increase in modernity and aesthetics. The situation was remarkable for ceramics, considering that was a traditional material. However, another traditional material, wood, marked setbacks in the case of elaborate design. It was obvious that the connotation of wood as traditional material did not match the upscaling given by the design.

When the level of design varied from minimal to exceptional (Experiment 2), a remarkable situation was observed, namely all values for all materials and all characteristics associated with the exceptional design were lower than those associated with minimal design. There was only one conclusion: the excessive design was detrimental to the perception of material characteristics. The excessive design brought certain advantages, but it certainly did not improve the perception of materials.

Regarding the presentation of the same product in different options of material (Experiment 3), it was found that the presentation in the same image of the options contributes positively to their evaluation.

The previous comments regarding the differences in perception introduced by the different levels of design were true, being supported in the vast majority of cases by the results obtained after the application of the t-tests.

5. Limitation and Future Research

One limitation was given by the segment of participants: students at a technical university. They were people who have studied disciplines such as: materials, the strength of materials, etc. They knew well the characteristics such as yield strength, resilience, corrosion resistance, etc. This influenced their perception of materials. It could be said that it was an anti-bias influence because they knew the reality well and they were not biased by the levels of design or the possible connotative aspects of the different classes of products.

Another limitation was given by the type of products used in the experiment, respectively low-tech products. Only one product was electric. No electronic or IT products were used. The structural and functional complexity of the products has been at a low level.

As not only the considered five material characteristics (quality, performance, durability, modernity, and aesthetics) are important for the observer, the subsequent research will and should focus on new perceptual characteristics such as elegance, prestige, finish, structural integrity, etc.

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