U.P.B. Sci. Bull., Series D, Vol. 85, Iss. 4, 2023 ISSN 1454-2358

PERCEIVED CHARACTERISTICS OF MATERIALS AS EFFICIENT TOOLS FOR DESIGNER

Andrei DUMITRESCU[1]

When conceiving a new product, the designer usually selects the materials based on strictly functional considerations, neglecting the perceived characteristics (like elegance, prestige, and timeless quality). This paper presents the results of two experiments aimed at ranking the main classes of materials (metal, plastic, wood, and ceramics) from the perspective of perceived characteristics. The influence of the design was considered, design being varied on three levels: minimal, elaborate, and exceptional. In the case of minimal design, metal and plastic occupied the first and last positions respectively, and ceramics and wood occupying intermediate positions. The elaborate design influenced in a certain degree the perception of the material characteristics, and the exceptional design considerably diminished the importance of the perceived characteristics in the observer perspective.

Keywords: materials perception, product aesthetics, perceived characteristics.

1. Introduction

When designing a new product, the designer has to solve a complex of requirements: functional, technological, financial, aesthetic, maintenance, etc., some of which are contradictory. Usually and incorrectly, these requirements are treated separately. Some of the requirements are fulfilled by choosing the proper material [1]. However, the proper material should be suitable not only from a functional and technological point of view, but also from an aesthetical one, so making the user to have a positive experience.

Even though today's material world includes over 100,000 members and the practical (functional and technological) characteristics are well-known for the majority of materials, the aesthetic characteristics of materials are understudied. One explanation is that it is much easier to determine the values of mechanical parameters than perceived quality or aesthetics, for example. But the ease of determination does not make certain characteristics more important than those that are more difficult to determine. It has no logic to study the mechanical characteristics in detail and ignore the non-functional characteristics. In fact, Gant [2] emphasized that materials are vectors through which designers build emotional connections between products and their contemplators. Considering that the

[1] Prof., Dept.of Manufacturing Engineering (TCM), University POLITEHNICA of Bucharest, Romania, e-mail: andrei.dumitrescu@upb.ro

market competition is so fierce today, any advantage should be used, and such an advantage is the aesthetic experience of use.

Each material possesses unique characteristics that can be creatively exploited by designer, while other characteristics constitute constrains. It is known that when newly invented materials appear, they stimulate designers to create new shapes, new colours and new textures and allow consumers to discover new paradigms of use. "Form Follows Materials" is the paraphrase of Ashby [3] which underline the robust influence of materials in the generation of products.

Materials of products greatly determine the variety of functions, durability, costs, maintenance, perceived quality, elegance, modernity, user feedback, and user experience. When consumers get into contact with products, their senses receive information from the materials the products are made and especially from their casings. Consumers see the colours of the materials, feel their texture and local deformation, and hear the sounds that the materials are producing when the product is functioning.

In the product world, materials serve different roles: agents that fulfil functional (mechanical, optical, chemical, etc.) requirements, sources of sensory experiences and vectors of product meaning. If in the case of the first two role categories there is much research, the influence of product material on the conveyed meaning has been little studied.

The materials are employed as codes that convey meanings for ignition of emotions. For example, wood and ceramics are often used in Zen-inspired design, which is regarded in East Asia as a balance between general and detail, simplicity, and ease of use [4]. Another explored direction was the relationship between the expressive qualities of the materials and the self-expression of the end-user [5], using various value systems, such as the Schwartz end values.

Beyond functional considerations, the designer inevitably asks herself/himself questions such as: “Due to the material chosen, will the product express quality, ease of use, convenience, durability?”. And the questions can continue: “Is it luxurious? Is it convenient for a cosy and friendly room?” [6]. In this direction, the reliability of material perception data and its relevance to materials was studied and the conclusion was that an objective selection of materials can be reached if it is used a database that includes the perceptions of a large number of people [7].

It should be emphasized that the product context can alter the perceived meaning of materials. A material may be branded ‘elegant’ when used in kitchenware, but it may appear as ‘cheap’ or ‘kitsch’ when embodied in office accessories [8].

Designers are required to transfer to products certain meanings. Materials, alongside with shape, colour, etc., are involved in this process of transfer. But from this regard, the process of selecting a material is quite difficult because there are a lot of proper functional materials and also because their meanings are not studied in-depth. Furthermore, traditional considerations such as ‘wood is cosy’, ‘metal is aloof’ or ‘plastic is cheap’ are less true in today’s design practice [4].

The meanings of materials as they are known today is the result of recording the general impression of society. These records were made by people of the theory world and less by practitioners. Objective approaches based on scientific experiments are occasional. Obviously, it would be helpful for designers to have an efficient dictionary of meanings for different materials.

Thus, ceramic is regarded as stiff, cold, and pretentious (especially because of its use for festive dinnerware) [9]. On the other hand, ceramic is perceived as a hygienic and abrasion-resistant material. Metal is associated with strength and toughness, but it is considered as a cold and distant material. After the Industrial Revolution, metal became linked with high precision, technological superiority, and economic power. Wood is for sure the warmest and nearest to the human soul of all existing classes of materials. Wood is easy to manufacture, and its anisotropy is creatively employed by designers. It has a strong link with the notion of craftsmanship.

The most critised class of materials in terms of meanings is undeniably that of plastics. Manzini [10] underlined that there was a "loss of meaning" for materials because of plastic. When they were invented at the beginning of the twentieth century, plastics were regarded as symbols of progress and modernism. They successfully substituted in certain applications traditional materials such as metal, wood, and ceramics. Designers created new product shapes using thermosetting materials (bakelite, melamine, etc.), then plastics went through an era of adoration in the sixties to fall into the position of hated materials, being associated with camp, cheapness and, especially pollution [11].

The semantic correlation between materials and shapes was also researched. It has been discovered that people associate certain materials with certain shapes as a result of their mundane experience of using products with cases made from a certain material has a certain shape [12]. For example, metals appear in objects with flat surfaces and straight edges, and plastics in objects with organic shapes. Actually, technological constraints have led to these correlations.

Another approach in research was to establish the tactile perception of quality and performance associated with different materials. Dumitrescu [13] studied the correlation between a series of parameters (quality, performance, price, warmth, and aesthetic preference) perceived by touch and different classes of materials, concentrating on the class of wood.

From the study of the literature, it can be concluded that there is little research regarding 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. An exception to this lack of research is a series of three experiments [14] aimed to determine the correlations between four classes of materials (metal, ceramic, wood, and plastic) and a series of perceived characteristics (quality, performance, durability, modernity, and aesthetics). The correlations were mediated by design which 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.

2. Method

The specialised literature revealed that few research focused on the materials meaning and how the inherent meaning of each material can be employed in design process. In line of previous research [13], it was decided to extend the field of perceived characteristics to be studied. So, the following research objectives (RO) have emerged:

RO1. Determination of a hierarchy of the main classes of materials (metal, ceramic, wood, and plastic) according to some perceived characteristics (elegance, prestige, finish quality, structural unity, and timeless quality).

RO2. Research the influence of design on the perception of the considered characteristics for the main classes of materials. The levels of parameter "design" to be consider were: minimal, elaborate, and exceptional.

Important note: The research aims at the perception of the considered characteristics and not at the determination of the real and effective value of those characteristics. For example, the finish quality is that perceived by the consumer and was determined with a Likert scale, regardless of the actual value of the roughness. (However, perceived finish quality is a more complex characteristic than roughness.)

For RO2, a certain number of null hypotheses were formulated. In order save paper space and not to bother the reader 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 design (minimal, elaborate, or exceptional).*

In order to perform the experiment, the following classes of materials were chosen: **metal; plastic; wood; ceramics**. And the following perceived characteristics were taken into account: **elegance; prestige; finish quality; structural unity; timeless quality**.

Because this research was a development of the previous research [13], it was decided that the same products (actually, computer generated images of products) were used. So, the products were desk lamp; stool; coat hanger; citrus juicer; soap dish; and ashtray. The reasons to choose these classes of products were as follows. To avoid the bias of results, the products used in the experiment were not the computer, electronic devices, or other high-tech gadgets. The structural and functional complexity of the products was at a reduced level, so the product materials would be more important to the observer. The difference between the material classes was achieved in terms of colour and texture [14].

Three levels of design were established: minimal, elaborate, and exceptional. The minimal design included products with a plain and functional appearance. The elaborate design referred to products that display a certain sophistication of shapes, colours, and textures to improve the look. Exceptional design contained products in which the designer's intervention was profound and revolutionised to some extent the product archetypal structure. For products with an exceptional design, the sources of inspiration were the accomplishments of revered designers such as Stefano Giovannoni or Philippe Starck. Figures 1 - 3 display examples of product images.

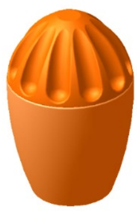

Fig. 1. Plastic citrus juicer – minimal design

Fig. 2. Ceramic lamp – elaborate design

Fig. 3. Metallic citrus juicer – exceptional design

It was settled that the experiment participants would assess the products using an electronic questionnaire in which each product image would be followed by this instruction: "Please assess the above product against the next characteristics:", followed by the list of five characteristics (elegance, prestige, finish quality, structural unity, and timeless quality). The assessment would be performed using 5-point Likert scales. To avoid the fatigue and boredom of the participants, two distinct experiments were setup. In Experiment 1, the design levels were minimal and elaborate, and the products used were: lamp, stool, and coat hanger. In Experiment 2, the design levels were minimal and exceptional, and the products used were: citrus juicer, soap dish, and ashtray.

3. Experimental results

3.1. Experiment 1

The experiment was carried-out with 150 participants (84 women and 66 men). All participants were students enrolled at a large technical university in Romania. The participants had basic training in product aesthetics. The accuracy of results was tested using *Z-score*. No *Z-score* were outside the interval [-3; +3], so no data sets were removed. The *Z-score* ranged between -2.69 and 2.43. The reliability of data was tested using the Cronbach's alpha coefficient. The calculated value for the complete set of data was $\alpha = 0.984$, value which stands for a particularly good reliability.

After collecting all the results, the average values were calculated for each material against each perceived characteristic. These results are displayed in Tables 1 - 3.

Table 1

Overall mean values for perceived characteristics in Experiment 1.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	2.978	2.965	3.198	3.141	3.049
Metal	3.398	3.271	3.535	3.433	3.383
Wood	3.210	3.138	3.328	3.342	3.238
Ceramic	3.246	3.204	3.311	3.297	3.284

At a comprehensive look at the results of experiment 1, it is observed (in a totally expected way) that plastic is placed in the last position regardless of the perceived characteristic. And it is logical: plastic is not an elegant material, it does not give prestige to the product owner, the finish quality leaves much to be desired, it is deformable and brittle and its surface wears easily over time. The big winner is the metal that occupies the first position in the hierarchy, regardless of the perceived characteristic. Next, ceramic occupies the second position in terms of reputation characteristics (elegance, prestige, and timeless quality) and is almost on a par with wood in terms of finish quality. Wood surpasses ceramics in terms of structural unity because it is common perception that ceramics is brittle.

Table 2

Mean values for perceived characteristics for minimal design in Experiment 1.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	2.787	2.807	3.030	3.010	2.910
Metal	3.385	3.235	3.467	3.402	3.357
Wood	3.215	3.110	3.290	3.317	3.240
Ceramic	3.045	3.018	3.092	3.130	3.113

The analysis of the results for products with a minimal design is significant, because in this case the perception of materials is not altered by design. Materials are perceived as they are. If in the case of the overall results there were differences in the hierarchy depending on the perceived characteristic, in the case of the minimal design the hierarchy is the same regardless of characteristic: metal in first place, followed by wood, ceramic and plastic.

Noteworthy is the solid placement of wood in second place, which means that using wood in minimal products can be a sure tactic in achieving a positive perception.

Table 3

Mean values for perceived characteristics for elaborate design in Experiment 1.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	3.168	3.123	3.365	3.272	3.188
Metal	3.412	3.307	3.603	3.463	3.410
Wood	3.205	3.167	3.367	3.367	3.237
Ceramic	3.447	3.390	3.530	3.463	3.455

When considering the products with an elaborate design, the situation changes surprisingly. Ceramics is favoured by the elaborate design, taking first place at the characteristics: elegance, prestige, structural unity, and timeless quality. Only in terms of finish quality, metal manages to surpass ceramics. In rest, metal takes second place, and wood scores close to plastic for the characteristics: prestige and finish quality. Obviously, the elaborate design support ceramics and, to a lesser extent, plastic.

In all cases (with two exceptions where the difference was negligible), the elaborated design brought an increase in the positive perception of the considered characteristics. The question was whether there was a real difference between the perception of the product characteristics with a minimal design and those with an elaborate design. It should be noted 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 *z-test* - two sample 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 < 0.05. Table 4 contains the results of the application of z-test - two sample for means. The difference was not significant for wood at all characteristics, meaning that the elaborate design does not contribute to a better perception of the considered characteristics. Also, the difference was not significant for metal in the case of elegance, structural unity, and timeless quality. So, no matter of the design level, the metal is perceived as elegant, solid, and timeless. In all the other cases, the elaborate design is beneficial for the perception of materials characteristics.

Table 4

Results of Z-Test - Two Sample for Means (minimal design – elaborate design)

	z (149) = 1.64	$p < 0.05$	*Difference is*
Variation of elegance for wooden products	0.02	0.49	not significant
Variation of elegance for metallic products	1,34	0.089	not significant
Variation of elegance for ceramic products	5.34	4.5×10^{-8}	significant
Variation of elegance for plastic products	4.35	6.6×10^{-6}	significant
Variation of prestige for wooden products	0.92	0.17	not significant
Variation of prestige for metallic products	1.77	0.038	significant
Variation of prestige for ceramic products	5.08	1.8×10^{-7}	significant
Variation of prestige for plastic products	2.85	0.002	significant
Variation of finish quality for wooden products	1.17	0.12	not significant
Variation of finish quality for metallic products	2.68	0.0036	significant
Variation of finish quality for ceramic products	5.91	1.7×10^{-9}	significant
Variation of finish quality for plastic products	6.04	7.7×10^{-10}	significant
Variation of structural unity for wooden products	1.26	0.103	not significant
Variation of structural unity for metallic products	0.64	0.26	not significant
Variation of structural unity for ceramic products	4.61	1.9×10^{-6}	significant
Variation of structural unity for plastic products	4.83	6.5×10^{-7}	significant
Variation of timeless quality for wooden products	0.25	0.39	not significant
Variation of timeless quality for metallic products	0.74	0.22	not significant
Variation of timeless quality for ceramic products	4.47	3.9×10^{-6}	significant
Variation of timeless quality for plastic products	4.42	4.8×10^{-6}	significant

3.2. Experiment 2

The experiment 2 was carried-out with 139 participants (83 women and 56 men). No participants were involved in Experiment 1. All participants were students enrolled at a large technical university in Romania. The participants had basic training in product aesthetics. The accuracy of results was tested using *Z-score*. The *Z-score* ranged between -2.36 and 2.43, so no data sets were removed. The calculated value of Cronbach's alpha coefficient for the complete set of data was $\alpha = 0.972$, value which stands for a particularly good reliability.

Table 5

Overall mean values for perceived characteristics in Experiment 2.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	2.510	2.511	2.942	2.892	2.637
Metal	3.019	2.896	3.229	3.174	3.025
Wood	2.529	2.486	2.867	2.837	2.583
Ceramic	3.002	2.879	3.186	3.170	2.903

After collecting all the results, the average values were calculated for each material against each perceived characteristic. These results are displayed in Tables 5 - 7.

Examining the results in Table 5, it can be observed that exceptional design levelled the differences between metal and ceramic noticed in Experiment 1, the metal retaining a sometimes minimal advantage. In turn, plastic overcomes the status of cheap and low-quality material and competes with wood, surpassing it in all characteristics except elegance. It is obvious that the exceptional design significantly affected the perception of the qualities of the materials in favour of the originality of constructive and aesthetic solution.

Table 6

Mean values for perceived characteristics for minimal design in Experiment 2.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	2.669	2.626	3.086	3.024	2.734
Metal	3.273	3.141	3.403	3.403	3.038
Wood	2.777	2.638	3.149	3.043	2.779
Ceramic	3.209	3.072	3.386	3.379	2.986

As in the case of Experiment 1, the analysis of the results for products with a minimal design is significant, because in this case the perception of materials is not altered by design, materials being perceived as they are. The hierarchy is similar: metal in first place, followed by ceramic, wood, and plastic. Noteworthy are the minor differences between wood and plastic, meaning that wood is not such a sure advantage as appeared in Experiment 1.

Table 7

Mean values for perceived characteristics for exceptional design in Experiment 2.

	Elegance	*Prestige*	*Finish quality*	*Structural unity*	*Timeless quality*
Plastic	2.350	2.396	2.799	2.760	2.540
Metal	2.765	2.650	3.055	2.945	2.825
Wood	2.281	2.333	2.585	2.631	2.386
Ceramic	2.796	2.686	2.986	2.962	2.820

The exceptional design brings a remarkable closeness of metal to ceramics, their positions in the hierarchy sometimes changing, but with very small differences. The exceptional design causes plastic to surpass wood, reaching the third position, regardless of the perceived characteristic. Unlike elaborate design, exceptional design strongly favours plastic.

Quite unexpectedly, all values of perceived characteristic for all materials are lower in the case of elaborate design compared to minimal design. The differences are consistent, being in the range [0.165; 0.564]. To check if the differences are really significant, it was applied again the *z-test* - two sample for means as in Experiment 1. 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 exceptional).* (The corollary of this hypothesis was that the difference was insignificant.) Table 8 contains the results of the application of z-test - two sample for means.

Table 8

Results of Z-Test - Two Sample for Means (minimal design – elaborate design)

	z (138) = 1.64	$p < 0.05$	*Difference is*
Variation of elegance for wooden products	4.94	3.8×10^{-7}	significant
Variation of elegance for metallic products	5.25	7.3×10^{-8}	significant
Variation of elegance for ceramic products	4.12	1.8×10^{-5}	significant
Variation of elegance for plastic products	2.94	0.0016	significant
Variation of prestige for wooden products	3.21	0.0006	significant
Variation of prestige for metallic products	5.61	1.1×10^{-8}	significant
Variation of prestige for ceramic products	3.71	1.1×10^{-4}	significant
Variation of prestige for plastic products	2.13	0.016	significant
Variation of finish quality for wooden products	4.93	4.2×10^{-7}	significant
Variation of finish quality for metallic products	3.77	8×10^{-5}	significant
Variation of finish quality for ceramic products	4.09	2.1×10^{-5}	significant
Variation of finish quality for plastic products	2.97	0.0014	significant
Variation of structural unity for wooden products	4.08	2.2×10^{-5}	significant
Variation of structural unity for metallic products	5.06	2.1×10^{-7}	significant
Variation of structural unity for ceramic products	3.89	5.1×10^{-5}	significant
Variation of structural unity for plastic products	2.51	0.0059	significant
Variation of timeless quality for wooden products	3.67	0.00011	significant
Variation of timeless quality for metallic products	3.8	7.1×10^{-5}	significant
Variation of timeless quality for ceramic products	1.75	0.038	significant
Variation of timeless quality for plastic products	1.87	0.031	significant

The test clearly indicated for all situations that the difference is significant, which means that when an exceptional design is applied the inherent characteristics of the materials become negligible.

4. Conclusions

When design does not alter the perception of the material characteristics (the case of minimal design), metal is the best perceived, plastic - the worst, and wood and ceramics occupy intermediate positions. When design is elaborated, ceramic is strongly advantaged and wood only slightly. The influence of the elaborated design was demonstrated by the z-test - two sample for means in most cases.

The exceptional design favours more plastic and less ceramics. What is really remarkable about the exceptional design is the fact that it blurs the importance of perceived characteristics, a reality confirmed for all materials and all perceived characteristics by the z-tests - two sample for means. The meaning is that the observer is more impressed by the remarkable quality of the design and far too little by the inherent meanings of materials.

The results of the two experiments constitute a simple guide for the selection of materials when the designed product should be perceived as elegant or prestigious or as possessing a timeless quality. Also, the designer should be aware that when, as a whole, his/her product will be an exceptional one, then certainly the perceived inherent characteristics do not matter much.

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