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EXPERIMENTAL SETUP FOR VISUAL AND TACTILE EVALUATION OF MATERIALS AND PRODUCTS THROUGH NAPPING® PROCEDURE

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Abstract

Selection and definition of materials surfaces in product design can be driven by the sensory effect conceived. Certain characteristics that can be perceived through the sense of vision can also be perceived through the sense of touch. As a consequence, the sense of touch also plays an important role in functional user-product interactions. In this paper, a specific setup dedicated to Napping® evaluation with a focus on visual and tactile modalities is presented, using untrained subjects. This procedure allows highlighting the main perceptions the subjects have about the materials. It enables to rank the sample attributes that are perceived by the subjects when different sensory modalities are used. In particular visual-tactual incongruity can be highlighted, which can be of interest in product design. For instance, with our set of materials, in tactile perception, the primary axis clearly opposes slick and scratchy perceptions. In the visual test, the samples exhibiting large features are clearly set apart from samples exhibiting no features (slick). The other samples are gathered in between. In the visuo-tactile test, a hybrid perception is observed.

Keywords: Research methodologies and methods, Human behaviour in design, Emotional design, User centred design

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1 INTRODUCTION

With the Industrial Revolution, technology somehow led innovation and product success during the 19th century. In the last few decades, a new industrial strategy is settling: pushed by market globalization, innovation is not restricted to technological innovation. New product specifications such as ergonomics, sensory characteristics, aesthetics, and personality…, have become fully associated to the product or service design process. They contribute to the strategically important paradigm of “brand identity” and to the recent transfer from software to product design of the “experience design” and “interaction design” concepts. These parameters define the relationship level between the user and the product. In particular, sensations can lead to an emotional interaction that could highly impact, positively or negatively, the perceived quality of a product. Well designed, sensory attractive products can generate strong user-product relationships. This can extend a product’s lifetime decisively as too early replacement is prevented, thus reducing energy and material consumption, a core factor in ecodesign and sustainability strategies (Tischner et al., 2000). Manufacturers are therefore eager to learn more about the effects of their product and its surface properties on the user’s perception (Kawazu et al., 2000).

From a design point of view, several studies indicate that visual information is of primary importance in user-product interactions, because it supports functional interaction, like executing tasks (Schifferstein, 2006). Certain characteristics that can be perceived through the sense of vision can also be perceived through the sense of touch. As a consequence, the sense of touch also plays an important role in functional user-product interactions. Material properties of objects tend to become more salient compared to geometric properties or cognitive associations when people base their judgments on touch rather than vision (Klatzky et al., 1987; Wastiels et al., 2008). Enhancing the congruence of sensory messages in product design is desirable from an ergonomic perspective, where congruence helps to clarify what a product is about and what it can do. However in some cases, designers may want to evoke surprise by introducing sensory discrepancies or uncertainties (Schifferstein et al., 2014). Up to 6% of designs presented in the international Design Yearbooks (1999-2004) incorporate some form of visual-tactual incongruity (Ludden et al., 2008). In many cases, these incongruities involve a material that has tactual properties that are different from a material with a similar appearance. Surprising products attract attention, offer new experiences to users and trigger further exploration of the product. However in order for these products to be perceived as pleasant and amusing, these visual-tactual incongruities have to be judged as appropriate (Ludden et al., 2012).

A perception of a surface or material is a combination of perceptions of different properties. One-to-one relations are not sufficient for understanding people’s subjective responses to surfaces and materials. Thus, the senses cannot be isolated and separately investigated if the objective is the real human behavior analysis. In a thorough review of experimental studies of visual-tactile cross-modality, Whitaker et al. highlighted the fact that most neuro-science and behavioural studies conclude to an independent early treatment of both sensory modalities and to the absence of a significant performance increase associated to cross-modality (Whitaker et al., 2008). The authors however point out the fact that most of these studies are based on ‘artificial’ simple textures (such as, e.g.: grids or raised-dot patterns) and raise the conjecture that for more complex ‘natural’ textures, texture identification and assessment is a higher-level cognitive process to which visual and tactile modalities may contribute synergistically. They point out the lack of experimental results to discuss this hypothesis. Using a set of slightly randomized raised-dot patterns, (Eck et al., 2013a, 2013b) Eck and coworkers point-out an apparent discrepancy between fMRI and behavioural data in this respect. Early cortex treatment of both modalities appears essentially disconnected in neuro-imaging (Eck. Et al. 2013a), whereas behavioural data reveal instances of early cross-treatment (Eck et al. 2013b). This apparent contradiction is resolved by the authors by introducing and elaborating on the concept of “familiarity” of the panellists with a texture (Eck et al. 2013b). Finally, from a materials and surface engineering point of view, it has to be pointed out that, in these studies, multiple surface properties that may affect surface perception differently are often aggregated under the unidimensional descriptor of “roughness”, which may be inadequate to render the complexity of surface-user interaction. The present work proposes an experimental setup and approach to address the seemingly conflicting aims of assessing a holistic perception of surfaces by non-trained panellists and rendering the multidimensional character of the sensory properties.

2 MATERIALS AND METHODS

In the last decades, sensory evaluation methods primarily developed for the food industry have been explored for non-food products. In particular methods that do not need heavy training of subjects are more and more appealing as they are cheap and easy to setup. Napping (Pagès, 2005) is a holistic approach of sensory evaluation that can be used with untrained subjects. The Napping test is a holistic sensory method to get sensory distances between products. It is a descriptive method in which the subject has to position the samples over a two dimensional limited surface. Ten to fifteen samples can be submitted simultaneously to each subject. The subjects have to place the samples on the delimited surface so that two samples that are close are perceived identical and two samples that are far away are perceived different. The subjects should not hesitate to use the whole surface. When all samples are placed, the subjects are asked to express their perception by associating a textual description of samples or sample clusters. The subjects have to do this according to their own criteria, those that are significant for them. There are no good or bad answers. The method has been mainly used for food and drink evaluations and is easy to organize and rather quick. One test requires about ten to fifteen minutes and eight to ten subjects are needed to be relevant (Pagès, 2005).
The evaluation test used in this work is derived from the napping test. A table was equipped to enable napping tests on materials and surface textures with a focus on tactile, visual and visuo-tactile perceptions. The shapes of objects are of no concern of this paper. In this study, the napping area is square shaped of dimensions 75 cm x 75 cm. In visual and visuo-tactile tests, the room lights are on. For tactile test the room is dark and the table is equipped with UV back lights that enable to see the sample holder shape without seeing the texture and details of the sample. In this setup, the subject can easily perform a tactile exploration of the sample surface and position the sample on the table (Figure 1). In a previous work, the subjects were blindfolded for the tactile tests but had difficulties to position the samples on the surface (D'Olivo et al., 2013). The tabletop is made of a translucent material and a camera is installed under the table to record the sample position at the end of each test. For each subject *j*, the data collected are the coordinates X_{ij} and Y_{ij} of each sample *i*. For all subjects, the words associated to the samples are also collected. The data collected have been statistically analysed using SensomineR® software (SensomineR, 2014). The statistical treatment is based on Multiple Factorial Analysis (MFA). This analysis method provides a representation of an average map on which two samples are near if they are globally perceived as similar.

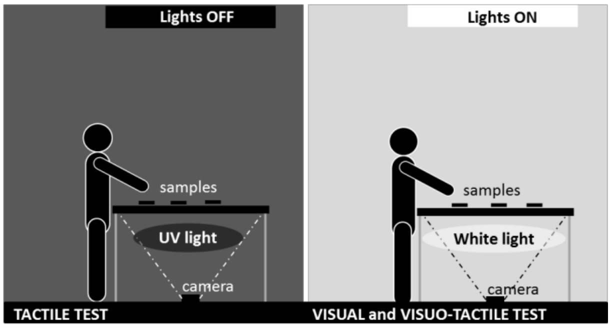

Figure 1. Setup for the tactile, visual and visuo-tactile test.

The evaluation tests have been divided in three sessions, performed at one week interval. The first test is a tactile test performed in the dark so that the subjects cannot see the surface textures of the materials. The second test is a visual test performed with the lights on. The subjects are asked to observe the sample surface without touching it. They can manipulate the sample holders by sliding the samples over the table surface but without holding them up in order to prevent effects of sample weight. The third test is a visuo-tactile test performed in similar conditions than the previous test, except that the subjects are allowed to explore the sample surface with their fingers. Ten subjects (7 males and 3 females, ages 20-50) participated in this study.

Eleven samples described in Table 1 have been selected for the tests (Figure 2). Different textures, materials and finishes have been chosen. This study focuses on the perception of surface textures, the samples have been positioned in a standard sample holder (10 cm x 10 cm) with a window (5 cm x 5 cm) showing the sample. The subjects were asked to explore the surface of the samples with their fingers without holding up the samples. The samples were marked on the back using a QRcode to enable the automatic extraction of the sample coordinates from pictures taken from underneath the table using a homemade software.

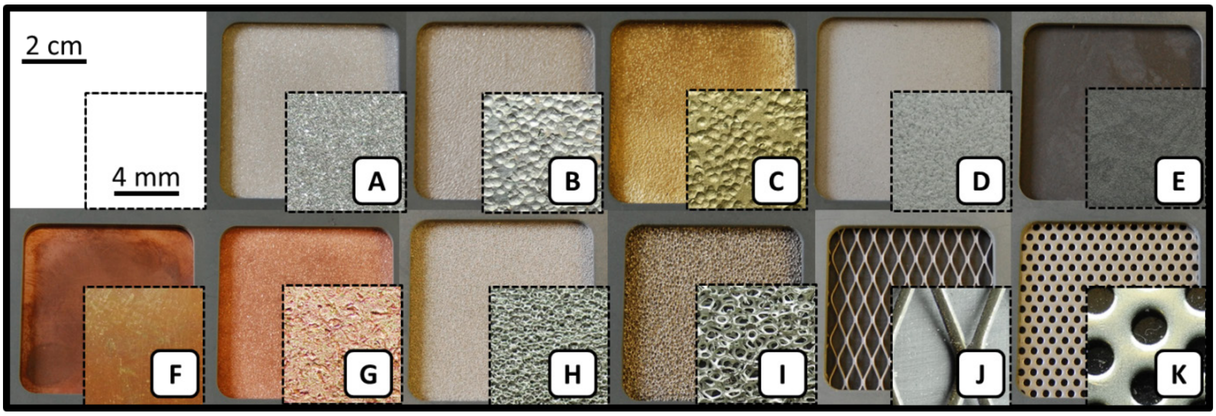

Figure 2. Pictures of the eleven samples of materials

Expended sheet in stainless steel (J) and perforated sheet in titanium (K) are final products that can be in direct contact and sight of users. They can be found in interior design, architecture and furnishing (screening, fencing, building facades, stair treads and risers…). Samples A, B, C, F and G are made of familiar metals, aluminium can be found in cans and cookware, Brass can be used in interior design and music instruments and Copper is used in coins and cookware for example. However, the finishes are homemade and not so common. Nickel foams (H, I) are used as electrodes in batteries. They are never in contact with the user. Samples D and E are recent composite materials called "cold plastics" in that they can be processed as plastics but exhibit thermal properties close to ceramics. They are not familiar in everyday products yet. Sample D has been painted with standard metallized paint.

Table 1. Description of the eleven samples of materials

Sample reference	Bulk material	Shaping and surface processing	Coating
A	Aluminum	Sandblasted (F24 corundum)	-
B	Aluminum	Sandblasted (S660 steel abrasive)	-
C	Brass	Sandblasted (S660 steel abrasive)	-
D	Composite material Ceramic fillers + Polymer matrix	-	Metallic paint
E	Composite material Ceramic fillers + Polymer matrix	-	-
F	Copper	Polished	-
G	Copper	Sandblasted (F10 corundum)	-
H	Nickel foam grade 500	-	-
I	Nickel foam grade 900	-	-
J	Stainless steel	Sheet expanded into grid	-
K	Titanium	Perforated sheet	-

3 RESULTS AND DISCUSSION

The duration of all tests has been collected. The average duration for the tactile test is 10 minutes and is clearly longer than the average duration of the two other tests, 5 minutes for the visual test and 4 minutes for the visuo-tactile test.

Figure 3 shows the Individual Factor Map (IFM) resulting from all three tests. This map is the mean individual factor map for all the subjects obtained after MFA. The % of inertia reported on the axes express the level of relevance given by the users to the given dimension. The horizontal axis carries 45-49% of inertia, it is the main dimension that the subjects decided to use to position the samples. The second dimension carries 16-20 % of inertia, thus the total inertia carried by these two dimensions is high and confirms that the samples can be efficiently described using these two first dimensions without considering higher dimensions obtained by MFA. Confidence ellipses around each product mean position have been added. These ellipses are built with the total bootstrap method (Cadoret and Husson, 2013), in which virtual panels are simulated. A whole analysis is ran on them and represented on the configuration obtained from the true panel. The ellipses represent the variability of the product position on the map in that they circle 95% of the positions obtained for a product. In particular, sample H exhibits a high variability in the tactile test. In all three tests, the first axis opposes sample cluster E-F and the sample J. The second axis seems to be more discriminative in the tactile test than in the two other tests. Sample K is perceived very differently in a tactile test compared to text with the vision modality. Indeed, it is completely isolated in tactile test while it is clearly associated to sample J in visual test and very close to samples J and I in visuo-tactile test.

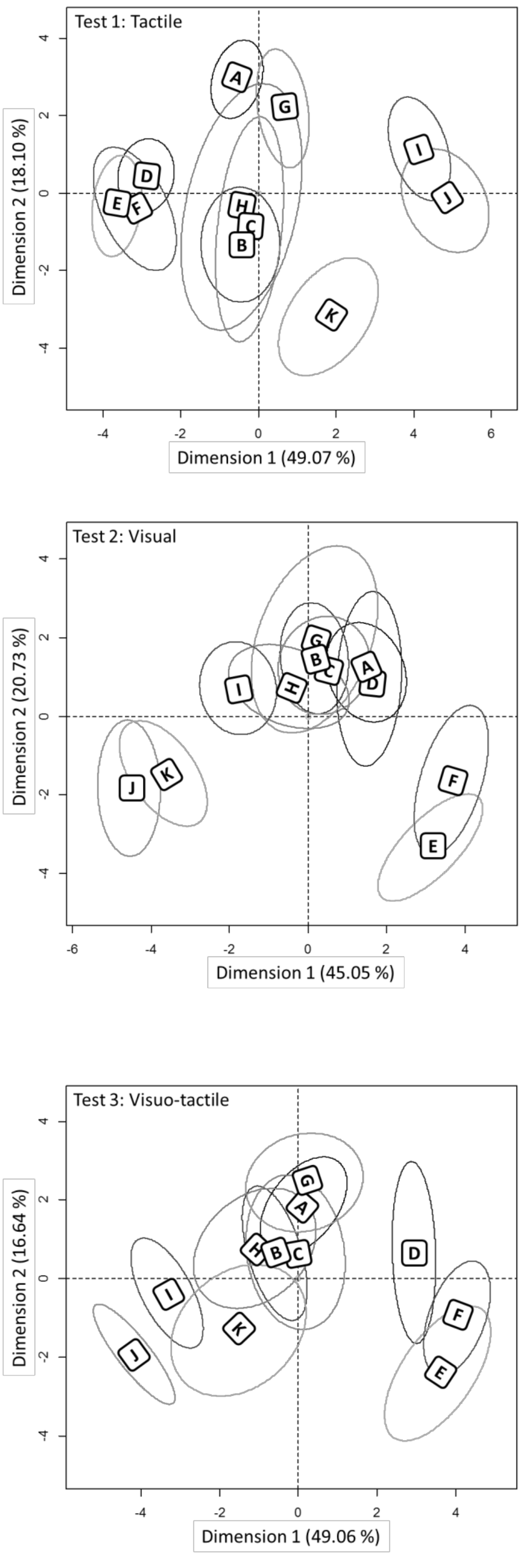

Figure 3. Individual Factor Map with confidence ellipses obtained from the three napping tests. Sample labels have been oriented along the long axis of the corresponding ellipse

For all subjects, the words associated to the samples have been collected in Table 2. Words that are semantically close are gathered together in column 2 and posted under a single keyword (column 1). The variety of words provided is larger when visual modality is requested during the test. The number of occurrence corresponding to each keyword is collected in Table 2. Words that are cited only once in total are not considered.

Table 2. Words associated to the samples by the subjects (column 2) and gathered under a keyword (column 1). Number of occurrences of each keyword for each sample is detailed.

TEST1: TACTILE		A	B	C	D	E	F	G	H	I	J	K	Total
TEXTURED	textured, grainy, like wood, like fabric, wavy, like concrete, like a grating	5	8	5	0	0	0	6	5	2	5	7	**43**
ROUGH	scratchy, rough, aggressive, abrasive	4	1	1	0	0	0	4	1	7	6	0	**24**
SLICK	slick	0	1	1	9	9	8	0	2	0	1	1	**32**
COLD	cold	0	1	1	0	0	3	0	0	0	0	1	**6**
STRANGE	bizar, funny, different	0	0	0	0	0	0	0	0	1	1	2	**4**

TEST 2: VISUAL		A	B	C	D	E	F	G	H	I	J	K	Total
TEXTURED	textured, fine, like foam, like coton	2	1	1	2	0	0	1	5	5	0	0	**17**
ROUGH	rough, abrasive	3	5	5	3	0	0	4	3	2	1	0	**26**
SLICK	slick	2	0	0	2	8	8	0	1	0	0	1	**22**
MACROTEXTURED	coarse, like a grating, alveolate, agglomerate, mottled	0	1	1	0	0	0	2	1	0	6	6	**17**
LIGHT-BRIGHT	light, bright, grey, golden	5	4	4	5	0	1	2	2	2	0	1	**26**
DARK	dark	0	1	1	1	3	2	1	2	2	3	2	**18**
PRECIOUS	precious	1	0	1	0	0	1	1	0	0	0	0	**4**
COLD	cold	0	0	0	0	0	0	0	0	1	1	2	**4**
WARM	warm	0	0	0	0	0	1	1	0	0	0	0	**2**
MATE	mate	0	0	0	0	0	0	0	1	1	0	0	**2**

TEST 3: VISUO-TACTILE		A	B	C	D	E	F	G	H	I	J	K	Total
TEXTURED	textured, grainy, like foam, fine texture	2	3	2	0	0	0	4	2	4	2	2	**21**
ROUGH	rough, aggressive, abrasive	9	8	8	0	0	0	9	8	5	4	2	**53**
SLICK	slick, flat	0	0	0	8	7	8	0	0	0	0	3	**26**
MACROTEXTURED	coarse, grating, alveolate	0	1	1	0	0	0	0	2	3	5	4	**16**
LIGHT-BRIGHT	bright	2	2	2	2	0	1	1	1	0	0	0	**11**
DARK	dark	0	0	0	0	1	0	0	0	0	1	0	**2**
STRANGE	strange, funny	0	0	0	0	0	0	0	1	1	0	2	**4**
COLD	cold	0	0	0	2	2	2	0	0	0	0	0	**6**
WARM	warm	0	0	0	0	0	0	0	0	1	1	0	**2**
MATE	mate	0	0	0	0	0	0	0	1	1	0	1	**3**
BEAUTIFUL	beautiful, nice	2	1	2	1	0	0	2	1	0	0	0	**9**

These supplementary variables used to describe the personal napping of each subject give insights on the meaning of the axes. The words are projected at the sample barycenter on the IFM (Figure 4), only the most cited words are represented. With these word projections, the first axis opposes slick and scratchy samples in the tactile test while it opposes slick and macrotextured samples when visual modality is used. In the tactile test, the second axis does not clearly bear word descriptions. It seems that subjects have positioned samples that they managed to qualify along the first axis and ejected the samples that they had difficulties to qualify outside of this first axis. The visual and visuo-tactile tests exhibit another IFM morphology in that three clusters are drawn and qualified. One cluster gathers the slick samples, another one the macrotextured samples and finally the last cluster comprises the scratchy-textured-bright samples. This last cluster is spontaneously qualified hedonically as beautiful. Sample K has a soft touch but exhibits a macrotexture that can be slightly perceived by touch also. It is ejected from the primary axis in the tactile test as it is neither slick nor scratchy. In the visual test, the macrotexture clearly overcome all other characteristics of the sample, it is positioned in a cluster with sample J. In the visuo-tactile test, the macrotexture characteristic also drives the sample position, however it is not as obvious as for the pure visual test.

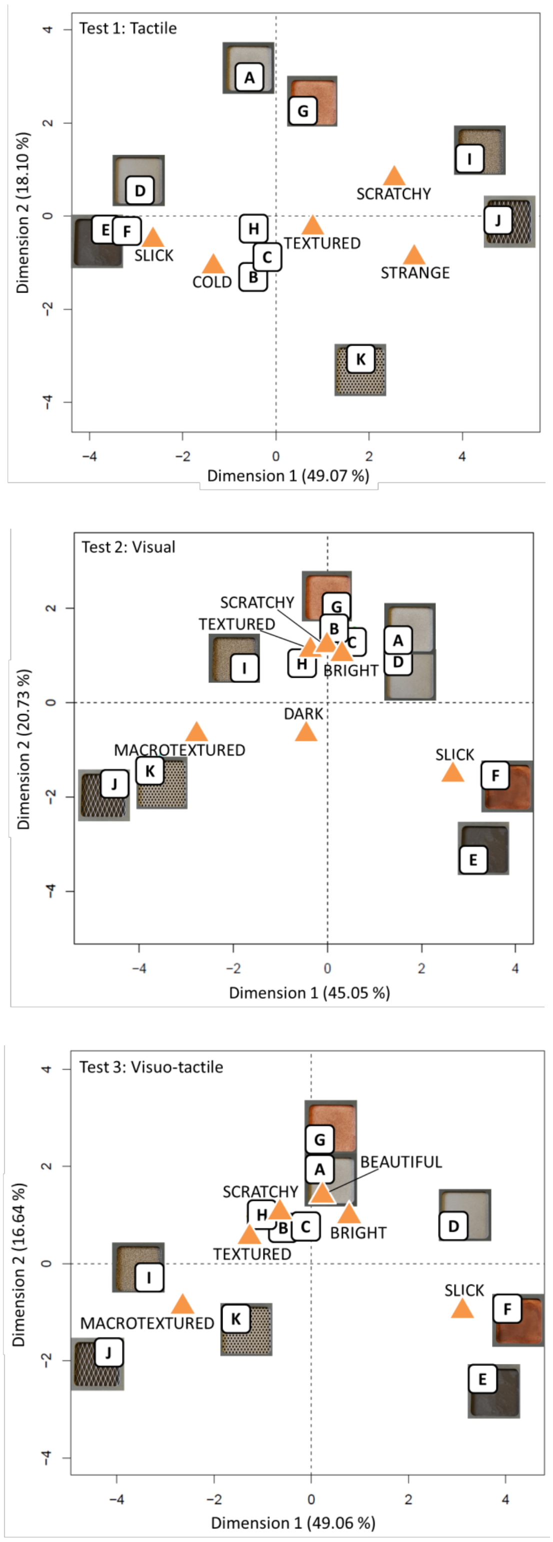

Figure 4. Individual Factor Map with word projection obtained from the three napping tests.

4 CONCLUSION

Sensations in product design can lead to an emotional interaction that could highly impact, positively or negatively, the perceived quality of a product. Well designed, sensory attractive products generate strong consumer-product relationships. Selection and definition of materials surfaces can be driven by the sensory effect conceived. In this paper, a specific setup dedicated to holistic sensory evaluation with a focus on visual and tactile modalities has been presented. The sensory evaluation procedure derives from the napping procedure used in food industry. In a napping test, the subjects have to place the samples on the delimited surface so that two samples that are close are perceived identical and two samples that are far away are perceived different. Based on the analysis of the Individual Factor Maps and the supplementary word descriptions, we get characteristics of the materials and the way subjects differentiate them. The words frequencies projection can be ambiguous and matches to an explanatory approach however it gives interesting insights on the meaning of the axes obtained after Multiple Factor Analysis of the sensory data. This step allows highlighting the main perceptions the subjects have about the materials. The experiments showed that this setup can be used to study the tactile and visual inter-modality in materials perception. It enables to rank the sample attributes that are perceived by the subjects when different sensory modalities are used. In particular visual-tactual incongruity can be highlighted, that can be of interest in product design. For instance, with our set of materials, in tactile perception, the primary axis opposes slick and scratchy while in visual and visuo-tactile perception, the primary axis opposes macrotextured and slick. It seems that the macrotexture overcome other materials characteristics once the visual modality is used. Within these samples, the titanium perforated sheet induces a different perception in tactile and visual exploration. In this study, we have introduced an empirical definition of the "familiarity" of a user with a material and/or a surface, which proved effective at rationalizing sensory data. Further investigations of this concept in connection with neurosciences, cognitive sciences and behavioural psychology hold promising perspectives.

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