A Conceptual Network Analysis of User Impressions and Meanings of Product Materials in Design

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Abstract
This paper focuses on tactile interactions with product materials to approach the essence of users’ interaction. We propose a framework for analysing tactile interactions based on users’ association-based in-depth impressions and interpretation-based created meanings. The aim of the study is to determine how in-depth impressions activate created meanings in tactile interaction and how they affect users’ preferences with regard to product materials. To detect and identify in-depth impressions and created meanings, this study applies original methods that analyse concept networks. To collect users’ freely expressed impressions and preferences, we conducted an experiment that involved seven material samples. The identified in-depth impressions and created meanings are connected with preference evaluations during a tactile interaction with product materials. According to the findings, the generation of fewer yet affect and abstraction-based in-depth impressions produces high-preference evaluations and gives rise to diverse created meanings with respect to a material. These findings should contribute to designs that lead users to form emotional bonds and gain meaningful experiences with products.

Keywords:
E. Properties of materials
H. Material property databases
H. Selection for material properties

1. Introduction
This paper pays attention on products that are expected to correspond with human impressions [1, 2]. Professionals involved in product design must provide designs according to users’ sensorial perceptions, emotions, and product experiences [3, 4, 5, 6, 7]. In previous studies, sensorial perceptions, emotions, and experiences have been conceptualized as components of users’ impressions of a product. Many attempts have been made to understand the impressions that products generate, but most fail to grasp the changing nature of such impressions.

1.1. Tactile interaction
Tactile user-material interaction has been recognized as a prominent topic in experiencing man-made objects [3, 4, 8]. It is important for designers to develop methods and a conceptual framework for the tactile sensory experience, particularly with respect to product materials. It has been suggested that an approach can be based on cognitive and perceptual learning [3, p.62]. However, product design practices do not yet offer such tools and methods.

The issue of the provision of methods for analysis of tactile sensory experience is related to understanding the formation of users’ sensory experiences and providing an effective approach to assessing this experience. In product design, designers have to understand how user impressions of materials are formed. Furthermore, an effective assessment approach (technology) would contribute to the development of products and materials by fitting the products to expected tactile experiences (various products with which users interact everyday).

People interact with various materials, perceive various characteristics of these materials, manifest different affects from these materials, and create different meanings from the materials [8], ultimately accumulating...
experiences and building bonds with, attachments to, or dislike of products. Previous studies have shown that the users’ impressions of materials in tactile interactions depend on how accustomed they are to the materials and how natural the materials are perceived to be [9]. Recent work on tactile experience, with respect to product materials, has represented these experiences using systematic approaches to the materials’ sensorial properties [10]. The findings of this work show that the meanings are attributed to materials depending on factors, such as meaning type, material type, the product, its usage, and the user’s background. Tools for facilitating material selection on the basis of these findings have been developed [8].

To gain an understanding and to systematize the sensorial properties of materials, we must focus on users’ interaction with these materials and answer questions on how users form an impression of product materials. Previous studies focus on perception and affect, paying little attention, however, to cognition in tactile interaction with product materials. Cognition of product materials is a critical conceptual component in users’ interaction, no less important than perception or affect. Analysis of the perceptual and cognitive processing of material is the next logical step.

1.2. Approach to understanding tactile interaction

Researchers have recognized the importance of gaining a deeper understanding of individuals’ interaction with materials, particularly in the tactile mode [3]. They argue that tactile interaction places one into a scenario in which experience is the foundation of knowledge. People need to touch to know and understand the man-made objects they are manipulating, to grasp their meaning. First attempts to penetrate deeper into this topic and to identify the causes of users’ impressions of product materials show that users’ impressions depend on how natural the material is perceived to be and how accustomed the users are to this material [9].

Thus, the importance of the current study lies in challenging the formation of impressions from product materials. To understand the formation process, we focus on human cognition as a conceptual component describing individuals’ interaction with objects, paying attention to in-depth impressions arising from this interaction.

‘In-depth impressions’ comprise an inner associative layer of users’ expressed impressions [9, 11, 12]. As such, in-depth impressions underpin explicit and, however, superficial impressions. Given the nature of in-depth impressions, they form within basic interactions. Thus, this study focuses on the most basic form of users’ interactions with products—namely, tactile interaction with the material of a product—in order to investigate in-depth impressions. Tactile interaction with materials is more central to the formation of a user’s impressions than are interactions involving the product’s visual form and colour. For example, the results of behavioural research point out that colour plays an essential role in helping one distinguish natural versus man-made objects [13]; however, tactile information involves the recognition of preference and impressions. Therefore, tactile interactions serve as a sound research target, in terms of examining impressions and the inner associative layer thereof.

Moreover, in this study, we see that in-depth impressions serve as a basis for activating created meanings with respect to materials and products. Such meanings, from the standpoint of users’ emotions and experiences, are critical to the designer’s understanding and eventual exploitation of users’ materials preferences; this has been the focus of recent research [14, 15]. Thus, creative design can be considered as that which generates original meanings.

This study uses the following definitions:
- ‘In-depth impressions’ are based on associations that evoke explicit impressions of the material
- ‘Created meanings’ are based on interpretations that result from explicit impressions evoked by the material

The research concerns are how in-depth impressions activate created meanings and how in-depth impressions and created meanings affect users’ preferences and evaluations in relation to product materials. The study seeks to address these concerns and gains insights into users’ interactions with product materials. Indeed, a fuller understanding of in-depth impressions and created meanings will contribute to design that better aligns with, or gives rise to, positive consumer emotions and product experiences.

2. Aim

The aim of the study is to answer the following two questions:
(A) ‘How do in-depth impressions activate created meanings in tactile interaction?’ and
(B) ‘How do in-depth impressions affect users’ evaluations with regards to product materials?’
In order to answer these questions, we pay attention to characteristics of the links (associations and interpretations) between in-depth impressions and created meanings. We assume that users’ preferences and created meanings, with regard to product materials, are connected to the characteristics and types of the in-depth impressions experienced during the tactile interaction.

3. Impressions and Meanings

3.1. Product materials

Unlike materials-selection approaches that are based on those technical characteristics of materials that are directly measurable [16], approaches that defer to users’ product-material preferences are based on emotions and experiences [1, 2, 17]. It is clear that emotions themselves are based on personal experiences; consequently, personal attachments or aversions are difficult to analyse and comprehend and are therefore difficult to consider when designing new products [8, 18]. Notably, emotions based on experiences can be investigated by examining the impressions that play an important role in users’ interactions with and preferences for certain products [12, 19].

Material preferences are believed to be influenced by the nature and characteristics of the in-depth impressions generated by those materials [9, 19]. They are central to users’ created meanings, which are generated through interactions with the materials. This viewpoint aligns with basic theories concerning the creation of meaning; it is also in accordance with the theory on image schemas [20]. In-depth impressions, particularly of tactile interaction, play a major role in forming deeper and long-term meanings that are, in turn, attributed to the material and the product itself. Users’ interactions with materials are affected by the impressions, associations, and meanings related to the product material [2, 9, 13, 14]. In product design, materials should not only adhere to technical requirements; they should also appeal to users’ senses and, thus, derive an intended meaning related to the final product [15]. Thus, the analysis of consumer impressions is essential to product design.

Research into tactile interaction indicates the presence of an important associative aspect that arises in tactile interactions with materials [9]; consumer preferences and impressions are found to be related to the tactile sensations associated with the product materials. Moreover, in existing research, associative and latent factors have been found to be critical to analysing human sensitivity [17, 18, 19]. However, along with such an associative aspect, users’ interpretative aspects during interactions with product materials play a role in the whole of that user’s attitude towards the product and, thus, in its selection in preference to competing products. This study therefore seeks to explore both the associative and interpretative aspects of interaction, introducing a formal approach to the study of associative and interpretational aspects of users’ interactions with product materials.

3.2. Framework of users’ interaction with product materials

To analyse product materials, this study proposes a framework of users’ interaction (Fig. 1). To identify in-depth impressions, attention was paid to theories of mental models, which support the view that humans need to recognise, predict, and explain the behaviour of the world around them and that mental models allow humans to interact with their environment [21].

![Fig. 1. Impressions and meanings-based framework of users’ tactile interactions.](image)
The proposed framework describes such a structure. Personally held associations affect the explicit impressions that users derive from materials; in this way, associations form certain meanings for those individuals. Materials are interpreted by way of both association-based in-depth impressions and interpretation-based created meanings: association-based in-depth impressions as connected with the visceral part of the interaction and, on the other hand, interpretation-based created meanings are connected with the reflective part of the interaction [1]. Both in-depth impressions and created meanings contribute to recognition of certain materials and the products they comprise. Thus, in-depth impressions and created meanings serve as rational bases of the framework through which one can understand the changing characteristics of human impressions—an understanding that is critical to successful design.

4. Methods and tools

4.1. Methods of identifying In-depth Impressions
To detect and identify in-depth impressions and created meanings, this study makes use of methods that analyse concept networks (Fig. 2). In practical terms, in-depth impressions and created meanings can be considered nodes that initiate and attract, respectively, higher numbers of connections in these concept networks. The numbers of connections can be assigned as weights. Thus, in the networks, in-depth impressions and created meanings can be identified as highly weighted associations. Explanations of the methodology follow.

After the users’ explicit impressions of a material are collected, the steps involved in identifying in-depth impressions are as follows (Fig. 2):
1) Explicit impressions are thought to be associated from certain associative words
2) All common pairs of such words (associative → explicit) are detected using a tool (as explained in the ‘Analysis tool for In-depth Impressions’ section, below)
3) Case-specific concept networks based on all the detected pairs are created (see the ‘Tool for creating concept networks’ section, below)
4) Highly weighted associative words are identified as in-depth impressions
5) The list of in-depth impressions is analysed

In this way, this study identifies in-depth impressions that are based on associations, which are the basis of each of the explicit impressions evoked by the person interacting with the material (associations are the stimulus words used to evoke the explicit impressions).

4.2. Methods of identifying Created Meanings
To identify created meanings, the steps are as follows:
1) Explicit impressions are thought to be interpreting certain words
2) All common pairs of such words (explicit → interpretative) are detected, using a tool (as explained in the ‘Analysis tool for Created Meanings’ section, below)
3) Case-specific concept networks are created based on all the detected pairs
4) Highly weighted interpretative words are identified as created meanings
5) The list of created meanings is analysed

In this way, this study identifies created meanings that are based on interpretations of explicit impressions, which, in turn, have been evoked by the person interacting with the material (interpretations are the words generated by the explicit impressions). Using these methods, lists of in-depth impressions and created meanings were identified. These can be quantitatively and qualitatively analysed to derive a greater understanding of the characteristics of users’ impressions—an understanding that is essential to creating designs that fit users’ impressions. These methods allow us to consider research question (A).

4.3. Concept networks theory
As structures that comprise words and the semantic relationships among them, concept networks are suitable for exploring and identifying the links among concepts. As computational structures, these networks can be used to model conceptual associations [22]. The idea of the concept network has its origins in the field of psychology: Concept networks depict human memory as an associative system, wherein a single idea can lead to many other ideas. Thus, both the associative portion underpinning impressions and the interpretation part above impressions (Fig. 1) can be independently analysed using concept networks, as shown with the methods in Figure 2.
In-depth impressions

Fig. 2. Methods to detect, identify, and analyse the in-depth impressions and created meanings.

On the other hand, graphs are a suitable means of constructing and visualising such concept networks. They are often used to visualise and analyse networks in terms of network theory [23]. The current study makes use of graph-based visualisations, in a later part of its methodology (Fig. 2).

4.4. Analysis tool for In-depth Impressions

To detect in-depth impressions, a universally applicable associative analysis tool (i.e. concept dictionary) was used. The ‘University of South Florida free association, rhyme, and word fragment norms’ database created by Nelson, McEvoy and Schreiber [24, 25] (referred to in this paper as the USF norms database) contains the largest number of English-language associative words [26]. It consists of more than 72,000 word-pair
associations (associates). The tool was constructed in a large-scale association experiment and considers nouns, adjectives and verbs in associative pairs. Such extensive coverage is suitable for searches of word-association pairs, thus it is used in the current analysis. This tool is widely applicable as opposed to the tools used in previous work [9] and contributes to the reliability of the presented method in this research.

4.5. Analysis tool for Created Meanings
To detect created meanings, a universally applicable meaning analysis tool was considered. WordNet is a very large electronic lexical database that contains information about the manner in which humans process concepts and language [27, 28]. This database contains more than 150,000 words. The current study made use of the ‘glosses’ of this database, which are descriptions of the words’ meanings. For every word, the content of all of its glosses was considered in the analysis.

To detect created meanings, two pieces of information can be used: the first part of the gloss, in which the word is explained as a specific instance, and the second part of the gloss, in which the word is used in an example. The glosses are lexicographically limited, but they systematically follow the standard principles of dictionary definitions and are thus applicable to analyses of meaning.

4.6. Tool for creating concept networks
To construct concept networks specific to each case, the visualisation software, Pajek [23, 29], was used. Using Pajek, the concept networks can be visualised as graphs and further used in the detection of in-depth impressions and created meanings.

4.7. Preference evaluation
The method by which research question (B) is addressed involves the placement of entities in order of preference—simulating selection, as it were, as might occur in daily life. In such a situation, a user’s preference evaluation is not framed by scale descriptors, such as semantic scales; rather, a preference evaluation is usually based on a comparative (rather than a formative) evaluation scale or set of ratings.

5. Experiment

5.1. Setting
To investigate hypotheses and thus gain insights into users’ interactions with materials, an experiment was conducted. This experiment focused on, but was not restricted to, tactile interactions. Attempts were made to analyse the interaction in a manner that simulated, as close as possible, daily-life situations, where users choose products based on comparisons of products or materials rather than on scores or semantic scales. Thus, the study included a collection of users’ freely expressed impressions and rankings (i.e. ordered placements) instead of scores.

The experiment involved seven material samples as well as questions and rankings pertaining to them. The purpose of the experiment was to address the two aforementioned research questions.

To answer question (A), identifying in-depth impressions and created meanings, the following were collected from human individuals:

1) Freely expressed impressions upon tactually interacting with each of seven material samples (i.e. regarding touch, look and feel)
2) Imagination of products comprising these material samples (in order to understand what products are related to the in-depth impressions and created meanings)

To answer question (B), obtaining preference evaluations, in addition to these two inquiries, the following were also collected:

3) Evaluations (ordered placements, from high to low) of the seven material samples in terms of visual preference, tactile preference, and feeling preference

The instructions for the first two areas of inquiry were as follows: 1) ‘Think about the texture of the material that you are touching. What are your impressions and image of this material?’ and 2) ‘What product or object did you want to create from this material, when you looked at and touched it?’ The instruction for the third area of inquiry, with regards to rankings, was as follows: 3) ‘Please order these materials according to your preference, based on their look and touch; please order these materials, according your feelings.'
5.2. Participants
Eleven subjects (five females and six males; mean age, 28.6 years; age range, 22–43 years) participated in this study. All were students, staff members, or researchers from a university. The participants provided answers in separate sessions for the two inquiries, as well as three rankings, for the seven material samples that had been presented in random order. All the words from the verbalised protocols (e.g. a total of 597 expressed impression words for the first question) of the verbally expressed free impressions were recorded and further transcribed into files, whereupon they were used in the analysis.

5.3. Material samples
The size of the seven material samples was approximately 20 × 10 cm each, allowing participants to tactually interact freely with the samples. Selections included materials that see a wide application in products (i.e. in many products that are frequently touched):
- Aluminium, plastic, and wood
There were also materials that see a narrower application in products (i.e. in products that are sometimes touched):
- Cork, glass, rubber, and steel net
The selections constituted materials commonly used in products used in daily life, limiting the set to seven. This limitation was set to keep participants from becoming bored and their impressions ‘exhausted’.

6 Analysis and results
6.1. Analysis of In-depth Impressions and Created Meanings
This part of the analysis looks to successfully identify in-depth impressions and created meanings from the verbalised protocols of all the participants’ answers, with respect to the first area of inquiry.
To detect in-depth impressions, the aforementioned method was employed, together with the USF norms database. Highly weighted associative words were considered in-depth impressions. The weighting limit was approximately set to the upper 50 percent of word groups, based on the number of connections they initiated (i.e. if groups of words were initiating eight, seven, six, five, four, three, two, or one connection, then all of the words from the groups initiating eight, seven, six, and five connections were taken as in-depth impressions). Lists of identified in-depth impressions are shown in Table 1, for each material that was tactually assessed. The total number of in-depth impressions is shown in the second column.
To detect created meanings, WordNet glosses were employed for all word meanings, including example uses of these words. To identify the significant parts of the meanings, a filtering rule was applied as follows. From a pool of words, we omitted connecting words such as prepositions (e.g. ‘of’, ‘on’, ‘for’, etc.), a few general verbs (e.g. ‘is’, ‘are’, etc.), articles (e.g. ‘a’, ‘an’, and ‘the’), and pronouns (e.g. ‘I’, ‘me’, ‘she’, etc.). Also, a small group of words typically used in explanations—such as ‘anything’, ‘something’, ‘especially’, ‘lacking’, ‘consisting’, ‘rather’, etc.—were excluded, as they were found to change meanings outside of their original context and are present in many glosses. The created meanings identified through this method are shown in Table 1, for each material that was tactually assessed. The total number of created meanings is shown in the second column.

6.2. Concept networks
Figure 3 shows the concept networks of in-depth impressions (left) and concept networks of created meanings (right) based on associations and interpretations as per material samples. The concept networks were simplified using an approach applied in previous studies [9]. This allowed an application of a systematic simplification method, preserving the characteristics of the networks, omitting low-weighted associative words. The same principle as in the case of in-depth impressions was applied in the creation of the concept networks of created meanings, omitting the low-weighted interpretative words.
Fig. 3. Concept networks of the in-depth impressions and created meanings.
<table>
<thead>
<tr>
<th>Material Sample</th>
<th>Identified in-depth Impressions and Created Meanings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumini...um</td>
<td>52 in-depth impressions:</td>
</tr>
<tr>
<td></td>
<td>27 created meanings:</td>
</tr>
<tr>
<td>Cork</td>
<td>26 in-depth impressions:</td>
</tr>
<tr>
<td></td>
<td>36 created meanings:</td>
</tr>
<tr>
<td>Glass</td>
<td>46 in-depth impressions:</td>
</tr>
<tr>
<td></td>
<td>Marble, Defrost, Pool, Shutter, Glass, Crisp, Detach, Extreme, Metal, Steel, Stone, Uncomfortable, Shatter, Windshield, Wipe, Delicate, Basement, Beer, Cellar, Clay, Dark, Darkness, Dead, Distant, Dry, Frozen, Handkerchief, Hate, Orange juice, Rigid, Severe, Shake, Sheet, Sore, Stethoscope, Symptom, Thermometer, Clear, Dresser, Bench, Brittle, Wood, Coffee, Seat, Shelf, Porcelain</td>
</tr>
<tr>
<td></td>
<td>44 created meanings:</td>
</tr>
<tr>
<td>Rubber</td>
<td>63 in-depth impressions:</td>
</tr>
<tr>
<td></td>
<td>49 created meanings:</td>
</tr>
<tr>
<td></td>
<td>Light, Cause, Great, Rubber, Strength, Life, Little, Physical, Time, Force, Wheel, Played, Good, Quickly, Object, Child, Rain, Get, Manner, Sound, Air, Set, Speech, Water, Man, Movement, Road, Strong, Very, Color, Heat, Person, Quality, Wore, Degree, Place, Act, Ice, Pressure, Room, Sun, Condition, Hard, Wanted, Voiced, Source, Stress, Thin, Cast</td>
</tr>
<tr>
<td>Steel Net</td>
<td>43 in-depth impressions:</td>
</tr>
<tr>
<td></td>
<td>Display, Clear, Defrost, Glass, View, Blind, Screen, Wipe, Computer, Blinds, Curtains, Door, Shade, Sill, Vent, Wall, Windshield, Bay, Bedroom, Cleaner, Curtain, Drapes, Frame, Glare, Ledge, Open, Pane, Rear, Shatter, Shield, Shingle, Shop, Shutter, Storm, Felt, Rigid, Smooth, Film, Lint, Movie, Patio, Television, Theater</td>
</tr>
<tr>
<td></td>
<td>29 created meanings:</td>
</tr>
<tr>
<td>Plastic</td>
<td>32 in-depth impressions:</td>
</tr>
</tbody>
</table>
The in-depth impressions and created meanings have quantitative differences, depending on the material sample. For example, the sample of aluminium material had given rise to fewer created meanings, compared to the number of in-depth impressions with which it was associated. Also, the sample of cork material had given rise to fewer created meanings, compared to the number of in-depth impressions.

Moreover, the impressions arising from the sample of aluminium material were associated with in-depth impressions like Harsh, Rigid, Accident, Extreme, and Rough, leading to the following interpreted meanings: Body, Physical, Act, Work, Book, and Energy. On the other hand, impressions arising from the sample of cork material were associated with in-depth impressions like Mild, Gentle, Spring, Cosy, and Sunshine, leading to the following interpreted meanings: Country, Body, Life, Force, and Voice.

### 6.3. Characteristics and types of the in-depth impressions

For the purpose of identifying the characteristics of the in-depth impressions, we divided the identified in-depth impressions into three groups according to the perceptual component they most likely relate to: (1) perceptual (e.g. Rigid, Mild, Crisp, Clear, Delicate, etc.), (2) affective (e.g. Cosy, Extreme, Harsh, Shatter, Influence, Power, etc.), and (3) cognitive (e.g. Steel, Plug, Marble, Tread, Display, Stage, Sun, etc.).

Figure 4(a) shows stacked bar graphs of in-depth impressions classified into perceptual, affective and cognitive characteristics. Conceptual characteristics show that the cognitive component of the inner associative layer of impressions is predominant in most cases.

For the purpose of classifying the in-depth impressions, we used a conceptual hierarchy of a concept dictionary database to identify their types. After examining all the identified in-depth impressions, we identified the following categories as appropriate to our case: (1) Artefact; (2) Abstraction; (3) Substance/Living thing (including a Natural thing and a Person)/Phenomenon; and (4) Others/Not classified.

Figure 4(b) shows stacked bar graphs of in-depth impressions classified into artefact, abstraction, and substance/living thing/phenomenon-related types. The proportions obtained with this classification show that those materials with applications to specific products (Cork, Glass, Rubber, and Steel net) contributed to users’ cognitive characteristics with the associative layer of in-depth impressions of artefacts (Fig. 4). The materials that have wide product applications (Aluminium, Plastic, and Wood) create users’ cognitive characteristics with the associative layer of abstraction-based in-depth impressions.
Fig. 4. Distributions among (a) Conceptual characteristics and (b) Typology of the in-depth impressions.

6.4. Imagination of products
This section presents participant answers from the verbalised protocols, in relation to the second area of inquiry. Participants stated the products they imagined, from their interaction with the material samples. The total list of products as indicated by the participants is provided in the last column of Table 2. The total number of imagined products is shown in the second column.

Table 2 Imagination of products as indicated by the participants

<table>
<thead>
<tr>
<th>Material sample</th>
<th>Imagination of products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>25 products: Bin, Box, Car Parts, Glass, Kitchen Knife, Lunchbox, Machine Parts, Penholder, Rain Collecting Thing, Roof, Roof Tray, Shelf, Structure, Tableware, Toy, Umbrella Stand, Wall, Canned beer, Trash, Card, Curve, Incense, Sound, Strange shape, Objet</td>
</tr>
<tr>
<td>Cork</td>
<td>27 products: Block, Board, Board, Book Cover, Building Blocks, Coaster, Cork, Cork Board, Diorama, Document Box, Flowerpot, Gift, Glass, Illumination, Mat, Mobile Cover, Mouse Pad, Objet, Paper, Photo Frame, Picture, Picture Board, Pot Stand, Puzzle, Stationary Object, Three-Dimensional Object, Wall</td>
</tr>
<tr>
<td>Glass</td>
<td>16 products: Box, Canvas, Glass, Glass, Light effects, Mirror, Ornament, Picture, Picture, Picture frame, Portable display, Showcase, Stained glass, Coffee boiler, Window, Window</td>
</tr>
<tr>
<td>Rubber</td>
<td>25 products: Cushioning material, Glasses part, Grip, Handle, Mobile, Notebook surface, Pen, Penholder, Racket, Sandals, Scrap, Seat Surface, Shoe, Shoulder massage device, Skid, Skid, Sport Equipment, Tire, Toy</td>
</tr>
<tr>
<td>Steel Net</td>
<td>25 products:</td>
</tr>
</tbody>
</table>
The indicated products show diversity (i.e. there is a number of different types of products). For example, from the sample of aluminium material, participants cited the imagination of products like Box, Kitchen Knife, and Roof; these products represent the existing applications of this material to the home environment, which users often touch. On the other hand, from the sample of cork material, the participants’ imagination of products like Diorama, Flowerpot, and Illumination was more diverse.

6.5. Preference evaluations
This section presents all participants’ rankings relating to the third area of inquiry. The participants placed the seven materials in order of preference, from high to low. These evaluations were averaged across all participants. Figure 5 shows the average scores of the visual-preference evaluation/tactile-preference evaluation, as indicated by the participants. Further, Figure 6 shows the average scores of the feeling-preference evaluation, as indicated by the participants.

All material samples having a wide array of product applications (e.g. aluminium, plastic, and wood) were ranked consistently in the visual-, tactile-, and feeling-preference evaluations. Meanwhile, material samples with a narrow array of product applications (e.g. cork, glass, rubber, and steel net) ranked rather inconsistently in the visual/tactile- and feeling-preference evaluations.

**Fig. 5.** Average visual-preference and tactile-preference evaluations of material samples (from 1 [Low] to 7 [High]).

**Fig. 6.** Average feeling-preference evaluations of material samples (from 1 [Low] to 7 [High]).
Correlations were observed:
- The imagination of products (number of imagined products) was positively correlated with the feeling-preference evaluation results (Correlation 0.881, 2-tailed significance p=0.009<0.01) (Table 1, Fig. 6)

Other weak correlation among variables was observed:
- The number of in-depth impressions was negatively correlated with the feeling-preference evaluation results (−0.538, n.s.) (Table 1, Fig. 6)

Table 3 shows the marginal correlations between characteristics and types of in-depth impressions and participants’ evaluations and created meanings. All other correlations, lower than 0.5, were omitted.

<table>
<thead>
<tr>
<th>In-depth impressions’ conceptual characteristics</th>
<th>Variable</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception</td>
<td>Created meanings</td>
<td>0.610</td>
</tr>
<tr>
<td>Affect</td>
<td>Visual evaluation</td>
<td>0.723</td>
</tr>
<tr>
<td>Affect</td>
<td>Tactile evaluation</td>
<td>0.688</td>
</tr>
</tbody>
</table>

| In-depth typology impressions’ Artefact          | Tactile evaluation| -0.559        |
| Abstraction                                     | Tactile evaluation| 0.645         |
| S. /Liv.(Nat.)/Phen.                            | Created meanings  | 0.589         |

In-depth impressions with affective conceptual characteristics contribute to higher visual and tactile evaluation, while those with perception conceptual characteristics contribute to more created meanings. Abstraction type in-depth impressions enhance the tactile evaluation, in contrast to artefact type in-depth impressions, which lead to lower tactile evaluation. Finally, substance/living thing/phenomenon-related type in-depth impressions create more meanings, according to the participants’ answers.

7 Discussion

7.1. Impressions, activated preferences and meanings
The observed connection between the preference evaluations and the number of imagined products, identified in-depth impressions (moreover, their conceptual characteristics and typology) explains how in-depth impressions activate created meanings during a tactile interaction with product materials.

Possible interpretations of these findings with respect to design are rather complex. In order to achieve a high feeling-preference evaluation for a product material (i.e. connected to design for emotions), a material’s impressions need to be associated with fewer in-depth impressions (i.e. connected via associations and previous user experiences) and have to contribute to a rich imagination of products (i.e. user experiences) (Table 1, Fig. 5, 6). In order for a product material to be evaluated highly in terms of tactile-preference, the in-depth impressions have to be based on affect and be of the abstraction type (Table 3). However materials also have to be associated with fewer in-depth impressions of the artefact type (i.e. connected with previous user experiences).

The material in-depth impressions with perception characteristics and of the substance/living thing/phenomenon-related type give way to a set of more created meanings (i.e. connected to meaningful product experience). The in-depth impressions with affective characteristics and of the abstraction type activate tactile (and partially visual) preference evaluation. These results provide an answer to question (A), regarding how in-depth impressions activate created meanings in tactile interaction.

The role of ‘figurative meanings’, referred in previous studies as related to product experience [5], can be interpreted as the substance/living thing/phenomenon-related type in-depth impressions contributing to the created meanings (Table 3), because the ‘figurative meanings’ are associated with social interaction and atmosphere. We can specify that in-depth impressions of such type provide meaningful product experience. Moreover, perception type of in-depth impressions probably contributes to the ‘literal meanings’ [5], because
‘literal meanings’ are related to the physical characteristics and comfort. The role of the abstraction type of in-depth impressions, based on a concept or idea not associated with any specific instance, can be understood as ‘figurative meanings’ leading to higher tactile evaluation, in opposite to the ‘literal meanings’ (artefact type in-depth impressions).

This finding extends the preliminary view that abstraction-based in-depth impressions play a role in experiencing new materials and contributing to users’ higher evaluations [9]. Moreover, the findings show that when users’ in-depth impressions are related to artefacts—i.e. associated with the result of previous experiences with such product materials—tactile evaluation is lower. In contrast, if a user’s imagination of products is richer, their feeling evaluation is higher. This can be interpreted as users’ tactile interaction with artefacts ‘exhausting’ their materials in impressionable terms, opening the way for new materials, which can be expected to provide different abstract-related associations and a richer imagination of products.

This contributes to our understanding of users’ tactile experience as a dynamic process and as an issue that needs to be better recognized in material selection for product design [3].

7.2. Preferences

Regarding question (B): how in-depth impressions affect user preferences and created meanings in relation to product materials, this preference is connected to a lesser number of in-depth impressions. In-depth impressions related to users’ perceptions (leading to ‘literal meanings’ [5]) and those of the substance/living thing/phenomenon-related type (leading to ‘figurative meanings’ [5]) lead to a set of diverse created meanings. This finding shows that the number of created meanings depends on perception and natural associations (of materials, beings, etc.) in tactile interaction. In other words, the more natural associations and perceptions stimulated by product materials, the more created meanings users will form.

However, the users’ tactile-preference evaluations of materials (Fig. 5) were connected to fewer numbers of artefact-based in-depth impressions from the product materials (Table 2). The feeling-preference evaluation tended to be lower in cases where there were more in-depth impressions. The probable reason behind this finding is that more in-depth impressions create incoherent feelings towards the product materials. For example, the plastic material sample ranked highly on the visual/tactile- and feeling-preference evaluations and had fewer in-depth impressions. The steel net material sample, meanwhile, had more in-depth impressions, but was connected with a small range of products in the home (see Table 1). Overall, the feeling-preference evaluation relates to the rich imagination of product applications and fewer in-depth impressions; also, tactile-preference evaluations relate to the affect and abstraction-based in-depth impressions.

The previous experiences of users with such product materials [9] seem to have double role in tactile evaluation. First, the positive effect of the affect/abstraction in-depth impressions on tactile evaluation was connected with materials that see a wide application in products (aluminium, plastic, and wood) (Fig. 4, Table 3). Second, the negative effect of the artefact in-depth impressions on tactile evaluation was connected with materials that see a narrower application in products (cork, glass, rubber, and steel net). Finding such relationships between meanings and products has been regarded as critical for designers in previous studies [8]. These findings show that the meaning of material [8, 14] is most likely to depend on the product in which the material is embodied and its usage, rather than the material type. Judging on the basis of observed imagination of products and artefact in-depth impressions, the extent of the use is also important.

Thus, from the user’s viewpoint, a ‘successful’ product material should involve fewer affective abstraction-associating—even though, not artefact-associating—in-depth impressions and a diverse imagination of product applications and created meanings. This finding should contribute to a product design that leads to users’ forming emotional bonds and meaningful experiences.

7.3. Implications of the findings

The outcomes can be justified in terms of material selection [4, 8], and understanding users’ emotions and product experience [5, 14]. A main result of the findings is the creation of a method for selecting product materials, addressing the need for comparable information [4], based on in-depth impressions [9]. The successful selection of product materials should involve a successful combination of certain types, with certain characteristics of in-depth impressions. The results of this study provide the first insights into such a selection method, which can be developed as a tool for selecting materials in product design.

The implications of this research include two directions in product design: design that appeals to users’ emotions and design that contributes to product experience. The in-depth impressions of a product material can, in part,
contribute to emotions and experiences, and a designer should be mindful of these contributors to the design process. Further implications can also be seen with regards to the design of long use sustainable products.

7.4. Limitations and future work
This study has limitations, including those derived from the limited number of material samples used therein. A wider range of materials and a higher number of subjects needs to be assessed, to verify the findings prior to implementing them in the material-selection stage of a product design process.

Future work should include:
- Experiments that examine combinations of materials, while investigating the users’ in-depth impressions and created meanings with regards to various materials for design
- The development of a method and tools for product material selection, for use by designers

8 Conclusions
This study sought to clarify the ways in which users’ impressions of product materials are formed and the implications thereof. A framework was proposed that took into account users’ interactions with product materials, based on their impressions and meanings. This framework allowed the application of rational concept network methods to analyse these impressions and meanings derived from tactile interactions. The original analysis methods seek to identify association-based in-depth impressions and interpretation-based created meanings.

These methods were adopted to identify users’ in-depth impressions and created meanings resulting from tactile interactions, within the context of a study involving seven material samples. Consideration was given to the ways in which users’ preference evaluations were influenced by these impressions and meanings, towards creating a total impression of the material. Use of the proposed analytical method confirmed its effectiveness in identifying essential aspects of user interaction, thus answering key questions about how in-depth impressions activate users’ preferences and created meanings. The nature and characteristics of in-depth impressions provide clues as to what can be considered a ‘successful material impression’ from the users’ perspective. The generation of fewer, yet affect and abstraction-based in-depth impressions gives rise to high-preference evaluations and rise to diverse created meanings with respect to a material. It was found that this condition was connected to a user’s overall stance with regards to a material. Creating a successful material impression should be the target of designers in their selection of product materials. Indeed, ‘tapping’ into user’s emotions and experiences in this way will result in successfully designed products.

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