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Sensory modalities and mental content in product experience

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Abstract

Contemporary research in human-technology interaction emphasises the need to focus on what people experience when they interact with technological artefacts. Understanding how people experience products requires detailed investigation of how physical design properties are mentally represented, and the theorisation of how people represent information obtained through different modalities still needs work. The objective of this study is to investigate how people experience modality-related affective aspects of products, using the psychological concept of mental content. For this purpose, we adopt the framework of user psychology, which is the sub-area of psychology involved with investigating cognitive processes implicated in human-technology interaction. In an experiment, $N = 36$ participants either looked at, touched, or both looked at and touched drinking glasses. The data was collected with thinking aloud protocols and analysed with inductive content analysis. Frequencies of key affects were observed to differ between the sensory modality groups. The differences are explained with the concepts of mental content. Different modalities involve differing content-based rules, which leads to variance in the feelings associated with the products. The theoretical framework and method utilised reveal the emotional values users associate with technologies, which can be used to inform experience driven design processes. The affective categories extracted in the study can be used in constructing evaluation frameworks, which in turn may serve as an effective tool for evaluation in the future. The method of experimentally separating modalities will also be useful when considering evaluation of products with emphasis on multiple modalities.

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1. Introduction

Environments and their objects are mentally represented by the people who interact in and with them. The concept of mental representation is therefore central in explaining human thought and behaviour. In human-technology interaction, such topics as user experience [3, 4, 5] and product experience, for example, can and should be discussed in terms of mental representation if the goal is to explain the experiences of people who interact with technological artefacts [6]. This paper discusses the theoretical and empirical level about applying the concept of mental representation in user experience research.

The application of such a psychological concept as mental representation for investigating theoretical and practical problems in human-technology interaction is part of the practice of user psychology [7, 8, 9]. User psychology provides a way of applying the concepts, methods, and theories of psychology to improve our understanding of human-technology interaction processes or human dimension of technology. The application of a hundred and fifty year long tradition of modern experimental psychology provides useful theoretical and methodological basis for the study of human-technology interaction topics.

Before the concept of mental representation can be applied in the context of human-technology interaction, its traditional formulations need to be addressed so that it can prove as a key conceptual tool in making psychological sense of interaction processes. Mental representations are always about some external states of affairs [10] and can entail cognitive and emotional information. They also have conscious and subconscious parts [6]. However, the most important property of mental representation is its information content. *Mental content* is an important conceptual part of mental representation in explaining why people behave as they do [8]. The difference between any two behaviours can be explained by analysing the differences in the contents of the thoughts of these people.

The objects are to people as they have been encoded in their minds. Representations are never exhaustive pictures of what the objects are but they are how individuals have encoded their sensations in their minds. Mental representations can entail such non-perceivable information of objects as facts about their history, the culture they have been produced or the myths around them. Thus, drinking glasses of Scandinavian style are often seen democratic compared to aristocratic mansion style. This kind of information, of course, cannot be seen in the objects themselves, but they are produced by cultural traditions.

One important aspect of mental content is that it unifies information from different sensory systems, such as visual and aural. Of course, our experience of technological objects with which we interact is based on multimodal information, and for this reason, it is important to investigate the role of different senses as well as the unification process itself in order to explain technology experience. In practical situations, people multimodally interact with technological artefacts. For example, when buying design objects, people tend to visually and tactually study them, such as is the case with drinking glasses. Our interactions with such everyday objects imply both seeing and touching. Therefore, it makes sense to ask how different sensory modalities contribute information to the contents of mental representations. What is the role of tactual and what is the role of visual information when people apperceive, i.e., construct the contents of their mental representations.

The basic question is the relationship between the modality of sensory information and the content of the representation. It is intuitively evident that colour information, for example, is visual and smoothness of surface is tactual. However, understanding what kinds of information contents has its origin in what kinds of sensory experiences. A simple way of operationalising the above questions can be established by limiting sensory experiences firstly to one modality comparing them and after that compare the situation with single modality input with the multimodal input. The actual analysis must be based on following content-based principles.

2. Method

2.1. Subjects, stimuli, and procedure

For the experiment, $N = 36$ university students recruited, 18 male and 18 female. The participants were divided into three groups, each with $n = 12$ participants (6 male and 6 female). The task of the first group was to inspect the stimuli visually, while the second group inspected the stimuli by touching, without seeing them. The third group was

allowed to both see and touch the stimuli. The task of the participants in all three groups was to describe their experiences by answering the following questions about the stimuli using thinking aloud [12].

- Describe freely the shape of the product.
- Evaluate the usability of the product.
- Evaluate the aesthetics of the product.
- What in the shape of the product do you find pleasant?
- What in the shape of the product do you find unpleasant?

The stimuli were four Scandinavian drinking glasses from Finnish design brand called Iittala (Aino Aalto, Kartio, Ote, and Grcic). Drinking glasses are a useful class of objects for studying everyday technologies [13]. In each group, the participants were presented all four drinking glasses in a counterbalanced order. The participants of the visual group were presented one drinking glass at a time on a table, and they were free to inspect it, but were not allowed to touch it. The participants of the tactile group were presented a ‘touch box’ – a cardboard box with a drinking glass inside, and were allowed to use their hands inside the box to investigate the glass (Figure 1). The eyes of the participants were also covered. The participants of the combined group were presented the drinking glasses on a table, and they were allowed to freely look at and touch the glasses.



Fig 1. The touch box.

2.2. Content analysis

Thinking aloud protocols were transcribed into textual format for the data analysing procedure. Data were analysed using content analysis [14]. The approach for the content analysis was data-driven because the focus was to detect the constructs from data through which participants describe the product experience. The analysis included four phases during which content categories were analysed from the data. During the first phase of the analysis, recording units were defined. Single words (such as attributes), phrases, and idioms that constituted semantic units for describing experiences of the drinking glass designs were recorded. In total, 2196 (visual group 642, tactile group 748, and combined group 806) semantic units were coded from the data. The second phase of the analysis was to critically evaluate the semantic units into initial categories. This classification phase of the coded semantic units resulted as 16 categories (form component, colour, size, pattern, texture, material, material durability, usability, user groups, context of use, emotion, sensation, aesthetic evaluations, desirability, associations, and value). In the third analysis phase, second level categorisation was conducted to construct higher-level categories from the initial categories.

The following four higher level categories were constructed during the content analysis. **Product form** category is seen as the description of the design of the product. It is constructed from sub-categories of *form component*, *colour*, *size*, *texture*, and *pattern*. The category can be described using the semantic units within its subcategories: form component (e.g., “wide”, “round”, “changing shape”, and “thick”), colour (e.g., “bright” and “not coloured”), size (e.g., “big”, “small”, “low”, and “fits the hand”), pattern (e.g., “stripes”, “rings”, and “no patterns”), and texture (e.g., “smooth”, “plane”, and “gradation”). **Product material** category expresses the experience about the material of the product. It includes two sub-categories: material (e.g., “glass” and “not plastic”) and material durability (e.g. “durable” and “fragile”). **Product purpose** category describes assumptions about the use of the product. It consists of sub-categories usability (e.g., “useful”, “good grip”, “working”, and “usable”), user groups (e.g., “good for a child”, “owned by an old person”, and “no children glass”), as well as context of use (e.g., “basic drinking glass”, “whiskey glass”, “suitable for drinking”). **Product affect** category outlines different affective responses about the product design. It consists of six sub-categories, emotion (e.g., “funny”, “surprising”, “nice”, “pleasant”, and “boring”), sensation (e.g., “weighty”, “light”, and “feels good to hold in hand”), aesthetic evaluations (e.g., “pretty”, “simple”, “clear”, “distinguished”, “beautiful”, and “minimalistic”), desirability (e.g., “desirable” and “would not want to purchase”), associations (e.g. “familiar”, “a can”, and “grandmother’s place”), and value (e.g., “good / great”, “fine”, and “bad”). In addition, some expressions in the aesthetic evaluations subcategory reflected the time period of the glass design. This subclass was also used to classify evaluations of professionalism of the glass design.

2.3. Frequency analysis

The frequency of semantic units within each category was counted for statistical analysis. The hypothesis that different interaction modes cause participants to use different number of words was tested using Kruskal-Wallis one-way analysis of variance. The test was conducted separately for each of the four content categories. Secondly, the hypothesis that the subcategories were used with different frequencies between the groups was tested using repeated measures analysis of variance. Four models, one for each category was constructed. The within-subject factor was the subcategory, and the between-group factor was the experimental group. The interaction effect between these two was tested to test the hypothesis. After the statistical analysis, further content-based analysis was conducted with an emphasis on the findings of the frequency-based analysis.

3. Results

The inspection of frequencies of semantic units in main categories and between the sensory modality groups showed that the product form category had the largest number of semantic units in every sensory modality group. In contrast, the fewest number of semantic units was found to be in the product material category. More detailed investigation of the frequencies of the semantic units showed that tactile group contained the largest number of semantic units related to Product form category, while semantic units related to Product material, Product purpose,

and Product affect category had the smallest number of observations. The combined group included the most semantic units related to Product material, Product purpose, and Product affect category. The frequencies of the semantic units in the four main content categories and their subcategories are presented in Table 1.

The mean number of words mentioned for each category between the three groups is displayed in Figure 2a. The hypothesis concerning different distributions of the categories between the groups was supported for the ‘form’ category, $K = 9.8$, $p = .007$. For other groups, the test was not statistically significant and the null hypothesis was retained. The interaction effect between the subcategories and the experimental group was statistically significant for the form category, $F(8,132) = 2.3$, $p = .022$, and not significant for the other three categories. The differences of the use frequencies of the form-related subcategories between the groups are shown in Figure 2b.

Table 1. Frequencies of the attributes within the categories and subcategories, by the experimental group.

Categories	Visual	Tactile	Combined
	c (%) / n	c (%) / n	c (%) / n
Product Form	261 (40.7%) / 12	413 / 12 (55.6%)	336 (41.7%) / 12
Form component	168 (64.4%) / 12	198 (47.9%) / 12	196 (58.3%) / 12
Colour	5 (1.9%) / 3	1 (0.2%) / 1	5 (1.5%) / 2
Size	68 (26.1%) / 11	148 (35.8%) / 12	94 (28.0%) / 11
Pattern	14 (5.4%) / 7	13 (3.1%) / 6	19 (5.7%) / 8
Texture	6 (2.3%) / 4	53 (12.8%) / 12	22 (6.5%) / 8
Product Material	7 (1.1%) / 6	5/2 (0.7%)	12 (1.5%) / 3
Material	2 (28.6%) / 2	3 (60.0%) / 1	5 (41.7%) / 3
Material durability	5 (71.4%) / 4	2 (40.0%) / 1	7 (58.3%) / 2
Product Purpose	116 (18.1%) / 12	86/12 (11.6%)	132 (16.4%) / 12
Usability	67 (57.8%) / 11	40 (46.5%) / 11	75 (56.8%) / 12
User groups	10 (8.6%) / 4	4 (4.7%) / 3	3 (2.3%) / 2
Context of use	39 (33.6%) / 9	42 (48.8%) / 12	54 (40.9%) / 11
Product Affect	258 (40.2%) / 12	244 / 12 (32.8%)	326 (40.4%) / 12
Emotion	48 (18.6%) / 12	49 (20.1%) / 10	51 (15.6%) / 11
Sensation	18 (7.0%) / 6	48 (19.7%) / 11	66 (20.2%) / 11
Aesthetic evaluation	140 (54.3%) / 12	100 (41.0%) / 12	145 (44.5%) / 12
Desirability	3 (1.2%) / 3	4 (1.6%) / 2	8 (2.5%) / 6
Associations	8 (3.1%) / 4	10 (4.1%) / 6	22 (6.7%) / 9
Value	41 (15.9%) / 9	33 (13.5%) / 9	34 (10.4%) / 10
	Total: 642	Total: 748	Total: 806

Note. $N = 12$. c = cases (total frequency), n = participants (frequency of participants).

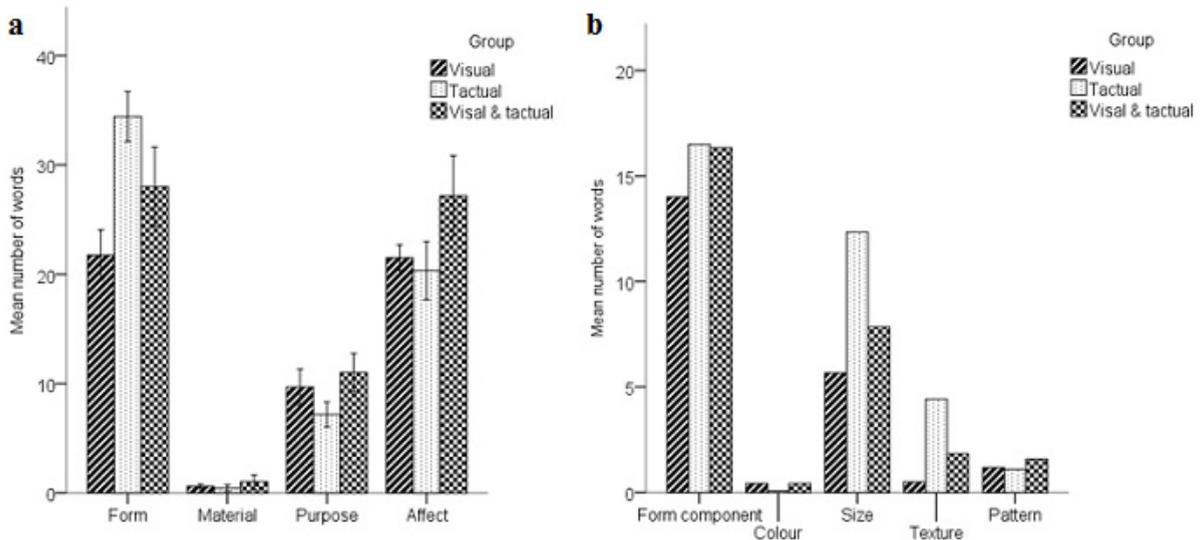


Fig. 2. (a) Mean number of words in the four content categories between the three experimental groups. The error bars indicate standard error. (b) Mean number of words used in the subcategories of the form category.

Although the frequency difference was statistically significant, in many of the product form subcategories, there were no content differences between the groups. For example, in all experimental groups, expressions of form component were found to be similar. References to, for example thickness, broadness, and geometric shapes (e.g., “cone”) were observed in all groups, and all participants of each group ($n = 12$) used words of this category. However, there were some subcategory content differences. For example, expressions of size differed between the groups: while the participants of the tactual ($n = 7$) and combined groups reflected how well the glass can be held, the visual group did not ($n = 1$). In the texture subcategory, the participants of visual group did not express contents related to the smoothness of the surface ($n = 1$), while in the other two groups in which the participants could touch the glasses, there were such expressions (tactual $n = 10$; combined $n = 7$).

The statistical analysis did not reveal frequency differences in the material category. In line with this, there were no content differences either. Participants of all groups reflected similarly the material of the stimuli. In the purpose category, although there was no statistically significant difference between the frequencies of the expressions of this category, there were some content differences. For example, reflecting the usability, the visual ($n = 7$) and the combined group ($n = 9$) had more expressions than the tactual group ($n = 2$). In other words, visual information was used to make inferences concerning the usability of the products. However, the expressions of other subcategories of purpose did not differ from each other between the groups. Thus, the small observable gap of the number of words for the tactual group visible in Figure 2 in the purpose category is explained by expressions of usability. Likewise, in the affect category, there was no statistically significant difference in the number of expressions between the groups, but some subcategory observations were made. For example, the participants of the tactual ($n = 5$) and combined groups ($n = 6$) reflected the familiarity of the glasses, while the participants of the visual group did not ($n = 0$).

4. Discussion

The experiment reported here was designed to study how people utilise different sensory channels to create sensible mental representations about everyday objects. The general result is that except for few exceptions, the mental content is not dependent on the sensory modality. This is because the unification of the raw data into actual experience occurs via the process of apperception [15], which restructures the raw sensory data into sensible contents of thought. Obviously, there are differences in the content of a mental representation depending on the sensory information. However, at least when people represent everyday objects, the contents are not specific on the

sensory channel, because they already have content-specific rules for representing these objects. The mind transforms raw sensory data into sensible contents. The results indicate that the unification process is not channel dependent, and product experiences are enriched through representations of non-perceivable semantic units.

Apperception constructs the contents of mental representations. It collects information from different sensory modalities creating the representation of the object, that is, how people perceptually represent the product. Form and colour expressions, such as round, small, or bright, indicate this. Apperception also integrates to mental representations non-perceivable information. Uses and purposes of objects, which are not used at the moment of interaction, are typical examples of such non-perceivable types of mental contents. Finally, affective expressions imply that apperception unifies emotional dimensions of mental contents through one of its most vital processes called *appraisal* [16, 17]. The results of the study reported here indicate that the emotion process, which is important in studying user and product experience, is unified in the mind's apperceptive process, which has theoretical and methodological implications for all studies of experience in human-technology interaction.

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