A Study on Designer's Mental Process of Information Categorization in the Early Stages of Design

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Abstract This research explores how designers mentally categorize design information during early sketching in the early stages of design. With the purpose of identifying various types of mental information and related cognitive operations, the empirical study has been conducted with 8 experienced product designers through the concurrent verbalization. The qualitative and quantitative analysis of the results is also presented. The concrete examples about mental information are defined in terms of 3 levels *(high, middle, low)* and 10 categories *(semantic words(Hs), values(Hv), analogy(Ha), style(Hy), sector name(Ms), context(Mc), function(Mf), colour(Lc), form(Lf) and texture(Lt)).* Finally the results showed that there are also three cognitive operations between working memory and long term memory: memory retrieval, association and transformation in order to generate early sketches.

Key words: Designer, Mental process, Information Categorization.

1. Introduction

Designers employ various levels of information in the early stages of design. Some information can be explicit such as collection of precedents in the form of product samples, product catalogues , pictures, slides, sketches etc.[8,22,27]; however, most information used in the early stages of design is implicit and abstract.

According to the work done by Bouchard et al.(2003), designer's information processing in the early stages of design can be described as an information cycle which includes informative, generative and decision-making phases (evaluation-selection) whose outcomes are intermediate representations (IRs) and iterates evolutionarily.

Since the early stages of design are considered as some of the most cognitively intensive stages in the whole design process, several research has been centered on designer's sketching activity, especially in the generative phase which is based on interior design and architecture design [3,10,18,30,32]. To date, there has been few research which has addressed the issues of designer's inspirational sources in the informative phase [8,22,29], ane moreover research on the bridge between the informative and earliest generative phase has been relatively neglected and not being treated specifically for product designers.

The generative phase consists of the generation of new ideas and new solutions. It begins by numerous mental images, memorized design brief and other information that comes from any design precedent project [5]. This phase is recognized as designer's individual process in repeating cognitive activities [21]. Here designers gradually categorize and synthesize their mental information in order to achieve design solution [23]. During the earliest generative phase, some parts of mental images can be externalized in early sketching. This early sketching is not mature to be shared, interpreted or used by other people. It can be served as an external representation, i.e. external memory, in which to leave ideas as visual tokens for later inspection [28,32]. External representations (e.g. early sketches) allow a reflexive conversation between the designer and the product to be created [28,30]. Previous studies showed that external representations allow designers to identify errors and to generate new ideas (e.g. Akin [1]). Consequently, we focus on designer's mental process of information categorization during early sketching in the earliest generative phase, which we call 'information categorization process'. More precisely, our goal is to determine what kind of the mental information is extracted and how this can be transformed or categorized during early sketching. To answer these questions, we led an empirical study with product designers in which they had to think aloud while sketching. We apply our own code scheme for extracting designer's mental information from video and audio protocols. Finally a subsequent protocol analysis allowed us to provide a concrete view of the 'information categorization process'.

2. Method: An empirical study

Verbalization and its subsequently protocol analysis have become the most experimental technique used in design research for capturing, understanding and analyzing of design thinking [2,10,11,17]. Generally two types of verbalization approaches have been used: concurrent and retrospective. During *concurrent* verbalizations, designers are instructed to design and simultaneously think aloud. This method points out detail sequences of information process reflecting the designer's working memory (WM); therefore it has been utilized to reveal the process-oriented aspects of designing [13,15]. Although, skeptical researchers claim that concurrent protocols hinder the nature of design process and cause incompleteness in revealing the design process [12,25]. In contrast, *retrospective* protocols have been used in experimentations which focus on the aspect of cognitive content because it could retrieve the trace of the cognitive process and reveal information partially in both WM and LTM. However this retrospective way may also cause insufficient and reinterpreted information due to the decay of LTM. More recently, Gero and Tang [17] showed that concurrent and retrospective verbalization protocols have very similar outcome in case of the process-oriented aspects of designing. As a result it is still unclear which approach is suit for certain protocol study, and therefore researchers choose one or other methodology depending on their goals.

Considering that our study focuses on design information and its related cognitive action, concurrent verbalization method fit well for our study. Semi-directive interview was also done to compensate the deficiency of the concurrent protocol at the end of the experiment. Following the work done by Lindlof and Taylor [24], the interviewer provides various questions in order to obtain the responses by using the designer's generated sketches as a clue and then repeated broad and open ended questions until the interviewer could gather the valuable answers, for example, 'What did you think when you received the design brief?', 'Tell me more about your thinking on that' or 'What is that?' etc.

2.1 Design of the protocol study

2.1.1Participants and Equipment

We recruited 2 third year undergraduate design students (D#4,D#6) and 6 expert product designers (one female and seven males). Among the six expert designers, the mean regarding years of experience is 9 years (M= 9 years, SD= 8.85). But taking out the designer (D#5) who has been working in product design for 28 years, thus the real mean of the sample is 5.2 years of professional experiences (M= 5.2 years, SD= 2.13). The experimentation was set up in their design agency in order to not change their natural working environment. As shown in Figure 1, we used two video cameras and one voice recorder for collecting the participant's verbalization. One of the video camera captured the movements of the hands of the designers and made a close-up of the sketches; and the second one recorded the designer as a whole.

Figure 1. Position of the equipment

2.1.2 Procedure

This study consisted of 3 phases: warm-up exercises, concurrent verbalizations and semi-directive interview. Warm-up phase (phase 1) lasted for about 15 minutes in which we explained the procedure of experiment and participants were used to the environment of concurrent verbalization. In the phase 2 - concurrent verbalization, the participants were asked to work on the design brief *'Designing Nike vacuum cleaner'*. They started to generate early sketches with the usual traditional tools and verbalized their thought simultaneously for around 1hour. At the end, a semi-directive interview (phase 3) was conducted. Generally, these three phases took about 1hour and 15 mins.

2.2 Protocol Analysis Coding Scheme

2.1.2 Procedure

The verbalizations were transcribed for coding and then the written transcriptions were attached to each related video intervals. Video analysis software 'INTERACT' [19] was used for reducing the time-consuming process and gathering reliable quantitative results. Most previous protocol analysis methods were used to divide the entire verbal protocols into small units, namely segmentation (also called segment), and then coded them in using their own suitable coding scheme [18,32]. In our study, specifically the verbal protocol was coded based on each single keyword in order to identify the type of designer's mental information and its transformation. Videotaped sketches were also used to complete and verify more accurately verbalized contents. Our coding scheme, listed in Table 1, is largely based on our previous work about Kansei words [7,9,33]. The level of information can be seen as the position of the considered information on an axis going from abstract (high level information) to concrete (low level information). In the same way, the aesthetic aspect entailed harmony rules that were applied between colour, texture and shape [9].

Table 1. Coding scheme of design information (developed from the list of Kansei words [7,9,33])

Level	Category	Code	Description	Examples
High level (H)	Values	Hv	These words represent final or behavioral values	Security, Well-being
	Semantic words	Hs	Often adjectives related to colour, form, or texture but also impressive words in the field of Kansei Engineering	Playful, romantic, Aggressive
	Analogy	Ha	Objects in other sectors with features to integrate in the reference sector	Rabbit→Speed
	Style	Hy	Characterization of all levels together through a specific style	Edge Design, Classic
Middle level (M)	Sector name	Ms	Object names describing one sector or sub sector being representative for expressing a particular trend	Sports
	Context	Mc	User social context	Leisure with Family
	Function	Mf	Function, usage, component, operation	Modularity
Low level (L)	Colour	Lc	Chromatic properties using qualitative or quantitative	Yellow, Light blue
	Form	Lf	Overall shape or component shape, size	Square, Wavy
	Texture	Lt	Patterns (abstract or figurative) and texture	Plastic, metallic

3. Results analysis

3.1 Idea categorization map

In order to examine what kind of mental information is extracted and how this information can be transformed or categorized during early sketching, *Idea categorization map* is presented in Figure 2. It is composed of verbalized keywords and external representations (e.g. early sketches).

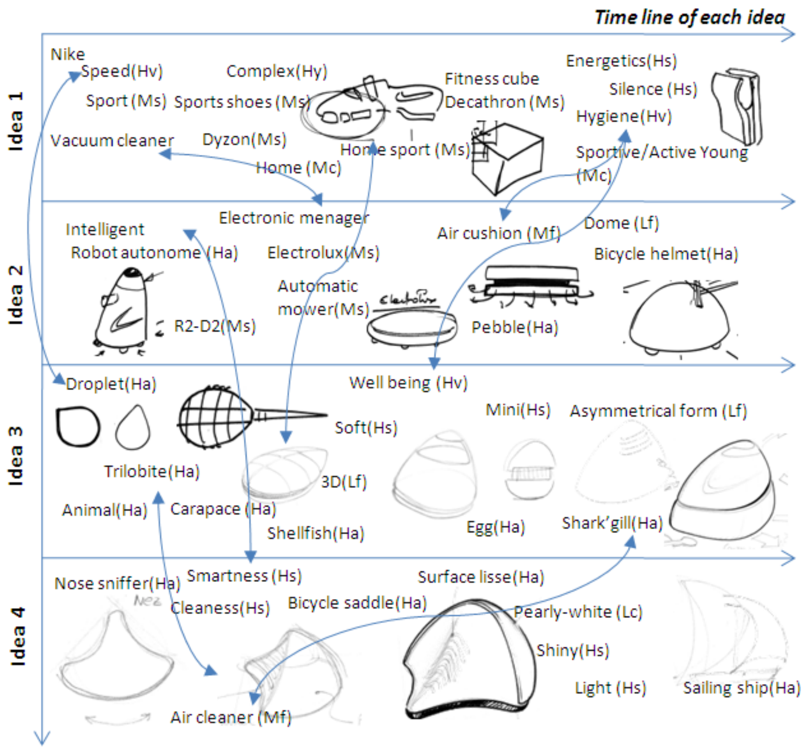


Figure 2. Idea categorization map based on Designer #5's work

Axis X represents the timeline of each idea in which we can observe the transformation of designer's mental synthesis into a single idea. Axis Y represents the global timeline during the task in which the categorization of information retrieved and transformed a previous idea. The arrows show the sequence that designers followed in developing the sketches.

Once the participants had read the given design brief *'Designing Nike vacuum cleaner'*, idea 1, the designer #5 started retrieving information from his memory and verbalizing it "I need to try to understand what a vacuum cleaner is", "Nike is a sport" etc. The combination of the related sector name became an idea of 'home sport'. At this moment some adjectives appeared in designer's mind such as energetic, speed, etc. and also some verbs and nouns to describe his mental representation. Designer also set the expected context such as 'for sportive and active young' and value 'hygiene'. In idea 2, as vacuum cleaner is a sort of electronic manager (revisited idea 1), amongst the electronic managers designer retrieves an 'automatic mower' and relates it to form of 'a pebble' by a chain of mental image. Next, in combining the product value 'intelligence', the source idea is transformed into a 'total automatic intelligent robot'. Then, this idea is shaped like a 'dome' and 'bicycle helmet' due to the similarity of the form. In idea 3, designer is interested in the form of droplet to represent how fast/speedy (Hv) Nike sports shoes are (revisited Idea1). During analogy making, interesting elements move from animal, trilobite to shellfish in relation to the formal attributes. Then, the previous value 'hygiene' (revisited idea1) is associated with emerging value 'well-being' that led him to draw new attributes: 'mini' like 'eggs'. Finally, the idea was arrived to an asymmetrical visual form (idea3). In idea 4, designer rearranged and reassembled previous elements 'trilobite' and 'animal' (idea3) to make interesting idea in joining the semantic words 'smartness' and 'cleanness'. It becomes associated with low level attribute such as colour and texture, for example smooth surface, shiny, pearly-white etc.

These findings have two implications: First, information categorization process contains three distinct cognitive operations: memory retrieval, association and transformation as Geneplore model [16] partially mentioned; second, as the continuity and discontinuity of ideas is observed, we can assume that there are a certain complex cognitive operations influencing designers. Further discussions will be shown in part 4.

3.2 Quantitative analysis

The verbalized keywords have been counted based on the present coding scheme (Table 1) into 3 levels (*high, middle, low)* and 10 categories of the design information *: analogy(Ha), semantic words(Hs), values (Hv), style(Hy), sector name (Ms), context (Mc), function(Mf), colour(Lc), form(Lf), texture(Lt).* Figure 3 shows the percentages of occurrences of each level of design information.

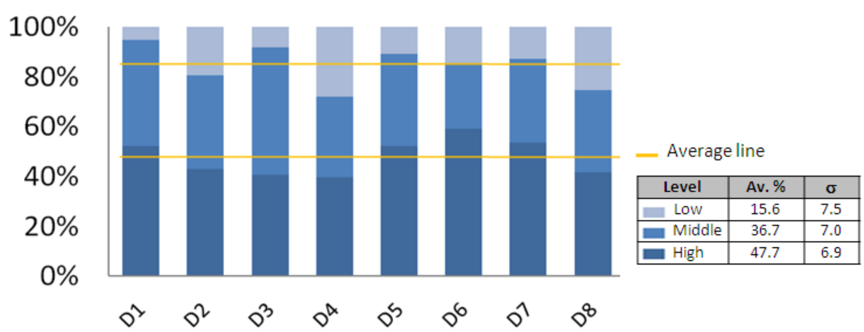
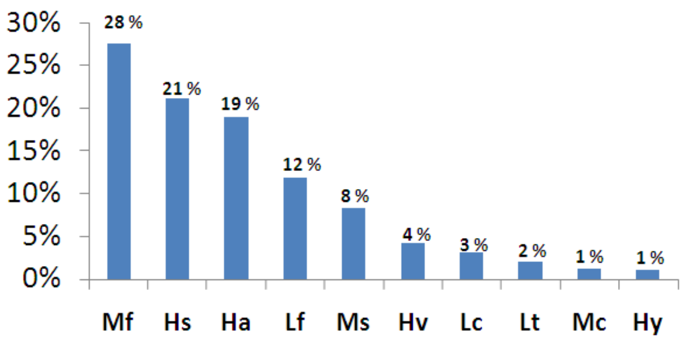


Figure 3 Percentages of occurrences of each level of design information

On average, *high level information* covers 47.69% (SD=6.91) of the total design information, *middle level information* 36.70% (SD= 6.96), while *low level information* 15.61% (SD= 7.54). Hence, *high* and *middle level information* cover 84.39% of verbalized words during early sketching. In case of *low level information,* even though the number of verbalized words is relatively less than *high and middle level information*, designers tend to express more often the *low level information* in their sketches. The details occurrence percentage of each category is presented in Figure 4. The first category is related to *function* (28%) that consists of some parts of the internal mechanics, units, usage and operations, such as 'fan', 'dust bag', 'air-cushion' etc. The second category concerns *semantic words* (21%) often including semantic adjectives related to colour and form such as 'sportive', 'dynamic', 'organic' etc. The third category concerns *analogy* (19%), which includes objects from other sectors that could be integrated in the reference sector such as nature, fashion, architecture etc. It is also used 'metaphor' which allows visual translation or transformation like morphing to adapt to the target domain. The results show that various analogies words had been appeared from extinct animals, trilobite to mp3. The forth category includes *form* descriptions (12%) such as shapes and silhouettes. Usually when designers are drawing, *form* descriptions are directly linked in. Furthermore, another 6 categories were measured: s*ector name* (8%), *value* (4%), *colour* (3%), *texture* (2%), *context* (1%) and *style* (8%) were followed.



Level	Category	Code
High level	Values	Hv
	Semantic words	Hs
	Analogy	Ha
	Style	Hy
Middle level	Sector name	Ms
	Context	Mc
	Function	Mf
Low level	Colour	Lc
	Form	Lf
	Texture	Lt

Figure 4 Occurrence percentages of categories

4. Discussions

4.1 Discussion of the results: *Information Categorization*

From protocol study, the results showed that eight designers naturally transformed and categorized different kind of levels and categories of design information during early sketching in generative phase. Specifically, designers employed these various levels of information in reducing abstraction through the integration of more and more constraints [4 ,8]. Supporting our previous work in modelling designer's informative phase [8], information categorization might be processed in using the attributes from low level such as from, colour and texture to high level descriptors. The high level descriptors are often semantic adjectives, but other grammatical forms were also possible as like the words used in Kansei dimensions such as semantic, sensorial, emotional context and product attributes [31].

As Figure 3 shows, the portion of use of information level is quite similar amongst the designers (*high level* > *middle level* >> *low level*). Considering that the use of *high level information* to link words with images and vice-versa imposed a much greater cognitive load than *low level attributes* [27], designers were able to naturally use *high level information*, especially *semantic words (Hs)* and *analogy (Hf).* According to the occurrence percentage of categories of design information (Figure 4), the most used categories, on average, were *function (Mf), semantic words (Hs). analogy (Hf)* and *form (Lf).* Unlikely, s*tyle (Hy)*, c*ontext (*Mc), *texture (Lt)* and *colour (Lc)* are relatively less verbalized. We discovered that diverse tendencies in using keywords also exist among designers due to the ages, sex and work experience etc. Since the participants were all French, the variables about cultural influence were not taken into account. However, cultural differences in the way of using design information could be a potential interesting point.

4.2 Methodological considerations

Effect of 'think-aloud' method

Some might question whether designer's mental process might be inferred with concurrent verbalization and/or the production of sketching could be retarded due to the pressure of think-aloud. In order to minimize uncertainty variable, a pilot test with three participants was conducted. All participants were asked to 'think-aloud' while designing for the first time. Even though some participants had doubted about whether this method is feasible or not, after the test the responses were positive. Similar observations were also taken by Gero and Tang [17] and Bilda [2]. In terms of production of sketches, we could not find significant differences between concurrent verbalization and non verbalization. Meanwhile, we observed that some designers could easily express their thought but others had more difficulties. In our experiment, designers verbalized 2 words per minute on average, but the variability amongst the designers was relatively high (Highest: 3.3 words/min, Lowest: 1.0 words/min) due to the inter-individual differences. As a result, data analysis was presented in percentages, especially tendency and the proportion of generated keywords which is of particular interest for our study in order to better understand designer's mental process underlying the categorization of information.

Reliance on designer's single mind alone

There are two concerns regarding the reliance on designer's single mind alone. The first concern is that designers were asked to sketch without using external resources such as product catalogues, pictures etc., even though the information process in the traditional design is a crucial part of the design process [6]. Because sources of inspiration and references are an essential base in design thinking, as definition of context, triggers for idea generation and anchors for structuring designer's mental representations of designing [14]. Since the aim of experiment is to understand designer's mental process of information categorization in the generative phase, the experimental condition specifically focused on questions about what kind of mental information is extracted from their memory-only and how this information could be transformed or categorized during early sketching. Few expert designers and especially novice designers expressed their needs to search existing products in the beginning of the experimentation, or when their idea flow was blocked. However, after they started to concentrate ideas started to flow and we observed that they adapted well to the experiment conditions. The reporting results also show the use of various and rich information without external sources in terms of *function (Mf), semantic words (Hs)* and *analogy (Ha)* (See figure 4).

The second concern is the external stimulation during experimentation. As noted above, it was necessary to give the participants environmental support to easily concentrate on the task to be performed only in use of their mind/memory, whereby the experimentation was set up in their design agency in order to minimize uncertainty variable/external stimulation during experimentation. Nevertheless we observed the continuity and discontinuity of the flow of idea during experimentation. At that moment designers tended to stop sketching and verbalizing and look around in order to distract their attentions. Designers might be stimulated by certain objects of the environment, and evidence is shown in their verbalization. For example, once one designer (D#8) watched the bicycle wheel in the experimental room, he sketched an object which was in 'form' to a bicycle and the verbalization was: *'I had seen the mini- sports shoes on the bicycle wheel in the show window'*.

5. Conclusion

In this study, we explored how designers mentally categorize information during the early sketching. An empirical study with 'think-aloud' and subsequent protocol analysis was conducted with eight experienced product designers. Data from protocol studies have been used to verify and enhance our previous descriptive model of information processing to generate ideas [23]. The results show concrete examples about mental information and also suggest three distinctive cognitive operations: memory retrieval, association and transformation during sketching which is linked to working memory (WM) and long-term memory (LTM).

For further research, the results of protocol study will serve as specification to develop software tools to support designer's cognitive activities, specifically 'information categorization mental process'. Up until now a design support tool in the early stages of design that contains intensive designer's cognitive process and implicit representations is still undeveloped [5,26]. Also software tools are not widely spread into designer's work space [29], even though those are composed of enormous and rich information which might enrich a software tool. On the other hand, in this study, we did not conduct any assessment session about the design outcome. We will conduct a further study in order to evaluate and judge the design outcome by expert designers who did not participate in our experiment. The interesting criteria will be creativity and how well the sketched design satisfies the design brief in terms of design solution. Finally, further research will try to identify the co-action between emotion and cognition. According to Isen [20], 'affection' could be perceived as facilitator effect on the perception of aspects and quality of artifact, and emotions could also modify the creative performance of designers, because cognitive flexibility is involved in creativity.

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