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How do Designers Categorize Information in the Generation Phase of the Creative Process?

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Abstract
In this paper, firstly we provide a wide range of literature review on designer's cognitive activity in order to bridge informative and generative phase in the early stages of design. In the generation phase of the creative process, designers use various levels of information and execute internal processing. We found that some of this internal processing (especially in encoding, storage and recall) can be described as information categorisation. In this respect, we propose a descriptive model of information processing to generate ideas by integrating a model from cognitive psychology. We conclude by discussing the limitations of current research and perspectives for further work.

Keywords:
Categorisation, information, design

1 INTRODUCTION

According to Jones (1970) [1], the designer has been described as a 'black box' because it was thought that designers generated a creative solution without being able to explain or illustrate how the solutions came out. Since the 1980s, the paradigm of 'design as a discipline' has led to a vigorous discussion on the view that design has its own things to know and its own ways of knowing them [2]. While in the past the design research community has focused on the former (related to products), nowadays the growth of interest is the analysis of designers' cognitive activities [3]-[11]. This interest has become a major interdisciplinary topic not only in design science, but also in psychology, computer science and artificial intelligence. Especially as the early stages of design are considered some of the most cognitively intensive stages in the whole design process [12], it is necessary to invest much more research in the early stages of design.

The early stages of the design process used to be characterized by information processing and idea generation (also called 'conceptualization') [5, 9]. In the early stages of the design process, designers use various levels of information in reducing abstraction through the integration of more and more constraints [6, 13]. In this respect the designer's cognitive activity has been considered to be an information processing activity.

This information processing activity can be described as an information cycle. An information cycle includes informative, generative and decision-making phases (evaluation-selection) whose outcome is an intermediate representation and also evolutionarily iterates (See Figure 1) [5, 14].

Insofar as much design research depends on findings from empirical studies [15], the dominant research interest was specific activities such as 'what and where' designers retrieve and collect inspirational sources and 'how' they represent their ideas using physical representations, such as in sketching activities [16]. Therefore, the results of these studies relatively neglected the use of implicit information and its internal processing which can bridge between informative and generative phases in the early stages of design.

These uncertain phases are in accordance with the question about creativity. According to well-known Walla's (1926) [17] four- stage model of the creative process – preparation – incubation – illumination – verification, the middle phases of how designers incubate information and how come they attain creative insight still remain incomplete as regards design in practice [18, 19]. In Howard's study [20, 21] on the comparison between the 'engineering design process' and the 'creative design process', the 'creative process' was defined as 'a cognitive process culminating in the generation of an idea. In this respect, it is supposed that cognitive studies as a creative approach bring insights to understand some uncertain phases as we mentioned above.

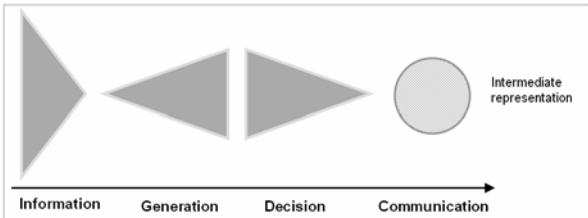

Figure 1: Description of an informational cycle [5]

In this paper, firstly we provide the state of the art on the study of designers' cognitive activities (Part 2) and also take into account a worldwide study about computational support for designer's activity through a wide range of literature review (Part 3). In part 4, we will provide a descriptive model of information processing to generate ideas by integrating a model from cognitive psychology.

Finally we discuss the limitations of current research and perspectives for further work (Part 5).

2 LITERATURE REVIEW ON DESIGNERS' COGNITIVE ACTIVITIES

The design information can be divided into external information, such as visual sources conveyed by photos and images; and mental representations of design [16]. The former comes from designers collecting inspirational information and the latter can be structured by cognitive mechanisms [3, 22, 23, 45]. Inspirational information is an essential base in design thinking and for other alternatives and even for other completely different ideas [3, 24].

However, as we mentioned above (in part1), insofar as much design research depends on specific activities from empirical studies, the link between the external information and representation in sketching and drawing is well established [15]. By contrast the importance of the use mental representations in the design was relatively neglected.

Currently, there are some pioneers who have stressed the necessity of defining internal processing and the important role of non explicit information. Restrepo[25] found in his empirical study that designers sometimes completely ignore other external information sources when they develop ideas, i.e they can generate ideas without the aid of external representations as the images sources. Recently Bilda's work [26] has shown quantitative results to show that the use of imagery alone supported idea development as well as sketching did. This way, even though there are still some questions about the different purpose and efficiency for the use of various levels of design information to generate ideas, we believe that both external and internal information evolutionarily interact with each other to generate ideas and that designers integrate various levels of information which will be gradually visually categorized and synthesized into design solutions [6]. This specific activity will be called 'Information categorization' in this paper.

To understand this internal processing, the authors intend to identify each cognitive action between the informative and generative phases. These 5 cognitive actions are Stimuli, Encoding, Storage, Retrieval (Recall, Recognition) and Externalization. These were chosen based on a human information processing model in cognitive psychology [27, 28].

Table 1 shows the list of key research concerning designers' cognitive activities to bridge informative and generative phases by classifying their research according to the 5 cognitive actions and the type of design information (External/Internal) as we defined above.

The most interesting finding in table 1, compared with the sequence of information processing model (Encoding –> Storage → Retrieval), is that designers operate information less systematically.

External information helps designers to structure mental representations of design ideas.

Phase		Cognitive action	Aims of research	Concerned discipline	Source
Informative	External information	Stimuli	The importance of source of inspiration for idea generation in design process	Design science	[3]
		Stimuli	Designer's collecting information behavior to solve design problem	Design science	[25]
	Internal information	Storage	Modeling of recollecting memory in creation process	Cognitive science Kansei eng.	[23]
		Encoding	Comparison level of Kansei preference with based on 'Kodawari' method between designers and non-designers	Psychology, Kansei Eng.	[30]
		Storage	Structuring knowledge establishing rules through the Values-Function-Solutions chain	Design Science, Cognitive science	[6,14]
		Storage	Use of visual analogy between expert and novice designer	Psychology, Architecture	[31,32]
Generative	Mental representation (Imagery)	Recognition /Recall	Comparisons of the different types and content of visualization in concept design	Cognitive science Marketing	[33]
		Recognition	The use of existing aids (information) to enhance creative thinking	AI, Creativity	[34]
		Recall	Intensive literature review to understand the role of imagery	Architecture,	[22]
		Recall	Comparison of the use of imaginary alone and sketching during conceptualization	Architecture	[26,35]
	External representation (Sketching)	Externalization	Sketching activities as a medium of visual thinking and study on the link between sketching and imagery	Creativity, Architecture	[24,36, 37]
		Stimuli	Modeling of the situated Function-Behaviour-Structure(FBS) framework	AI, Creativity	[38]
		Stimuli	Protocol analysis : why the freehand sketches as external representation are essential for crystallizing design ideas	Cognitive science, Architecture	[39]

Table 1: Key research concerning designer's cognitive activity in the early stages of design

These structured mental representations are reused for generating other refined ideas which can re-stimulate further ideas under externalised form, like as, diagram, sketching etc. and be stored under the type of internal information for being potentially evocated in other design context [29].

This goes largely over their professional designers' activities. Specifically, modeling the mechanism in its entirety, from internal information in the informative phase to mental representation in the generative phase, bring us valuable clues to explain the activity of "information categorization". It was concurred that, this stage of work, although essential, has been concealed. This finding will be provided with a descriptive model in part 4.

3 CURRENT COMPUTATIONAL SUPPORTS ON DESIGNERS' ACTIVITIES

Nowadays, with the penetration of Information Technology (IT), there is a growing trend in using computational tools and internet centered on designers' activities. Designers tend to build their digital databases of design, increasingly giving them more and more importance within their activities [7, 8, 11]. In this respect, computational support encompassing the design process is very important.

However, as shown in Figure.2, the evolution of the computational support has been developed in reversed order of the design process. In contrast to later stages of execution phases which are primarily involved in prototyping technology like CAM (Computer-aided Manufacturing), CAD (Computer aided Design), CAS (Computer-aided Styling), computational support to help idea generation and to explore designer's creativity in the early stages of design (conceptualisation) are relatively undeveloped [5].

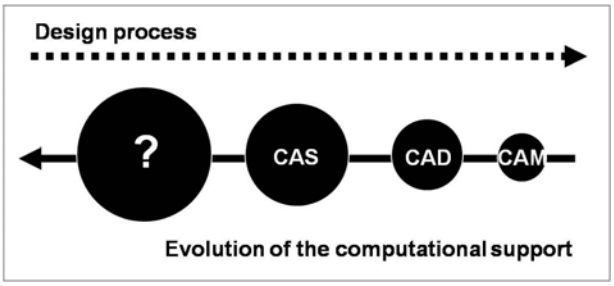

Figure 2: Evolution of the computational support (Developed model [16])

Even though commercial image retrieval websites, for instance, 'Google', 'Getty images' and 'Flicker' etc. allow designers to easily get a bunch of information, but retrieving external sources from the web is laborious and inadequate in order to become inspirational sources for designers. Moreover, given the growing size of databases, structuring the design information is increasingly difficult [16]. Also these tools cannot integrate the internal sources which are generated through the cognitive mechanisms.

In order to develop the computational tool to support designers' cognitive activities in the early stages of design, it is very important to understand designers' cognitive activities and study to formalize the cognitive design process with the extraction of design knowledge, rules and skills [6]. Also, based on the theoretical account for cognitive psychology, we need to translate design rules into design algorithms in order to develop computational tools.

4 DESCRIPTIVE MODEL: HOW DESIGNERS CATEGORIZE INFORMATION?

Having reviewed the literature in part 2, a descriptive model of information processing to generate ideas is proposed as a linkage between internal process and external process encompassing between informative and generative phases. This model was largely based on the study of memory in cognitive psychology, especially from the work of Atkinson and Shiffrin[27] which is labelled the 'stage theory'.

Our descriptive model of information processing to generate ideas well explains the use of various levels of information between the informative and generative phases.

Especially because the authors are interested in information categorisation as the internal processing, we found the strong similar mechanism of information categorisation linked to long-term memory (LTM) like designers did in design practice.

In design practice, even though the purpose on information categorisation might be different depending on the context of application, the information categorisation activity provides an unique opportunity to see how the designer's needs for information are shaped by the information already accessed [7]. Also it is very specific inasmuch it includes the ability to diverge and to generate new categories and to converge and classify image resources to fit in existing categories at once.

Moreover, in observing designers' activities, we could find that designers try to discover a 'new' or 'previously hidden' association between a certain piece of information and what they want to design [34].

In detail, information categorization is based on the use of attributes from low levels such as formal, chromatic and textural to high levels descriptors - semantic adjectives, for instance, 'warm colours' to represent colours from the red series. The use of semantic adjectives to link words with images and vice-versa impose a much greater cognitive load than low level attributes [40].

Similarly to our descriptive model from psychology (see figure 3), 3 marked cognitive actions - Encoding, Storage, Recall which are linked to LTM strongly related to the cognitive mechanisms of information categorisation.

The definition of three cognitive actions in cognitive psychology is following [27, 28].

– **Encoding,** The conversion of incoming information into a form that can be stored in memory.

– **Storage,** Retaining information in memory over time.

– **Recall,** Information reproduced from memory can be assisted by cues e.g. categories , Imagery

According to the agreed theory about LTM, if the information is transferred from short-term memory (STM) to LTM, information should be encoded in a type of chunk to enter into LTM. Then LTM stored information in associative network with nodes and links. A node may contain concepts, words, images, or any other information, and link is an association between 2 nodes [27, 28, 41]. Then categorised information in LTM can be retrieved through reproducing new information, this process is called 'recall'.

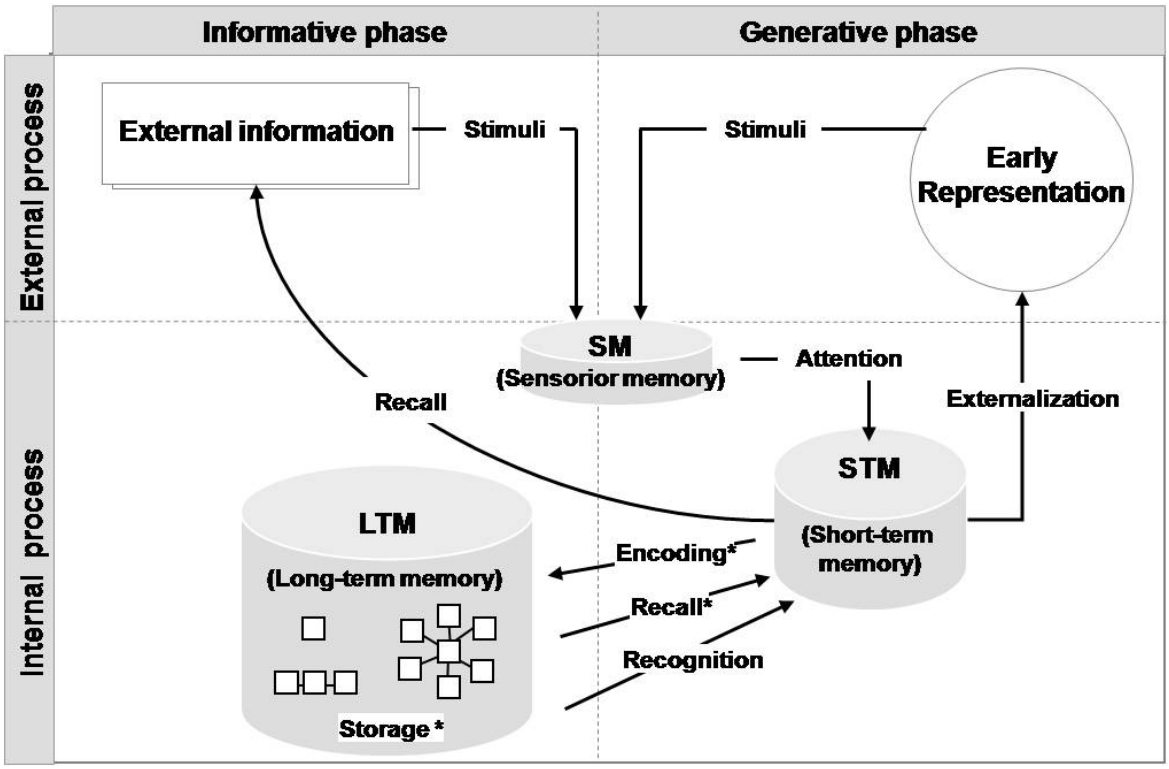

Figure 3: Descriptive model of information processing to generate ideas

5 DISCUSSION

In the generation phase of the creative process, designers use various levels of information and internal processing. Both external and internal types of information interact with each other in generating ideas. Designers integrate many categories of information that will be gradually categorized and synthesized into design solutions [6].

These implicit activities between informative and generative phase can be described as information categorization. So, in part 4, a descriptive model of information processing to generate ideas was suggested. Specifically three cognitive actions– encoding, storage, and recall were founded as the possible clues to explain the cognitive mechanism of the information categorisation. These 3 cognitive actions can also serve as a starting point for future experimental studies close to designers.

According to further development of computational tools for information categorization, the computational tools in the early stages of the design process should allow designers to easily communicate with others designers and professionals involved in the early collaborative design process [6, 45]. Specifically, the need for computational support on the 'information categorization' phase was raised in this paper.

The limitations emerged of current research are two.

One might come from the ambiguity of the process that stems from the fact that the information categorization is mostly mental and is a subjective task [8, 42, 43]. Even though in this paper, we found out possible cognitive mechanisms which are related to information categorization as we discussed above.

The other limitation is the holistic nature of design information including multidimensional data. In design practice, when designers meet design information, they are naturally familiar with using the various levels of descriptors to characterize it, from high-level descriptors (sociological vales, abstract semantics), to middle level (style) and low-level ones (colour, shape, texture) [6].

Especially the high-level descriptor is also used for a source of creativity because it contains strongly the designers' personal sensibility and ability to diverge design ideas.

So, it could bring the problem of a semantic gap between designers' subjective descriptors and digitalized/ generalized ones which are translated into a computer algorithm [44].

6 CONCLUSION

The question of 'How do designers categorize information in the generation phase of the creative process?' was raised in this paper.

A wide range of literature related to the designers' cognitive activities and computational support encompassing between informative and generative phases in the early stages of the design process has been reviewed. A descriptive model which has the interesting clues in order to answer our question was also provided.

In the early stages of the design process, one of most interesting property is that the iterative process in diverging or converging ideas to arrive one design solution. Especially our research point was to link between informative and generative phases, which are the passage from divergence phase to convergence phase. It is described as a quiet internal process and the use of lots of implicit information. So, it is necessary to understand designers' cognitive activities with interacting with the work from other disciplines for example cognitive psychology. Our descriptive model of information processing to generate ideas can be benefited from this enlarged approach.

In the industrial context, as the customers/users expect a variety of the new product in short time, the market and designers are willing to formalize the earliest design process and improve the computational tool to shorten the duration in the early stages of the design process which are relatively undeveloped.

In this respect, the analysis of designers' cognitive activities and computational support are recognized as a major interdisciplinary topic not only in design science, but also in cognitive psychology, computer science and artificial intelligences.

Further research can benefit from various insights from all these areas and communities.

7 ACKNOWLEDGMENTS

The authors are grateful to the European Commission for funding this project, and express their gratitude to all partners of the TRENDS Consortium for their collaboration. www.trendsproject.org

This study also refers to GENIUS project, funded by the ANR (AGENCE NATIONALE DE LA RECHERCHE) and runs from 2008 to 2011. www.genius-anr.org

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