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KANSEI INFORMATION PROCESSING IN PRODUCT DESIGN
EXPLORING THE ROLE OF VISUAL INFORMATION IN DESIGNER'S ACTIVITY

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ABSTRACT

Images play an important role in design activity. Not only are they a tool which designers intensively use and highly appreciate but they are also proved to enhance designers' creativity. How are images perceived and processed by designers ? In order to get a deeper understanding of design implicit processes with a focus on the use and effects of visual information, we chose to look at the design process through the prism of cognitive neuroscience. Therefore, we report here some recent neuroscientific findings on visual perception and visual processing which we found relevant in the context of design science. Based on them, we draw perspectives for future research on the role of visual information in design activity.

Keywords: design cognition, kansei information, visual processing, creativity

Why are image-retrieval interfaces such as IRIS [24], TRENDS [7] or Moodstream [34] highly appreciated by designers? Far different from tools like Google, these tools actually attempt to take designer's *kansei* into account, which make them popular among users and tend to enhance designer's creativity [35]. In the context of *kansei* information processing [17] in design activity, our research goal is to understand the role of visual information and images in the design activity and to describe implicit process of design. More precisely, our investigations aim at linking the content of inspirational images visualized by designers and

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characteristics of design external representations generated by designers (sketches, artifacts) such as creativity. Neuroscience findings on visual processing are essential to explore designer's visual cognition. Thus, our paper is made of three parts: a survey of design studies on inspirational stimuli, a survey of neuroscience studies on visual processing and finally, a tentative connection of both fields.

As described in section 1, images are widely used by designers at several steps in the design process: in the early phases, to get "inspiration", or at later stages, to find relevant information for detail design. So far, design studies have mainly shown **that** images are useful in enhancing designer's creativity. We think that further investigations are necessary to discover **what kind** of images are useful in the design process and in what way these images impact the design outputs. Therefore, in section 2, literature in neuroscience is reviewed and relevant findings on visual perception and **visual processing** are listed. Although there is very few neuroscientific investigations on design practice so far, studies done with general population suggest interesting directions for design studies. Indeed existing literature helps to identify characteristics of images which might impact design outputs (e.g. **represented object** or **emotional impact**). As reported in last section, this state-of-the-art from neuroscience literature allows us to build hypotheses and questions to be answered by bringing neuroscience tools into analyses of design protocols.

1. VISUAL INFORMATION IN THE DESIGN PROCESS

1.1. Ethnographic studies show the intensive use of images by designers

Among others, a famous example of visual inspiration in the design process is the Dancing Building in Prag, designed by Frank O. Gehry, which is said to be inspired by a movie dancing scene with Fred Astaire and Ginger Rogers [19].

Figure 1: Dancing Building, by F.O. Gehry, and its inspirational source [19]

In the design process, visual information are a major support for inspiration, the use of images within the design process has been much investigated through ethnographical studies [16][35][39][40]: it has been shown that product designers and architects intensively browse images from magazines or websites, build and use collections of precedents, i.e. representations of previously-designed and manufactured artifacts. These images are mainly used to support the inspirational processes to prepare graphic displays for presentations, such as trend-boards. To support this common practice among designers, design-dedicated softwares or interfaces have been developed to retrieve images of precedents from large databases, e.g. ProductWorld [39], Semio-trends [16], Cabinet [20] or TRENDS [7].

1.2. Images of precedents support designers' creativity

Several studies have demonstrated that images have a positive impact onto design creativity. For instance, [10] and [26] showed that the use of visual stimuli helped designers to produce more outputs in a limited time, proving thus that visual stimuli lead to the production of more numerous ideas. [14] compared the level of creativity of designers' outputs, in two environments : surrounded by pictures or not. This study showed that visual stimuli not only help designers to produce more ideas but also they help designer to produce outputs with a higher level of creativity.

1.3. Towards a taxonomy of inspirational stimuli

Images help designers in their tasks, but what images ? Most design studies focused on two types of classification of images used by designers: by domain and by level of abstraction.

1.3.1. Classification by domain

Analogical-reasoning is often seen as a key process in design thinking: it is defined as the retrieval of information from memory, followed by the mapping of selected retrieved information into a new context. In other words, inspirational sources can be gradually distant from the target. Studies about analogical reasoning are based on a classification of information by domain. In product design, according to [5], inspirational sources can be broken down into three types of domain, based on the proportion of shared properties with the target product:

A source is judged as :

-**intra-domain** if, without any ambiguity, it pertains to the category, which the object to be designed belongs to.
-**close inter-domain** if it keeps some properties of the target-object category but not the most prototypical ones.
-**far inter-domain** if it obviously does not belong to the category of the target object.

Table 1: Classification of inspirational stimuli by domain

Study	Reference	Type of information observed
Effect of images onto design creativity	[9]	within-domain, between-domain
Analogical-reasoning in general population	[30]	close associate, remote associate
Analogical-reasoning in architectural design	[26]	direct link, indirect link, extra-contextual link
Analogical-reasoning in product design	[5]	intra-domain, close inter-domain, far inter-domain
Role of timing in analogical reasoning	[41]	surface similarity, structural similarity

In this study [5], names of artifacts were told to designers who had to describe what element in this object was useful in the context of a given design problem. One of the findings was that inter-domain sources had a higher positive impact on the evocation of new ideas than intra-domain sources. Besides, depending on the domain of origin, the sources led to the evocation of different components: e.g. intra-domain sources mainly led to the evocation of functional aspects (rather than structural, affective or aesthetic aspects). In another study carried out with a sample of car designers, [35] observed that sources from other domains than car design, as architecture and fashion, had a positive impact onto the level of creativity of designers' sketches assessed by external judges.

1.3.2. Classification by level of abstraction

Transforming keywords into visual images is a common operation processed by designers, which was studied by [37]. This study focused the way designers think with drawings in order to generate mental imagery of an artifact. In doing so, designers have to link low-level information (drawings, artifact) with high-level information (abstract keywords) and thus, the creative thinking process needs an overall high abstract level when having to create a visual image from a verbal stimulus. The transformation of a verbal stimulus into visual imagery can be seen as a specificity of design practice.

Table 2: Classification of inspirational stimuli by level of abstraction

Study	**Reference**	**Type of information observed**
Transformation of keywords into images	[37]	low-level, high-level
Perception of architectural sketches	[33]	formal, symbolic
Process of evocation in product design	[5]	functional, structural, aesthetic, affective aspects
Selection of inspirational images by designers	[36]	low-level, high-level

In the study by [33], architectural designers had to visualize conceptual sketches and to describe them verbally. The formal references were defined as related to physical characteristics (e.g. square, lines...) and the symbolic references were related to analogies and elements that were not represented in the drawings. The results showed that non-architectural sketches were described with symbolic references to a much larger extent that the architectural ones. These findings show that intra-domain images tend to inspire low-level information to the designers, while images from another domain would rather lead to higher-level information.

1.4. A preliminary experiment to explore images perception by designer

To investigate how designers actually perceive visual information, with a focus on the "level of abstraction". We set up an experiment with four subjects, professional designers in Italian car-design companies. After receiving a design brief, the designers had to browse a selection of magazines from various fields, to retrieve the images they found interesting in the context given by the brief and to annotate each selected images with explanations about the reasons of the selection. Based on the annotations, the images were then broken down into three categories, high / medium / low level of abstraction, by the experimenter, as described in table 3.

Table 3 : Levels of abstraction to describe the content of visual materials

Abstraction level	**Typical content**	**Examples of keywords given by designers**
High	Atmospheres, sensations	Cool. Provocation. Warm.
Medium	Products, sectors	Architecture. Hat. Fiat 500.
Low	Materials, colors, textures	Sharp edge. Color.

Most selected images were annotated with high level terms (29/70 images) or low level terms (26/70 images). It can be assumed that designer either chose images which create an atmosphere or provide sensations (high level) or images which give detailed information about concrete design elements (low level). These findings showed that designers retrieve different kinds of images when browsing visual information.

Our hypothesis is that **high-level images** might be more useful at the beginning of the ideation, when exploring the problem-space process and **low-level images** when the representation of the designed artifact is more advanced. In other words, we think that we should investigate the use of all kinds of images as inspirational sources in the design process, not only images of precedents as it has been done in most design studies so fat. Neuroscience advances on visual processing might help to define other taxonomies of visual information, not only a classification by "domain".

2. NEUROSCIENCE CONTRIBUTION TO DESIGN STUDIES

2.1. Recent studies in neuroscience of designing

As [6], we share the vision that designing is an information processing activity in which the human brain is involved in several higher cognitive functions: attention, perception, spatial reasoning, memory, visual perception and processing, language processing, creativity...

How are images perceived and processed by designers ? Are there any specificities linked to designer's brain and/or designer's expertise ? Is design practice modeling human brain in a specific way ? We assume that findings in neuroscience can help to explain how designers transform information from various types (textual, visual) up to the visual representations of an artifact. But so far, very few neuroscientific studies focused on design process itself. There are already a numerous studies on **creativity**, but most of creative thinking tasks which are studied in cognitive and neuroscientific research are basic types of tasks (e.g. finding a word as the last relevant one of a serie), usually based on tasks consisting of verbal stimuli. Thus, these experiments can only end up with findings on partial aspects of design practice. Besides, most of creativity studies investigated brain activity patterns in samples of students or normal population, very rarely in samples with creative practice (musicians, painters, dancers, chess-players), and even more rarely in samples of designers [27].

However, we notice a recent interest in neuroscientific studies of the practice of design, related to kansei information processing [28]. In an on-going investigation [1] aim at understanding the neurological basis of design thinking. The panel is asked to think of a furniture layout in a room, either in a fully-constrained way (problem-solving task) or in a ill-defined way (design task). During the tasks, the activity of subjects' brain is observed through functional magnetic resonance imaging (fMRI). The findings suggest that design and problem solving involve distinct cognitive functions associated with distinct brain networks. Another investigation [23] aimed at explaining the neuronal foundations of creativity in design. The subjects were asked to design a new pen. During the design task, the activity of subjects' brain was observed through fMRI and the originality scores given to the design outputs were analyzed in combination with brain activities. The results were compared between designers and novices and this study tends to show that that training increases creativity through a reorganization of intercortical interactions.

From these studies on **neuronal correlates of designing**, we can keep in mind that:

- brain processing in design is different from brain processing in problem-solving
- training and expertise in design impact brain processing and increase creativity

In these neuroscientific studies of design, the focus was mainly creativity and spatial reasoning. Based on the evidence that visual materials play a prominent role in the design process, we rather aim at understanding visual perception in the context of designing. Thus, we think that it is essential to first review the existing knowledge on visual perception and visual processing in the general population.

2.2. Visual brain processing and design

2.2.1. Semantics of an image and brain processing

Since [15], it has been accepted by neuroscientists that **visuo-motor interaction** with objects is a function which a large part of the visual cortical system is dedicated to. It means that it is necessary for the survival of humans to understand what kind of action is necessary right after looking at an object, and to lead to either appetitive motivational state (looking at a fruit and eating it) or to defensive one (looking at a bear and running away). Therefore the organization of the human visual system is based on **high-order objects recognition processes**.

Neuropsychological studies of brain damaged people, as well as functional magnetic resonance imaging (fMRI) studies of healthy subjects, have shown the existence of distinct neural systems that are specialized in representing knowledge of different **conceptual domains**. It is usually known that the brain has a system specialized in face recognition, but less known is the fact that the brain is made of several systems specialized in various other domains. The human brain discriminates images based on their content [8][13][18][25] but the reason why the information are processed differently is still actively debated by neuroscientists. Several theories are proposed (crowding theory, sensory-functional theory, domain-specific theory); in the context of design science, we keep in mind that the brain is structured into various category-specialized areas.

In fact, several fMRI studies reported by [29] have shown that the brain discriminates living things/animate objects vs. non-living things/inanimate objects and manipulable objects vs. non-manipulable objects. It has been described that non-living objects are represented in semantic memory with a larger weighting for **functional properties** (manipulability and affordance), while living objects are represented with a larger weighting for **visual/sensory properties** (color, shape, texture) [3]. Besides, representations of visual and functional properties are processed in distinct neural systems in the semantic memory. This differentiation in brain processing is particularly relevant in the context of design where **designers visualize all kinds of images**, not only images of precedents (manipulable non-living things), as studied by most design investigations so far, but also images of highly-contextualized objects as scenes or landscapes or images containing human figures [36].

2.2.2. Emotional content

Another aspect of an image is its emotional impact onto the watcher. Kansei-based retrieval system take this emotional impact into account [2][4][38]. Number of neuroscience studies have been carried out on the topic, which we will not detail here. However we must keep in mind that emotions generated by an image might have effects onto designers' work at several stages. At first, the emotional impact might influence the process of images selection when designers browse large collections of images. Then the emotions generated by an image might influence the ideation flow and the creativity, for instance, it has been shown that emotional

state generated by images and cognitive performance (in an arithmetical task) were correlated [42].

In studies which investigate emotions generated by the visualization of images, experimenters usually use the International Affective Pictures System [11], a database of 480 color images which were rated by a large panel of observers based on pleasure, arousal and dominance criteria. Using this database allows to study the effects of normative emotional stimuli.

On top of the above-mentioned criteria, we suggest to refer to the classification by Norman [38], who distinguishes three types of emotions:

- **visceral responses** : subconscious, not context-dependent, universal, driven by innate biological systems.
- **behavioral responses** : subconscious, expectation based-emotions
- **reflective responses** : conscious, highly-learned and culturally-dependent.

Thus, the emotional impact of images used as inspirational materials should be taken into account when studying the role of images in the design process.

3. TOWARDS INVESTIGATING VISUAL PROCESSING IN DESIGN

In the above sections, we reviewed existing knowledge on visual perception and visual processing in both fields of design studies and cognitive neuroscience. So far, the taxonomies of visual information used by designers proposed by these two fields are quite different :

– On one hand, design researchers investigated the use of images by designers with a classification based on **domains** (intra-domain vs. inter-domain) and the images used in these studies were mainly limited to images of **precedents** (designed artifacts) from various domains. Findings show that intra-domain images mostly lead to the evocation of formal references while inter-domain images mostly lead to the evocation of symbolic references [33] or affective aspects [5], which can be seen as "high-level information".

– On the other hand, studies in cognitive neuroscience have shown that brain processes images based on their **living/non-living** and **manipulable/non-manipulable** aspects, with distinct processing areas. Each type of objects triggers a specific motivational state, appetitive or defensive, and various visuo-motor interactions. Design precedents mainly fall into the category of "manipulable non-living things", thus images of design precedents used in most design studies are only a part of all possible, and maybe more beneficial, inspirational images.

What kind of visual inspirational materials support the evocation of affective aspects ?

Affective aspects are reflecting sensations or feeling produced by an artifact and designers usually aim at bringing a high affective quality to the artifact they are designing [31][38]. A good product should not only "work" well, it should also involve the user in a rich interaction. A study [5] demonstrated that *when participants were provided with far inter-domain sources, they mainly expressed affective aspects.* In this study, far inter-domain sources were picked up within a set of manipulable non-living things.

Extrapolating this result and based on findings on category-profiled visual processing, we formulate the hypothesis that designers would evoke a higher number of affective aspects when provided with images from various kinds, including images of living things, images of natural scenes or images of abstract representations. Indeed, we assume that different inspirational images, not only precedents, might lead to products that have a higher affective quality and thus that better satisfy user's *kansei*.

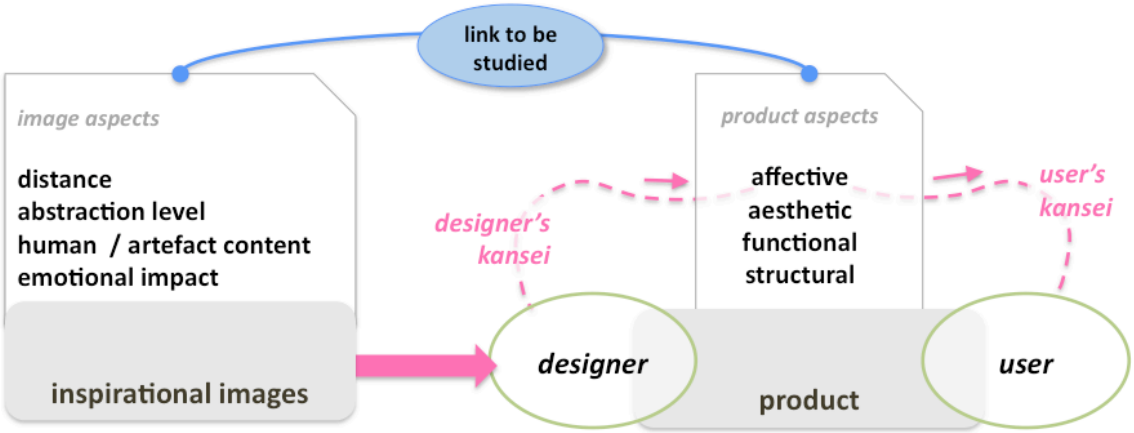

Figure 2 : Which images can support the evocation of affective aspects ?

To explore this proposal, our future work will investigate the use by designers of images containing not only design precedents, but also human figures and scenes, and evaluate the impact of such visual representations onto designers' production, especially by evaluating the affective quality of products proposed by the designers.

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