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Towards understanding and supporting creativity in design: analogies in a constrained cognitive environment ☆

N. Bonnardel*

Research Center in Psychology of Cognition, Language and Emotion (PsyCLE), Université de Provence, 29, avenue Robert Schuman, 13621 Aix en Provence, France

Abstract

In order to show that the emergence of new ideas takes place in a "constrained cognitive environment", we conducted two experimental studies in a creative professional area: non-routine design. The first study is focused on the role of analogical reasoning in creativity and, especially, on the nature of potential "sources" of inspiration, which facilitate the evocation process. The second study aims at understanding on which ground designers of different levels of expertise construct their own constrained cognitive environment. Based on the obtained results, we suggest ways to facilitate creative acts from designers.

Keywords: Creativity; Design; Analogy; Constraints

1. Creativity: questions and views

Creativity can occur in a variety of situations, going from artistic situations (e.g. painting or music composing) to situations of technological innovation. However, creativity is both difficult to define and to explain. According to the dictionary, creativity refers to "the ability to produce *new and original ideas and things*", and creation has been defined as "to bring into being or form *out of nothing*" (dictionary definition quoted in Ref. [2]). Contrary to this last definition, we argue that one of the mechanisms that contributes to the emergence of new ideas is *analogy-making*. It implies that new ideas would be in fact inspired, at least partially, by previous situations, which can belong or not to the same area than the current situation of creation. This claim is in accordance to certain authors' descriptions of creativity, such as the ones by Koestler [20] or Boden [2]. Thus, Koestler [20, p. 121] explains creativity by "the sudden interlocking of two previously unrelated skills, or matrices of thought".

However, several important questions remain to be answered to understand the use of analogies in creative activities better.

- What is the nature of the situations (or "matrices of thought") that can be used as sources of inspiration?
- What makes someone thinking of an analogy and/or seeing an analogy where no one saw one before?

Concerning this last issue, Koestler [20, p. 201], points out the fact that analogies used in creative acts were not "hidden" anywhere but "created" by the imagination, and that such analogies could be considered as the result of a relation established in the mind through a process of selective emphasis. However we still have to define *how such a selective emphasis can occur*.

We argue that the selective emphasis described by Koestler results from the construction by the creators themselves of a "constrained cognitive environment". This claim contrasts to views of creativity as an "expression of freedom". It is, however, in accordance with certain views that acknowledge the intervention of constraints in creativity (see, for instance, Ref. [2]), but we wish to go further by identifying on which basis the designers construct their own cognitive environment.

Such a constrained cognitive environment could evolve during the creative activity and would comprise constraints of different types. Some of these constraints can result from *unconscious processes* and remain unconscious, showing themselves through apparently *intuitive* acts. However, other constraints—the ones we wish to analyze—are the object of a more *conscious treatment*. In order to define

* Tel.: +33-4-42-95-3740.
E-mail address: nathb@newsup.univ-mrs.fr (N. Bonnardel).

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them, the creators can take into account data from both the *external context* of the creative situation (e.g. for instance, certain constraints, such as a deadline specified by other stakeholders) and from their own *internal context*, e.g. the activation of certain knowledge. Therefore, a part of the data used by creators to construct their own constrained cognitive environment would be dependent on situations of creation encountered previously.

Towards the end of contributing to answer the above questions and, therefore, to know more about: (1) the role of analogies in the emergence of new ideas; and (2) the construction by creators themselves of their own constrained cognitive environment, we are going to analyze real-world activities in which professionals have to be creative, to some extent: *design activities*. Therefore, we first characterize this domain of study and we will show, based on the description of a real event of discovery of a new solution, how analogical reasoning can be a source of creativity. Then, we will present results of two experimental studies conducted with designers in order to determine:

1. The nature of sources that can facilitate the evocation of creative analogies.
2. The parameters on which designers of different levels of expertise can focus in order to construct their own constrained cognitive environment.

2. Design activities

In Cognitive Psychology, design activities are described as specific problem-solving situations, as design problems are both *ill defined and open-ended.* Design problems are considered ill defined because designers have, initially, only an incomplete and imprecise mental representation of the design goals [11,28]. The designers' mental representation evolves as the problem-solving progresses. This specificity of design problems has been described as based on an iterative dialectic between *problem-framing and problem-solving* [27,29]. To summarize this process, during problem-framing, designers refine design goals and specifications and, thus, refine their mental representation of the problem. During problem-solving, designers elaborate solutions and evaluate these solutions with respect to various criteria and constraints [3,5]. Thus, each designer constructs her or his own representation of the design problem and deals in fact with a problem that has become specific to her or him. Indeed, different designers dealing with a same problem, develop different ideas and reach different solutions, materialized, for instance, by drawings or plans [1]. Therefore, design problems are also considered to be open-ended as there is usually no single correct solution for a given problem, but instead a variety of potential solutions [15].

In such design activities, and especially in "non-routine" activities, designers have to create an innovative product as well to satisfy certain specifications. Although certain designers wish to keep their activities in some way "mysterious", we argue that their creativity can be, at least partially, explained by analogical reasoning, in accordance to certain research works—though not directly related to design—such as the ones of Boden [2], Hofstadter [17] or Kolodner [21]. Schematically, in order to solve the problem at hand (or "target" problem), the designer would refer to a similar problem or situation, for which a solution already exists ("source" solution) and she/he would transfer certain features of this solution to develop the solution ("target" solution) for the problem at hand.

In favor of this idea, we can describe examples of creative acts we observed in an area of high technology: the design of aerospace products [4]. During long term observations conducted in this area, we noticed that, when designers had to deal with new problems which required an innovative concept (or solution), these designers could be inspired by familiar objects, which did not belong to their professional domain. For example, to develop an innovative solution for a reflector, which had to be spread out in orbit (and which was fundamentally different from the usual reflectors), one of the designers in charge of this project took into account the principle for drawing the curtains that were settled in front of his office. The analysis of the observed functioning allowed him to invent a mechanism for drawing, on earth, the reflective surface of the reflector without risks of tangling in the underlying metallic structure, and for, later, easily spreading it out in orbit.

Such observations can be found both in design domains (see also Refs. [9,31]) and in other domains of innovations (see, for example, the invention of the computer by Charles Babbage [18]), but we consider that design activities constitute a particularly interesting domain of study as creativity is intended to be a part of designers' activities (and despite the fact that, obviously, we miss certain events that can contribute to the creative acts, when they occur outside the professional area).

3. Analogies and emergence of new ideas

In order to reach a better understanding of the role of analogies in the emergence of new ideas, we are going to present results of a first study [7], which allowed us to control the sources designers could take into account for an analogical reasoning as well as to analyze the impact of different types of potential sources on the evocation process developed by designers.

3.1. Description of the experimental situation

This study was conducted with 10 volunteer students in Applied Art (in a technical school of Marseille, France). These students had acquired knowledge and skills in design

The object to be designed was intended to be used in a Parisian "cyber-café". It should be a particular stool with a contemporary design in order to be attractive for young customers. Such stools should allow the user to have a good sitting position, holding the back upright. Towards this end, the users should put their knees on a support intended to this function. In addition, these stools should allow the users to relax, by offering them the possibility to rock.

Fig. 1. Brief description of the object to design.

and were really involved in real design projects, therefore, we will refer to them as "designers".

We asked them to design a new product, defined in collaboration with their professor of Applied Art, in order to be sure that the design problem will be really new for the students and to present it in the same way than the design problems they were used to deal with. Therefore, the designers were provided with a schedule of conditions consisting, first, in a scenario describing both the object to design and its use (see Fig. 1) and, secondly, in a reminder of the main requirements to satisfy.

Such a description leads to the evocation of objects we already know. In particular, the designers can evoke known objects or "sources", in order to understand the object to be designed better together with the transfer of certain properties of the sources to the problem at hand ("target").

In order to identify the sources evoked by the designers who participated in this study, we asked them to *think aloud*. Though limits of this method have been pointed out (see, for instance, Ref. [12]), it allows the access to, at least, a part of the designers' thoughts and it is, therefore, frequently used in studies about design activities as well as in certain studies about analogical reasoning (see, for instance, Ref. [16]). The designers' verbalizations as well as their graphical activities were video recorded. Then, the verbalizations were transcribed and matched with the drawings made by the designers. In order to avoid too much subjectivity during the analysis, two "judges" analyzed the data separately, which allowed us to discuss possible points of disagreement in the interpretations. We observed that we reached a good degree of agreement (no point of disagreement appeared).

The experiment was 50 min long, which is a realistic duration to realize a rough draft of the ordered object. More precisely, it consisted of two phases of 25 min each.

1. During the first 25 min, the designers were assigned to one out of two experimental conditions (five designers in each condition):
   - *a free condition*, in which the designers could freely solve the problem and spontaneously evoke known objects ("spontaneous sources") they could refer to;
   - *a guided condition*, in which we provided the designers with *names of objects* that could play the role of "suggested sources". Two of these potential sources for an analogical reasoning were considered *intradomain*, as they were belonging to the category of "seats". Two other potential sources were considered *interdomain*, as they referred to objects very different from seats. In addition, one intradomain object and one interdomain object had been studied by the designers during their Art Applied class, whereas the two other objects had never been studied (see Table 1). Each of the names of objects were written on folders and delivered to the designers in a random order. In this first phase of the experiment, we chose to provide the designers with only *names of objects* and not graphical representations of specific objects (or "instances"). These names refer to categories of objects and may lead the designers to infer what general principle or feature(s) can be extracted from this class of objects as relevant for the object to design. For instance, the designers may reflect on what could be relevant on a canoe-kayak or on a logotype for designing the specific stool described in the schedule of conditions.
2. During the following 25 min, the designers of the two groups were in a similar situation: they had *both names and a graphical representation* of each type of potential source, i.e. an "instance" of each category defined by the names. Contrary to the sources' names, the graphical representations may facilitate more the identification of precise features that designers can transfer to the object to design.

Table 1
Characteristics of the potential sources proposed to the designers

Sources	Intradomain	Interdomain
Studied	"Nomadic" stool	Logotype
Never studied	Rocking chair	Canoe-kayak

Designers who belonged to the "guided" group could directly open the folders they had been provided with, to find out the specific graphical representations. During this second phase, designers who belonged to the "free" group were provided with both the names and the graphical representations.

3.2. Findings about the evocation process

Two findings, related to the evocation process developed by designers, seem particularly interesting.

- The designers who belonged to the guided group evoked,

Table 2
Nature of the evoked sources according to the experimental conditions

Nature of evoked sources	Experimental condition	
	Free condition	Guided condition
Intradomain	6	14
Interodomain	1	19

in mean significantly more "spontaneous sources" than the designers of the free group: respectively, a total of 33 sources vs. 7, which corresponds in mean to 6.6 sources by designer vs. 1.4 ($p < .05$). This effect appeared in the two phases of the experiment but was higher in the first phase.
  - During the first phase, 26 sources were evoked in the guided condition vs. only 6 in the free condition.
  - During the second phase, 7 sources were evoked in the guided condition vs. 1 in the free condition.
- This result can be explained with regard to another one: the designers who belonged to the guided group evoked, in mean, significantly more interdomain sources than the designers of the free group: respectively, 3.8 interdomain sources by designer vs. 0.2 ($p < .05$). Therefore, wholly the sources evoked by the designers of the free group were intradomain contrary to what we observed for the designers of the guided group (see Table 2).

3.3. Discussion

As we just pointed out, the designers who belonged to the guided group evoked, especially during the first phase, a lot more sources than the designers of the free group. Such a result shows a "snowball" effect of the potential sources we suggested to the designers of the guided group: we only suggested them four names of sources, whereas they evoked 26 "spontaneous sources" during the first phase of the experiment.

Therefore, it seems that the presentation of names of objects, which refer to categories of these objects, has a facilitating effect on the designers' evocation process. Such an effect differs from previous findings both about the general human cognitive functioning and about, more specifically, the designers' cognitive functioning. Indeed, a "design fixation" effect (Ref. [19], quoted in Ref. [26]), similar to a certain extent to phenomenons of "functional fixedness" and "mechanisation of thought" (see Refs. [10,22,32]), had been previously observed: individuals, in general, and designers, in particular, tend to reproduce features of the examples they were provided with. Thus, Jansson and Smith [19] showed that designers (and, especially, professional designers) tend to reproduce numerous features of objects' graphical representations they saw before, comprising features irrelevant to the task at hand. The effect we observed is opposite to such previous findings and can be explained with regard to two types of interpretations.

1. The effect of "design fixation" may be dependent on the *designers' level of expertise*: such an effect might become higher as the designers acquire expertise. Experienced designers, such as the professionals who participated in the study of Jansson and Smith [19] could be more influenced by the suggestion of objects specifically related to the object they have to design (i.e. objects that directly belong to a same category). On the contrary, less experienced designers, such as the students who participated in our study, could be more influenced by objects that are familiar to them, even if these objects are not a priori directly related to the object to design. Other results and, especially, the ones of the study of Purcell and Gero [26] are also in favor of this interpretation.

Such an interpretation seems to fit particularly design problem-solving: these problems being open-ended, they allow the designers to refer to various sources of inspiration. Therefore, less experienced designers or novices have the opportunity to evoke sources that are familiar to them though not directly linked to the object to design.

2. The effect we observed can also be explained with regard to the *nature of the sources* we suggested to the designers of the guided group, during the first phase. These sources were presented as *names of objects*, related by different ways to the object to design. Such names reflect categories of objects and may lead the designers to think of *general principles or features* that could be transferred to the object to design. Therefore, contrary to what could have happened in the study realized by Jansson and Smith [19], our designers did not focus on specific features of instances. Indeed, the sources we suggested led them to extend their space of research.

Moreover, as two of the suggested sources were *interdomain*, such potential sources may have facilitated the evocation of other interdomain sources. For instance, the suggestion of a canoe-kayak as a potential source shows the designers that objects, which seem, a priori, very far from the object to design, can inspire them. Thus, the main part of the sources spontaneously evoked by the designers who belonged to the guided group consisted in interdomain sources; whereas the designers who belonged to the free group mainly evoked intradomain sources.

These two characteristics (names of objects and interdomain sources) of some of the sources we suggested to the designers of the guided group have led them to be less focused on surface characteristics of the object they have to design and more focused on deep principles (e.g. linked to the functioning of objects). Therefore, they have been able to take into consideration various domains and to look for functioning principles common they could transfer to the new object.

4. Construction of a constrained cognitive environment

Our hypothesis is that, in order to construct their own *constrained cognitive environment*, designers are going

A manufacturer wishes to renew the image of torches. Towards this end, he/she asks you to think of a new concept of torch use, based on a new gesture, due especially to the removal of the traditional switch.

In order to reach a renewal of the image of torches, you do not have only to process to a styling treatment but also to rethink the concept of light appearance and disappearance.

Fig. 2. Limited description of the object to be designed.

both to look for data in the *external context* and to activate specific elements of their *internal context* (i.e. for instance, certain knowledge elements). The internal context depends on several factors, such as the state of problem-solving and the designers' level of expertise.

Since we wish to analyze the role of these two types of contexts, we are going to present certain results from another experiment [6] settled in order to reach a double objective, namely:

- to identify the data designers take into account in the external context;
- to determine how the designers' level of expertise influences the taking into account of data from the external context.

We assume that designers select among all the information elements existing in the external context, the elements they consider to be important to design a new product. Such elements are going to underlie the definition of "prescribed" constraints. Moreover, in order to construct their own "constrained cognitive environment", the designers will add to the prescribed constraints, at least, two other types of constraints [3,5]:

- "constructed constraints", when they derive from expertise acquired in a specific domain;
- "deduced constraints", when they result from an analysis by the designer of the implications of the current state of problem-solving or from an analysis of the implications of already defined constraints (through a process of constraint propagation).

Such constraints orient the designers' focus of attention and therefore lead them to think of already existing objects, those functioning may satisfy the constraints taken into account. Therefore, the analogical reasoning we described in the first study would be based on the focalisation of the designer on certain constraints.

Table 3
The effect of the designers' level of expertise on the number of information elements asked and used

Designers' level of expertise	Information elements	
	Asked	Used
Professionals	10.5	16.5
Students	5	11.25

4.1. Description of the experimental situation

Six volunteer designers participated in the experiment:

- two professional designers, having two and six years of expertise in an office of Design;
- four students in Applied Art, in their second year (out of a three years degree course) of specialized training in a technical school.

In order to identify the data or parameters on which they focused, we used the experimental paradigm of "information on request": the designers were provided with a description of the design problem as limited as possible (see Fig. 2) and they had to ask questions to the experimenter in order to be provided with the information elements. Usually, the selection of information elements in the external environment remains implicit, as the designers are provided with a relatively specified schedule of conditions. In our experiment, such a selection became more explicit because the designers had to formulate questions about the features they were looking for.

In order to give to the designers exactly the same information elements, when they inquired, the experimenter referred to a table that provided her with a precise description of the different possible answers. If one of the designers' questions appeared to go beyond the planned answers, the experimenter answered "we don't know (yet) this information element". In addition, when the designers requested technical information elements, they could access to descriptive documents, and a traditional torch was at their disposal for possible manipulations.

Each designer had a 2 h time to deal with the proposed problem. In order to determine how the designers used the gathered information elements, we also asked them to "think aloud".

As it was the case in the previous experiment, we video-recorded the designers activities, we transcribed their verbalizations and matched them with their graphical productions. In order to avoid too much subjectivity, the data analysis was again conducted by the two judges, who reached a good degree of agreement.

4.2. Findings about the data taken into account

We conducted a quantitative and qualitative analysis of both the information elements the designers requested and the information elements they really referred to during the design problem-solving.

4.2.1. Quantitative results

The quantitative results we obtained (see Table 3) show that:

- the professional designers asked, in mean, twice more information elements than the students (respectively, 10.5 vs. 5);
- the same tendency occurs during the problem-solving itself, since *professional designers referred, in mean, to more information elements than students* (respectively, 16.5 vs. 11.25).

In addition, the comparison of these two types of results shows another finding: *both the professional designers and the students added new information elements* to the ones they were provided with. Such new information elements were therefore assumed by the designers, and they could underlie the definition of new constraints, probably specific to each designer.

4.2.2. Qualitative results

In order to know more about the information elements professional designers and students dealt with, we analyzed qualitatively the information elements they inquired and/or referred to. It allowed us to define *five topics of interest*, which are each composed of different information elements.

1. Information elements about the company from which the demand is originated.
2. Information elements about preexisting similar products.
3. Information elements about the users and the conditions of use of the future product (target, age of the target; planned use; conditions of storage; etc.).
4. Possible technical features (source of energy, such as battery; type of bulb; materials; etc.).
5. Marketing information elements (name of the product; marketing places; production amount; price; range of products).

Certain topics appeared to be of interest for *all the designers, whatever their level of expertise*. Thus, three types of information elements were taken into account by all the designers and deeply analyzed.

- *Preexisting similar products.* Preexisting products were taken into account by all the designers in order to perform *an analysis of the advantages and inconveniences of certain of the products' features*. Preexisting products constitute in fact "*intradomain*" *sources of inspiration*: the designers assessed certain of the products' features and transferred those they considered as interesting for designing the new product. Designers could also rethink and improve features that they considered as presenting drawbacks. Therefore, the designers should be able to reach a new product, more efficient than the ones already existing. Such an analysis of preexisting products constitutes an important and necessary stage in the designers' activities and, consequently, it is taught to students in Applied Art. Therefore, we observed it from both professional designers and students.
- *Conditions of use of the future product.* Such a topic was broached by the designers after having defined who will be the user of the future product (i.e. the target). The analysis of the conditions of use of the future product allowed the designers to define new constraints, such as "to let the user free of moving as she/he wishes" or "to allow him or her to hang the torch on the car"). On such bases, the designers then looked for specific features for the new product.
- *Sources of energy.* Such a technical feature constitutes an essential component for the new product to design. It is a determinant of its functioning and it appeared to have consequences on other features, such as the shape of the new product (for instance, "the use of cylindrical batteries involves a cylindrical shape").

Other topics were specifically taken into account either by professional designers or by students.

The two following topics were broached *only by professional designers*:

- *Information elements about the company from which the demand is originated.* Contrary to students, both professional designers took into account information elements related to this topic. Especially, they asked questions about the considered sector of activity and the company's production network (manufacturer or subcontractor). Students may have considered such information elements having no consequence on the design of the new product. However, professional designers adopted a different view, since they used such information elements to assess features they envisaged for the new product (e.g. "this feature goes beyond competencies of Mazda"—the company which is intended to have expressed the demand) and it also allowed a professional designer to define possible means of manufacturing ("since it is Mazda, they will be able to offer themselves molds, especially for an industrial quantity").
- *Marketing information elements.* Information elements about the production amount and the marketing places were only taken into account by professional designers, for instance, in order to know the extent of the company's sectors of activities and its categories of customers (e.g. diffusion to professional vs. to consumer public).

It also appeared that only one information element was taken into account *specifically by students*. It consists in a *technical feature of the new product*, related to the beam of the torch (large vs. precise beam). This seems representative of the approach students adopted: they analyzed in details the new object to design and were more focused on specific features than professional designers.

4.3. Discussion

The results we obtained tend to show that the designers' level of expertise led to the adoption of different approaches for dealing with the problem at hand:

- Students appear to be *specifically centered on the new product to design*. Indeed, they took into account information elements about the users and the conditions of use of the future product as well as about technical features related to this object. Moreover, they seem to remain focused on specific features, which can constitute sources of difficulties for them (such as the beam of the torch).
- Professional designers appear to adopt a *more general approach* than students, which allow them to take into account information elements related to other aspects than their "local" stage of design (e.g. information elements related to the characteristics of the company or to the marketing).

The taking into account of information elements and constraints related to other stages than the one of design itself, shows that, though numerous design steps occur individually, they are in fact integrated in a *collaborative partnership* among, for instance, the designer, the customer and/or the user of the new product, the manufacturer, etc. Therefore, we observed that professional designers are able to adopt points of views of other stakeholders, involved in the design process at a more general level; whereas, it does not seem to be the case of students, at least, during the early stages of design problem-solving. However, the adoption of different viewpoints by a designer in the early stages of problem-solving can be essential in order to avoid decisions that will appear, later, either impossible or difficult to apply, due to incompatibilities with the objectives of other stakeholders (e.g. incompatibilities between planned technical features and the manufacturer's means). Moreover, as pointed by Fischer [13], having different viewpoints can allow the designer to discover alternatives, to develop a reflection based on a more enriched and meaningful perspective and, therefore, to enhance the quality of the designed artifact.

5. Towards supporting creativity

The different results obtained in the two studies we presented allow us to identify possible weaknesses of designers and, on this basis, to suggest certain ways to support them in their creative activities.

5.1. Supporting the emergence of new ideas

Results of the first study we presented can be used in order to suggest, at least, three ways to support designers in their creative activities (as well as, possibly, other types of creators):

- It seems important to propose to users of knowledge-based systems not only "cases" or examples of already designed objects (as it is the case, for instance, in the KID system, which supports architectural design [24]), but also more *general categories of objects*, which could lead, less specifically, the designers towards new directions, to which they would not think of spontaneously.
- Still in order to open up the space of research of preexisting objects that can facilitate the understanding and the solving of design problems, it seems useful to suggest to users of support-systems *interdomain sources of inspiration related*, to a certain extent, *to the problem at hand*. This would imply to characterize both features of the object to design and features of the objects stored in the system's knowledge-base. Such a characterization should be based not only on the objects' surface characteristics but also on their structural characteristics (such as functioning principles), in order to allow innovative pattern-matching between the object to design (target) and various preexisting objects (sources)—including objects a priori far from the one to be designed.
- A third way to open up the space of research and to facilitate the creation of new analogies could be also to provide designers with images of objects that apparently are *not related* to the object to design (for instance, images of randomized objects originated from various areas). Though these objects are a priori completely independent of the object to design, designers could *invent relationships* among these objects and, therefore, "see analogies where no one saw them" (see Ref. [25] for an example of such a process of invention of analogical relationships in order to design a specific object, such as a chair).

5.2. Supporting the taking into account of various viewpoints

The results obtained in the second study we presented showed that students seem to have more difficulties than professional designers to adopt, at least during the early stages of design, a general approach combining different points of view.

Certain support-systems could, therefore, be useful to designers that are novice in a specific area, but also to experienced designers. It could be the case of systems with a "blackboard" architecture, such as the HOBS system [23], which supports the design of steam turbine, by presenting to the users knowledge sources reflecting different viewpoints (e.g. geometrical or electrical requirements, viewpoints related to the manufacturing or to the marketing).

Other systems and, especially, "critiquing systems" could also support designers in taking into account other constraints that the ones they define themselves and, therefore, facilitate the adoption of new viewpoints. Critiquing systems seem, to fit particularly the "open-ended" and "ill defined" characteristics of design problems (see, for instance, Ref. [14]): these systems allow the user to define her or his own design solution and they assist her or him in evaluating this solution. Such critiquing systems appeared, moreover, to be useful to both novices and experienced designers, though the benefits are different according to the designers' level of expertise (see Refs. [8,30]).

6. Conclusion

We have presented in this paper two studies about cognitive mechanisms that seem to go towards opposite directions.

- Analogical reasoning based on high level and interdomain sources, which appeared to open up the space of research of new ideas.
- The construction of a constrained cognitive environment, which tends to delimit the space of research, on the basis of constraints resulting from the taking into account of the "external context" (e.g. prescribed constraints) and/or from the taking into account of the "internal context" (such as "constructed" constraints, which depend on the designers' expertise, or such as "deduced" constraints, which can depend on the current state of problem-solving).

Our objective was to show that the combination of these two cognitive mechanisms underlie creative acts and we believe that it is the case not only for design activities but also for other creative acts, comprising artistic activities, such as painting (e.g. painters can respect the "gold number" or constraints such as "to avoid to center attraction points").

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