Evocation Processes by Novice and Expert Designers: Towards Stimulating Analogical Thinking

Nathalie Bonnardel and Evelyne Marmèche

Design activity occurs in many professions, ranging from technical to more artistic domains. Whatever the domain, it is a constant challenge for designers to introduce creativity in each design project they work on and minimize the tendency to repeat familiar design features. The goal of this paper is to present a cognitive approach to design problem solving as well as an experimental study. This study aims at determining whether creative ideas can be enhanced by the presentation of external sources of inspiration. In particular, we analyse the effect of the presentation of different kinds of sources (intra- versus interdomain sources, which are presented as graphical representations or as verbal labels) according to the designers’ level of expertise (lay-designers versus professionals). Results show that it is possible to enhance evocation processes in design, but that it is dependent on both the nature of sources of inspiration and the designers’ level of expertise. Based on these results, we suggest ways for enhancing creative ideas in design tasks.

Introduction

Design activities are performed in a very large range of professional areas, such as the design of everyday life products (e.g. Norman, 1993), website design (e.g. Bonnardel, Lanzone & Sumner, 2003), software design (Détienne, 2001) or even the design of aerospace products (Bonnardel, 1999). Whatever the design area, the final products have both to be useful, usable and attractive for customers or users. The usefulness depends on the functionality planned for the products at hand, which should be in accordance with users’ needs. In order to create usable (or easy to use) products, designers can refer to guidelines and ergonomic principles or criteria (see, for instance, Norman, 1993; Nielsen, 1993, 2000; Scapin & Bastien, 1997). Though applying guidelines or ergonomic criteria appears not to be easy (Bonnardel & Chevalier, 2001; Chevalier & Ivory, 2003), designers can attend human-computer classes and training in order to reach more usable products. Developing attractive products is also a major challenge, since the decision of purchase frequently depends on the users’ first feelings about the considered product.

So the first main question is: how to stimulate the design of such useful, usable and attractive products? Our objective in this paper is to better understand how creative ideas occur in design activities, and whether it is possible to enhance the emergence of such ideas by stimulating analogical thinking.

The role of analogy-making in creativity has been stressed by several authors; for instance, Koestler (1975), Kolodner (1993) and Boden (1990). Analogical thinking is also considered as having a positive role in creative design activities or in ‘cognitive generative tasks’ (see Bonnardel, 2000; Ward, Smith & Vaid, 1997). Koestler (1975, p. 121) explained creativity as ‘the sudden interlocking of two previously unrelated skills, or matrices of thought’. According to Ward, Smith and Vaid (1997), people engaged in generative cognitive activities have to extend the boundaries of a conceptual domain by mentally crafting novel instances of the concept.

This paper first presents a cognitive approach that characterizes design problem-solving and describes cognitive mechanisms involved in creative design activities. Next, an experimental study is described. It aims both at determining whether it is possible to define...
EVOCATION PROCESSES IN DESIGN

Creativity in design: A cognitive psychology view

Design problem solving

In cognitive psychology, design activities are described as problem-solving situations: designers have to produce an artefact, which should fit a specific function and satisfy different requirements (Malhotra et al., 1980).

These requirements define to some extent the goal to reach, but designers have to complement their mental representation of the design problem, since these problems are ill-structured or ill-defined (Eastman, 1969; Reitman, 1964; Simon, 1973). Indeed, at the beginning of the problem, the designers have only an incomplete and imprecise mental representation of the design goal. It is only through the problem-solving process itself that designers can complete their mental representations by choosing design options (see Falzon et al., 1990). Thus, the design problem solving results from a co-evolution of problem and solution spaces (Cross & Dorst, 1999; Dorst & Cross, 2001). This specificity of design problems has also been described as based on an iterative dialectic between problem framing and problem solving (Rittel & Webber, 1984; Simon, 1995). 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, which guide the designers in performing subsequent stages of design problem solving (see, for instance, Bonnardel, 1993, 1999). Continuous interactions between the problem space and the solution space allow a reflective conversation between the designer and his/her external representation of the artefact (see Schön, 1983).

Each designer constructs his or her own mental representation of the design problem and deals in fact with a problem which has become specific to him or her. Different designers dealing with a same problem, develop different ideas and reach different solutions, materialized, for instance, by drawings or plans (Bisseret, Figeac-Létang & Falzon, 1988).

Design problems are also considered to be open-ended since there is usually no single correct solution for a given problem, but instead a variety of potential solutions (Fustier, 1989), which satisfy different criteria or constraints to varying degrees.

Opportunistic process

The dialectic process between problem framing and problem solving contributes to another characteristic of design problem solving: it is viewed as an opportunistic process. Several years ago, much debate centred on whether design activities were hierarchically organized (see, for instance, Adelson & Soloway, 1985; Jeffries et al., 1981) or opportunistically organized (for a review, see Visser, 1994). The seminal study of Hayes-Roth and Hayes-Roth (1979) and later research (see, for instance, Bisseret, Figeac-Létang & Falzon, 1988; Guindon, 1990; Visser, 1990) provided arguments on behalf of an opportunistic organization of design activities, though they possibly include hierarchical episodes. The design process was thus described as multi-directional: decisions included both top-down and bottom-up instances and they could be made at different levels of abstraction etc. Such an activity was characterized by the authors as opportunistic because ‘each decision [was] motivated by one or two immediately preceding decisions, rather than by some high-level executive program’ (Hayes-Roth & Hayes-Roth, 1979, p. 381). Such decisions could lead to reconsidering previous decisions or postponing certain decisions (Bonnardel, Lanzone & Sumner, 2003; Hayes-Roth & Hayes-Roth, 1979; Visser, 1990).

Emergence of new ideas

Understanding how designers opportunistically develop new ideas and reach innovative products remains a major issue. Models of creativity have been proposed in order to highlight the sociocultural context in which individual creativity occurs (see Boden, 1990; Csikszentmihalyi, 1996; Fischer, 2000; Liu, 2000). Other approaches describe characteristics of creative individuals (e.g. motivation, attitude, knowledge, skills) in relationship with positive or negative effects of the environment (Amabile, 1996). In particular, the ‘investment approach’ (Sternberg & Lubart, 1991, 1995) points out necessary resources for creative persons (e.g. intelligence, knowledge, motivation and so on) as well as the necessity...
order to engage in analogy-making for solving disposal. Experts can refer to such cases in they have a large library of cases at their Marmèche, 2003;). Case-based reasoning is a Bastien-Toniazzo, 1999; Didierjean & Chi, Feltovitch & Glaser, 1981; Besnard & for instance, Bonnardel & Marmèche, 2003; ing on the participants’ level of expertise (see, A lot of results showed that the cognitive treat- the source (a previous similar situation) belong to the same conceptual domain; and the source belong to different conceptual domains. In addition, relationships are established between the target and the source. Intra- domain analogies would be based on both sur- face similarities and structural similarities between the target and the cible, whereas interdomain analogies would be based only on structural similarities (or underlying prin- ciples) between the target and the sources. A way to influence people in developing ideas is to provide them with suggestions or examples. Thus, several experiments were conducted, in the case of ‘cognitive generative tasks’, in order to determine the impact of the presentation of examples on participants’ pro- ductions. Experimental tasks were defined in various areas: to design technical artefacts, such as spill-proof mugs or bicycle racks (Jansson & Smith, 1989, 1991; Purcell & Gero, 1992), to design novel space creatures to inhabit a distant planet, to provide novel ideas for reducing traffic accidents (Marsh, Landau & Hicks, 1996; Smith, Ward, & Schumacher, 1993; Ward, 1994; Ward & Sifonis, 1997). Whatever the final objective, mainly similar results were observed: when they are provided with examples, participants’ productions conform to experimenter-provided examples. Such an effect has been called ‘design fixation effect’ in the case of design activities (Jansson & Smith, 1989, 1991). This type of effect appears, to a certain extent, similar to phenomena described for years, in psychology, under the terms of ‘functional fixedness’ and ‘mechanisation of thought’ (see Duncker, 1945; Luchins, 1942; Maier, 1931, Weisberg, 1988).

In contrast to these results, we argue that it is possible to enhance the evocation of new ideas and, especially, to lead designers to
extend their space of research, by providing them with different kinds of sources of inspiration. The objectives of our study are to determine:

- What is the nature of the sources of inspiration spontaneously evoked by lay designers and professionals.
- Whether it is possible to support designers in extending the boundaries of the conceptual domain related to the object to be designed, by providing them with different kinds of sources.
- Whether designers’ evocation processes are different according to their level of expertise.

Experimental study

Hypotheses

- Throughout the design activity, professional designers should globally evoke more intra- and interdomain sources than lay designers, since they are used to make analogies in their professional activities.
- In line with previous research about the design fixation effect, we expected that designers, whatever their level of expertise, would evoke mainly intra-domain sources directly related to the object to be designed.
- However, we hypothesized that professional designers may extend their space of research of ideas, when they are provided with interdomain sources. The suggestion of interdomain sources could lead professionals to develop a reflection based on principles underlying these interdomain sources, and to adopt various points of view, which lead them to evoke new creative ideas. In contrast, we hypothesized that lay designers will be more focused on surface features of the object to be designed. Therefore, they would not realize the potential interest of interdomain sources, which are apparently far from the object to be designed.

In addition, we compared two formats of presentation of the suggested sources: graphical representations versus verbal labels. In previous research, examples were always presented as graphical representations, which could limit the space of research more than verbal labels.

Participants

75 designers participated in this study:

- 25 professionals, who have been working in design offices for at least three years. They were between 26 and 66 years old and they had superior degrees in industrial design, graphical or applied arts, architecture. With regard to these characteristics, participants were assigned to each of the five experimental groups, in order to have matched groups.
- 50 ‘lay designers’, who were students in their first or second year of Psychology, and who had no experience at all in industrial design.

Experimental task

All the participants had to perform the same task: to design a new seat (see Figure 1). This task was defined in collaboration with a professor of industrial design and presented to participants as a scenario describing the object to design and its use, as well as the main requirements to satisfy. The object they had to design belongs to a category of objects well-known by everyone, novice or expert, since it is a specific seat. Participants had to express ideas and evoke sources, and though they realized drawings, our analysis is not focused on the quality of the drawings (which would require more technical skills), nor on their role.

The object to be designed was intended to be used in a Parisian ‘cyber-café’. It should be a particular seat with a contemporary design in order to be attractive for young customers. Such seats 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 seats should allow the users the opportunity to relax, by offering them the possibility of rocking.

Figure 1. Brief Description of the Object to Design.
in the design task. Data analyses are only focused on the evoked sources, either without any suggested source of inspiration, or after the presentation of some sources, intra- or interdomain.

Experimental conditions and procedure

The participants had to solve the design problem in their own office. They were assigned to groups corresponding to the following experimental conditions:

- a ‘free’ condition, in which the participants were only provided with the description of the design problem.
- Four ‘guided’ conditions in which the participants were first provided with the description of the design problem and, immediately after, with two potential sources of inspiration. These sources were either intra-domain or interdomain sources, and presented in a verbal or in a graphical format (see Figure 2).

The suggested intra-domain sources pertain to the ‘seat’ category, which is the category the object to be designed belongs to. They consist of a rocking chair and an office chair. The suggested interdomain sources do not belong to the category of the object to be designed. They consist of a climbing position and a logo.

Each participant had about 50 minutes to begin to solve the design problem at hand. The designers’ drawings were video-recorded in order to allow us to analyse their evolution. In addition, in order to allow us to identify the sources of inspiration they referred to, the participants were invited to think aloud (see Gero & Mc Neil, 1998; Piolat & Pélissier, 1998).

The designers’ verbalizations were transcribed and presented in a format (see Figure 2).

The results indicated three significant interactions: the interaction between expertise level, kind of conditions and the nature of the evoked sources, $F(1,71) = 5.71; MSe = 5.71; p < 0.05$, the interaction between the kind of conditions and the nature of the evoked sources, $F(1,71) = 10.33; MSe = 14.32; p < 0.01$. The effect of the conditions was non-significant. The results indicated no significant interaction between expertise level and kind of conditions.

A second ANOVA was conducted on the number of evoked sources, with the ‘expertise level’ (lay designers versus professionals) and the ‘kind of condition’ (free condition versus guided conditions) as between-subject factors. The results yielded a significant effect of the expertise level $F(1,71) = 4.22; MSe = 5.71; p < 0.05$, and the triple interaction between expertise level, kind of conditions and nature of the evoked sources, $F(1,71) = 4.63; MSe = 5.71; p < 0.05$.

In accordance with our first hypothesis, lay designers evoked less sources than professionals; in mean, respectively, 2.9 versus 6.4 (see Table 1). Thus, with the acquisition of expertise, the space of research is extended.

In line with our second hypothesis, whatever their level of expertise, designers spontaneously evoked (i.e. in the free condition) more intra-domain sources than interdomain sources (see Table 1).

The effect of the ‘condition’ factor (i.e. free versus guided conditions) is not globally significant: there is no significant difference in the number of sources evoked in the ‘free’ condition versus in the different ‘guided’ conditions taken together. However, planned comparisons show that though there is no significant effect for lay designers, for professionals, a significant interaction between conditions and the number of evoked sources does exist (intra- and interdomain sources). In the free condition, professionals evoked more intra-domain sources than interdomain sources, whereas lay designers evoked more interdomain sources than intra-domain sources.

A first ANOVA was conducted on the number of evoked sources, with the ‘expertise level’ (lay designers versus professionals) and the ‘kind of condition’ (free condition versus guided conditions) as between-subject factors. The results yielded a significant effect of the expertise level $F(1,71) = 10.33; MSe = 14.32; p < 0.01$. The effect of the kind of condition was non-significant. The results indicated no significant interaction between expertise level and kind of conditions.

Results

Number and nature of sources evoked by laydesigners and professionals in the free and guided conditions

A first ANOVA was conducted on the number of evoked sources, with the ‘expertise level’ (lay designers versus professionals) and the ‘kind of condition’ (free condition versus guided conditions) as between-subject factors. The results indicated three significant interactions: the interaction between expertise level and the nature of the evoked sources, $F(1,71) = 5.96; MSe = 5.71; p < 0.05$, the interaction between the kind of conditions and the nature of the evoked sources, $F(1,71) = 4.22; MSe = 5.71; p < 0.05$, and the triple interaction between expertise level, kind of conditions and nature of the evoked sources, $F(1,71) = 4.63; MSe = 5.71; p < 0.05$.

A second ANOVA was conducted on the nature of the evoked sources (intra- versus interdomain sources), with the ‘expertise level’ (lay designers versus professionals) and the ‘kind of condition’ (free condition versus guided conditions) as between-subject factors. The results indicated three significant interactions: the interaction between expertise level and the nature of the evoked sources, $F(1,71) = 4.63; MSe = 5.71; p < 0.05$, and the triple interaction between expertise level, kind of conditions and nature of the evoked sources, $F(1,71) = 4.63; MSe = 5.71; p < 0.05$.

In line with our second hypothesis, whatever their level of expertise, designers spontaneously evoked (i.e. in the free condition) more intra-domain sources than interdomain sources (see Table 1). Thus, with the acquisition of expertise, the space of research is extended.

Three judges independently categorized these sources as being intra- or interdomain sources. A high degree of agreement was obtained (0.95). In case of hesitation, a short discussion allowed us to reach a complete agreement.

Data analysis

Since we focused on the designers’ evocation processes, two indicators related to these processes were taken into account:

- the number of new sources evoked by the designers all along the design activity;
- the nature of new evoked sources, by distinguishing intra-domain sources and interdomain sources.

By ‘new’ sources of inspiration, we mean that, for the four guided conditions, the account was performed on sources of inspiration that were not the suggested ones, but really newly evoked sources (for instance, a camping seat, a sledge, a wave or a nest).
Figure 2. Suggested Sources of Inspiration

<table>
<thead>
<tr>
<th>Nature of sources</th>
<th>Intradomain</th>
<th>Interdomain</th>
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<tbody>
<tr>
<td>Format of presentation</td>
<td><img src="image1" alt="Intradomain Graphical representations" /></td>
<td><img src="image2" alt="Interdomain Graphical representations" /></td>
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<tr>
<td>Graphical representations</td>
<td><img src="image3" alt="Intradomain Verbal labels" /></td>
<td><img src="image4" alt="Interdomain Verbal labels" /></td>
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</tbody>
</table>

- **Intradomain**
  - Verbal labels: OFFICE CHAIR, ROCKING-CHAIR
  - Graphical representations: Office Chair, Rocking-Chair

- **Interdomain**
  - Verbal labels: CLIMBING POSITION, LOGO
  - Graphical representations: Climbing Position, Logo
condition, professionals mainly evoked inter-domain sources, whereas it is the reverse in the guided conditions, in which interdomain sources are predominant.

Number and nature of sources evoked by lay designers and professionals according to the kinds of suggested sources and their format of presentation

A first ANOVA was conducted on the number of evoked sources, with the ‘expertise level’ (lay designers versus professionals), the kind of ‘suggested sources’ (intra- versus interdomain sources) and the ‘presentation format’ (graphical representations versus labels) as between-subject factors. The results yielded a significant effect of the expertise level, $F(1,52) = 15.52; MSe = 13.40; p < 0.001$, a significant effect of the factor ‘suggested sources’ $F(1,52) = 9.56; MSe = 13.40; p < 0.01$ and a significant interaction between the factors ‘expertise level’ and ‘suggested sources’ $F(1,52) = 12.89; MSe = 13.40; p < 0.001$. The effect of the presentation format was non-significant, nor any interaction involving this factor.

A second ANOVA was conducted on the nature of the evoked sources (intra versus inter), with the ‘expertise level’ (lay designers versus professionals) and the kind of ‘suggested sources’ (intra- versus interdomain sources) as between-subject factors. The results indicated a significant effect of the expertise level, $F(1,56) = 16.05; MSe = 6.48; p < 0.001$, of the suggested sources, $F(1,56) = 9.48; MSe = 6.48; p < 0.01$, and of the number of intra versus interdomain sources that are evoked, $F(1,56) = 13.33; MSe = 6.48; p < 0.001$. The interaction between expertise level and the kind of the suggested sources is significant, $F(1,56) = 26.71; MSe = 5.63; p < 0.001$. The interaction between the suggested sources and the evoked sources is also significant, $F(1,56) = 12.12; MSe = 5.63; p < 0.001$. The triple interaction between expertise level, suggested sources and nature of the evoked sources is not significant.

To summarize, for lay designers, the suggestion of sources, whatever they are intra- or interdomain, did not appear to enhance the production of new creative ideas.

In contrast, for professionals, the interdomain condition significantly facilitated the evocation of sources (in mean, 10.5 evoked sources), whereas the intra-domain condition appeared to limit the evocation of sources (in mean, 3.8 evoked sources) with regard to the result obtained in the free condition (6.4 evoked sources). In the guided conditions, whatever the nature of suggested sources, professionals evoked more interdomain sources than intra-domain ones (see Table 2). However, the space of research of interdomain sources appears to be even larger for professionals when they are provided with interdomain sources (in mean, 3.8) than with intra-domain sources (in mean, 2.8).

Thus, expertise seems to be related to the possibility of accessing interdomain sources, _a priori_ far from the object to design.

No significant difference due to the format of presentation (graphical representations or verbal labels) of the initially suggested sources was observed, whatever the designers’ level of expertise.

Discussion

This study highlights interesting findings:

- The evocation of creative sources of inspiration mainly results from analogy-making with interdomain sources.

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Table 1. Number and Nature of Sources Evoked by Lay Designers and Professionals in the Free and Guided Conditions

<table>
<thead>
<tr>
<th>Experimental conditions</th>
<th>Free condition</th>
<th>Guided conditions</th>
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<tr>
<td>Level of expertise</td>
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<tr>
<td>Lay designers</td>
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<td></td>
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<tr>
<td>Intra</td>
<td>1.8</td>
<td>2.0</td>
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<tr>
<td>Inter</td>
<td>1.1</td>
<td>1.2</td>
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<tr>
<td>Total</td>
<td>2.9</td>
<td>3.2</td>
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<tr>
<td>Professionals</td>
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<tr>
<td>Intra</td>
<td>3.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Inter</td>
<td>3.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>6.4</td>
<td>7.2</td>
</tr>
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</table>
• It is possible to exert an influence on the designers’ evocation processes, but this influence depends on the designers’ level of expertise.

Our results appear very different from previous findings (such as the ones of Jansson & Smith, 1989, 1991):

• For lay-designers, the presentation of sources of inspiration – playing the role of examples – did not limit the number of new evoked sources, though it did not expand it.

• In contrast, for professionals, we observed a limitation of the evocation of sources when they were provided with intra-domain sources. This result is in line with the one obtained by Jansson & Smith (1989, 1991). These authors analysed the effect of intra-domain sources presented as examples to professionals in order to design a bicycle-rack. However, our study showed that an opposite effect is obtained when professionals (but not lay designers) are provided with inter-domain sources. In this case, these sources highly facilitated the evocation of new sources.

Thus, with regard to the number of evoked sources, the evocation processes of professionals can be more easily facilitated than the ones of lay designers. In addition, professionals appear to be very sensitive to the type of sources they are provided with.

Concerning the nature of evoked sources, we found that, in the free condition, both professionals and lay designers spontaneously evoked mainly intra-domain sources. However, we observed that, in contrast to lay designers, professionals can avoid such spontaneous behaviour, when they are provided with external sources, whatever the nature of these sources. Indeed, professionals who were provided with sources mainly evoked inter-domain sources, whatever the nature (intra- or interdomain) of the suggested sources.

The cognitive treatment of the suggested sources seems to be performed differently according to the designers’ level of expertise. Some research showed that experienced designers are able to take into account a multiplicity of aspects of suggested sources (functional, structural, aesthetic and so on), which could allow them to activate in long-term memory very heterogeneous new sources, or conflicting aspects from different domains (see Bonnardel & Marmèche, 2003; Dorst, 1997).

Towards enhancing creative ideas in design

Various techniques and divergent thinking guidelines – such as the classical brainstorming technique (Osborn, 1963) – have been proposed in order to foster creativity (see Dewulf & Baille, 1999; Nickerson, 1999). In the case of professional situations, such as design, the challenge is to provide designers with a specific support in accordance with their level of expertise. Moreover, it is also necessary to provide designers with a ‘contextualized’ support and to present it ‘at the right moment’, i.e. when designers look for new ideas and progressively define their space of research. Though there is a co-evolution of problem and solution (Cross & Dorst, 1999; Dorst & Cross, 2001) as well as an iterative dialectic between problem framing and problem solving (Rittel & Webber, 1984; Simon, 1995), if suggestions occur too late in the design process, designers may not consider these suggestions, since they will be more focused on graphically representing their own design ideas.

Table 2. Number and nature of sources evoked by lay-designers and professionals in the guided conditions, according to the nature and format of presentation of suggested sources

<table>
<thead>
<tr>
<th>Suggested sources</th>
<th>Intra-domain sources</th>
<th>Inter-domain sources</th>
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<td>Graphical</td>
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<td>Lay-designers</td>
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<tr>
<td>Intra</td>
<td>3.3</td>
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<td>Inter</td>
<td>0.2</td>
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<tr>
<td>Total</td>
<td>3.5</td>
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<tr>
<td>Professionals</td>
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<tr>
<td>Intra</td>
<td>0.8</td>
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</tr>
<tr>
<td>Inter</td>
<td>1.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Total</td>
<td>2.4</td>
<td>5.2</td>
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</table>
Towards the end of adapting support to the designers’ level of expertise, our findings show that only experts benefit from the presentation of external sources of inspiration, and especially of interdomain sources. Such sources allow experts to explore new conceptual domains. In contrast, for novices, the fact of being provided with sources, either intra- or interdomain, does not significantly modify the evocation of new sources. Our interpretation is that the suggested intra-domain sources are in fact very similar to the sources they would spontaneously evoke. Concerning interdomain sources, the main problem for novices would be that they cannot envision the potential utility of such sources, these sources looking for us too far from the object to design. Such results can lead to useful benefits in two areas: enhancing novices’ analogical thinking and supporting expert designers in spontaneous evocation of new sources. Our interpretation is that the suggested intra-domain sources are in fact very similar to the sources they would spontaneously evoke. Concerning interdomain sources, the main problem for novices would be that they cannot envision the potential utility of such sources, these sources looking for us too far from the object to design.

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Koestler, A. (1975) The Act of Creation. Publisher?


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