Addressing complexity in design a systemic model of creativity and guidelines for tools and methods

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Addressing complexity in design: a systemic model of creativity and guidelines for tools and methods

The aim of this paper is to show how the systemic approach makes it possible to redefine creativity; it highlights new ways to stimulate it in complex industrial contexts. A model was constructed from a state-of-the-art review categorized according to three conceptual scales (environment, individual, and object) using the systemic approach. It highlights three fundamental interactions (perceptual, cognitive, and social) that synthesize the mechanisms of creativity as a whole. From this model, three guidelines were proposed: the use of analogical tools to stimulate perceptual interactions, the use of a language based on visual forms to stimulate cognitive interactions, and the use of a cyclical process alternating individual, social and expert creativity to stimulate social interactions. Deployed together as an embedded method, we argue that these guidelines improve creative performance in complex contexts by focusing on interactions that stimulate the overall creativity system. We conclude with an implementation of this method in our industrial context (a car manufacturer), and test the guidelines in the context of real industrial projects.

Keywords: creativity, complexity, design, systemic, model

1. Introduction

Our research is motivated by the needs that we have identified as both researchers and active professionals working in industry (the Innovation Department of an automobile manufacturer). Our work involves the organisation of creativity workshops, in the context of a search for new creativity management methodologies. Our day-to-day activities rely on existing tools and methods that are widely used by practitioners (Brainstorming, lateral thinking, TRIZ, etc.), and the analysis of their results and effectiveness in driving innovation. However, we have encountered two main problems.

The first concerns the increasing technical and organizational complexity of the projects that we are involved in. We have observed a need to change ideas about design and find new ways of thinking (Charnley *et al*., 2011). It is often the case that solutions to our complex problems cannot be found, as they consist of a large number of systems and subsystems that are both interconnected and evolving. This creates conflicts and contradictions that make it difficult to have an overview and carry out analyses (Alexander, 1964; Manzano, 1998; Lindemann 2010).

The second problem concerns the tools we use on a daily basis, which do not appear to be particularly effective in stimulating creativity. Our industrial context seems to exceed their capabilities and they are of no help to designers who are attempting to solve complex problems in a systemic network of conflicting requirements (Alexander, 1964). Nor does the selection of ideation techniques based on the type of ideas we wish to stimulate, the stage of the process, or context improve things (Gryskiewicz, 1988; Brightman, 1988; Van Gundy, 1988). We have observed that while they increase productivity by directing and improving the quality of ideas, the results are often poorly structured (Jones *et al.*, 2001). Consistent with other authors, we find that the effectiveness of workshops is essentially based on the facilitator, notably their experience and abilities. Formal methods are particularly questionable, especially recipe-type techniques derivative of "brainstorming", that lack a rigorous theoretical framework (Thiebaud, 2003; Degrange, 2000; Hatchuel et al., 2009; Lindemann, 2010; Tyl, 2011). Instead, we need flexible and generic procedures that support creative design processes (Lindemann, 2010).

Our investigation of these issues is based on the systemic approach. This makes it possible to consider a problem as a whole, identify and use the relationships between its various aspects, and develop transdisciplinary skills (Charnley *et al*., 2011). It relies on the capacity to intellectually and graphically represent physical and historical reality as a complex combination of relationships and inter-relationships, and to highlight and create similarities (Durand, 1979; Minati, 1997). The approach, which is based on the mutual reinforcement of individual and social processes, appears to be effective in enhancing creativity (Fisher *et al*., 2005) seems to be an improvement on older, linear views (Chanal, 2004). While work on computational simulation has highlighted the interaction between the individual and society (Sosa and Gero, 2005), little attention has been given to pragmatic methodologies that test the systemic approach to creativity in real and complex industrial contexts in terms of problems, actors and environments.

In this article we synthesise a bibliographic corpus through the lens of the systemic approach, in order to identify some drivers for improving creativity in complex environments. We then compare these potential improvements to our industrial context and apply them to current projects. The questions we ask are:

(1) What elements are highlighted by the systemic approach?

(2) How can they be combined into a comprehensive and coherent synthesis?

(3) Does this synthesis help to guide the choice of suitable tools and methods?

We address the first question through a state-of-the-art review categorized using three conceptual scales (Section 3). We address the second question by proposing a systemic model of creativity and guidelines for creativity management (Section 4). Finally, we address the third question by validating the theoretical model through the implementation of the new guidelines in an industrial context (Section 5). However, we begin with the methodological framework that underpins of our work (Section 2). This is divided into two parts: the action research method, and systemic modelling.

2. Methodology

2.1 The action research method

As both researchers and working professionals we use the action research method. Emerging from the social sciences (Lewin, 1946) action research was initially described as a spiral of steps with the same structure:

- Identification of a problem through field observation (theory → practice)
- Thinking about and establishing an action plan (practical → theory)
- Taking action (theory → practice)
- Analysis and evaluation the effects (practice → theory)

Applicable to both theory and practice, the method helped to diagnose how to integrate creativity in our context, and identified the systemic approach as a relevant theoretical modelling method (Section 3) in order to develop drivers for improvements (Section 4). We then tested these drivers in our industrial context (Section 5), and reassessed their effects in order to draw some 'actionable' conclusions.

2.2 Systemic modelling

The systems approach is used in parallel with the action research method. It is divided into three steps: system analysis (Section 3); system modelling (Section 4); and system simulation (Section 5). See the work of De Rosnay (1975) and Le Moigne (1990, 1995) for further details of the methodology. The approach relies on the construction of a hypothetical model developed from a state-of-the-art synthesis, followed by the identification of variables to be simulated in order to improve system performance. To be useful in practice, the model must be comprehensive and coherent. At the same time it is itself a complex system; a complex model of a phenomenon that is perceived as complex. In system modelling, it is important to:

- Avoid simplify processes and couplings to avoid irreversible imbalances
- Differentiate between system components to draw out a picture of an organized whole

- Decentralise elements in order to restore system equilibrium or symmetry
- Include environmental influences in the definition and development of the system

Once the model is established, we need to:

- Include internal and external constraints to maintain the system
- Identify sensitive points that can push the system in a given direction
- Consider information processes as an important source of energy
- Observe the organization's response times and combined system effects

3. State-of-the-art review

3.1 Design, creativity and complex systems

Models of the design process do not provide a good representation of creative processes (Howard *et al*., 2008) and, paradoxically, the definitions of design and creativity are very similar (Bonnardel, 2006): the expression of an idea, the gradual and parallel construction of a mental and external representation, the achievement of goals or problem solving. The iteration of design and cognitive tasks seem to be merged (Finke et al., 1992; Maher et al., 1996; McKoy et al., 2001; Benami and Jin, 2002; Jin and Chulsip, 2006), and designers tend to work alone (Bonnardel, 2006).

The creative process has become analogous to the design process (Basadur et al., 2000; Kryssanov et al., 2001), and the various phases overlap (Wallas, 1926) rather than unfold as a sequence of steps (Kryssanov et al., 2001; Cortes Robles, 2006; Bouchard, 2010; Tyl, 2011; Taura and Nagai, 2013). Creativity and design only differ in terms of scale, the complexity of the output and the actors involved (Howard et al., 2008), leading some authors to claim that the design is the "science of generativity" (Hatchuel et al., 2011).

Various approaches to design creativity have proved effective in stimulating systemic relations between the individual and their social environment (Csikszentmihalyi, 1996, 1999;

Hatchuel et al., 2009). As for the (resolutely holistic) systems approach, it consists in explaining a phenomenon in terms of multiple elements (cultural, social, psychological, physical, etc.) based on a model of the (complex) system. The model highlights structural and functional principles that support the transmission of knowledge, action and creativity (De Rosnay, 1975). Such arguments provide the foundation for our decision to analyse creativity through the lens of the complex system.

According to Cilliers (1998), a complex system has three main criteria:

- it consists of a large number of elements that interact dynamically;
- it is non-linear; and
- it interacts with the environment.

Traditionally, research focuses on four main areas (Rhodes, 1961; Murdock and Puccio, 1993. Basadur et al., 2000) namely, the creative “process”, the creative “product”, the creative “person” and the creative “environment”. However, consistent with our systems approach, we use three conceptual scales: the environment; the system itself (here, the individual); and the (internal and external) objects making up the system. Processes are therefore described in terms of cross-cutting links between each of these three scales. Figure 1 shows this classification.

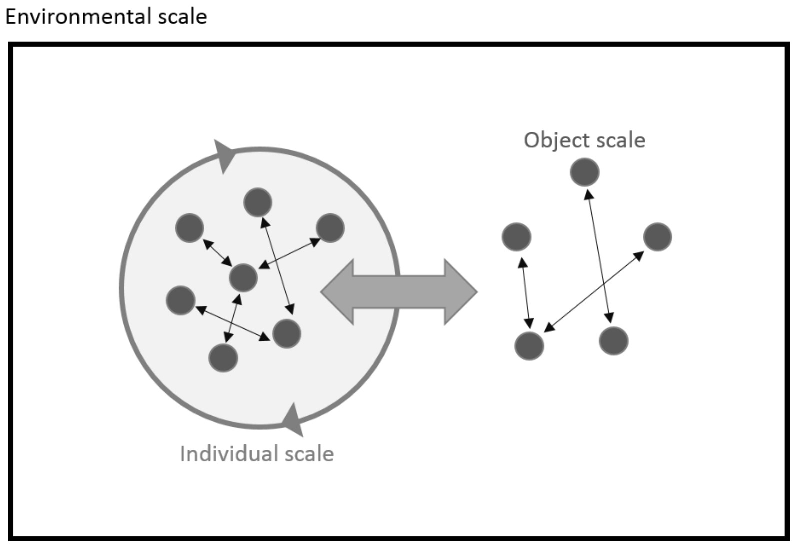

Figure 1. State-of-the-art categorization according to the systemic approach

3.2 Environmental scale

Our brain organises itself by comparing perceived information with past experience (De Bono cited in Aznar, 2012). Creativity is not a series of steps, rather it is a long process that is intrinsic, reflexive, iterative, evolutionary and cyclical, permanent and continuous (Hybs and Gero, 1992; Weisberg, 1988, 1993, 1999; Ward, 2007; Lubart *et al*., 2003). It can be seen as an auto-poïetic system made up of discoveries that are constantly reproduced, and which develop over time (Iba, 2010). This system is composed of interacting processes that mutually reinforce each other: between an individual and society, and between an individual and a given technical environment (Chanal, 2004; Fisher *et al*., 2005). The environment stimulates the individual both physically and socially, to begin generation and evaluation (Lubart *et al*., 2003; Fischer *et al*., 2005) at the same time, the problem and solution spaces constantly co-evolve (Maher, 1994; Maher and Poon, 1996; Wiltschnig *et al*., 2013). It is important to note that collaborative processes are convergent and limit divergent creative performance (Hoegl and Parboteeah, 2007). For greater efficiency, it is therefore necessary to switch between individual creativity for production, and group creativity for development and evaluation (Gordon, 1961; Drazin *et al*., 1999).

3.3 Individual scale

It is necessary to distinguish creativity (a potential capacity) from creation (a validated output) (Anzieu, 1981; Csikszentmihalyi, 1999), which must be new and suited to the context in which it takes place (Lubart *et al.*, 2003; Bonnardel, 2006). The creative act consists of the identification and exploration of potential associations, and then building and modifying the right combinations (Poincaré, 1908; Oxman and Planning, 1997). This happens through the externalisation of knowledge structures present in representation and re-representation (Oxman and Planning, 1997). It is also the ability to identify multiple cross-references between various analogue matrices that were previously separate (Koestler, 1964), and comparing and contrasting (concept-blending) different elements side-by-side using analogical reasoning (Gordon, 1961; Nagai and Taura, 2006). Consequently, we can argue that the cognitive processes that come into play are fundamental and commonplace; they are not specific to creativity (Weisberg, 1988, 1993, 1999; Ward, 2007; Lubart *et al*., 2003).

The psychoanalytic approach suggests that creativity results from the creation of a new equilibrium after a period of psychic crisis (Anzieu, 1981). When analytical capabilities reach their limit, frustration triggers a period of unconscious incubation (Hadamard, 1956; Lubart e*t al*., 2003.). The unconscious then highlights useful combinations, for example by linking ideas with evaluation criteria (Koestler, 1964; Ritter *et al*., 2012.). This is similar to the emotional resonance model, where emotions that are reactivated by an environmental stimulus reveal the source concepts associated with them (Lubart *et al*., 2003). Awareness can be put to one side, which leaves room for the unconscious to work without inhibiting the ability to react (Bernèche cited in Aznar, 2012). That is why switching between conscious and unconscious work reduces mental fatigue and allows a new and unbiased perspective to emerge (Poincaré, 1908; Posner, 1973; Smith and Blankship, 1989; Melcher and Schooler, 1995).

While the unconscious plays a role, emotion is also essential and has an impact on the motivational, contextual and functional aspects of creativity (Ribot, 1900; Lubart *et al*., 2003.). For example, a negative attitude is effective for long-term problem solving, while a more positive mood is better in the short-term (Kaufmann and Vosburg, 1997; Davis, 2009; Yang *et al*., 2012.). Similarly, the concept of 'flow' describes the merging of action and attention, focused commitment, concentration and enthusiasm (Csikszentmihalyi, 1988, 1999). Finally, the last phase of creation is ambivalence; this features an alternation between separation anxiety from the work and the desire to communicate it to the public (Rogers, 1951).

3.4 Object scale

Creativity is a cyclical reconfiguration and reinterpretation of traditional ideas and existing knowledge (Alexander, 1964; Hybs and Gero, 1992; Lubart *et al*., 2003; Hatchuel and Weil 2003, 2009), together with a slow accumulation of new elements where the quality of the material used is important (Weisberg, 1988, 1993, 1999; Ward, 2007; Lubart *et al*., 2003). The initial cognitive material is the result of sensations: the percept. This changes over time into a mental image, then into an idea-concept (Alexander, 1964; Bernèche cited in Aznar, 2012). Pictorial thought therefore dominates the unconscious, as it is more primitive (Koestler, 1964; Ritter *et al*., 2012). In preconscious processes, the symbol is used allegorically and figuratively without being translated into words (Koestler, 1964; Kubie, 1958; Leboutet, 1970). Consequently, these mental images are recalled from associative memory in order to understand a perceived object (Oxman and Planning, 1997).

This is why forms are used, individually or together, as a symbolic language that can describe, store and process (Oxman and Planning, 1997, 2002). They structure relations in the consciousness of the individual, and interact with their mental images (Bruner, 1996; Van der Lugt, 2000, 2005; Visser, 2006, 2009; Iba *et al.*, 2009). As the form encodes information and the knowledge that helps in reasoning, it must be qualitative and imprecise (Oxman and Planning, 1997, 2002; Visser, 2006, 2009; Iba *et al.*, 2009). It is a hybrid contextualized representation (modelling and representation) that evolves along with knowledge, often called an intermediate representation, or intermediate object (Mer, 1998; Blanco, 1998; Jeantet, 1998; Prudhomme, 1999; Bouchard *et al*., 2005; Lattuf, 2006).

Thus the individual transforms one representation into another; although they are different, they represent the same artefact (Visser, 2006, 2009). On a larger scale there is a parallel with the concept of 'memes': units of information whose integration is needed to develop the culture (Csikszentmihalyi, 1996). Individual knowledge, judgment and personal meaning form the foundation for ideation and evaluation (Boden, 1990, 1994, 1999; Runco, 1992; Gardner, 1995; Fischer *et al*., 2005). Similarly, there is no criterion that does not require assessors or peer-reviewers, whose evaluations are a function of their expectations and cultural norms (Csikszentmihalyi, 1999; Karni and Shalev, 2004). These judges give particular weight to novelty (based on their knowledge of the timeline of similar inventions and the characteristics of similar products); and utility (based on their knowledge of how many people use the product, for how long, and how much effort they put into using it) (Sarkar and Chakrabarti, 2008, 2011).

4. The systemic model of creativity

4.1 Creativity as a complex system

Based on the principles set out in Section 2.2, we modelled creativity as a complex system. Specifically, it is represented as a simultaneous coupling between:

- The individual and the objects in their environment: a cycle of externalisation and the re-representation of forms

- The individual and other individuals: a cycle that alternates individual and collective work
- Other individuals and objects in the environment: social evaluation and evolution of 'memes'

At the individual level, there is a second coupling: an alternating cycle of unconscious and conscious work. This fosters the emergence of a new internal 'environment' composed of remembered images based on analogical categorization principles. Each element is represented as an ongoing process, and illustrates the evolving nature of each of the subsystems that organize the creativity system. This model highlights:

- At the level of the environment: three sub-environments: technical, social, internal
- At the level of the individual: three sub-processes: formal (externalisation/ representation), analogical (conscious/ unconscious) and social (individual/ collective)
- At the level of the object: three sub-systems: information, mental images, knowledge

And three couplings between sub-environments:

- The internal–technical coupling via the individual: individual creativity
- The internal–social coupling via the individual: social creativity
- The social–technical coupling via other individuals: validated creation

Consequently, it also highlights three interactions between the individual and their sub-environments:

- 'Perceptual' (shown in blue)
- 'Cognitive' (shown in green)
- 'Social' (shown in red)

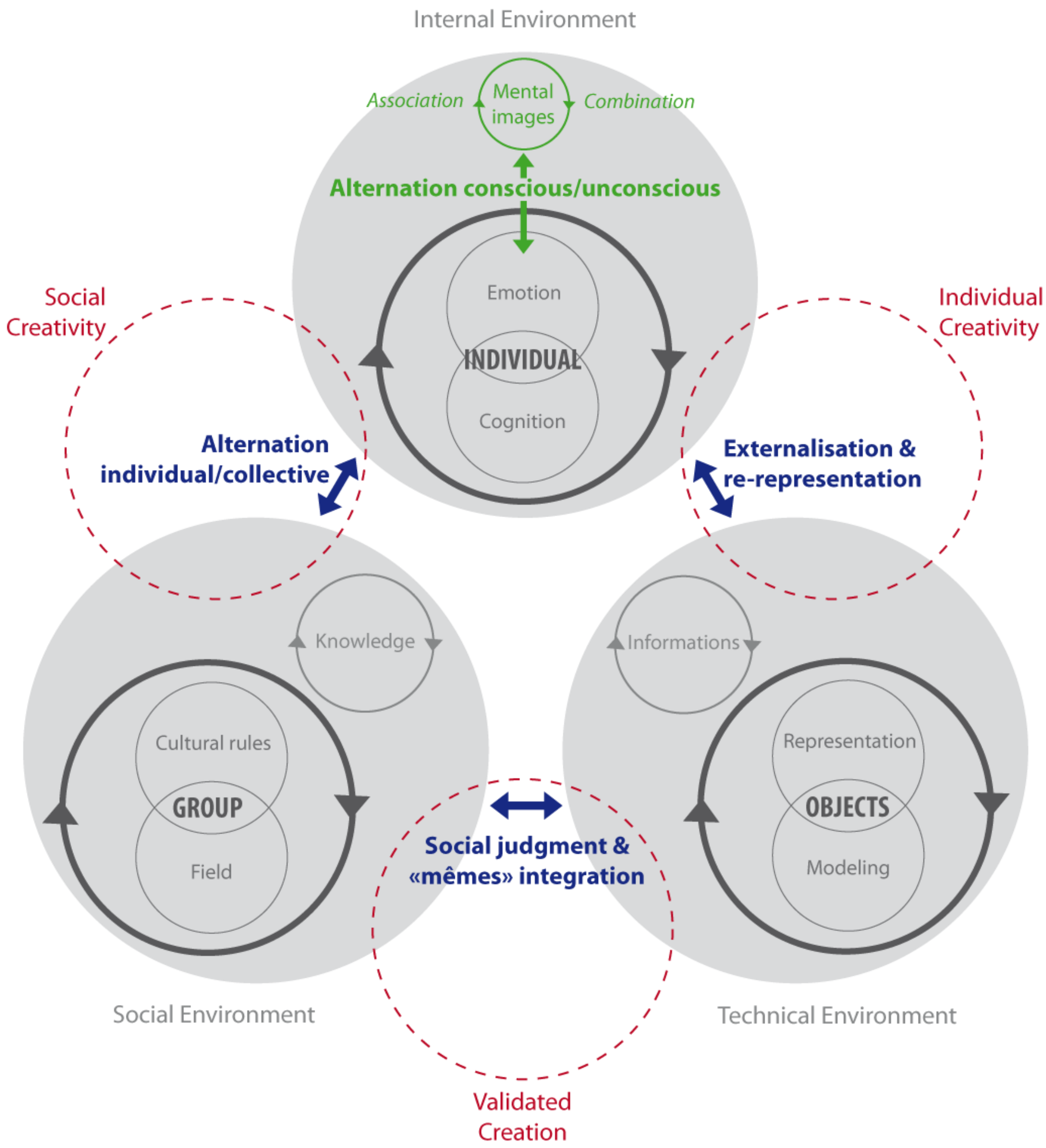

Figure 2. Systemic model of creativity

4.2 Guidelines for the design of tools and methods

Our systemic model of creativity places more emphasis on the interactions between elements than on the elements themselves. Highlighting these interactions reveals three drivers:

- 'Perceptual' interactions where the individual interacts with objects in their environment through a cycle of externalisation and analogical re-representation

- 'Cognitive' interactions where the individual interacts with their internal imaginary world through an alternating cycle of conscious (processing of representations) and unconscious (processing of mental images) work
- 'Social' interactions where the individual interacts with others through an alternating cycle of individual and collective work (which can be evaluated by society)

We hypothesize that these three interactions must all be stimulated to improve system performance, and therefore creativity. We therefore propose the following three guidelines:

- Analogical stimulation tools improve the performance of the externalisation and re-representation cycle; they aim to stimulate perceptual interactions in order to obtain new information. There is evidence that presenting a stimulus upstream may have a positive or negative effect on creativity (Agogué et al., 2014). However we focus on analogue stimuli, i.e. with conceptual links that offer both a certain degree of divergence (expansive example), but at the same time are not too distant from the source in order to improve the coherence of solutions and initial constraints (tree structured). These analogies, through their capacity to create links, perform better in complex systemic contexts where the creation of relations between the elements of the problem is crucial. However, we recognize that the optimal degree of depth and breadth of these analogies remains to be determined (Casakin 2004; Bonnardel, 2006).
- A language based on visual forms improves the performance of the conscious and unconscious cycle; it aims to stimulate cognitive interactions in order to obtain new images. It is known that the use of visual stimuli can have a positive or negative effect on creativity (Jansson and Smith, 1991; Goel, 1995). However, here we focus on the use of basic geometric shapes (Oxman, 1997, 2002), i.e. halfway between abstract (to

reduce fixation effects) and figurative (a conscious reminder of mental images). This formal language is therefore easily understood by novice users of representation techniques, which reduces the risk of a lack of understanding due to the quality of the formalization.

- A cyclical process of individual, group and expert creativity improves the performance of the individual and group cycle; it aims to stimulate social interactions in order to obtain new knowledge. If the cyclical nature of a process is not enough in itself to improve creativity, it is because it traditionally alternates design activities (information, generation, evaluation, etc.). Here we focus on alternate modes of social interaction, i.e. the establishment of a routine that improves creativity because it allocates time to develop individual motivation, then for constructive criticism (Gordon, 1961; Drazin et al., 1999; Csikszentmihalyi, 1999), and because it reduces frustration during the selection (the creator of the idea does not evaluate it). Cyclicity therefore becomes necessary (Lubart, 2003) in order, on the one hand, to establish a dynamic of social stimulation in the long term and, on the other hand, to interface with other business processes while remaining autonomous.

5. Implementation in the industrial context

Based on the three drivers identified, we developed a set of guidelines consisting of analogical tools, language based on visual forms, and cyclical process alternating individual, social and expert creativity, that provide a coherent creativity method (tools, formats, processes). They improve performance in complex contexts by focusing on perceptual, cognitive and social interactions that stimulate the overall creativity system.

We tested our three guidelines individually in three experiments:

- Experiment 1: The hypothesis that the use of analogical tools improved creativity was tested in a creativity workshop (with Group X) focused on the 'premium sedan'. The aim of the workshop was to generate idea sheets on the theme of 'performance' for a car brand (A).
- Experiment 2: The hypothesis that a language based on visual forms improved creativity was tested in a creativity workshop (with Group Y) focused on the 'premium sedan'. The aim was to generate concept sheets from the idea sheets generated in Experiment 1 on the theme of 'performance' for a car brand (A).
- Experiment 3: The hypothesis that a cyclical process alternating individual, group and expert work improved creativity was tested through a retrospective analysis of creativity workshops (with several groups Z) the carried out in the context of 10 recent industrial projects for several car brands (A, B and C). The aim was to identify methodological factors that positively or negatively influence group creativity.

Given that these projects are confidential, we will not describe the exact brief, the materials and actual deliverables that resulted from the workshops; however we will describe the experimental protocol in as much detail as possible.

5.1 Experiment 1: Analogical tools

5.1.1 Objectives and hypotheses

This workshop aimed to generate innovative ideas related to 'vehicle performance' on the theme of the 'premium sedan'. Participants were asked to familiarise themselves with technological, sociological, marketing and strategic input data, then generate idea sheets. These sheets were evaluated *a posteriori* by two expert project managers (brand and target).

This experiment tested differences in the output of ideas measured by innovativeness, and the extent to which they met the specification (brand and target). It compared a classical random brainwriting technique against a brainwriting technique that included an analogical stimulation tool.

5.1.2 Procedure

The creativity workshop was divided into four phases:

(1) Familiarisation with the input data.
(2) Brainwriting to generate usage ideas.
(3) Categorization and formalization of a usage mapping.
(4) Formalization of Idea Sheets (IS) resulting from the categories that were developed.

The protocol was as follows:

- Two identical groups (A: Target, B: Control) of 10 people with multidisciplinary profiles (3 technical, 3 marketing and 4 design).
- Formalization of the input data in the form of identical posters for both groups.
- Identical idea sheet templates for both groups (Figure 3).
- A single change for the target group (A). An analogical stimulation phase was added in phase 2, using the keywords ‘refinement’, ‘serenity’, ‘comfort’, ‘dynamism’ and ‘personalized’. The control group (B) was exposed to a random stimulation.
- A questionnaire was distributed to both groups at the end of the workshop, which consisted of one question: “Were you able to easily use all of the inputs in the generation phase?” Responses were ranked using a 5 point Likert scale.

Figure 3. Idea sheet templates for both groups

5.1.3 Assessment

Results were evaluated *a posteriori* by two expert project managers, who were given time to discuss and prepare a joint response. All of the idea sheets were formatted in the same way by the same person. Each sheet was read once, and scored according to three criteria: the extent to which it met 'brand' requirements, the extent to which it met 'target' requirements, and its innovativeness. Table 1 present a summary of the quantitative results and qualitative evaluation by experts. 'Categories' refers to ideas assessed by the experts to be grouped under a similar theme. A category can therefore be 'shared' (produced by group A and B) or 'unique' (only produced by A or B).

RESULTS TYPOLOGIES	**GROUP A (TARGET)**	**GROUP B (CONTROL)**
Total of Idea Sheets (IS)	**20/36 (56%)**	16/36 (44%)
Shared IS in shared categories	14/36 (39%)	**16/36(44%)**
Unique IS in shared categories	**10/14 (71%)**	10/16 (63%)
Unique IS in unique categories	**6/36 (17%)**	0/36 (0%)
IS meeting 'brand' requirements	**18/20 (90%)**	12/16 (75%)
IS meeting 'target' requirements	**18/20 (90%)**	11/16 (69%)

IS judged as innovative	**19/20(95%)**	5/16 (31%)
IS consistent with all assessment criteria	**16/20 (80%)**	3/16 (19%)
IS consistent with 0 assessment criteria	0/20 (0%)	**3/16 (19%)**
Concept Sheets produced (in a subsequent workshop) linked to three IS or more	**7/9 (78%)**	2/11 (18%)
Concept Sheets linked to less than three IS	2/9 (22%)	**9/11 (82%)**
Question asked to participants	**4.3/5 (yes a little)**	2.8/5 (not really)

Table 1. Analysis of the output of idea sheets

In conclusion, group A produced more idea sheets, but fewer in the same categories as group B. On the other hand, group A not only produced more unique ideas in the same categories as group B, but also more unique ideas in unique categories (not produced by group B). We can therefore say that group A (which used the analogical tool) produced more idea sheets than group B. Moreover, these sheets were more innovative, closer to the requirements specification and participants seemed to be able to exploit the data more easily. Finally, when the idea sheets were reused to create concept sheets, the sheets produced by group A were far more useful than those produced by group B.

5.1.4 Discussion

The analogical stimulation tool appeared to stimulate the perceptual interactions of participants, who were able to exploit the input data more easily. It appears that it improved performance in the externalisation and re-representation cycle. The ideas that were generated had greater intrinsic combinatorial power and a greater degree of innovation, while respecting the constraints of the project. However, although we used intra-domain analogies (brand values), their representation could be seen as cross-cutting (i.e. the words used evoke very generic concepts). It remains, therefore, to more precisely define the analogies that should be used and their influence on output. This should take the form of a more detailed analysis, notably in terms of the depth and breadth of analogical relationships.

5.2 Experiment 2: language based on visual forms

5.2.1 Objectives and hypotheses

This workshop aimed to generate innovative ideas related to 'vehicle performance' on the theme of the 'premium sedan'. Participants were asked to familiarise themselves with technological, sociological, marketing and strategic input data, together with the idea sheets generated during the earlier workshop. They were asked to develop these ideas and identify concrete pathways for innovation in the form of 'Concept Sheets' (CS). These sheets were evaluated *a posteriori* by two expert project managers (brand and target).

This experiment tested differences in the output of concepts measured by innovativeness, and the extent to which they met the specification (brand and target). It compared the use of a free-form template against a template guided by visual forms.

5.2.2 Procedure

The creativity workshop was divided into three phases:

(1) Familiarization with the input data and the idea sheets from the previous workshop.
(2) Categorization and formalization of an idea sheet mapping.
(3) Formalization of Concept Sheets resulting from categorized themes.

The protocol was as follows:

- Two identical groups (A: Target, B: Control) of 10 people with multidisciplinary business profiles (3 technical, 3 marketing and 4 design).
- Formalization of the input data in the form of identical posters for both groups.
- Identical creativity techniques for both groups (Brainwriting and sketching).
- For group (A): a template structured by visual forms was used to formalize concept sheets (Figure 4)

- For group (B): a simple template without visual guidelines was used (Figure 5)
- A questionnaire was distributed to both groups at the end of the workshop, which consisted of one question: “Were you able to easily use the template that was provided to generate your concept sheets?” Responses were ranked using a 5 point Likert scale.

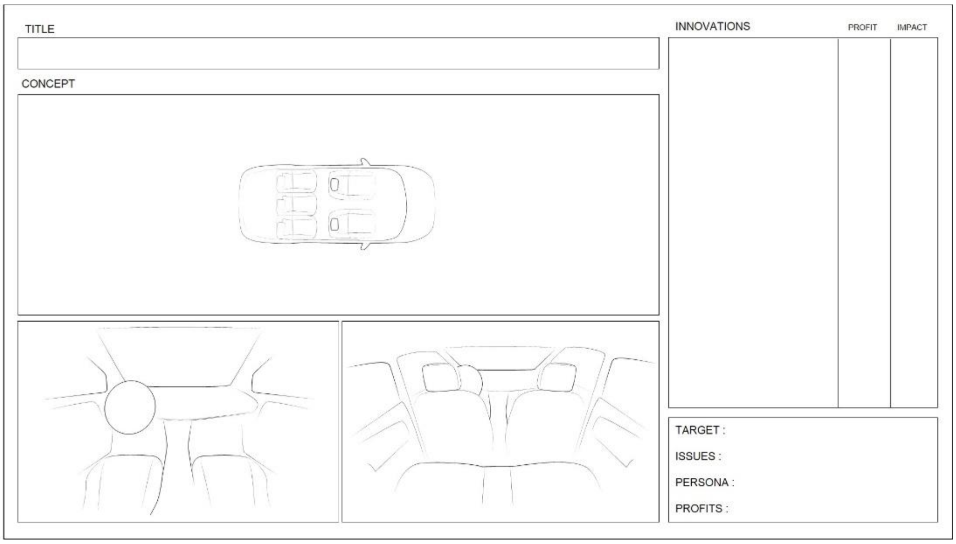

Figure 4. Concept sheet template for group A

Figure 5. Concept sheet template for group B

5.2.3 Assessment

Results were evaluated *a posteriori* by two expert project managers, who were given time to discuss and prepare a joint response. All of the concept sheets were presented in the same way by the same person. Each sheet was read once, and scored according to 26 criteria: 8 related to the extent to which it met 'brand' requirements, 15 related to the extent to which it met 'target' requirements, and 3 related to the extent to which the assessor was able to understand the concept. Table 2 presents a summary of the quantitative results and qualitative evaluation. A concept can be 'shared' (by group A and B) or 'unique' (to group A or B). 'Theme' refers to concepts assessed by the experts to be similar in terms of meaning.

RESULTS TYPOLOGIES	**GROUP A (TARGET)**	**GROUP B (CONTROL)**
Total of Concept Sheets (CS)	9/20 (45%)	**11/20 (55%)**
Shared CS (common to both groups)	3/10 (30%)	**7/10 (70%)**
Unique CS	**6/10 (60%)**	4/10 (40%)
Unique CS for theme 1 (comfort)	1/7 (14%)	**3/7 (43%)**
Unique CS for theme 2 (personalization)	**3/4 (75%)**	0/4 (0%)
Unique CS for theme 3 (technology)	**2/9 (22%)**	1/9 (11%)
CS meeting 'brand' requirements (meeting 5/8 criteria and more)	**7/9 (78%)**	4/11 (36%)
CS meeting 'target' requirements (meeting 8/15 criteria and more)	**7/9 (78%)**	2/11 (18%)
CS 'very understandable' by the assessors	**7/9 (78%)**	1/11 (9%)
CS 'reasonably understandable'	2/9 (22%)	**9/11 (82%)**
CS 'poorly understandable'	0/9 (0%)	**1/11 (9%)**
CS consistent with all assessment criteria	**5/9 (56%)**	0/11 (0%)
Question asked to participants	3.6/5 (don't know)	**4.4/5 (yes a little)**

Table 2. Analysis of the output of concept sheets

While group A produced fewer concept sheets overall, fewer of them were shared with group B. On the other hand, group A produced not only more unique concepts than group B, but also more concepts related to two themes (compared to only one for group B). In conclusion, group A (which tested the template structured using a language based on visual forms) produced more concepts sheet that met the requirements and were more understandable, than group B. This is despite the difficulties that the group seems to have encountered in understanding the new template.

5.2.4 Discussion

A lack of familiarity with the new visual form of template clearly led to a decline in output. Nevertheless, it may have improved performance in the conscious/unconscious work cycle leading to more original and diverse concepts that respected project constraints. The new template appears to have stimulated cognitive interactions, and assessors had a better understanding of the concepts that were generated. However, the visual forms that were used were somewhat abstract. Further work should define more precisely the balance between figurative and abstract formalization, and investigate the participant's understanding of symbolic forms, in order to analyse their influence on output.

5.3 Experiment 3: Cyclical processes

5.3.1 Objectives and hypotheses

This experiment was based on 10 industrial projects whose characteristics are summarized in Table 3. The objective of each creativity workshop was to become familiar with various input data, and generate ideas and concepts. Tools, data formalization and the phase of the project varied. Workshops were led by two creativity experts with over five years' experience, who participated in the associated industrial projects.

Given the complexity of the evaluation, the analysis focused on correlations between positive and negative feedback from the two experts, and the methodological characteristics of the workshops.

PROJECT NAME	**TEAM SIZE**	**TEAM PROFILE**	**SYSTEMIC**	**PROCESS**	**TOOLS**
V	Big	Multi-disciplinary	Yes	Generation; Evaluation; Generation; Evaluation; Summary	Sketching; challenging questions; subjective dot voting
VO	Medium	R&D	Yes	Generation; Evaluation; Generation; Evaluation; Summary	Mapping; sketching; **subjective dot voting**
K	Medium	Multi-disciplinary	Yes	Generation; Evaluation; Generation; Evaluation; Summary	Brainstorming; sketching; **subjective dot voting**
C	Big	Multi-disciplinary	No	**Evaluation; Generation; Evaluation**	Scale modelling; sketching; subjective dot voting
D	Small	Researchers	Yes	Evaluation; Generation;	Scenario planning;
R	Small	R&D	No	Discussion; Generation;	Role playing; user flow
K2	Medium	R&D	Yes	**Generation; Summary; Summary**	Quick n dirty prototyping
P	Small	R&D	Yes	Individual; Collective; Summary	Concept map; mindmap
V4	Big	Multi-disciplinary	Yes	**Generation; Discussion; Expert**	Scenario planning; brainstorming; **expert voting**
P2	Big	Multi-disciplinary	Yes	Individual; Collective; Expert	Brainstorming; sketching; **expert voting**

Table 3. Context for the 10 industrial projects

5.3.2 Procedure

The analysis was divided into three phases:

1. Identification of the criteria to evaluate (top row of Table 4).
2. Where possible, criteria were scored as a function of two values: positive or negative (Table 4).
3. Free-form qualitative and spontaneous remarks from experts on elements common to the 10 projects.

PROJECT NAME	**METHOD STRUCTURE**	**METHOD PROCESS**	**CONTENT FORMAT**	**CONTENT ORIGIN**	**TOOLS USE**	**PERSONAL MOTIVATION**	**SOCIAL COHESION**
V	Negative		Positive		Negative		

VO			Positive			**Negative**	**Negative**
K				Positive		**Negative**	**Negative**
C		**Negative**	Positive		Negative		
D	Negative		Positive		Positive		Negative
R					Positive	Positive	
K2		**Negative**	Positive			Negative	Negative
P	Negative		Positive		Positive		Negative
V4		**Negative**	Positive		Positive	**Positive**	**Positive**
P2				Positive		**Positive**	**Positive**

Table 4. Analysis of creativity workshops

5.3.3 Assessment

The results were evaluated by the two creativity experts several months after the workshops had been held. All of the feedback was collected during a single session by the same interviewer.

For projects V, V0 and K, generation and the evaluation of the productivity is correlated with negative feedback in terms of personal motivation and group cohesion. This observation is consistent with recurring comments about frustration – sometimes from participants, sometimes from the experts – when the evaluation is carried out subjectively by the group. Similarly, there is negative feedback regarding the management of the method for projects C, K2 and V4, which correlates to the ‘evaluation-generation-assessment’, ‘generation-summary-summary’, and ‘generation-discussion-summary’ processes. These processes are linked to time-consuming tasks that require a lot of group investment, which is difficult to achieve in the short timeframe of a workshop. Conversely, there is a positive correlation between positive feedback in terms of personal motivation and group cohesion in projects V4 and P2, with the introduction of an external expert for the evaluation. This observation is confirmed by recurring comments that the expert evaluation was more efficient, reduced frustration and limited subjectivity. With respect to processes, very few other observations emerge from the analysis. On the other hand, other recurring comments concern content formats, which are very positively received in projects V, V0, C, D, K2, and V4. This evaluation correlates with the highly-illustrated visual typology of the input data, and the entertainment provided by visual tools used in projects D and P.

In conclusion, this *a posteriori* analysis of 10 projects that were carried out before the guidelines were deployed confirms several points:

- The graphical formalization of data or tools influences the responses and understanding of participants.
- It is important to make time upstream for individual work, and only use workshops for time-consuming and cumbersome group activities (debates, summaries, etc.).
- There is an overriding need for *a posteriori* expert evaluation, both to limit frustration during the session and to ensure rigor.

5.3.4 Discussion

The use of a cyclical process that alternates individual, group and expert creativity seems to improve both the output and motivation of participants and increase output in both individual and group cycles. However, a period of acclimatization or regular practice seems to be essential in effectively mobilizing the group as a whole. The stimulation of social interactions at the organisational level is a complex and ambitious challenge that cannot be fully explored in one experiment. Further research should investigate our hypothesis in different contexts and other industries in order to statistically confirm our results, particularly with respect to different potential biases (related to participants, experts, facilitators, etc.).

6. Conclusion

This article attempts to identify drivers for improving creativity in complex environments. It highlights important theoretical elements through the lens of the systemic approach. Our research questions were:

(1) What elements are highlighted by the systemic approach?

(2) How can they be combined into a comprehensive and coherent synthesis?

(3) Does this synthesis help to guide the choice of suitable tools and methods?

We answered our first question through a state-of-the-art review that ended in a categorization based on three conceptual levels (environment, individual, object) derived from the systemic approach. The review highlighted the permanent co-evolving nature of interactive processes found at, and between, these levels. It identified three axes to improve creativity: changing interactions (environment); analogical stimulation (individual); and the processing of forms (object).

We answered our second question through a creativity model theorized as a complex system. This model highlighted three sub-environments (technical, social, internal), three individual sub-processes (formal, analogical, social), and three object sub-systems (information, images, knowledge). It also highlighted three couplings between sub-environments (individual creativity, group creativity and validated creation), and finally three types of interactions between the individual and their sub-environments (perceptual, cognitive and social). We hypothesized that these three drivers should be stimulated together in order to improve system performance, and therefore creativity.

Finally, we answered our third question by implementing guidelines that aimed to stimulate these three drivers based on: analogical tools; a language based on visual forms; and the alternation of individual, social and expert creativity. Next, we evaluated the implementation of these guidelines and their impact on creativity in the context of actual, complex industrial projects in three experiments in the automobile industry. The first experiment showed that the analogical tool not only produced better results, but also improved understanding of complex inputs (expansion of the information domain). The second showed that the language based on visual forms produced better results and increased the assessor's understanding of the concepts that were produced (expansion of the image domain). Finally the third showed the importance of framing creativity workshops: both upstream – through an individual preparatory phase; and downstream – through an expert evaluation carried out after the workshop. All of which means that the workshop itself should focus on bringing together idea contributors, and encourage and monitor their interactions within an ongoing cyclical process of individual, social and expert creativity (expansion of the domain of knowledge).

Although we were able to validate our model and deploy a more robust method, it is important to note that this paper summarizes research that is in its infancy and remains to be proven. In particular, future work should take the form of experiments in diverse project and industrial settings, to ensure statistical validity and establish the extent to which our work can be generalised.

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