MODULATION OF AMBIGUITY, A COGNITIVE FUNCTION OF REPRESENTATIONS DURING IDEA GENERATION

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Abstract

The role of the representations that are developed in creativity sessions is often overlooked as a potential factor, which can influence the progression and the results of those sessions. Through the qualitative analysis of a case, observed in an open innovation center called Ideas Lab, we will explain the use, the nature and the functions of representations developed during a creativity session. We aim at articulating Duval's representational cognitive functions and the mode of attribution of meaning, polysemic versus monosemic, in creativity sessions as specific situations. In addition to the classical cognitive functions of Duval's framework, we propose a new cognitive function of representation that we call the modulation of ambiguity specific to the creative process. The representation allows the adjustment of the ambiguity level to give way to a variety of interpretations. This potential of the modulation of polysemy supports the idea generation activity by introducing or preserving a variety of interpretations, and prepares the idea evaluation phase by reducing polysemy and supporting the construction of a common understanding.

Keywords: Creativity, Early design phases, Innovation, Teamwork, Design methodology

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1 INTRODUCTION

Creativity sessions entail complex activities and several factors are important for their success. The choice of the creativity method (Mednick, 1962, Shah, 1998, Paulus and Yang, 2000), the construction of the group (Taggar, 2001), the location (Kristensen, 2004), the facilitator (Isaksen, 1983, Svanaes and Seland, 2004) and many other factors can influence the progression and the results of the meeting. These factors are widely discussed in the scientific community. However, the role of the representations that are developed in those sessions is often overlooked as a potential factor. By representations, we mean the traces, the inscriptions and the "configurations of inscriptions using a two-dimensional plane (e.g. paper, screen)" (de Vries, 2012, p. 2016), which emerge during creative sessions. The first objective of our work is to understand the process of the construction of representations during the creative phases of innovative design. The focus on representations inevitably leads us to consider the particular tools used to support a creativity session and to actually construct representations. We distinguish between physical tools and socio-technical tools. Whereas physical tools allow building representations and performing actions in the physical sense (e.g., a whiteboard and marker enable the writing of a word), socio-technical tools offer a methodology and help to achieve goals through the construction of representations (e.g., Mind Map diagrams not only record ideas but also organize, structure and connect them together). The representations constructed with socio-technical tools become new intermediary objects in the activity of idea generation (we will express the notion of intermediary object in the section 4). The material existence of these new objects is possible through the physical tools. We aim at articulating the cognitive functions of representations and the mode of attribution of meaning in creativity sessions as specific situations. By "cognitive function" we mean the actions in terms of communication, reflexion, generation, etc. supported by these representations. The cognitive functions of the representations are achieved by supporting cognitive activities undertaken during a collaborative activity. Socio-technical tools assist the achievement of cognitive functions. In a case study, through a qualitative analysis, we will explicitly explain the use, the nature and the functions of representations developed during a creativity session. We intend to answer the following questions: What representations are constructed? What are the functions of these representations?

To answer these questions, we analyze the work practice of an open innovation center called Ideas Lab, an interdisciplinary creativity platform located in the Rhône-Alpes region in France that aims at enabling the generation and emergence of disruptive concepts in the domain of microelectronics and new emerging technologies by combining usage forecasting and new technologies that arise in industry and technology of the French Alternative Energies and Atomic Energy Commission (CEA). This think-tank is a place of prospective reflection mobilizing the scientific resources of the social sciences. In this context, creativity sessions are organized in order to facilitate the emergence of cross-cutting issues, to work towards knowledge acquisition, to develop scenarios of use and to look into the future and anticipate needs. We chose to analyze a creativity session, focusing on this latter objective, looking at the use of representational tools and methods from a representational perspective and including a semiotic dimension.

2 CONCEPTUAL FRAMEWORK

We focus on the cognitive processes occurring during a creative session and more specifically on the roles and functions of representations. We adopt a view of creative sessions as a two-step cognitive process mobilizing divergent and convergent modes of thinking. Furthermore, we combine this with Duval's (1995) representational functions in order to analyze the role of representations in this context. We build on both conceptual frames to explain the role of graphical representations in supporting cognitive processes during a creative session. Finally, the semiotic dimension refers to the mode of attribution of meaning, polysemic versus monosemic, which may influence the creative process. In fine, the presented frames will be exploited to build a reflection on representations (construction, objectives, tools, constraints) and their cognitive functions.

2.1 Divergent versus convergent thinking

Divergent thinking is an important component of complex creative processes (Runco, 1991). A creativity session can be seen as a sequence of successive steps of divergent and convergent thinking (Basadur, Graen and Green, 1982, Basadur, M., Gelade and Basadur, T., 2013). Specifically, in idea generation, participants engender as many ideas as possible in a limited time. They are encouraged to unleash their creativity: an instant of divergent thinking. During the evaluation phase, ideas are structured and considered: an instant of convergent thinking. Both thought patterns are mobilized according to the objectives of the session (Brophy, 2001) and seen as stimulators for creative activity (Coskun, 2005). We focus on divergent thinking in the phase of idea generation and how it is reflected in the representations.

2.2 The cognitive functions of representations

We propose an analysis of representations as products of a creativity session in terms of the cognitive functions proposed by Duval (1995). As a result of the first function, *objectification*, an idea is externalized, takes form, and becomes accessible to perception. As a result of the second function, *communication*, an idea, through its representation, becomes subject to exchange and discussion. The third function is *computation*; representations allow operations that would be too cumbersome internally. These functions have been identified for individual representations and subsequently adapted to describe representations constructed in groups (de Vries and Masclet, 2013). Although Duval's three cognitive functions were originally expressed in a mathematics context, it seems feasible to apply them to the analysis of representations produced during a creative session. The similarity between mathematical representations and idea representations as a product of brainstorming sessions lies in the impossibility of a direct access to the content. In design, as has been formulated by de Vries (2006): "An artifact is imagined and drawn at the same time; it is constructed through its representation and represented through its construction". This also seems true for idea generation, where ideas become meaningful when expressed or represented. In an idea generation session, ideas and representations appear simultaneously. An idea is shared through its representation or elaborated through its representation. So it seems important to study the semiotic aspects of representations in order to study the creative process, especially in idea generation.

2.3 Polysemy and monosemy

Another relevant framework for the analysis of representations in idea generation refers to the semiotic dimension. Bertin (1967), regarding the signification attributed to signs, distinguishes monosemy and polysemy. Bertin (1967-1983) defines the monosemic and polysemic systems as follows: "A system is monosemic when the meaning of each sign is known prior to observation of the collection of signs." And "Conversely, a system is polysemic when the meaning of the individual signs follows and is deduced from consideration of the collection of signs." (Bertin, 1983, p. 2). Polysemy might be seen as problematic and a source of confusion. This is not the case in our framework since multiple interpretations are considered to be factors favoring the variety in idea generation sessions. We refer to Tversky et al. (2003) who consider polysemy as a potential, i.e. a favorable factor for creativity. Accordingly, we will use the concept of polysemy to analyze the ways in which representations can support a creative session.

3 THE CASE OF "CITY 2030"

The creativity session analyzed in our case study took place in the open innovation center described in the introduction. The meeting was held in a room of about 50 square meters, equipped with individual seats, arranged in a circle where 11 participants could comfortably work. The room was equipped with physical tools in order to realize the group's idea generation. Flipchart and whiteboards allowed tracing the proposals; post-it and magnetic boards facilitated exposure and selection of ideas. The moderator of the session used socio-technical tools, such as Mind Mapping, brainstorming techniques, as well as content structuring and organization techniques.

3.1 The project and its objectives

The idea generation phase aims at predicting city life in the near future (in 15 years). Four imaginary cities are to be proposed along two dominant axes: "environment" and "political autonomy of

citizens". We observed one of the four sessions which were organized. The participants received an assignment with the following question: " What would a city with strong local political power and with ecological rather than economic governance look like in 2030? During the meeting, other instructions were given to the participants. The first session lasted one day and a half during which product concepts, early life scenarios including characters, and scenes of production, entertainment, distribution or consumption situations were produced. This content will be the basis for scriptwriters and designers for proposing product and service concepts, and a scenario depicting life in this imagined city.

3.2 Observation of idea generation

We systematically recorded about twelve hours of discussions and photographed the objects. We conducted structured interviews with the facilitator and the illustrator late in the session to clarify the objectives and the choice of tools and methods. We selected the first part of the session (the idea generation, about four hours) to extract representations and analyze their design and functions. In the following, we analyse the objectives and instructions.

Phases of individual and collective work alternated. The work was organized in phases: idea generation and evaluation. The idea generation is itself divided into two parts: generation of global (life in the city) and of targeted ideas (concepts, objects or services). We will focus on the first part of generating global ideas. In the beginning of the collective part of the session, the aim was to project oneself into the future and to imagine scenes of everyday city life, products and services. Participants were free to express the aspect of life of their choice or to imagine a fictional character. This aim of this divergent brainstorming phase was to find a maximum of characteristics of different types of city lives and to build a common field of reflection.

First statement: *"Imagine the city. Which elements are characteristic of life in this* city?" After the construction of a first overview, participants went into more detail as the session progressed. The facilitator then narrowed the field, spheres, threads, and topics for which it was necessary to generate ideas. This phase mobilizes divergent thinking, whereas the idea evaluation phase is dedicated to convergent thinking.

Second statement: *"Imagine the city, the people, the buildings, and transportation. Imagine everyday life, in this city, how people move, work, have fun, etc.?"*

The representations constructed in order to fulfill these two statements will be analyzed below.

4 ANALYSIS OF REPRESENTATIONS

We observed different representations emerging during the work session. We identified five kinds of representations: Mind-Map-type diagrams (Figure 1), inventory lists (Figure 2), Post-it clouds (Figure 3), tables (Figure 4) and illustrations (Figure 5).

Different representations supported the collective and individual phases of the session. During the collective work phases, the facilitator noted and organized the participants' ideas on a whiteboard or on a flipchart. The Mind Maps, inventory lists and Post-it clouds were built by the group. The Mind Maps and inventory lists were built in the first part, thus used for global idea generation. The Post-it clouds were built in a second part, thus targeted at idea generation. During individual or two by two work phases, participants completed tables (Figure 4).

The illustrator's role was to select some ideas and to translate them into iconic illustrations. This resulted in a particular type of representation: illustrations produced by a professional (Figure 5).

The representations were built progressively during the sessions and were displayed on magnetic boards. The construction and display of the representations also supported the objectives of the creative session. For example, by displaying the illustrations of the group, the facilitator intended to encourage idea generation. These iconic representations triggered new interpretations (Boujut and Hisarciklilar, 2012) and enabled new impulses in the discussion.
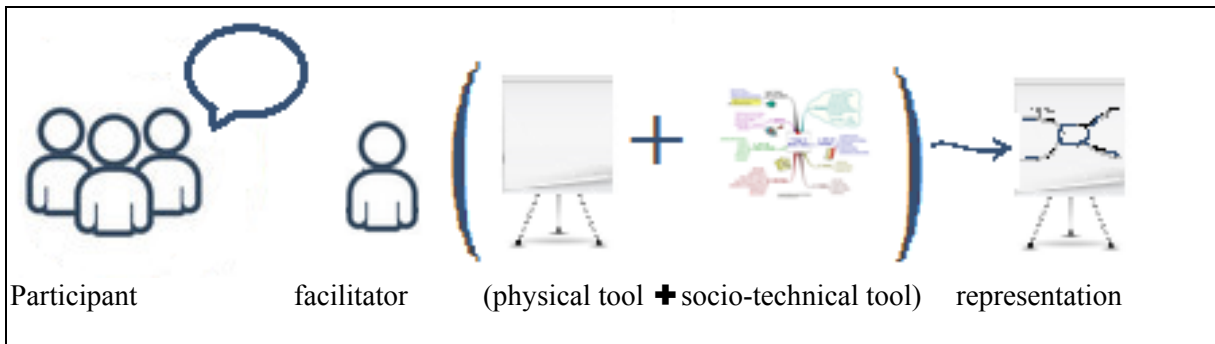
Figure 1. Mind-Map-type diagram

Figure 2. Inventory list

Figure 3. Post-it cloud

Figure 5. Illustration

Figure 4. Table

We propose to look more deeply in the construction process and the cognitive functions of two early representations, the Mind-Map-type diagram (Figure 1) and the inventory list (Figure 2). These representations were built with generic tools which are not specifically designed to support idea generation sessions. That is why it appears important to understand how they actually supported creative sessions.

4.1 Construction

The construction of these representations was mediated by several actors and artifacts. The facilitator noted the proposals of the participants by concisely rephrasing the verbal formulations of the participants. For example, one participant uttered: "I guess that in this city, it will be possible to work at the time I want, and not according to an imposed schedule." After several clarifications this sentence was noted in the table as follows: "I work at any time I want." Figure 6 shows the process schematically.

Participant   facilitator   (physical tool ✚ socio-technical tool)   representation

Figure 6: The path of representation construction

4.2 Cognitive functions

How do representations support the divergent step of idea generation? We propose to focus our attention on the cognitive functions of representations proposed by Duval and to analyze the implementation of these functions in more detail.

4.2.1 Objectification

The *objectification* of the idea of a participant involves three stages. First, the participant states an idea. At this stage, the idea begins its life in the outside world as an *enunciation*. The next stage involves a micro calibration between the facilitator reformulating the idea and the participant validating or adjusting the formulation of the idea. Lastly, the facilitator finds a place on the board (arbitrarily, depending on the space available) and writes the sentence. After these three stages, the idea is objectified textually or graphically on the board. From that moment on, it is part of the representation of the ideas of the group.

The three steps are repeated with the participants until all group members spoke at least once. The objectification of the ideas of the group is then considered to be final. At the end of the idea generation phase, once the facilitator has recorded the ideas of all participants on the board, a graphical representation is constructed: it is the objectification of the ideas of the whole group. This representation is then an artifact or an object produced by the group. It is an intermediate object as coined by Jeantet (1998) since it has been created through interaction between the originator and the facilitator and it is shared by the group and used later on for selecting or refining the ideas. This path of objectification is identical for both types of representations Mind Map-type diagram (Figure 1) and inventory list (Figure 2). We will discuss the value of changing the type of representation in section 5.

4.2.2 Communication

All ideas are expressed orally before being objectified as representations accessible by visual perception. A representation, by its existence as an object, enables discussion around it. The ability to repeatedly read a group idea allows returning to and resuming an abandoned idea or redirecting the discussion. The two representations Mind Map-type diagram and inventory list were recorded on flipchart and on board and were directed towards the participants. Communication around these representations took place during the session allowing a homogeneous sharing of the ideas and potentially building on top of each other. Communication is a key element of idea generation sessions, since one of its main principles is to bounce ideas off each other.

4.2.3 Computation

A representation offers the possibility for computation during a phase following the idea generation. The computation allows for operations like organizing or structuring and is performed according to the session goal. In our case, the Mind Map-type diagram and the inventory list may serve, one after another, as starting points to convert existing representations into new representations. Specifically, the facilitator consulted the Mind Map-type diagram as a starting point for constructing the inventory list. In the same way, both representations (Mind Map-type diagram and inventory list) were later consulted to construct a new representation (Post-it cloud) of ideas in preparation to the evaluation phase. Through these processes, the ideas generated were reworked, reorganized, recorded, and

evaluated, while keeping the loss of elements to a minimum. In the idea generation phase, the computation function is not fully realized compared to other more intense situations such as simulation or modeling, but clearly distinguishes itself as a function.

4.3 Tool-related constraints

There is no universal process regarding representations in support of a creative session. Many factors such as working format, the actors involved, the objectives of the session are important and require finding an ad-hoc procedure. This procedure involves the manipulation of different tools to construct different representations in order to achieve the objectives of the session. Physical and socio-technical tools have constraints that impact on the creative process. We propose an analysis of the constraints inherent in these tools.

The tools used to support collective idea generation are the physical tools (whiteboards and flipchart) and the socio-technical tools (Mind mapping, Post-it). One of the constraints inherent to these tools is the spatial constraint. Indeed, the board or paper size and group work format all require a readability of the content from at least two meters and there are limitations on the number and/or size of inscriptions that can be entered or displayed. The socio-technical tool Mind-Map requires synthesizing and inscribing only words or collocations (appearing in the same location; a juxtaposition of words) on the branches of the diagram.

Constraints of tools coincide with the constraints of the collective idea generation process, namely the intention to recode all ideas, so as to facilitate the rhythm of the session and keep proposals visible to rework them immediately. All these constraints make (purposely or not) the representations ambiguous and polysemic.

4.4 Polysemy

The previous paragraph mentions the choice of the *form* representing the *content*. Specifically, for the creativity sessions, the ideas expressed by the participants were gathered in a synthetic representation. Synthesizing ideas makes the representations ambiguous and subject to multiple interpretations. This ambiguity of the representation in turn supports the idea generation activity. Indeed, ambiguity or polysemy prior to the actual design phases is seen as conducive to the creative process (Suwa and Tversky, 1997), when others consider it as a drawback for design communication (Stacey and Eckert, 2003). Polysemy appears beneficial for fostering multiple interpretations and fueling idea generation, but in return appears detrimental to communication and to the creation of a common understanding.

The *Mind-Map-type diagram* in Figure 1 contains textual elements. These textual elements represent the ideas synthesized in words, collocations or short sentences around the name of the imaginary town placed in the center. Some words have been replaced by signs, for example, the word "more" was replaced by "+". This saves space without compromising interpretation.

Synthetizing ideas, in which only words and collocations are kept, leave interpretation open. Yet, the representation at this level of content abstraction provides sufficient information to the participants who attended the construction of the representation. They can rely on the contextual elements they have in mind to recall the proposals. Textual elements and their organization allow reading of content, but do not possess sufficient elements (objective, sequence and background) for a unique interpretation even for people who attended the meeting.

After reviewing the ideas regarding the topic of the session, the participants were asked to continue the production of ideas on more focused topics that describe life in the city. The diagram constructed during the previous phase triggers this discussion.

The representation constructed during this phase was of another type since another socio-technical tool was used. The constructed representation performs the functions of objectification, communication and computation in the same way as that of the previous phase. Therefore we cannot explain the representation switch based only on the cognitive functions offered by Duval. This is why we propose to introduce another type of function that accounts for what we observed.

5 MODULATION OF AMBIGUITY

5.1 The dynamic of attribution of meaning to representations

From a cognitive point of view, this stage of the creativity session still requires divergent thinking, but with a more concrete goal. The objective of this concretization brings us back to the question of attribution of meaning to the representations. The concretization is reflected in meaning. To make an idea more concrete is to reduce the span of potential interpretations. Differences of significations of words are connected to the differences of contexts (Yarowsky, 1995, Pichon and Sébillot, 1999). More elements of context, more details assist to obtain the unique interpretation of the proposal. The need to change the level of polysemy justifies a change of tool. Production of this phase should be more concrete, so the representation in turn should reflect this concretization; the facilitator must change the level of detail of the representations' content. The concretization therefore encourages the switch of socio-technical tool. Indeed, the level of generality of the Mind Map type representation does not correspond to the work objectives which is give more precision and details in the previously chosen spheres of city life. The concretization needs to be reflected in the representation. The words or collocations from Mind Map type representation are not sufficient anymore; one needs explanations, details, sentences and more explicit sketches. The representation of ideas generated during this phase took the form of an organized text composing an inventory list. Participants' proposals are reformulated (see previous phase) and form a list of sentences on the board, in an order of utterance that goes from top to bottom. Through representation, the progress of the session can be seen. At the same time, the illustrations of the participants' ideas made by professional illustrators are shown to the group. These are proposals of the materialization of the ideas. The illustrations rouse discussion and precisions of details and provoke "Aha!" reaction of understanding of expressed ideas.

Semantically, the content of these representations are always polysemic, but less ambiguous for the participants, than the collocations on the map of the previous phase, the representations advance common understanding. The session moves forward during the divergent step because the ideas must meet more specific and concrete objectives. This advancement transpires from one representation to another by a dynamic going from the polysemy of the content to its monosemy. In the world of external objects, that is to say, in the world of representations, this advancement results in the change of the form of representations and the socio-technical tool used for their construction.

5.2 Proposal of a new cognitive function: The "modulation of ambiguity" function

The ambiguity is inherent in any collaborative design process for the reason that the result (object / service) is unknown and represented only by projection of mental images into the external world. In the case study, the participants were undergoing this ambiguity and the facilitator was trying to manage it using various socio-technical tools and his own experience. Nevertheless, the role of ambiguity is not the same in all stages of design. During the idea generation phase, the result is also unknown, but the ambiguity is not a constraint, rather it is the engine of divergent thinking and creativity (Suwa and Tversky, 1997). Through representation, the facilitator can explicitly modulate, define and even control, the level of ambiguity to support the creative activity of the participants. Modulation of ambiguity is an operationalization of a characteristic of the representation along a polysemy – monosemy axis. According to the objectives of a creativity session, the facilitator moderates the degree of polysemy of the representations he proposes to the group. By preserving a variety of interpretations, through less precise, more polysemic representations (Mind Map-type diagram) the facilitator supports idea generation. By providing more details, the facilitator constructs less polysemic, more precise representations (inventory list) with the group. This supports a common understanding and leads the way to idea evaluation. Modulation of ambiguity allows a group to move from divergent to convergent thinking through advancing common understanding. By concretization in sentences, the facilitator reduces opportunities for different interpretations, which is important to reach a common understanding of the ideas and prepare the group for evaluation and selection the most relevant ideas. The reverse is also possible, by synthesizing the participants' ideas the facilitator opens interpretations. For example, when he wishes to come back to a divergent phase, he can pick-up some elements from a concretized idea, encrypt it like a single idea and begin a new round of idea generation. This function is related to both physical and socio-technical tools by which the representations are built. We define an axis with monosemic non-ambiguous representations at one

end and ambiguous polysemic representations at the other end. In order to get good convergence and decision making it is important to provide tools that are clearly positioned at each end of the spectrum. In the City 2030 case, it was succession of a mind map diagram and an inventory list to support the group divergence round, a post-it session to support the dyad divergent round and group convergence for selection of the more relevant ideas. Constraints, tools, objectives of the meeting, ways of thinking associated to the mode of attribution of meaning have their importance in changing the representation type in the creative session.

6 CONCLUSION

The presented study focuses on the nature and functions of representations. Our observations showed that the tools used by the facilitator of creativity sessions could be characterized as socio-technical tools and physical tools. This distinction is very helpful for distinguishing the cognitive dimension of the representations produced by the socio-technical tools. We have discussed the realization of Duval's cognitive functions of representations in a creative session context. Based on the semiotic dimension and divergent / convergent steps of the idea generation phases of a creative session, we have proposed, in addition to the classical cognitive functions of Duval's framework, a new cognitive function of representation that is specific to the creative process – the modulation of ambiguity. The representation allows the adjustment of the ambiguity level to give way to a variety of interpretations. This potential of the modulation of polysemy allows supporting idea generation activity by introducing or preserving a variety of interpretations, and to prepare the idea evaluation phase by reducing polysemy and supporting installation of common understanding. The results of this analysis could be used by innovation professionals to guide the selection of a type of representation and tool for its construction. It is important to carry out an extensive field study to confront these preliminary results to a significant number of other cases. Particularly cases where other socio-technical tools are involved, or different types of creativity sessions. These results could help to develop methods for steering more efficient creativity sessions especially by producing richer representations that could allow creating a better refined vocabulary or forms of signs contained in the representations used by the facilitators.

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