Fostering design creativity at the border between technology and human cognition

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Abstract:* *This paper aims at discussing about the interplay between ICT solutions and cognitive studies to foster design creativity, meant as the ability to produce something new and useful through imaginative skill. In this perspective, the author shares some of his educational experiences and research projects about creativity heuristics and the use of ICT technologies for enhancing the generation of creative solutions.

Keywords : Design creativity, innovation, design education, ICT for creativity

1. Introduction

Creativity is an essential feature of human being and, as such, attracts the interest of scholars in many different domains ranging from engineering to sociology, from cognitive science to education and several more. The common thread across these different domains is that creativity is associated to the production of something novel and valuable (where value assumes different meanings according to the specific contexts).

In this perspective, design is intrinsically related to creativity, as clearly emerging from Nigel Cross' words about design thinking: *"We all design when we plan for something new to happen, whether that might be a new version of a recipe, a new arrangement of the living room furniture, or a new layout of a personal web page*" [1].

However, only in the last two decades "design creativity" has become a specific topic for research, as for instance witnessed by the limited number of journal articles dedicated to the topic (Figure 1).

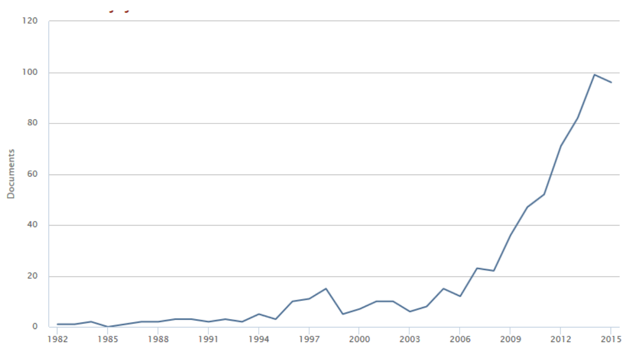

Figure 1. Journal articles (in English) yearly published dealing with "design creativity".

The chart plots the yearly publication in English on Scopus-indexed journals. It clearly represents just a subset of the scientific publications in the field, e.g. the recently established International Journal of Design Creativity and Innovation [2] is not counted. Nevertheless, it is evident a significant increase of research activities in the last ten years. Not surprisingly, the journals where those articles appeared belong to quite different subject areas as depicted in Figure 2. In a sense, it is possible to infer that design creativity is characterized by the intersection of researches in different ideas. From a different perspective, performing research on design creativity requires multi-disciplinary competences, across the borders of engineering and human sciences and this probably justifies why only recently design creativity emerged as a specific research theme.

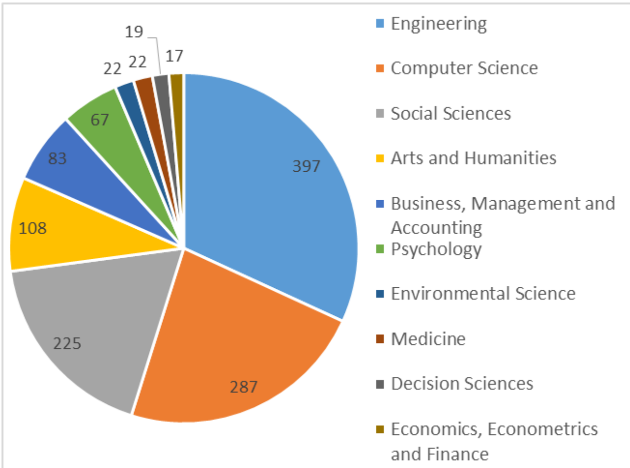

Figure 2. Subject areas of the papers on "design creativity".

In this context, the author would like to share some insights emerging from his educational and research experiences, with a particular focus on the potential role of ICT technologies for creativity enhancement. After a brief overview of some state-of-the-art concepts on creativity stimulation in design in section 2, the paper proposes two alternative ICT approaches for enhancing design creativity suitable for supporting design education, as well as design practice. A section with concluding remarks wraps up the most relevant findings and suggests possible directions for further investigation.

2. Creativity in Design and related Stimuli

The design process is not a process of mere generation of ideas. The definition of one or more design proposals usually entails a more articulated sequence of steps. The systematic/prescriptive design methods (e.g. [3]) usually define a sequence of steps to be carried out to come to the definition and the selection of a design concept. Despite several differences emerge in literature, the workflow is always characterized by a first phase of requirements and objectives formulation [4]. Just once the situation to be addressed has been properly identified, it is possible to generate novel and useful ideas.

The whole set of idea, moreover, has to be further scanned in order to select the most promising ones and discard the others having a poor potential. Such organized sequence of actions is also confirmed by the various studies concerning the behaviour of designers in very diverse field of applications [5]. These analyses, on the other hand, have highlighted that it may happen that the generated ideas are very similar to each other, thus showing a poor variety both in terms of working principles introduced for exploiting the solution concept and as structural characteristics. Such impossibility to produce a wide variety of concepts goes under the name of design fixation, as defined by Jansonn and Smith [6]. It is a blind adherence to previous concepts and ideas that limits the generation of design alternatives. Despite the condition of being "stuck" may appear along the entire design process design fixation is more evident when it is necessary to synthesize new solution concepts. From this perspective, analogy is probably the most studied operator that produces creative outcomes [7]. Analogy is the capability to create the link among different examples by identifying at a higher level of abstraction a common characteristic that all of them have to share.

Indeed, the search for appropriate analogies has a paramount role in the design process. It allows the introduction of useful clues for overcoming phenomena of design fixation. In this sense, abstraction processes can produce a valid contribution to improve the identification of meaningful analogies. The process of abstraction is the process of extracting a number of common features from a number of existing objects [8].

To this purpose, the stimulation of creativity has been often conceived in terms of strategies capable of triggering new ideas by means of conscious or unconscious analogies. In other words, creative stimuli have been intended as the content (both abstract and concrete) having the capability to enable analogical reasoning in designers, leading them towards the definition of solution concepts, whatever they appear as the results of a structured and sequence of logical steps or as a sudden enlightenment.

Several sources of inspiration have been taken into account to produce creative stimuli; they can range from basic geometrical shapes to works of art; from objects to phenomena from nature. Bio-Inspired design methods, for instance, aim at defining required functions for a design concept at an abstract level, with the purpose of identifying existing biological systems that potentially have already fulfilled similar requirements through specific physiological functions or characteristic shapes [9].

The Ask-Nature Database of natural effects is just an example of a potential source from which creative stimuli can be drawn. Still at an abstract level, existing physical, chemical and geometrical effects represents also a good source from which it is possible to draw the needed inspiration [10].

Stimuli have been classified as within-domain or between-domains, depending on the distance between the world in which the designer works and the world the source of inspirations derives from. To this purpose, it is also worth saying that the various sources of inspiration may have different detail levels, being they presented in the form of abstract text or design sketches, as well as more detailed architectural precedents or technical drawings with a less ambiguous representation. In details, prototypes and detailed drawings produce more within-domain analogies (surface analogies). On the contrary, sketching produces more distant-domain analogies (structural analogies).

Moreover, a stimulus can be perceived both in the real world and in the internal representation of the designer (Interpreted world), e.g. respectively a physical object and a mental imagery [11]. Examples presented in pictorial, textual, three-dimensional formats witness that more ambiguous stimuli tend to be less fixating, enabling designers to produce more -and more diverse-ideas as a result [12].

3. Exemplary research activities on the interplay between ICT and design creativity

Among the author's research interests, the development of ICT systems suitable to study and possibly foster design creativity occurred in several projects, some of them still ongoing. This section overviews two exemplary projects that represent alternative approaches to this topic, namely the OPEN-IT and the SPARK projects.

Before introducing these two projects, it is worth mentioning Lubart's classification on potential roles of computers in supporting creativity [13]:

- for facilitating the management of the working process, encouraging the perseverance of designer in the research of innovative solutions;
- for easing the communication between design team members, since circulation and integration of ideas play a relevant role in the creative process;
- for aiding the designer with a coaching activity, acting as an expert system that guides the user throughout cognitive processes;
- for cooperating in the creative process, thanks to the Artificial Intelligence systems that contribute to idea generation.

3.1 OPEN-IT, a dialogue-based tool for coaching the analysis of an inventive problem

The OPEN-IT project, co-funded by the EraSME EU Programme, aimed at developing an "IT Tool to support SMEs in systematic innovation based on open innovation paradigm". Within this project, the author led the development of a dialogue-based module aimed at guiding the analysis stage of an inventive design activity, according to the third class of Lubart's categorization.

The module relies on a TRIZ-inspired algorithm available in [14] aimed at tackling design problems characterized by the need of radically change a given design paradigm because of requirements that appear as non-mutually compatible and such that trade-off solutions are not satisfactory. The description of the algorithm is out of the scope of the present paper. However, its main features, as well as its structure are briefly mentioned to allow some reflections about the lessons learned through this experience:

- the framework is based on a human-computer interaction that relies on a written sequence of questions and answers that employs a common terminology, avoiding TRIZ jargon;
- the nodes of the algorithm are either open questions, choices or messages, intended to provide proper hints in performing the problem solving process;
- the text of questions and suggestions uptakes previously introduced terms and items;
- some examples of answers are provided, as well as their grammatical form, in order to clarify the purpose of the open questions and to provide a more sound text in the downstream nodes of the algorithm;
- the questioning procedure proposes questions aimed at checking user's inputs and communication nodes for providing feedbacks about the state of the analysis.

The implemented algorithm has been tested with both engineering design students and SMEs. However, only tests with students allowed to perform a statistically significant assessment of its performance. As detailed in [14] and briefly summarized in Table 1, the software tool has a noticeable impact on students' capability to properly frame the problem, so as to broaden the space for solution search and reduce design fixation.

Further refinements of the algorithms, as in [15], led to a broader applicability of the ICT tool, now suitable to address quite a large set of engineering design tasks.

Table 1. Comparison between the results obtained by the students that performed the design analysis with the support of the OPEN-IT system and those who worked without any aid.

	Outcomes of the procedures			
	Good	Satisfactory	Unsatisfactory	Total
Computer-Aided	13 (43.3%)	10 (33.3%)	7 (23.3%)	30
Individual	4 (18.2%)	6 (27.3%)	12 (54.5%)	22
Total	17	16	19	52

Among the positive outcomes observed in the application of the tool to different design tasks, it is interesting to notice that users tend to learn the logic of the algorithm; in other terms, the dialogue-based interaction has the potential to be transformed in a learning-by-doing platform, thus fulfilling to the maximum extent the coaching mission proposed by Lubart. On the other hand, the author and his colleagues clearly observed the birth of boredom and frustration when the user happens to incur repetitions and logical loops, due to the inadequate definition of some design requirements or conditions. In this perspective, a static algorithm as the one here described has limited margins for further improvement. Better results could be expected by adopting more recent advancements of AI technology, adding the capability to adapt the system behavior to the specific circumstances, as for instance described in [16].

3.2 SPARK, Spatial Augmented Reality as a Key for co-creativity

Another ICT project related to creativity enhancement here proposed belongs to the second class of computer support tools according to Lubart's classification scheme, i.e. to those that enable a more efficient communication between design team members, to foster ideas circulation and exploitation.

The SPARK project, namely "Spatial Augmented Reality as a Key for co-creativity" [17], is an ongoing project funded by the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 688417). It aims at realizing a responsive ICT platform that exploits the potential of Spatial Augmented Reality for supporting and fostering collaborative creative thinking in the design process by reducing language barriers due to diversity of background and sketching skills of the design team members. Spatial Augmented Reality is here conceived as a technology to facilitate brainstorming and to enable the early assessment of design solutions in a Co-Design environment.

While Augmented Reality (AR) so far has been used only for design review tasks or for improving the attractiveness of customizable products, the key idea of SPARK is to use AR within a design session to allow the collaborative generation of ideas. By projecting AR images (the so called SAR, Spatial Augmented Reality) on the surface of a design object under study, team members can visualize the current design layout and propose variations through a physical interaction with the hybrid prototype (Figures 3 and 4).

Figure 3. Gesture interaction with a physical prototype enriched with SAR projections.

Figure 4. Collaborative design session supported by the SPARK technology.

The first applications of the SPARK technology deal with the design of packaging of consumer products and with the interfaces of small appliances, i.e. with products characterized by a seemingly defined geometry where to project texture and surface elements that are the object of the design activity. However, on a longer perspective, the members of the SPARK Consortium would like to extend the application to a wider range of applications, e.g. by adding a real-time 3D scanning system in the loop, so as to allow the design team to modify the geometry of the design object, e.g. with clay or deformable elements.

According to the end-users involved in the project, the SPARK technology is expected to produce extraordinary benefits in terms of reduction of lead-time, thanks to radical reduction of iterations between the client and the design team (-40% of development time from design request to concept selection, according to a first estimation). Further benefits are expected in terms of reduction of design efforts and prototyping cost savings. Public experimental campaigns will be announced on the project website in the follow-up of the project.

4. Concluding remarks

Despite apparently disconnected, the above-described projects reflect a uniform ambition pursued by the authors, as well as by other scholars in the field: ICT as a means to augment human creativity in design.

In both cases, as with several other projects, ICT is not supposed to substitute humans: the creative ambitions of AI systems are weaker than a few decades ago. However, it is not the author's intention to express skepticism about the potential of AI technology. On the other hand, it is certainly evident that human creativity is largely underexploited, due to a still partial understanding of its underlying mechanisms. At the same time, there are several proofs of successful introduction of ICT systems as a sort of companion of individuals and teams in creative activities, e.g. as information support systems.

This paper has briefly described two peculiar usages of computers in this perspective, i.e. as methodological coach and as a tool for cognitive barriers reduction. Indeed, while many professional tools already exist to provide information support to designers, these two usages of ICT systems need further studies, but can bring to significant achievements in the field.

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