FOSTERING IDEATION IN THE VERY EARLY DESIGN PHASES: HOW TEXTUAL, PICTORIAL AND COMBINED STIMULI AFFECT CREATIVITY

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Abstract

Creativity is critical to the success of design outcomes. Several research contributions investigate the effects of different stimuli on the creativity of conceptual solutions. Studies still lacks dedicated to early New Product Development activities focused on the definition of new product ideas in terms of unprecedented benefits and product attributes. The paper deals with the forms through which stimuli are delivered to support ideation for the recalled design activity. The objective of the paper is to assess if and how different stimuli affect designers' ideation performance. An experiment was performed, in which participants were asked to produce new ideas or product attributes for an existing product category, by exploiting textual, pictorial and combined stimuli as source of inspiration. The results show that the inspiration fashions play a limited role on the outcomes of the ideation process, if the latter are assessed through the most acknowledged creativity metrics. However, the experiment reveals that significantly different ideas have emerged in groups using diversified forms of stimuli.

Keywords: Creativity, New product development, Design process, Ideation, Stimuli

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1   INTRODUCTION, BACKGROUND AND OBJECTIVES

The great role of creativity in design is of anecdotal evidence, besides being acknowledged by the design community at large. At the same time, the Fuzzy Front End, and especially the very early design phases during which objectives of New Product Development (NPD) are defined, are recognized as the most critical activities with respect to the future market success. These remarks encourage investigating the ways creativity is fostered in the initial design activities, with a specific reference to the definition of new ideas in terms of unprecedented benefits and product attributes. The present paper particularly deals with the media stimuli are delivered in order to support ideation for the above design task.

1.1 Factors affecting designers' creativity and innovation

Various sources of inspiration range among the most common strategies designers use in creative activities. In particular, they leverage associations and analogies from accumulated experience and knowledge, e.g.(Goldschmidt and Smolkov 2006). The use of stimuli is capable of improving the performances of brainstorming and ideation sessions across various dimensions of creativity, particularly quantity and variety(Guo and McLeod 2014, Bacciotti et al. 2016a, 2016b). In this sense, the possibility of introducing appropriate stimuli that boost creativity in an effective way is crucial in design. Much research is concerned with the elicitation of successful designers' behaviour in order to extrapolate common patterns. For instance, Laamanen and Seitamaa-Hakkarainen (2014) interviewed professionals from particularly creative domains and individuated at least four main typologies of approaches that are combined during design activities, namely graphic, material, mental and verbal.

The domain is populated by insightful studies in the last few years and various approaches have been followed in order to unveil the most profitable techniques. Overall, the main aspects that have been taken into account can be summarized as follows.

- The influence of personal traits, as well as their level of expertise;
- The goodness of stimuli according to their capability to trigger "near" or "far" analogies(Tseng et al. 2008, Fu et al. 2013), or, likewise, their semantic homogeneity with the scope of design(Guo and McLeod 2014);
- The media through which analogies' primers are provided, with a special attention on textual and pictorial stimuli.

In order to fine-tune tools that support the very early design phases, the first two topics have a limited relevance, as clarified in the followings; hence, they are not fully investigated for the scopes of the present paper.

- The expertise and the individual preferred practices of candidate designers are not known a priori;
- New candidate benefits for products that undergo development cycles are abstract descriptions in essence, therefore stimuli can be provided either in an abstract form or through reference artefacts that embody specific benefits. Given the need to stimulate abstract reasoning, the process could be not activated if driven by stimuli with significant analogical affinities. Similarities with the specific treated domain might give rise to limited innovativeness, by suggesting fulfilling needs that are already met to a considerable extent. Moreover, as a specific set of stimuli is supposed to be valid for any industrial field, its distance from any case study cannot be planned a priori.

In this sense, if we can compare the three main considered aspects (first bullet list) and the reasons behind poor controllability of two of them (second bullet list), the way stimuli are administered represents the condition that can be best mastered. The description of the literature that follows primarily focuses on discussions and findings concerning this specific aspect.

1.2 Relevant background about the kinds of stimuli deployed by designers

Goldschmidt and Sever (2011) illustrate the variegated sources of inspiration deployed by talented designers in various fields. Many designers store in their memory (or collect) particular concepts and representations that can fuel innovativeness in NPD. The concept is shared by Gonçalves, Cardoso and Badke-Schaub(2014), who suggest that the number of interiorized and ready-to-use concepts is clearly greater for experienced designers with respect to students and freshmen. Still in(Goldschmidt and Sever 2011), the use of textual stimuli in conceptual design tasks has been experimented. Testers were requested to work with both texts that were consistent with given problems and seemingly unrelated stimuli. The paper reveals that both kinds of textual sources of inspiration positively affected originality

and scarcely affected practicality of results; contextually, it was not possible to assess which typology of stimuli was the most supportive for testers.

The generation of ideas for a chosen problem at the conceptual design stage is investigated by Cardoso, Gonçalves and Badke-Schaub(2012), by comparing different stimulating conditions. In particular, different groups have tackled the problem without any support (control group), domain-tailored pictorial stimuli with solution examples and textual descriptions of these images. The results show that this specific kind of stimuli, both in pictorial and textual fashion, does not guarantee proliferation of ideas and has instead led to a not negligible amount of fixation. This fact is observed despite the claimed preference of designers towards pictorial representations, which, however, is confirmed just by few studies, e.g.(Sarkar and Chakrabarti 2008).

The identification of effective inspiration sources is the thrust of the already mentioned(Gonçalves et al. 2014): in this case, the study is based on investigating designers' self-reported practices rather than conducting experiments. The study reveals that both professional and less experienced designers tend to deploy pictorial stimuli to a larger extent, although this choice is supposed to give rise to fixation and biases. On the one hand, the latter exploit text sources more frequently, probably because of the reliance on teaching materials to which they have been exposed. On the other hand, the former seem to select pictorial representations also due to time pressure. In a subsequent study of the same research group(Gonçalves et al. 2016), the search for stimuli carried out by design students is subjected to a protocol analysis, which reveals different strategies to prompting idea-inspiring sources. The research activity focuses on the different significance of various typologies of search and on the relevance of keywords when the search is purposefully activated (especially with regard to activities that involve Internet tools).

1.3 Open issues

As it can be inferred from the above reference divulgations, studies involving stimuli for ideation purposes are either carried out by introducing ad-hoc pictorial or textual representations or they attempt to investigate designers' practices in their domain of expertise. Some recently divulgated approaches aim to perform the search for valuable concepts without any reference to domain-specific conditions. In this context, it is worth mentioning the following design support tools.

- The Combinator(Han et al. 2016), whose search for new product structures is carried out by juxtaposing and superimposing pictures of different objects;
- Design heuristics (Yilmaz et al. 2016) who use combinations of texts and consistent images in order to support the search for new products embodiments; the set of stimuli comprises diffused evolution patterns of systems' architectures and is deliberately inspired by TRIZ concepts;
- Large-scale Needfinding(Schaffhausen and Kowalewski 2015), whose objective is supporting the disclosure of individual needs by means of examples in the fashion of both pictures and texts;
- iDea method and prototype software application(Bacciotti et al. 2016a), whose scope is browsing the design space of Product Planning with the aim of individuating new benefits that a reference product can provide.

Even if media through which stimuli are divulgated seem to represent a relevant factor, these contributions seem to have overlooked this aspect so far. With reference to the majority of the above items, the form of stimuli is intrinsic to the theoretical constructs underpinning the correspondent method. The last technique in the list represents an exception in this sense. Indeed, the set of stimuli that constitutes the backbone of the tool lends itself for a representation in different fashions. In other words, although the original instrument administers stimuli in a textual form, nothing has been pointed out that could hinder the use of other kinds of media.

1.4 Objective and structure of the paper

The objective of this contribution is to assess if and how different kinds of stimuli affect designers' ideation performance in the discussed NPD task. For the sake of clarity, in the present paper, textual, pictorial and combined stimuli are considered, the latter being composed of both a textual and a pictorial part. Constructs were borrowed from the iDea method, as explained above, and adapted in the different forms, as the following sections document in details. Still in Section 2, an experiment is described aimed to contribute to a major understanding with respect to the effect of the kinds of stimuli on designers'

creativity. Section 3 presents the results of the experiment and the most relevant findings. Discussions and conclusions are drawn in Section 4.

2 RESEARCH METHOD

To the scope of the paper, an experiment was organized and conducted, in which participants were asked to generate new product attributes for an existing product category, by exploiting textual, pictorial or combined stimuli as a source of inspiration. Details concerning the design of the experiment (sub-section 2.1), the proposed stimuli (2.2), the execution of the test (2.3) and the procedure adopted to evaluate the results (2.4) are thoroughly described in the following subsections.

2.1 Design of the experiment

The experiment was conducted by a sample of 81 undergraduate students attending a course in Industrial Design at the University of Florence, Italy. The sample was randomly divided into three groups, which were asked to use the different kinds of stimuli considered in the study (textual, pictorial or combined). Fifteen different stimuli were used for each group, which have been proposed into the three kinds considered in this study, according to the criteria described in the next subsection. In order not to overburden the students with an excessive number of stimuli and to allow them to dedicate a sufficient amount of time to each stimulus, the authors submitted only five stimuli to each participant, randomly drawn from the set of fifteen. Therefore, the 81 students were divided into three groups of 27 students and 5 stimuli from the set of 15 were assigned to each participant. According to the organization of the sample, each stimulus exactly recurred 9 times within each group.

Each participant was asked to generate new product attributes for the same product category, i.e. outfits for new-borns, individually. This product category was chosen thanks to the opportunity to collaborate with a firm operating in this sector.

2.2 Stimuli

As already mentioned, the starting set of stimuli originates from the methodology recently proposed by Bacciotti, Borgianni and Rotini (2016a) and implemented in a software for idea generation (iDea). This methodology submits several textual hints to designers in order to provide them with triggers for idea generation. It employs, among the others, a group of textual stimuli called general demands (GDs), which strive to represent an all-encompassing set of benefits' categories. Therefore, GDs are used to help the designer to examine the benefits that can be provided by a product systematically. The hints provided by GDs are expressed in a textual form and are therefore appropriate for representing the category of textual stimuli in this study without any need for modifications. The fifteen stimuli selected for the experiment (reported in Table 1) were chosen among all those provided by GDs according to the availability of images capable of evoking their content. The images (no matter if photographs or drawings) were not selected with the intent to provide a direct representation of the textual stimulus, but rather to represent a possible illustration (more or less abstract) of its meaning (examples are reported in Figure 1). With this aim, the images were selected following a two-step procedure:

- first, a general web search was performed by employing keywords contained in or directly related (e.g. synonyms) to the textual stimulus; a preliminary set of images was preselected coping with the meaning the stimulus should be actually attributed of;
- subsequently, for each stimulus, three expert designers were asked to agree upon the choice of a single image, which supposedly best exemplified the concept expressed by the textual stimulus.

Additional measures were undertaken in order to reduce the differences that could be caused by the adoption of different sets of stimuli for the three groups of participants. As for combined stimuli, it was established that the textual and pictorial components corresponded to the matching textual and pictorial stimulus, respectively.

Table 1 summarizes the set of textual stimuli used for the experiment, which were subsequently adapted also in a pictorial and combined fashion. Figure 1 shows illustrative adaptations of stimuli 4 and 5 into the pictorial form. The whole set of combined stimuli used in the experiment can be found at the following link: https://drive.google.com/open?id=0B3hz6M0qt5qYT081ZUpOa2Q2RHM.

Table 1. The set of textual stimuli employed in the experiment

1	Quality of expected outcomes
2	Quantity or extent of the expected outcomes
3	Duration of the expected outcomes
4	Fun and adventure
5	Suitability of the product according to different demands
6	Adaptability of the product in diverging conditions with respect to the designed preferred ones
7	Expand or upgrade the range of product functionalities
8	Controllability of the system in order to obtain the expected outcomes
9	Integrity of the product itself, its resistance to planned or accidental stress or collision, the strength against wear or corrosion
10	The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories
11	The reduction of the information and skills to be gathered during the product life cycle
12	The environmental sustainability
13	The aesthetical requirements and the emotional dimension of the product, the style, the fashion content
14	Product/service cheapness
15	Lightness and portability

Figure 1. Illustrative images used for the experiment. When proposed in combination with text, the images were coupled with the textual stimuli 4 (left picture) and 6 (right picture) of Table 1. Credits: Bjørn Christian Tørrissen (left picture) and Hamdan Zakaria (right picture).

2.3 Materials, information and rules for the execution of the experiment

Before the beginning of the experiment, fundamental indications were orally provided to all the participants concerning the execution of the text and the exploitation of the stimuli. In addition, a written report could be used for detailed test instructions, which can be obtained through the following link: *https://drive.google.com/open?id=0B3hz6M0qt5qYYXRFQVVNUy1haFk*.

Subsequently, a booklet containing five random stimuli was provided to all the students in the predetermined assigned fashion. In order to compel participants to focus the attention on a single stimulus at time, the stimuli were presented in separate pages in all the booklets; a specific space for listing generated attributes was provided in each page as well.

In order to avoid some students starting the execution of the test before their colleagues, the product category for which they were asked to generate new attributes was revealed only after that all the participants had received their booklets. From that moment, the participants were given one hour time to complete the whole task. No limitation of time was imposed to the exploitation of each single stimulus: indeed, the participants were free to reflect on each of the five stimuli as long as they deemed necessary.

During the experiment, students were not allowed to talk to each other and to use books, slides or electronic devices.

2.4 Criteria for the assessment of the outcomes

In the followings, the metrics are described that have been used for the assessment of the attributes generated by the participants involved in the test. As stated by Shah, Smith and Vargas-Hernandez (2003) and several other scholars, novelty, variety, quality and quantity are the most widely acknowledged parameters for evaluating the outcomes of an ideation process supported by design methods and tools. Although the objective of the present investigation is not the evaluation of the effects produced by the use of specific design methods or tools, stimuli represent, however, means to enhance (or at least affect) the creative process and they can be considered a sort of "aid". Therefore, the authors assumed that the four above parameters are still appropriate for the presented investigation.

However, existing literature contributions, including the seminal work of Shah, Smith and Vargas-Hernandez(2003), are clearly conceived to assess the outcomes of intermediate phases of design, when the product specifications have been already defined. On the contrary, the expected outputs of the presented experiment are product attributes, which characterize very early design phases. Technical solutions to satisfy these needs are unimportant in the treated design phase, in which the product specifications should still be defined.

Consequently, existing strategies to assess the above reference parameters are not suitable for evaluating the attributes produced during the experiment. Therefore, in order to assess novelty, quality and variety of these attributes, adapted procedures will be proposed and thoroughly described in the followings. The way of measuring quantity, instead, is simply represented by the number of generated attributes and it is therefore applicable for the present study.

The attributes generated by the students during the test were evaluated according to the following procedure.

- At first, in order to ensure that identical or similar attributes were counted only once during the measurements that follow, two designers, holding a Master Degree, were asked to evaluate generated attributes and to group similar ones. Attributes had to be considered similar if they aimed to satisfy the same need. For example, the attributes "clothes adaptable to different seasons" and "romper suit suitable for different climates" were considered similar and grouped, since they both refer to the adaptability of the clothes to different temperatures.

- Subsequently, already existing attributes were identified and discarded, so that they should not be considered in the final assessment steps. Indeed, the aim of the experiment was to evaluate the effects of different kinds of stimuli on designers' ideation effectiveness and, consequently, only new attributes represented relevant outcomes. Boden (2009) distinguished between two kinds of novelty: Psychological and Historical novelty. A psychological-novel idea (or P-creative idea) is new to the person who generated it, while a historical-novel idea (or H-creative idea) is both P-creative and unprecedented. As already outlined, participants were asked to record only new attributes and, therefore, all the generated attributes were P-creative. The latter could represent interesting information, but it is not possible to ensure that all the participants strictly followed the instructions of the assignment. Moreover, psychological novelty is a less interesting result in the development of a product. For these reasons, all the generated attributes were evaluated by a panel of experts in the field of apparel for new-borns in order to establish which of them should be considered H-creative attributes. The attributes that were not evaluated as H-creative by the experts were discarded and not considered for further evaluations.

- Quantity, novelty, quality and variety of new, i.e. not-discarded, attributes were subsequently evaluated. The procedures adopted to assess each of the four measures are thoroughly described in the next section.

3 RESULTS

The authors analysed the results by considering two main aspects:

- The impact of the kind of stimuli on the parameters that feature creativity in ideation (Subsection 3.1), based on metrics and terms described in 2.4;

- The overall affinities and differences among the sets of attributes generated with different kinds of stimuli (Subsection 3.2).

3.1 Kinds of stimuli and creativity metrics in ideation

3.1.1 Quantity

Each participant has generated a given number of new, i.e. H-creative, attributes by leveraging one of three kinds of stimuli. This number features the *quantity* parameter for each ideation activity, which is then describable through a "continuous" variable.

Here and in the following analyses concerning novelty and quality:

- The textual kind of stimuli has been considered as a control condition.
- Therefore, the role of the other two kinds of stimuli, i.e. pictorial and combined, has been investigated by means of statistics.
- Dummy variables have been introduced to indicate whether the tester has benefitted from pictorial or combined stimuli.

A linear regression function has been calculated that associates the quantity of attributes generated through the test and the above dummy variables, which, as a result, represent the two regressors. Otherwise said, the capability of pictorial and combined stimuli to increase attributes' productivity is investigated. Regression coefficients and p-values are shown in Table 2. The former express the magnitude of the influence of the dummy variables with respect to the studied parameter; for instance, a coefficient equal to 1 can be interpreted as the expected growth of a new attribute per participant with respect to the control condition (textual stimuli). The latter indicate the statistical significance of the relationship between the investigated creativity metric and the kind of stimuli; as a common rule of thumb, statistical significance takes place for p-values lower than 0.05.

3.1.2 Novelty

H-creative product attributes generated during the experiment were evaluated more in detail by the panel of experts. In order to assess the degree of novelty, they ranked the attributes according to a qualitative scale. This scale was established in agreement with the experts, who said to be able to distinguish between low and high novelty, without using intermediate nuances. Therefore, a two-level Likert's scale was introduced.

As a consequence, new attributes are classified in two different clusters according to their attributed degree of novelty (1 or 2 with reference to the employed Likert scale). Since the degree of novelty represents a binary value, an ordinal regression is unnecessary. A linear regression function has been calculated, similarly to 3.1.1, where the continuous dependent variable is represented by the number of attributes featured by the higher degree of novelty. Therefore, the capability of pictorial and combined stimuli to augment attributes' level of novelty is surveyed. The outcomes are presented in Table 2.

3.1.3 Quality

For the purpose of this experiment and the treated design task, quality was defined as the supposed capability of attributes to fulfil relevant needs of products' stakeholders and their supposed consequent capability to enable business success, which should take into account the supposed technical feasibility too. This aspect is generally deemed relevant and it shall be evaluated despite testers were encouraged to include seemingly unfeasible and weird ideas; this notice was indeed addressed at not limiting their productivity and creativity to be subsequently evaluated. The experts established that a four-level Likert's scale was suitable for assessing such a qualitative parameter.

Since, in this case, the experts used a four-level scale, a different form of regression, i.e. ordered logistic, had to be computed. According to the fundamentals of this kind of statistical functions, regression coefficients are calculated in terms of odd ratios. Hence, they are not to be directly interpreted as indexes of growth for the investigated parameters. Despite their different meaning with respect to previous cases, it is possible to state that positive values of odd ratios feature the tendency of making the dependent variable (in this case, the level of quality) increase. The interpretation of p-values is consistent with the other regressions. The outputs of the ordered logistic regression are illustrated in Table 2.

Observed parameter	Pictorial stimuli		Combined stimuli	
	Regression coefficient	**p-value**	**Regression coefficient**	**p-value**
Quantity	-0.444	0.505	-0.148	0.824
Novelty	0.111	0.825	0.148	0.769
Quality	-0.034	0.916	0.036	0.908

3.1.4 Variety

Shah, Smith and Vargas-Hernandez's (2003) criteria to assess variety could not be employed, since they refer to product functions, which are clearly not defined yet at the investigated stage of the design process. A consolidated procedure to evaluate the distance among different attributes at the very early stages of the design process still lacks and this prevents the possibility to assess the variety for the sets of attributes generated by each single participant. Therefore, the measurement of variety was performed globally, by computing the number of distinct (i.e. not-overlapping as clarified in Section 2.4) attributes emerging from the whole group of participants using the same kind of stimuli. Overlaps were expected as the same specific stimuli were repeated across the groups.

This way of assessing variety is not much different from others already adopted in literature. Kohn and Smith(2011), for example, used a similar method to assess the variety of attributes generated with different brainstorming (Osborn 1957) procedures. The scholars sorted attributes in different categories according to their content and then evaluated the variety of each brainstorming procedure by counting the number of categories covered by the corresponding generated attributes.

The numbers of distinct new product attributes generated by the participants follow; the sums of the quantity of new attributes listed by each participant are also indicated, so that interested readers can infer redundancy levels.

45 attributes, out of 76, using textual stimuli;
45 attributes, out of 64, using pictorial stimuli;
56 attributes, out of 72, using combined stimuli.

3.1.5 Comments to the results

Quite surprisingly, the analysis of the results has highlighted no significant effect of the kind of stimuli on creativity metrics. It can be noted that no regression coefficient presents p-values that address the existence of statistical significance. As for variety, where just qualitative conclusions can be drawn, the similar number of new non-redundant attributes can be underlined, although combined stimuli present a slightly higher performance than the two other kinds of stimuli.

As different tests in the design field have given rise to diverging outcomes, the emerged limited influence of kinds of stimuli on ideation creativity cannot be generalized. In this context, it is worth remarking how certain test conditions could have influenced the results, among the others:

- The specific set of selected stimuli including 15 items;
- The chosen images;
- The duration of the test;
- The specific product family for which new benefits had to be individuated;
- The background of testers.

3.2 Further qualitative observations

The knowledge of new attributes exhibiting affinities, which were considered to assess variety primarily, allows the investigation of commonalities between product attributes arising from the three clusters. This kind of observation offers an insight into the convergence towards similar concepts exerted by the different kinds of stimuli. Figure 2 depicts the discussed overlaps, by showing the quantity of attributes that were generated just through a kind of stimuli and the number of redundancies across clusters.
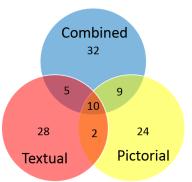
Figure 2. overview of the number of distinct attributes generated through each kind of stimuli and redundancies across the three groups

The results show that a significant number of attributes would have not emerged if a single group of students had participated in the experiment. Even the most prolific cluster, that used combined stimuli and produced 56 distinct attributes, has not individuated 54 new product benefits that required textual and/or pictorial stimuli. Of course, it is not possible to assess whether the whole production of attributes would have reached such a high overall volume in case all the 81 participants had employed combined stimuli, which, besides, include both textual and pictorial dimensions. As well, a role could have been played also by individual talent, which could not be monitored and was used as a random condition. To date, it is just possible to highlight noticeable differences in the specific attributes that have been generated in the three clusters.

4   DISCUSSIONS AND CONCLUSIONS

The paper has described an experiment aimed to investigate the influence of various kinds of stimuli on ideation creativity, namely textual, pictorial and combined stimuli. The context of the test is, more specifically, the definition of new directions for NPD (in terms of new benefits to fulfil) in the very early design phases. An overall sample of 81 students participated in this activity, who were requested to individuate new potential needs to be satisfied in the field of apparel for new-borns.

From the viewpoint of the impact of the various kinds of stimuli on widely acknowledged creativity metrics, the present study supports the results of other experiments, which have focused on different design tasks, showing that kinds of stimuli play a limited role. However, as clarified in Further qualitative observations3.2, the experiment reveals that significantly different attributes have emerged in groups using diversified kinds of stimuli. This is likely due to the dissimilar analogical processes that underpin idea generation when a designer is submitted to different media. This aspect should be carefully taken into account by those scholars that aim to fine-tune ideation methods enabling a very large exploration of the design space. A further contribution of the paper is represented by a proposal of adapting shared creativity metrics to the specific design activity that has been investigated. More specifically, the absence of descriptions of solutions at a structural level hinders the possibility to assess variety according to established practices.

The authors are planning to repeat similar experiments in order to strengthen the evidences concerning the role of kinds of stimuli.

Besides, the supposedly different thinking patterns induced by the different typologies of stimuli deserve an adequate attention too. In this sense, the authors have individuated two potentially meaningful research directions. On the one hand, major insights can emerge by evaluating the pertinence of generated attributes with respect to submitted stimuli or, at least, to the meaning that authors have attributed them. For instance, the authors are aware that provided pictorial stimuli (see Figure 1) could have not been interpreted through the corresponding key of reading expressed in a text fashion (see Table 1). On the other hand, the individual experience of participants in the ideation process is worth being investigated, especially with regard to the development of appropriate tools supporting the very early design stages. The mental stress caused by analogical processes clearly represents an important dimension within designers' experience. Other aspects are likewise influential and can affect ideation creativity and performance, including the size of the test group, the background of individuals, psychological inertia, frustration and boredom. The latter is presumably dependant on the duration of the design activity. With reference to the time assigned in the presented experiment, it can be

hypothesized that boredom was not critical, or, at least, it emerged equally across the three groups leveraging different kinds of stimuli, given the emerged similar extents of design creativity.

REFERENCES

Bacciotti, D., Borgianni, Y. and Rotini, F. (2016a), "An original design approach for stimulating the ideation of new product features", *Computers in Industry*, (75), 80-100.

Bacciotti, D., Borgianni, Y. and Rotini, F. (2016b), "A CAD tool to support idea generation in the product planning phase", *Computer-Aided Design and Applications*, 13(4), 490-502.

Boden, M. A. (2009), "Computer models of creativity", *AI Magazine*, 30(3), 23-34.

Cardoso, C., Gonçalves, M. and Badke-Schaub, P. (2012), "Searching for inspiration during idea generation: pictures or words?", in *DS 70: Proceedings of DESIGN 2012, the 12th International Design Conference*, Dubrovnik, Croatia.

Fu, K., Chan, J., Cagan, J., Kotovsky, K., Schunn, C. and Wood, K. (2013), "The meaning of "near" and "far": the impact of structuring design databases and the effect of distance of analogy on design output", *Journal of Mechanical Design*, 135(2).

Goldschmidt, G. and Sever, A. L. (2011), "Inspiring design ideas with texts", *Design Studies*, 32(2), 139-155.

Goldschmidt, G. and Smolkov, M. (2006), "Variances in the impact of visual stimuli on design problem solving performance", *Design Studies*, 27(5), 549-569.

Gonçalves, M., Cardoso, C. and Badke-Schaub, P. (2014), "What inspires designers? Preferences on inspirational approaches during idea generation", *Design Studies*, 35(1), 29-53.

Gonçalves, M., Cardoso, C. and Badke-Schaub, P. (2016), "Inspiration choices that matter: the selection of external stimuli during ideation", *Design Science*, 2.

Guo, J. and McLeod, P. L. (2014), "The Impact of Semantic Relevance and Heterogeneity of Pictorial Stimuli on Individual Brainstorming: An Extension of the SIAM Model", *Creativity Research Journal*, 26(3), 361-367.

Han, J., Shi, F. and Childs, P. R. N. (2016), "The Combinator: a computer-based tool for idea generation", in *DS 84: Proceedings of the DESIGN 2016, 14th International Design Conference*.

Kohn, N. W. and Smith, S. M. (2011), "Collaborative fixation: Effects of others' ideas on brainstorming", *Applied Cognitive Psychology*, 25(3), 359–371.

Laamanen, T. K. and Seitamaa-Hakkarainen, P. (2014), "Interview Study of Professional Designers' Ideation Approaches", *The Design Journal*, 17(2), 194-217.

Osborn, A. (1957), *Applied imagination*, New York: Scribner.

Sarkar, P. and Chakrabarti, A. (2008), "The effect of representation of triggers on design outcomes", *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 22(02), 101-116.

Schaffhausen, C. R. and Kowalewski, T. M. (2015), "Assessing Quality of User-Submitted Need Statements From Large-Scale Needfinding: Effects of Expertise and Group Size", *Journal of Mechanical Design*, 37(12).

Shah, J. J., Smith, S. M. and Vargas-Hernandez, N. (2003), "Metrics for measuring ideation effectiveness", *Design Studies*, 24(2), 111–134.

Tseng, I., Moss, J., Cagan, J. and Kotovsky, K. (2008), "The role of timing and analogical similarity in the stimulation of idea generation in design", *Design Studies*, 29(3), 203-221.

Yilmaz, S., Daly, S. R., Seifert, C. M. and Gonzalez, R. (2016), "Evidence-based design heuristics for idea generation", *Design Studies*.