Influence of environmental information on creativity

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Abstract

The positive effect of having environmental information is generally taken for granted in design for sustainability and ecodesign. Research in the field of creativity, however, has shown that the exposure to examples can provoke fixation and reduce the overall creativity of the idea-generation process. Different sorts and levels of information e commonly available for designers e was delivered to 56 people, all of whom were asked to generate different design ideas. Results prove that having detailed information e be it of previous models or of competing products e significantly reduces the creativity of the design ideas. Soft information, on the other hand, does not present this effect. Successful tools in the future must deliver relevant information avoiding this fixation effect.

Keywords: Creativity, Environmental impact, Product development, Ecodesign

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Introduction

Sustainable development (Brundtland, 1987) is leaking more and more into public discourse. What started out as the concern of only specialists has now made its way into political (United Nations (U.N.), 1992) as well as media agendas. Governments began to give importance to sustainability some decades ago, and during the past number of years markets have also shown a strong interest in this matter, thus strongly encouraging industries to react accordingly. Issues such as electricity consumption, CO2 emissions or overpackaging have been introduced in public culture, and manufacturers cannot neglect their influence on the purchase decision.

Literature has spawned a great many methods and tools. Many design methods were "environmentalized", as well as new ones generated (Collado-Ruiz, 2007; Lofthouse, 2006; Ostad-Ahmad-Ghorabi & Wimmer, 2005; Pamminger, Huber, & Wimmer, 2007; Wimmer, Züst, & Lee, 2004). Gomez-Navarro, Capuz-Rizo, Bastante-Ceca, and Collado-Ruiz (2005) speak about more than 60 categories of methods, many of them with several tool implementations. Nevertheless, most companies did not apply these methods (Baumann, Boons, & Bragd 2002; Mathieux, Rebitzer, Ferrendier, Simon, & Froelich, 2001), as well as found great barriers for the internalization of the principles embedded in those techniques (Collado-Ruiz, 2007), such as complexity of implementation, need for specific training, or scope of the solutions proposed.

It has been proven that sustainability is something unattainable unless radical changes happen in society (Carillo-Hermosilla, Del Rio, & Könnölä, 2010; Freeman & Perez, 1988 chap. 3, pp. 38e66; Tukker & Butter, 2007). In literature, the concept of eco-innovation has been densely discussed. It consists of any innovation process that aims at reducing environmental impacts caused by consumption and product development (European Commission, 2006; Fussler & James, 1996). To reach eco-innovation, literature points out the need to create changes in society, technology, and institutions (Pujari, 2006; Rennings, 2000; Tukker & Butter, 2007).

With current technologies, incremental changes reach a small percentage of improvements (Carillo-Hermosilla et al., 2010), but there needs to be e and most particularly in some areasechanges in the order of magnitude (Factor 10 Club, 1997; Von Weizsäcker, Lovins, & Lovins, 1997). In order to achieve eco-efficiency of a factor of 10 or higher, very high levels of innovation are required (Reijnders, 1998). Creativity is already a key aspect in design, and sustainable products, more than any other sector, will need groundbreaking ideas. However, many ecodesign strategies (Brezet & Van Hemel, 1997; Wimmer & Züst, 2003) are sometimes perceived as conservative incremental approaches (like changing materials or reducing the product's weight). Eco-efficiency approaches (Bastante-Ceca, 2006; Lehni, 2000; Park & Tahara, 2008) optimize current technologies, and they rarely conclude in radical innovation. The fact of assessing a known product, and of focusing on very detailed traits of it seems to deliver the feeling that most solutions are fixed. After all, to apply an ecodesign strategy, some details of the product must have already been defined.

Surprisingly, this seems to be strongly against the most basic principles of design. Some authors strongly stress the importance of thinking outside of the box or divergently exploring different solutions (Pahl & Beitz, 1996; Roozenburg & Eekels, 1995). The question that arises would then be: what is the difference between ecodesign and traditional design that limits the application of this principle?. The only apparent difference is that most of them share an initial stage of environmental evaluation, from which improvement strategies are developed. Creativity is generally perceived as having a rather mysterious nature (Baer, Kaufman, & Gentile, 2004; Boden, 1996; Dorst & Cross, 2001; Goldschmidt & Tatsa, 2005; Liu, 2000). Since the work of Guilford (Guilford, 1950; Nguyen & Shanks, 2009; Sternberg, 2005) the research field that studies the creative process and creativity of individuals has expanded dramatically. However, after almost 60 years it still holds an aura of obscureness (Liu, 2000; Sternberg, 2005). Experts tend to agree on who are creative subjects, or what are creative ideas, despite the fact that up to now there is no strictly objective measurement of this figure (Baer et al., 2004). Furthermore, creativity of people has been given much more attention e due to the intrinsic possibilities in training and recruiting e than that of the process or their results (Goldschmidt & Tatsa, 2005; Liikanen & Perttula, 2008; Van der Lugt, 2003). Nevertheless, some authors have presented methods for assessing the creative qualities of a produced result, be it out of those uniform opinions of experts (Baer et al., 2004; Christiaans, 1992; Dorst & Cross, 2001; Rietzschel, Nijstad, & Stroebe, 2007), numerical analyses (normally of fluency (Batey, Chamorro-Premuzic, & Furnham 2009; Preckel, Holling, & Wiese, 2006; Silvia, Martin, & Nusbaum, 2009)), or self-judgment (Goldschmidt & Tatsa, 2005; Van der Lugt, 2003).

It has been proven that pre-conditioning effects the direction and quantity of the solutions generated in a creative process (Liikanen & Perttula, 2008; Purcell & Gero, 1996; Tseng, Moss, Cagan, & Kotovsky, 2008), and most particularly those of high-quality ideas (Rietzschel et al., 2007). It would thus be expected that the pre-conditioning derived from exposing the subjects to different levels of environmental information, if any, will induce a different creative behavior. Technologies described in the reference product's brief would be expected to be repeated in the new product; e.g. if an electric torchlight is described, then the solutions are bound to be based on electricity. This would have the effect of increasing the quantity of incremental improvements, and decreasing the quantity of groundbreaking sustainable solutions. This paper proposes to measure the influence of environmental information on the creativity assessments of a group of ideas generated by 56 students of a trans-disciplinary subject including mechanical engineers, architects, environmental scientists, etc. The relationship between the environmental information given and the creativity of the generated ideas has been studied. The proof of this assumption beyond intuition gives insight into how future environmental assessment tools should look in order to foster more creative solutions.

Environmental assessment

The concept of including environmental considerations has been given names such as Ecodesign, Design for the Environment, Environmentally Conscious Design, Green Engineering, Sustainable Design, and Design for Sustainability amongst others (Coulter, Bras, Foley, 1995; Howarth & Hadfield, 2006; Karlsson & Luttropp, 2006; McAloone, 2003; Waage, 2007). A quantification of the environmental impact of products is generally conducted at the beginning of the design process. A common approach is that of Life Cycle Assessment (LCA) (Ernzer, Grüner, & Birkhofer, 2001; Germani, Mandorli, Corbo, & Mengoni, 2004; Jeswiet & Hauschild, 2005; Nielsen & Wenzel, 2002). LCA consists of a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle (ISO, 2006). It is considered nowadays as one of the most widespread environmental evaluation tools. Nevertheless, amongst the design community, it is common to find detractors (Ernzer & Birkhofer, 2003; Jönbrink, Wolf-Wats, Erixon, Olsson, & Wallen, 2000; Millet, Bistagnino, Lanzavecchia, Camous, & Poldma, 2007; Sousa & Wallace, 2006), mainly because:

- Performing an LCA is a time consuming task that is difficult to fit in the product development process.
- A correct LCA requires much information, not generally available in the initial stages. Later on, that information is available, but the results of an LCA are no longer as useful.
- LCA involves complex modeling, which does not necessarily go hand-inhand with the models used during design.
- LCA is a complex task that generally requires special training.
- There is always some level of uncertainty in the results, although the apparent exactness may be a source of over-confidence.

As time consuming or complex as it may be, it is still considered in many methodologies as the standard to measure the environmental performance (Collado-Ruiz, 2007; Millet et al., 2007; Stevels, Brezet, & Rombouts, 1999). Some even define it as the core of an environmentally conscious product development (Nielsen & Wenzel, 2002; Wenzel, Hauschild, & Alting, 1997). Even in alternative assessments that claim to perform better in some aspects (Brezet & Van Hemel, 1997; Ernzer & Birkhofer, 2003; Erzner & Wimmer, 2002), principles of LCA are included in some way (Goedkoop, Oele, & Effting, 2004; Goedkoop & Spriensma, 2001; Ostad Ahmad Ghorabi et al., 2006).

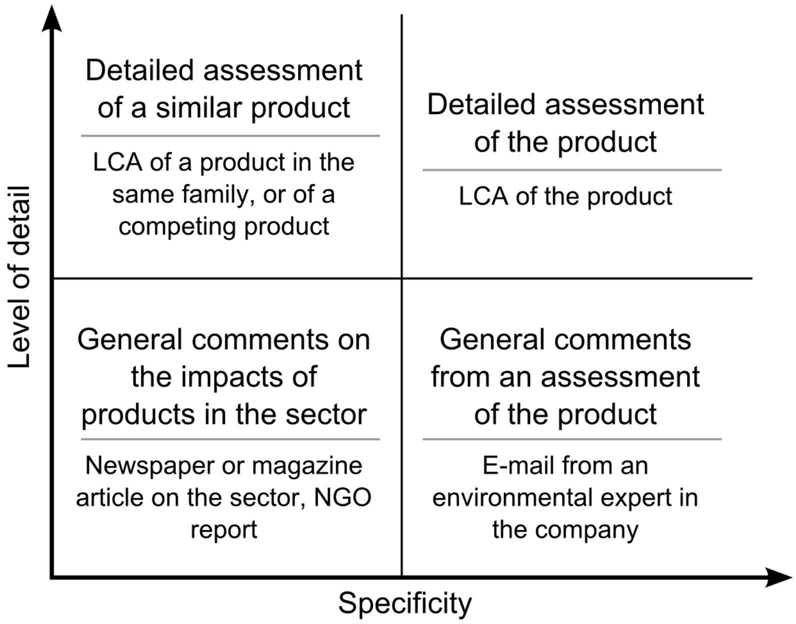
Conducting an LCA will confront designers and engineers with a high amount of additional data, numbers and facts, which can be particularly complicated in the early product development stages. Simplified tools have been developed for environmental assessment to assist in this handling of data (Collado-Ruiz, 2007; Lofthouse, 2006; Ostad-Ahmad-Ghorabi & Wimmer, 2005; Pamminger et al., 2007; Wimmer et al., 2004).

To be able to derive conclusions for product improvement, it is necessary to put absolute figures into perspective. Comparing environmental evaluation results becomes therefore essential. As stated in Finnveden and Moberg (2005), one of the aspects to be considered in any kind of tool for environmental assessment is its type of comparison, and whether or not it is a comparison between alternatives within a studied system or against a reference. The latter is the most complex one (Keoleian & Kar, 2003). However, studies have been conducted to ease this approach (Collado-Ruiz & Ostad-Ahmad Ghorabi, 2010a, 2010b). Information gathered from any kind of environmental evaluation can be categorized by two dimensions as shown in Figure 1: Specificity and Level of detail. Specificity describes up to which point the information refers to a product similar to the one at hand. Information of high specificity refers to the product that is being designed or redesigned. Lower levels refer to competing products or sector comparisons. Level of detail refers to the amount and detail of environmental information available. General comments as presented for example in articles or popular science magazines constitute of information with a lower level of detail, whereas presenting LCA data has a higher level of detail. Using the two dimensions introduced, four categories of environmental information can be set up to be used for further research within this paper (see Figure 1): Low specificity and low level of detail, low specificity and high level of detail, high specificity and low level of detail and high specificity and high level of detail.

Creativity and its assessment

Although the word creativity is very widely used as a vague term (Kampylis, Berki, & Saariluoma, 2009), its understanding is still far from clear. Consensus among researchers as to its general definition is that creativity involves the generation of ideas that are novel and appropriate (Boden, 1996; Goldschmidt & Tatsa, 2005; Kampylis et al., 2009; Nguyen & Shanks, 2009; Rietzschel et al., 2007). Most research analyzes the capability of specific individuals for this process (Liu, 2000; Preckel et al., 2006; Silvia et al., 2009; Sternberg, 2005), thus defining creativity as the traits from those people that empower them for such a task.

Figure 1 Dimensions of environmental information used for the study



The two broadest interpretations relate to the creativity of generating something unique and relevant for a society, and that of coming up with a novel and valuable solution for a problem at hand, even if it has been generated somewhere else previously. Different names are given to this by literature (Kampylis et al., 2009), with one of the most popular in recent publications being that proposed by Boden (1996): historical or h-creativity for the first and psychological or p-creativity for the second. Design tends to be dealt with on the second level (as it is the most commonly studied (Goldschmidt & Tatsa, 2005)), although good designs have an interaction and impact on a societal level as well (Sosa & Gero, 2003). The purpose of this paper is to assess creativity of ideas. This has been assimilated previously to idea quality in the design field (Goldschmidt & Tatsa, 2005; Van der Lugt, 2003), although with some exceptions as pointed out by Dorst and Cross (2001). To assess idea quality, it must be ensured that the ideas are original and appropriate (Goldschmidt & Tatsa, 2005; Rietzschel et al., 2007; Silvia et al., 2009), and in some cases surprisingness is also assessed (Nguyen & Shanks, 2009). Originality can normally be assessed when enough knowledge about existing products is available. For design products, appropriateness would mean feasibility or usefulness, in the sense of up to which point the concept will meet the demands of the market (Stevens, Burley, & Divine, 1999), as well as the specification and requirements of the design team. Interest (Boden, 1996) of the idea has to be considered in reference to the investor, the user, and in general for the whole value chain. Surprisingness refers to the effect on the designer (or the assessor) when being presented with an idea that is both original and appropriate.

The most common approach for measuring creativity is that of subjective expert judgments (Baer et al., 2004; Silvia et al., 2009). Subjective ratings generally provide with very high inter-rater correlation coefficients, even in nonparallel cases where the assignment is not identical, and especially when assessing the creativity of artifacts (Baer et al., 2004; Christiaans, 1992; Dorst & Cross, 2001; Preckel et al., 2006). For the purpose of this paper, it is proposed to assesses such artifacts, i.e. design ideas. The assignments are not identical, but correlation is still expected to be high (Christiaans, 1992; Dorst & Cross, 2001). Although there seems to be agreement on the general terms of creativity, specific definitions pose difficulties to experts (Dorst & Cross, 2001; Kampylis et al., 2009; Liu, 2000). In popular belief, some people even link it directly to the novelty of the ideas or the fluidity of the person in developing them, which is understandable from the great many measures that only relate to originality or amount of ideas. Although uniformity in assessments (Baer et al., 2004) suggests that this would be a sturdy enough measurement, many authors use different scales to assess specific traits of the ideas and then average them (Silvia et al., 2009). One of the most agreed upon scales is the assessment of originality and feasibility (Rietzschel et al., 2007).

Another approach found in literature is self-assessment of the participants (Goldschmidt & Tatsa, 2005; Van der Lugt, 2003). Creativity is measured by making the participants select the four most surprising ideas with red stickers, the four most feasible ideas with green stickers, and the most exciting idea (the one that they would be most excited about developing further) with a blue sticker. Then, Equation (1) is used (Van der Lugt, 2003).

$$\text{Score}_{\text{Self Evaluation}} = N_{\text{Green stickers}} + N_{\text{Red stickers}} + 2 \text{ x } N_{\text{Green and red stickers}} + 4 \text{ x } N_{\text{Blue stickers}} \qquad (1)$$

Van der Lugt (2003) admits that self-assessment does not provide as strong of conclusions as does expert judgment, although for design experiments like the one proposed by him e and the one proposed in this paper e participant’s perception is considered to be relevant. Some ideas might be perceived by all participants as highly creative, although they have been repeated throughout the groups, as was the case in the studies conducted by Dorst and Cross (2001) and Christiaans (1992). This tends to happen with ideas that come from information presented within the definition of the problem (Dorst & Cross, 2001). It thus seems relevant to compare results with subjective assessments in order to control this phenomenon.

Other ways of indirectly assessing creativity of the ideas can be found in literature. If an aggregative approach is taken, delivering one single indicator for the creativity of the whole sessions, fluidity of ideas (or quantity of ideas) can be assessed (Batey et al., 2009). This measure can be appended with assessments of novelty, variety and quality of the solutions by using a pre-established judgment and decomposition (Shah, Vargas-Hernandez, & Smith, 2003). Other numerical methods have proved to correlate with this measure (Goldschmidt & Tatsa, 2005; Preckel et al., 2006; Rietzschel et al., 2007; Silvia et al., 2009). Other authors analyze the process through which the ideas are generated. This requires specific recordings of the creativity session (and the consequent development of protocol studies). However, it has been proved that variables such as the reconsiderations in the setting of the problem

(Christiaans, 1992; Dorst & Cross, 2001) or how much an idea is interlinked with others (Goldschmidt & Tatsa, 2005; Van der Lugt, 2003) can be a good proxy of the final creativity assessment of the ideas themselves. In this paper the strict definition of the problem is one of the controlled parameters, making some of these measurements unfeasible. The process-oriented approach will thus be disregarded. Another approach is to categorize the design solutions (Liikanen & Perttula, 2008; Purcell & Gero, 1996). Although it has been successfully used to analyze fixation phenomena, this approach does not deliver a numerical value.

Methodological approach

The main goal of this paper is to gain insight into the relationship between the availability and nature of environmental information and the creativity of the final output of a conceptual design process. Environmental information can present itself in different ways, as seen in Section 1. This main research inquiry has been summarized in the following set of research questions:

- RQ1: Does the presence of environmental assessment information influence the creativity of the final solutions?
- RQ2: Does the level of detail of available environmental assessment influence the creativity of the final solutions?
- RQ3: Does the generality of environmental assessment information influence the creativity of the final solution?

An experiment was carried out with a sample group of 56 students of the Vienna University of Technology taking the subject Creativity engineering. There were 8.9% Ph.D. candidates, 37.5% master students and 39.3% under-graduate students, and 14.3% unknown. Their backgrounds were comprised of mechanical engineering, architecture, civil engineering, computer science, physics, chemistry, mathematics, industrial engineering, industrial design, electrical engineering and environmental science. Domain-specific effects such as those shown by Purcell and Gero (1996) are limited by the variety of participants. Additionally, design teams are bound to include people across all of these disciplines. Therefore, the results should be representative of the phenomena in the design process.

The participants were given the task of coming up with design ideas which would reduce the environmental impact of an office chair. During the initial 15 min of the workshop they were provided with details about the specification of the product and its requirements, as well as the goal and scope of the redesign process. Briefing included a verbal and written description of the task. Attention was paid to brief participants uniformly, to avoid differences in cueing (Liikanen & Perttula, 2008; Purcell & Gero, 1996). The subjects where then divided into five groups. Four groups received different environmental information responding to each one of the quadrants in Figure 1. The fifth group was defined as the control group, and was not given any additional information other than their background knowledge.

The different groups were named with the convention shown in Table 1. An element that could unintentionally influence the cues for creative thinking is the familiarity with environmental information, most particularly LCA. Participants were surveyed regarding this matter. Randomly distributed, 30.4% had some sort of environmental studies, 14.3% had specific knowledge on environmentally assessing a product (by LCA or similar), and 8.9% had specific knowledge about ecodesign. This effect will be studied in the results by analyzing the amount of ideas that the different groups had, representative of the time that they had to come up with them.

The participants were then given 45 min to come up with as many ideas as possible, and to have all of them explained and documented (with drawings if necessary). Since part of that time is used for going through the documents and internalizing the information, attention was paid to generate documents of similar length. The LCA studies given were two-page summaries with different figures, and the news item and e-mail in Groups B and C respectively were one page long, and could be expected to take a similar time to read. The group without information did not have to invest that time, although it can be assumed that 45 min should, in most cases, provoke some level of saturation in the amount of ideas they generate in less time (Snyder, Mitchell, Ellwood, Yates, & Pallier, 2004). Most studies that analyze this phenomenon study durations of 20 - 60 min, with a strong decline in the first 40 min (Liikkanen, Björklund, Hämaäläinen, & Koskinen, 2009). Due to this phenomenon, most studies stop even before this time (Liikkanen et al., 2009; Snyder et al., 2004; Tseng et al., 2008).

They were then given 15 further minutes to describe their ideas and to fill in a standardized form in which they had space for a name, short description, and a small sketch. This was done to try and bring all ideas to a similar level of development, as well as to avoid the effects of some people having more or less time to generate and document the ideas, i.e. Group A. Ideas were then
coded with information on the subject that had generated them. A total of 262 ideas were recorded.

Table 1 Groups arranged in the study

Name	Information given
Group A	No information
Group B	Newspaper item including environmental information of office chairs
Group C	Internal corporate e-mail about the environmental impact distribution of the previous model (with no numerical data)
Group D	LCA report (two pages) of a competitor’s office chair
Group E	LCA report (two pages) of the corporate’s own previous model

After this process, the participants assessed the different parameters of creativity (Goldschmidt & Tatsa, 2005; Van der Lugt, 2003) needed in order to complete Equation (1). Due to the fact that each participant had the same number of stickers representing their most surprising, feasible and exciting ideas, Equation (1) gives a relative interpretation. One participant's most exciting idea - assuming it is also surprising and feasible - would receive the same rating as a colleague's less creative idea. This was however not likely to be representative of the general creativity of the solution, since some participants come up with better solutions than others. For this paper, measures were weighted depending on the authors' subjective assessment of the subject's ideas. This assessment was the result of individual evaluation and further discussion to reach a consensus, thus giving an expectedly robust measurement. A continuous scale from one to five was used to assess the best ideas, as shown in Table 2.

Once both assessments are done, to accumulate their effects they were multiplied as shown in Equation (2). This way, the best idea receives a score proportional to the subjective assessment, and other ideas self-evaluated as worse will proportionally receive less points.

$$Creativity = ScoreSelf\ Evaluation \ x\ AssessmentBest\ Idea \qquad (2)$$

Equation (2) gives a measure of creativity for each idea. This assessment will be used to check the influence of the environmental information, by analyzing its relationship with the group of information that the subject received. The results will show whether the information provided influences the creativity of ideas. No interpretation can be done as to the quality of the idea itself and no conclusions can be driven whether more or less creative ideas will lead to more or less environmentally benign solutions. An assessment will be also carried out for the 56 participants, and conclusions will be derived from a combination of provided environmental information and creativity.

Results

The assessment of idea creativity was analyzed to see if there were statistical differences between the five groups shown in Table 1. Kruskale-Wallis test shows whether three or more samples (independent from each other) follow different statistical distributions, without the requirement of being any particular distribution. The null hypothesis in this test states that the samples do follow the same distributions, and $p < 0.05$ for a significance level of a ¼ 0.05 will be considered as proof of groups not following the same distribution. The Mann-Whitney U-test was later used for pairwise comparisons between groups.

Table 2 Scale for subjective assessment of the best ideas

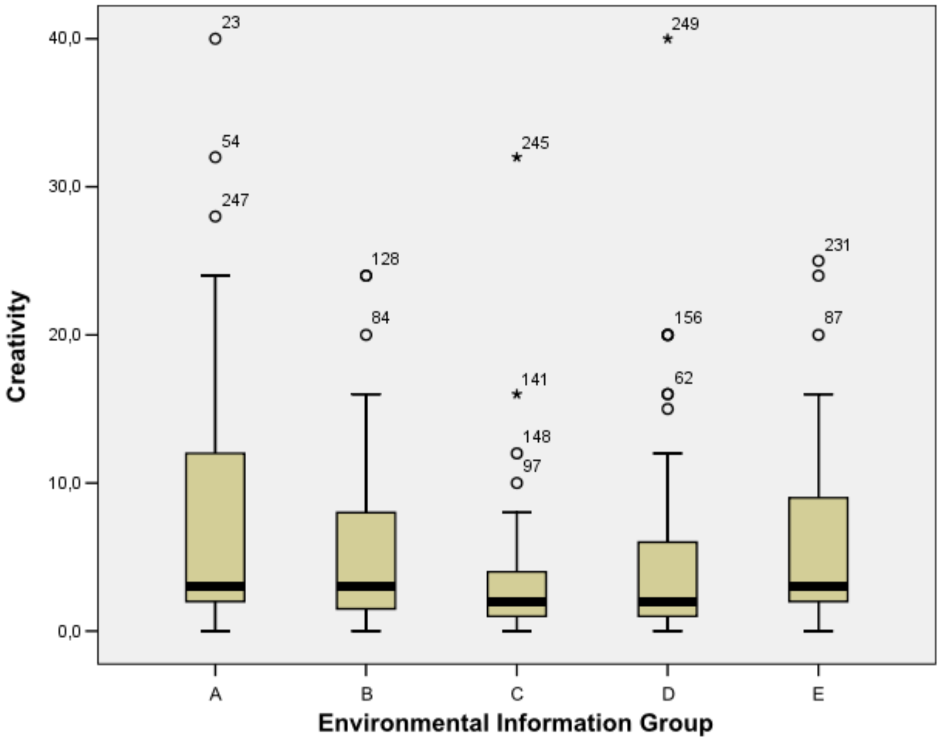
Value	Description
1	Common ideas, optimizations that spawn from the text, or stereotypical proposals.
3	Novel ideas for the product, but that have been seen in other contexts or similar products.
5	Surprising ideas, that seem to point at relevant concepts.

The first assessments of creativity (Equation (2)) for all five groups resulted in p ¼ 0.002 < 0.05, indicating high deviation from the null hypothesis. This proves that assessments done with different types of information affect creativity level of the final outcomes. Figure 2 shows the distribution for each one of those groups. This motivates the further study of each one of the axes defined in Figure 1.

For the axis Level of detail, i.e. merging Group B with C, and D with E, significance was $p = 0.001 < 0.05$. A pairwise comparison of both levels of information (Group B-C versus Group D-E) yielded a p-value of $p = 0.001 < 0.05$, with a higher mean rank for Group B-C. This showed that having LCA information pushed the participants to more conventional ideas than having broader environmental descriptions. The difference between having environmental information or not (Group A versus the rest of the groups altogether) also showed the fixation effects produced by environmental information ($p = 0.036 < 0.05$). However, a further test comparing participants with non-detailed information (Groups B and C) to those without literature (Group A) proved not significant ($p = 0.267 > 0.05$). Therefore, the strong differences seemed to be in the LCA based groups. Table 3 shows the comparison of groups with LCA information (D and E) compared to the other groups.

As can be seen, differences of this group always have a p-value of $p > 0.05$, with Group D-E having lower mean ranks. This can be interpreted as a systematic reduction in the creativity of the ideas when LCA information is present, whatever the source. The next step was to study the second axis of Figure 1, the accordance of environmental information to a specific product at hand. Three groups were considered for this: those with no information (Group A), those with information regarding competing products (Groups B and D), and groups with information regarding their own product (Groups C and E). Distinction between these groups did not prove significant ($p= 0.102 > 0.05$), although pairwise comparison between the two first groups was significant ($p= 0.046 > 0.05$), showing that those people with no information were significantly more creative than those with information about other products. The rest of the pairwise comparisons did not, however, show significance (p-values of 0.061 and 0.623).

Figure 2 Box-and-Whiskers plot of idea creativity assessment for all five groups considered in the study



Pairwise comparisons were also done between all five groups, as is shown in Table 4. This test corroborates that groups with LCA information of their own product (Group E) presented a systematically lower level of creativity in comparison to those without LCA information. Groups with LCA information of a competing product (Group D) also showed lower levels in comparison to Groups A and C, but not to B. They cannot be proven to be taken out of a different distribution.

Table 3 Comparison of groups with LCA information with other combinations of groups

Group	N	Mean rank	p-value
Group A	43	91.1	0.005
Group D-E	107	69.3	
Group B-C	111	123.1	0.001
Group D-E	107	95.4	
Group B	68	97.4	0.050
Group D-E	107	82.1	
Group C	43	95.1	0.000
Group D-E	107	67.3	
Group A-B-C	154	145.1	0.000
Group D-E	107	110.7	

Table 4 p-values for pairwise comparisons. Values in italics indicate significant differences between the distributions (p-values ≤ 0.05)

	Group A	Group B	Group C	Group D	Group E
Group A	X				
Group B	0.146	X			
Group C	0.753	0.126	X		
Group D	0.029	0.174	0.004	X	
Group E	0.006	0.050	0.000	0.850	X

This seems to point out that in order to interpret LCA in Group D, participants extrapolated conclusions closer to those in the news item. It can also be seen that specificity does not yield a strong difference among groups. Possibly the strongest effect comes from having data that appears precise (even if it comes from competing products), since it blocks the designer into current solutions, independent of whether these solutions are for a reference product or not. This is shown in the lack of difference between the distributions on Groups D and E (both with LCA information). Giving information with a lower level of detail can be considered positive, as it cannot
be proven by the study to reduce the creativity of the resulting solutions. It is also possible to perform analogous tests for the different participants instead of testing the ideas. Different participants could be considered to be more or less successful depending on diverse parameters. The most common to consider is fluency (number of ideas generated). Even though this parameter proved to be significantly different in the five groups ($p = 0.048 < 0.05$), analysis of each of the axes did not prove significant (p-values of 0.113 and 0.054 for Level of detail and Specificity respectively).

When developing the study, there were some concerns about the time that each of the participants had to invest in order to go through the documentation. Regardless of idea creativity, most studies mention the effect of time on fluency, i.e. the total number of ideas generated (Liikkanen et al., 2009; Snyder et al., 2004). However, Group A did show statistically representatively higher
figures than any of the others. Therefore, the effect of spending some additional minutes can be considered secondary in comparison with the effect studied in this paper.

The score given by the assessors to each candidate's best idea (also an indicator of success) yielded a much more positive result. Significance for differences in all five groups was of $p= 0.015 < 0.05$, provoked by the very strong differences in Level of detail ($p = 0.002 < 0.05$). Specificity did not prove to be significant at this level ($p = 0.210 > 0.05$). This supports the results shown for idea evaluation, making the conclusions more robust.

Conclusions and outlook

The evidence supports that environmental information has a strong effect on the creativity of the ideas generated by individual designers. RQ1 (Does the presence of environmental assessment information influence the creativity of the final solutions?) has been answered by the fact that the five groups proved not to be taken out of the same distribution, i.e. the different sources of information varied the distribution and mean of the population. Further examination yielded a progressive decrease in creativity as information grew in amount. This effect was somewhat expected when considering phenomena such as fixation (Liikanen & Perttula, 2008; Purcell & Gero, 1996), although up until now it had not been tested. More to the contrary, in many methods and methodologies, use of environmental information is a preliminary step that is very much encouraged (Brezet & Van Hemel, 1997; Nielsen & Wenzel, 2002; Wimmer & Züst, 2003).

Further questions RQ2 and RQ3 (Does the level of detail of available environmental assessment influence the creativity of the final solutions? and Does the generality of environmental assessment information influence the creativity of the final solution? respectively) analyzed each one of the axes in Figure 1.

RQ2 referred to the axis Level of detail, and proved to be the most differentiating factor. RQ3 was answered negatively. More specifically, it was proven that having detailed LCA information (Groups D and E) provokes a considerable decrease in creativity. A potential cause of this is the fact of having a sample product description, which is expected to produce a fixation state, thus limiting the diversity of solutions in some cases (Purcell & Gero, 1996). The study in this paper corroborates this reasoning. This brings up a problematic matter. It is necessary for designers to know about the environmental impacts of their products in order for them to focus on the relevant aspects. However, providing detailed information will systematically decrease their potential for generating groundbreaking creative solutions, which is not affordable for design or for sustainability. Information must be available, but fixation avoided. A positive result of this research is the mid level (or even low level) of detail presented in Groups B (news item) and C (e-mail). Although this level of detail has been traditionally disregarded, this study proved that it does not significantly influence the final creativity. What we could call soft information, seems to be the most appropriate source if sustainability is expected to be attained by design, as opposed to traditional hard information derived from specific studies.

Nevertheless, an additional question arises from the results. This study presented two levels of detail (hard and soft) only. There might be many possible levels in which information is presented. Different sorts of visualization, truncated reports, or subjective descriptions with a low amount of data could yield different results. It is important to know which elements bias or influence creativity negatively, and to be able to provide the necessary information with no bias. Further research is being done by the authors in this direction in order to gain more insight about the influence that different amounts and levels of detail included in information have on creativity.

This has a strong influence on how tools influence the performance of designers. During the previous years there has been a strong effort for developing methods, more than there has been for testing them (Lindahl, 2005; Tukker et al., 2001). Mostly direct feedback is considered, but effect on creativity has not been recorded to date. It is important to consider the conclusions of this paper in the development or adaptation of methods and tools, since neglecting the effect on creativity can result in a tool having an unrecorded negative influence. Furthermore, a future line of research that spawns from this is the analysis of different design methods and tools as to their influence on creativity.

Most critical is the effect on the early stages. Although many ecodesign methods claim to be addressed to the early stages (Gomez-Navarro et al., 2005; Lindahl, 2005), the truth is that their negative effect on creativity would strongly limit their success (Stevens et al., 1999). It is important to overcome this obstacle before addressing the early stages, or sustainability concerns
will hardly be considered systematically at this stage. This paper also provides insight into how environmental information can be presented in current computer tools. LCA tools deliver complex sets of data that might not be suitable for direct use in design, albeit adaptable to this purpose. Simplified assessments should also ensure that they deliver simplified soft information that does not limit creativity. Finally, there have been several efforts to integrate environmental assessment into Computer Aided Design (CAD) platforms (Ostad-Ahmad-Ghorabi & Collado-Ruiz, 2009). Presentation of results should pay attention to fixation effects, to avoid mere incremental optimization.

To develop environmental information, detailed models are generally required (Ernzer et al., 2001; ISO, 2006; Millet et al., 2007). Since soft environmental information must be presented, this required level of detail seems unjustified and unpaired with the requirements. The results of this paper point out the need for methods to carry out similarly soft assessments, out of analogously soft product information. Further research should be carried out on ways to derive general information about product categories, general product performance variables, or requirements in the Product Design Specification documents. Some efforts have already been carried out in this direction (Collado-Ruiz & Ostad-Ahmad-Ghorabi, in press; Singhal et al., 2004), although much more information needs to be publically available as to environmental impacts and life cycles of conventional products.
This paper studied ideas generated by individuals. Be it positively or negatively, literature deals extensively with the influence of groups on idea generation. It is thus important to study how this fixation is affected by a group. Detailed information could guide the discussion towards the environmental data, or could increase the probability of having unbiased partici-

pants. Further study is required in this area in order for teams to be configured and informed as efficiently as possible.

The effects studied are surely different from person to person, and are bound to be influenced by the participant's discipline (Purcell & Gero, 1996). In the experiment presented here, a random combination of disciplines was assessed, which partly eliminates the influence of any specific one. However, it would be relevant to extend this study by analyzing how different disciplines behave to this effect, in order to ensure that information is presented and communicated correctly to different sectors within companies. This paper studies for the first time the effect of environmental information on creativity. It has been proven that having detailed environmental information constitutes a bias towards more conventional and conservative solutions, which challenges many of the ecodesign tools and approaches previously presented. It is critical to preserve creativity in the design team if truly sustainable solutions are expected to be attained, as incremental innovation is not enough to ensure high values of factor X (Reijnders, 1998). For paradigmatic change, it is necessary to reconceive the way sustainability is generally considered in design, and the way tools are introduced in the design team. The study conducted clearly showed that the existence of environmental information influences the creativity of ideas. As a consequence, more conventional ideas are produced. The study is not able to conclude whether more creative ideas will lead to more sustainable solutions. In fact, analyzing the bi-directionality of conclusions is an interesting question which must be dealt with in future research. In the scope of future research, it is also a necessity to assess the influence of the proposed ideas in regard to occurring environmental impacts in the final product. Longitudinal studies should be carried out, tracking the evolution of an idea from its birth until its implementation into a product, where it can then be environmentally assessed.

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