# Relaxing or arousing environments (through color and music) for fostering designer’s creativity

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## Abstract

Within the literature devoted to studying the influence of environment factors on people's creativity, the majority analyzed these factors as isolated elements and assess individual’s creativity in general. The aim of this work is to analyze the influence of some of these environment factors on the design outcomes in terms of creativity, considering the potential emotion it can cause (relax or arouse). An experiment was developed to test the results generated in different settings combining environment factors that enhance creativity, in which designers were asked to develop different creative concepts. Different col-ours and music were combined in order to set arousing and relaxing environments. Results point to differences in the creativity parameters, according to the environment in which designers worked.

**Keywords:** Creative process; emotion; concept generation

## 1. Introduction

Creativity and innovation are two terms that totally condition business success. New products that are launched must meet a set of innovation standards and this responsibility is often determined by the creativity of the design engineer in charge of developing these products (Alves et al., 2007; Taura, 2016). For this reason, the designer’s creativity and the design process have frequently been the subject of study  (Amabile, 1996; Csikszentmihalyi, 1998; Aizpun et al., 2015; Hu & Reid, 2018; Morin et al., 2018). From these numerous studies it has been observed that creativity does not only depend on internal factors within the designer, but that there are also external factors that can have an effect on people's creativity – the so-called environment factors. In other words, there are external elements that, consciously or unconsciously, have an influence on people and which make them improve their creative capabilities (Dul et al., 2011).

Among the studies devoted to the influence of environment factors on creativity, we can observe a number of different parameters with which the designer will have to interact either directly or indirectly. This could be the case of the layout of the furniture he or she is working on (McCoy & Evans, 2002), the “shape” of the workplace (Wu et al., 2020) or the decorative elements in the work environment (Stone, 1998). These elements may include living elements, such as plants (Ceylan et al., 2008; Shibata & Suzuki, 2004). This positive effect of the nature on creativity can be even simulated with artificial elements that represent the natural environment (Batey et al., 2021; Chulvi et al., 2020).

The effect of interaction with human beings has also been studied, whether direct (Alves et al., 2007; Samani & Alavi, 2020) or virtual (Chulvi et al., 2017). It has also been demonstrated that simply their presence can cause an effect on creativity, even though there is no interaction (Aiello et al., 1977; Stokols et al., 2002). Likewise, the stimulation of different senses has also been studied, including sight (Knez, 1995), hearing (Mehta et al., 2012), smell (Knasko, 1992) or other sensory receptors (Alencar & Bruno-Faria, 1997).

This preliminary research on environmental factors has identified several questions that should be further explored. First, it can be seen that all of them have been analyzed as isolated elements. The question could therefore be posed as to whether the enhancement of creativity is due to the fact that the stimulus generates a particular emotion in the individual, which is what improves his or her creative capabilities. This topic of the influence of the mental reactions of the designers on their design outcomes has already been addressed and analyzed in recent times (Jung &Chang, 2017; Mulet et al., 2016; Nguyen, Nguyen, & Zeng, 2018). Nevertheless, on comparing several of these isolated studies, we see that two opposite stimuli frequently enhance creativity, as in the case of cold (Ceylan et al., 2008) or warm colors (McCoy & Evans, 2002; Stone & English, 1998) or that of music or silence (Stokols et al., 2002). This does not mean that they get contradictory results, since both stimuli were tested isolated, comparing them with the neutral state, although in real situations it is difficult to find circumstances in which only a single sensory stimulus affects the subject. The most usual is to work in environments where several stimuli of different types (visual, auditory, olfactory...) affect the individual at the same time, so it is also interesting to study the interaction when combining several stimuli. The results of this study would be of interest in different fields, since the topic of how the physical working environment can affect creativity is gaining interest among companies and educational institutions (Thoring et al, 2021).

Additionally, and in relation to the subject matter of the study, all these factors have been analyzed mostly for the creativity of a generic (non-specific) individual, but few of them are focused on particular cases. This is the case of the work of Chulvi et al. (2020), who analyze the particular case of designers during the design process, working in natural environments in order to increase the creativity of their results. Accordingly, the aim of this work is to analyze the influence of some of these environment factors on the design outcomes in terms of creativity. To do so, a practical experiment was developed to test the results generated in different settings, in which attempts were made to combine environment factors that enhance creativity: color and music. The purpose is to analyze possible interactions between different stimuli and to discern which of the parameters related to creativity are affected in each case.

## 2. Methods & Materials

### *2.1 Experimental design.*

For the experiment 18 students from the last year of the Bachelor’s Degree in Industrial Design and Product Development Engineering of the Universitat Jaume I of Castellón were selected – 7 men and 11 women, aged between 20 and 30 years. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at the Universitat Jaume I. Informed consent was obtained from each participant. Each of the participants was asked to attend three sessions in which they had to perform an individual creative task. On each of the three occasions the conditions of the working environment were modified, as explained below. The students were divided into three groups (groups 1, 2 and 3) so that the type of environment could be alternated with the problem posed in each case.

The first environment generated, which we have called environment A, was illuminated using red light in order to enhance creativity, in accordance with the studies of Stone and English (1998) and McCoy and Evans (2002), who claim that warm colors stimulate creativity. Moreover, it was combined with music, which also stimulates creativity according to Stokols et al. (2002) . As, also according to Stone and English (1998) and Ceylan et al. (2008) blue is a relaxing color and red is an arousing color, the type of music chosen for the room with red light was also arousing, in order not to offset the effect of the warm color. It was also selected unfamiliar music, based on the selection by Kuan et al. (2017), in order to avoid causing different emotion regarding to personal experience with the music. The arousing songs proposed by Kuan et al. (2017) are “Conquerors of the Ages (Edmond De Luca)”, “The Great Gate of Kiev (Mussorgsky)” and “The Gadfly Suite Finale (Shostakovich)”. In the second environment, called environment B, we used blue lighting since, according to Ceylan et al. (2008), cold colors enhance creativity. As music to enhance creativity in this case we chose that listed as unfamiliar relaxing, because of the same reasons described before, according to the same selection by (Kuan et al., 2017). The relaxing works chosen were “Appalachian Spring: Ballet for Martha (Copland)”, “Sunset - Near the Plantation (Frederick Delius)” and “The Birds: The Dove (Respighi)”. As a control environment we set up another one without any colors or music, which we called the environment C.

The laboratory in which the experiment was conducted was a 3×3 meters room with windows looking outside and a door that gave onto an adjacent room. In order to achieve the A and B environments, the glass of the windows was covered with thick red (environment A) and blue (environment B) paper so that the light that came through matched the corresponding color hue in the room. Additional lighting was provided using four smart LED color bulbs BeeWi of 530 lumens, with blue light for environment B, red light for environment A and white light for environment C. The color specifications selected can be seen in Figure 1. Also, Figure 2 shows the room under environment B conditions.

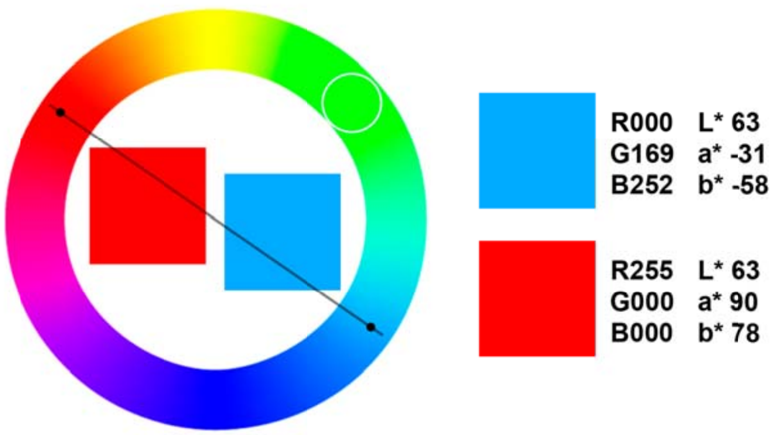


Figure 1. Colour specifications selected for the experiment

Figure 2. Environment B

The participants were asked to go to sessions held within the same time bracket over a period of three consecutive weeks in order to perform an individual creative task. A different design problem was used in each session. As can be seen in Table 1, during the first week participants were given Problem 1, which referred to generating ideas about new concepts for organizing elements for clothes to be used in wardrobes; the second week the aim was to come up with ideas for containers for taking food to university (Problem 2); and during the third week participants had to develop new concepts for organizing drawing material (Problem 3). In all three cases, the students were told that they had to come up with the greatest possible number of creative ideas and, finally, they had to select the one that they thought was the most creative.

The order in which problems were presented has not been randomized, with the aim of preventing students from sharing information about the problems they had to solve. As the designs preformed for each student were carried out in different weeks, the effect that one ambient could have had on the participants will not affect in this way in their next activity. On the other hand, the environments were randomized, as can be seen in Table 1.

Table 1. Organization of the experiment

| | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| **Week 1 – Problem 1** | Environment A | Environment B | Environment C |
| **Week 2 – Problem 2** | Environment B | Environment C | Environment A |
| **Week 3 – Problem 3** | Environment C | Environment A | Environment B |

The experiment was performed as follows:

- Initially participants had 5 minutes to read the instructions and to ask the facilitator about any doubts they may have about them.
- They then had 20 minutes to come up with as many ideas as possible about the proposed problem, outlining each of them on a different piece of paper by means of sketches and written explanations. In the room, they also had available to them all the drawing material they could need to do the sketches.
- On completing the task, they had another 10 minutes to select the most creative solution and convey it on a sheet that they were given for this purpose.

All the material generated was coded according to the number assigned to each participant, the environment (A, B or C) where the experiment was conducted and the problem (P1, P2 or P3) solved in that environment. For example, the code 1AP1 indicates that the solutions were generated by participant number 1 in room A referring to problem 1.

### *2.2 Assessment method*

The creativity of the results was evaluated using the method developed by Shah et al. (2003), in which four effective parameters are taken into account to measure the creativity of the ideas generated: quantity, variety, novelty and quality. This metric has been used in many researches for evaluating creativity (Chan et al., 2011; Linsey et al., 2011; Sarkar & Chakrabarti, 2011, Royo et al., 2021, Chulvi et al., 2022). Moreover, this metric has been chosen because, in addition of the dimensions of novelty and quality of the solutions, which are the most common features measured in product creative metrics (Chulvi et al., 2012), it also measures the quantity and variety of ideas during the ideation phase. These parameters have been considered interesting for this study, since we pretend to evaluate the creativity in the early design stages, including the idea generation phase.

According to (Shah et al., 2003), quantity is the total number of ideas generated by the individual during the time allocated in the experiment for generating ideas. It is given as the direct sum of the proposals. Variety is measured by examining how each of the functions is performed in each of the proposals and they are divided according to the level of abstraction into which they are differentiated. The proposals are grouped according to how different they are from each other. Using a different physical principle to satisfy the same function makes two proposals very different. On the other hand, if two proposals differ only in some secondary level detail, they are only slightly different. The grouping is done by generating a tree on which, at the first level, the ideas are differentiated according to physical principles that satisfy the same function. On the second level, the ideas are separated according to their working principles derived from each physical principle. The third differentiates the ideas according to their embodiment and, lastly, the fourth level indicates their level of detail. The value of variety is established as the total sum of products of the number of branches at each level of abstraction multiplied by a coefficient according to that level: 10 for the physical principle, 6 for the working principle, 3 for embodiment and 1 for detail.

To measure novelty, the problem is broken down into key functions or characteristics, which are weighted according to their importance. The idea produced is analyzed to identify how to carry out each of these functions at the conceptual level, each of them being valued by means of a scale from 0 to 10 depending on the degree of rarity achieved to perform that function. In this case, the following functions with their score according to the rarity and the weight of each of them were taken into account for the different problems (Table 2).

Table 2. Reference values for determining the degree of novelty of the proposals

| | | | | |
|---|---|---|---|---|
| **P1 – Clothes organizers for wardrobes** | | | | |
| Function | 3 | 7 | 10 | weight |
| F1 – way of separating/ organizing the clothes | Drawers / shelves / fixed hangers | Drawers / shelves / mobile hangers | Others | 0.6 |
| F2 – way of installing it in the wardrobe | Placed | Screwed in | Others | 0.4 |
| **P2 – Containers for taking food to university** | | | | |
| Function | 3 | 7 | 10 | weight |
| F1 – way of separating the food | Several containers | Compartments | Others | 0.6 |
| F2 – transport / storage after use | Storage in handbag or rucksack | Facilitates transport / storage (handles, folds up, etc.) | Others | 0.4 |
| **P3 – Organizers for drawing material** | | | | |
| Function | 3 | 7 | 10 | weight |
| F1 – way of organizing the material | Compartmentalized | Individual holder | Others | 0.6 |
| F2 – transport / location | Fixed horizontal | Facilitates transportation / vertical installation | Others | 0.4 |

The level of quality is calculated using the same functions that were defined in the case of novelty, but now what is analyzed is how effectively each of them is fulfilled at a purely functional level. To do so, each of the functions will be scored on a scale from 0 to 10, where 0 indicates that the solution is unable to comply with the desired function, 5 indicates that it fulfils the function but only to the lowest acceptable level, and 10 indicates that the function is performed in the best possible way.

The weights assigned to each function are the same as those applied in the previous section.

As an example of evaluation, in the case of the concept for organizing elements for clothes to be used in wardrobes showed in Figure 3, the participant thought on three different proposals: One of them consisted of modular cubes to be inserted inside a wardrobe; another, of modular drawer units with dividers, to be inserted inside a wardrobe as well; and a third, the one selected as the definitive one, which consisted of a rotating cylinder with shelves.

The value for quantity is 3, as there are three different concepts.

For calculating variety (Figure 3), the next considerations were taken into account:

- For the function “F1 – way of separating/ organizing the clothes”, there were no differentiation at physical level. At working level, two of them consider separating clothes into large shelves/bins, while the other proposes individual separation, using dividers. There are therefore two groups of ideas at this level. At the level of embodiment, the two proposals that follow grouped together can be differentiated, as one separates them into cubes of different sizes, while the other considers shelves of the same size. As the three ideas are already differentiated, there are no differentiations at the level of detail. Variety value for this function is, then, $V_1$ = 0x10 + 2x6 + 2x3 + 0x1 = 18.

- For function “F2 – way of installing it in the wardrobe”, there were also no differentiation at physical level. Two of them must be screwed to be installed, while the other (cubes) is simply placed, so cubes can be removed and reconfigured when desired. They have therefore been differentiated into two working level groups. At the level of embodiment, the two bolted proposals have been found to be very similar, so the differentiation has been considered at the level of detail, since one is installed by inserting the screws horizontally, and the other vertically. Variety value for this function is $V_2 = 0x10 + 2x6 + 0x3 + 2x1 = 14$.

The robustness of the coding related to variety measure was calculated with a Fleiss Kappa assessment, with a value of 0.847.

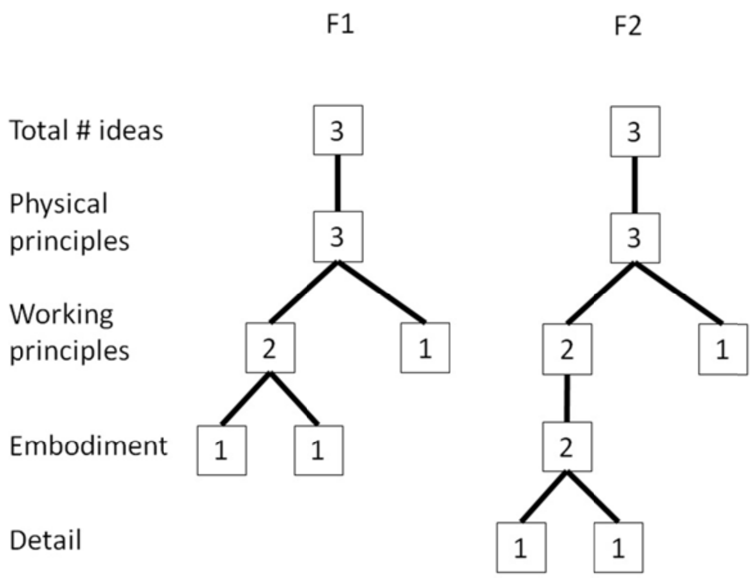


Figure 3. Genealogy tree for variety assessment

The novelty of the selected proposal (the one showed in Figure 4) was calculated according to the considerations of Table 2. For the first function, it is considered that the shelves are mobile (the structure can turn). So, the value for this function is 7. In the second function, it is considered that it is screwed in, as said previously, so its value is 7. The final value obtained by weighing the functions is: N = 7x0.6 + 7x0.4 = 7.

Lastly, the following considerations have been considered for quality assessment. For the first function, it is considered that the proposal achieves the minimum acceptable level for separating the clothes, and also, it has been considered to raise slightly its rating because it facilitates slightly the access by having a turning movement. A score of 6 has therefore been considered. Regarding the second function, the installation requires screwing vertically, which is not difficult, but not as easy as installing screws horizontally. In addition, it is likely that more than one person will be needed to install it. Therefore, a rating of 4 has been considered. The final value for quality obtained by weighing the functions is: Q = = 6x0.6 + 6x0.4 = 5.2.

### *2.3 Data analysis*

All the evaluations were carried out by two different raters, both experienced in the field of Engineering Design and in creativity evaluation. The reliability of the agreement was calculated with a Fleiss Kappa assessment, with a value of 0.790.

All the statistical analyses were performed using SPSS, PASW Statistics 23 software. First, correlation analysis was applied to the creativity factors, in order to check possible relationships between their scores. The Spearman's Rho coefficient was used to find out the degree of relationship between the variables, since not all them followed a normal distribution (Kolmogorov-Smirnov test results revealed significant differences with normal distribution for variables quantity, quality and novelty, $p<0.05$, while for variety, a normal distribution could be assumed, $p = 0.20$). The correlation analysis was applied for each environment, and also jointly.

Second, to conclude if the scores of the variables quantity, variety, novelty and quality differ depending on the environment applied, significant differences were searched for in these creativity factors depending on the environment. Two different tests were applied. For variety, analysis of variance (ANOVA) was applied (as it could be assumed to follow a normal distribution), considering variety as the dependent variable, and the environment (A, B, C) as the independent one. Bonferroni was used as a post-hoc coefficient. As the rest of creativity factors could not be assumed to follow a normal distribution, Kruskal-Wallis tests were applied in order to check the influence of the environment on their scores.

In the second phase of the analysis, all proposals of each participant (and not only the one selected) were analyzed. The proposals with maximum values for each of the quality and novelty parameters were compared with the quality and novelty scores of the proposal selected by each participant. In order to analyze whether the participants had chosen the proposal with the highest quality and novelty, two new variables were generated, the difference in quality (Q_DIF) and novelty (N_DIF) scores between the original proposal and that chosen by the rater. The aim of this analysis is to study the influence of the environment on the selection of the proposal.

The Kolmogorov-Smirnov test showed that normal distribution could be assumed for Q_DIF, $p = 0.200$, but it could not be assumed for N_DIF, $p = 0.002$. Analysis of variance (ANOVA) was applied to determine whether significant differences could be identified for Q_DIF (dependent variable), depending on the environment (independent one). Bonferroni was used as a post-hoc coefficient. For N_DIF, the Kruskal-Wallis test was applied, considering the environment as the independent variable.

## 3. Results

Each participant developed all his/her proposed solutions in the pre-established time and later chose the final proposal considered to be the most creative one from amongst all of them. Each participant solved three different problems, one in each established environment

(A, B and C). This resulted in 54 sets of solutions (some examples are shown in Figure 4), which were evaluated on the four factors that measure creativity according to (Shah et al., 2003): quantity, variety, novelty and quality. The results of these evaluations can be seen in Tables 3 (quantity) and 4 (variety), considering all the solutions developed by each participant, and Tables 5 and 6, that show the values of novelty and quality of their selected final proposal respectively.

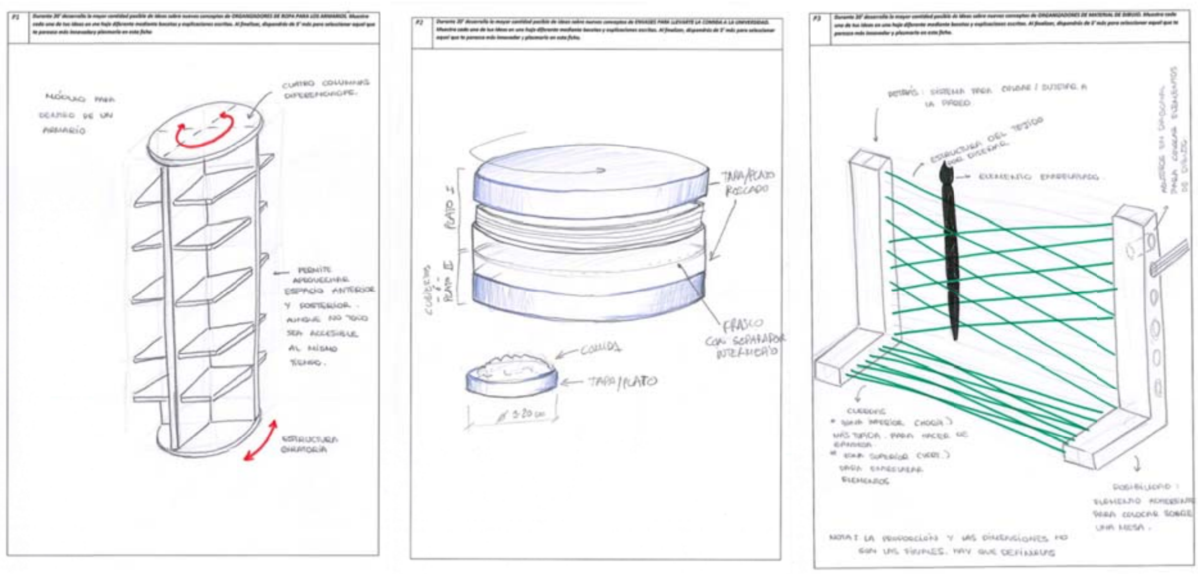


Figure 4. Solutions provided by the participants to problems 1, 2 and 3 respectively

Table 3. Scores for Quantity

| | P1 | | | | | | P2 | | | | | | P3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 7 | 3 | 4 | 4 | 5 | 5 | 5 | 2 | 9 | 5 | 4 | 6 | 2 | 3 | 2 | 3 | 3 | 4 |
| **B** | 3 | 3 | 1 | 3 | 3 | 3 | 6 | 4 | 3 | 4 | 4 | 5 | 4 | 3 | 8 | 3 | 3 | 5 |
| **C** | 4 | 3 | 5 | 2 | 3 | 5 | 3 | 2 | 3 | 3 | 6 | 2 | 5 | 2 | 4 | 3 | 2 | 4 |

Table 4. Scores for Variety

| | P1 | | | | | | P2 | | | | | | P3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 5.14 | 2.34 | 2.86 | 3.43 | 3.20 | 3.71 | 1.73 | 0.53 | 4.49 | 1.82 | 1.02 | 3.40 | 1.20 | 1.30 | 1.50 | 1.75 | 3.15 | 1.75 |
| **B** | 2.34 | 1.37 | 0.00 | 0.11 | 2.51 | 2.00 | 2.56 | 0.80 | 0.09 | 1.02 | 0.93 | 1.53 | 3.45 | 2.25 | 2.70 | 1.75 | 1.80 | 1.35 |
| **C** | 2.83 | 2.06 | 2.00 | 1.20 | 2.57 | 2.06 | 1.33 | 0.80 | 1.82 | 0.93 | 3.80 | 1.33 | 3.15 | 1.50 | 2.48 | 1.50 | 0.90 | 2.40 |

Table 5. Scores for Quality

| | P1 | | | | | | P2 | | | | | | P3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 5.2 | 5.2 | 3.8 | 5.0 | 3.6 | 4.4 | 2.0 | 2.0 | 4.2 | 2.0 | 1.2 | 6.2 | 5.8 | 5.8 | 5.4 | 5.0 | 3.0 | 5.4 |
| **B** | 5.8 | 5.2 | 5.0 | 3.8 | 6.8 | 4.4 | 8.8 | 0.0 | 5.0 | 6.2 | 1.2 | 2.8 | 6.0 | 2.4 | 3.8 | 2.6 | 6.8 | 5.0 |
| **C** | 4.4 | 6.8 | 6.8 | 3.2 | 3.2 | 3.4 | 5.6 | 2.0 | 2.0 | 5.0 | 0.4 | 2.0 | 5.6 | 4.0 | 7.4 | 5.6 | 4.2 | 3.8 |

Table 6. Scores for Novelty

| | P1 | | | | | | P2 | | | | | | P3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 5.8 | 7.0 | 7.0 | 3.0 | 7.0 | 7.0 | 2.8 | 2.8 | 3.0 | 2.8 | 1.2 | 4.6 | 3.0 | 3.0 | 5.4 | 4.6 | 7.2 | 3.0 |
| **B** | 3.0 | 5.8 | 7.0 | 4.6 | 10.0 | 5.8 | 4.6 | 1.2 | 7.0 | 4.6 | 1.2 | 2.8 | 7.0 | 1.2 | 4.6 | 5.4 | 7.0 | 3.0 |
| **C** | 3.0 | 8.2 | 3.0 | 5.4 | 5.8 | 3.0 | 4.6 | 2.8 | 2.8 | 7.0 | 4.0 | 2.8 | 4.6 | 7.0 | 7.0 | 4.6 | 3.0 | 4.6 |

### *3.1 Correlations between creativity factors*

Applying correlations between the creativity factors shows a positive significant relationship between the variables quantity–variety (r(52)= 0.605, $p<0.01$), quality–novelty (r(52)= 0.489, $p<0.01$) and variety–novelty (r(52)= 0.289, p=0.034) ), where r is the Spearman's Rho coefficient, the value in parentheses corresponds to the degrees of freedom, and p is the critical value (the correlation is considered significant for values of $p < 0.05$). .

If a distinction is made by environments, in C a significant correlation is identified between the results of quantity–variety (r(16)=0.796, $p<0.01$) and quality–novelty (r(16)=0.506, p=0.032). In environment B a significant positive relationship is detected between quality–novelty (r(16)=0.627, $p<0.01$), whereas a negative correlation is produced between quantity–novelty (r(16)= 0.469, p=0.05). In environment A a significant positive relationship is detected between quantity–variety (r(16)= 0.725, $p<0.01$) and novelty–variety (r(16)= 0.551, p=0.018).

### *3.2 Influence of the environment on creativity factors*

Figure 5 shows the box and whiskers plots of the distribution of the values of novelty, variety, quality and quantity. The values of the mean and standard deviation (M, SD) for each parameter depending on the environment are shown next. In the case of novelty, there is little difference in the mean value, in this order: environment B (M=4.77, SD=2.40), followed by environment C (M=4.62, SD=1.76) and environment A (M=4.46, SD=1.96). Regarding to variety, in environment A (M=2.46, SD=1.27) the mean was higher than in C(M=1.92, SD=0.83) and B (M=1.59, SD=0.98). In the case of quality, the mean of environment B (M=4.58, SD=2.08) is higher than environments C (M=4.21, SD= 1.89) and A (M=4.18, SD=1.55). As regards the quantity of proposals, environment A obtained the highest value of the mean (M= 4.22, SD=1.83), followed by environment B (M=3.78, SD=1.52) and C (M=3.39, SD=1.24).

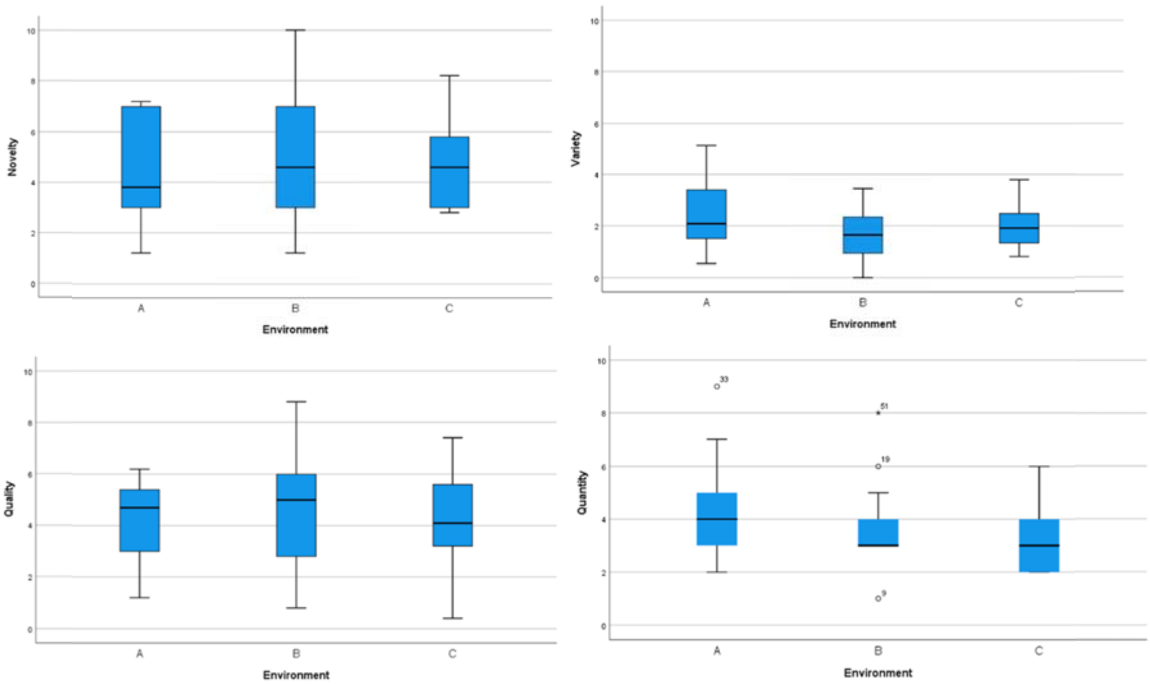


Figure 5. Box and whisker plot for the scores of a) quantity, b) variety, c) novelty, and d) quality of the problems according to the environment

The ANOVA test shows a significant influence of the environment on the variable variety, since the value of the observed significance level, p, is smaller than 0.05, so the hypothesis of equality of means is rejected and it is concluded that not all means are equal (F(2, 51)=3.23, p=0.048). F is the statistical coefficient, and the numbers in parentheses correspond to the inter- and intra- group degrees of freedom, respectively.

The variance homogeneity test (Levene's test) showed that equal variances could be assumed, so the Bonferroni coefficient was applied. In particular, in environment A the variety achieved was significantly higher than in B.

From the Kruskall –Wallis test, no significant differences are observed in the scores for novelty, quality or quantity according to the environment.

### *3.3 Influence of the environment on the selection of the proposal*

The proposal selected by the participant is considered to be correct (wise choice) if the difference between the score of this selected proposal and the highest score among the rest of the participant's proposals is positive or null, and it is considered to be a wrong choice if the value of this difference is negative. Figure 6 shows the box and whiskers plots representing the distribution of the values of Q_DIF and N_DIF. The ANOVA analysis (F(2, 51)=3.75, p=.03) of the variable Q_DIF showed that the value is significantly higher in environment B (M=0.33, SD =2.44) than in A (M=-1.30, SD =1.37), as can be observed in the Figure 7. This Figure shows the total of wise choices and wrong choices for each of the environments regarding to quality. There, it can be seen that the number of wise choices is much higher in environment B than in environment A. So, the environment of the room has an influence on the difference in the scores for quality between the proposal chosen by the participant and the one with the highest score amongst those he or she discarded. In the case of the environment A, in fact, the value of the difference is negative, which shows that, at least in some cases, the participants could have proposed solutions with a higher quality than the one chosen. On the other hand, from the Kruskal-Wallis test, no significant difference was detected in the case of novelty (N_DIF).

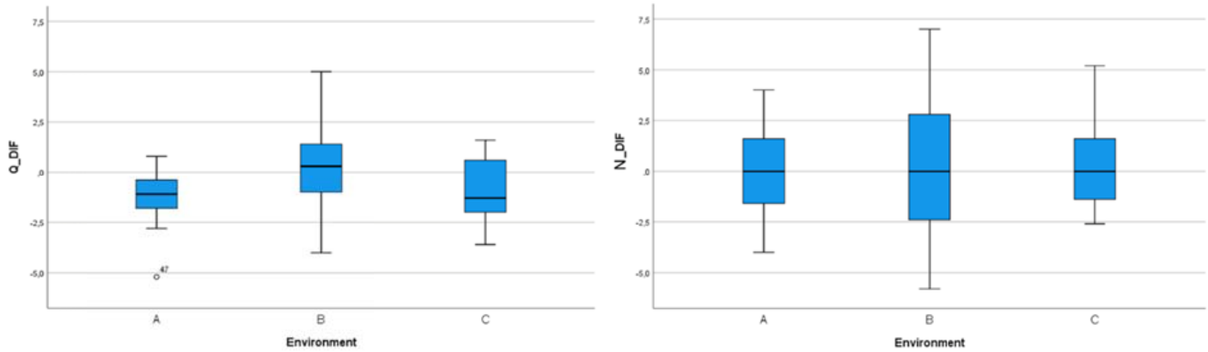


Figure 6. Box and whisker plot for the difference in scores for quality (Q_DIF) and novelty (N_DIF), according to the environment

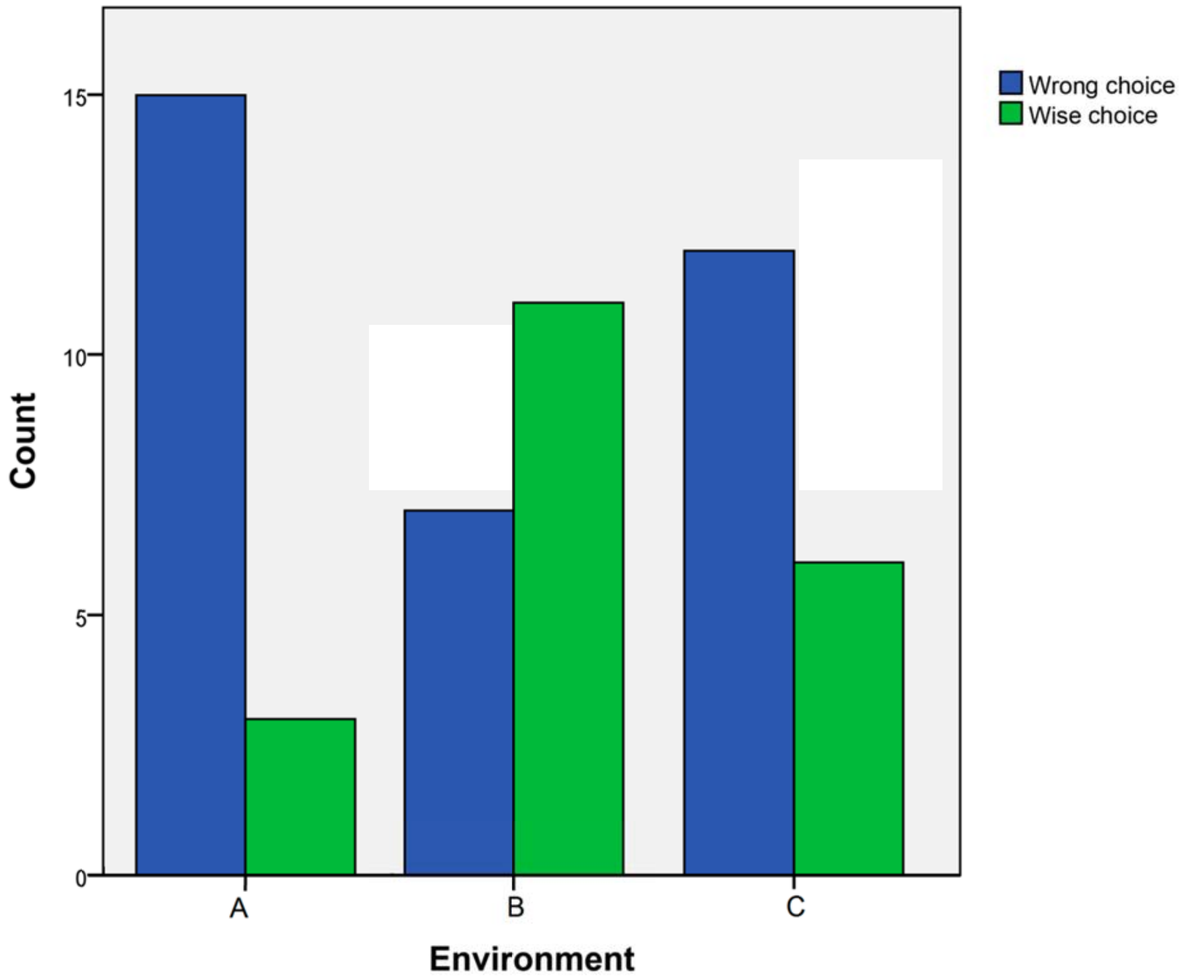


Figure 7. Participants' right and wrong choice of the quality of proposals

## 4. Discussion

After the experiment we found that designs produced in the room with warm colors and arousing music (environment A) present significant better values for variety. This would be in line with the hypotheses of both Stone and English (1998) and McCoy and Evans (2002),  who defended the idea that warm colors enhance creativity. However, according to Shah et al (2003), creativity is defined by the factors quantity, variety, quality and novelty, so, this study has been able to identify which specific phase of the creative process which is really affected by the arousing  stimuli incorporated to the environment A. It has been seen that arousing environments are related to a greater variety of ideas generated from designers. Therefore, this effect occurs in the phase "solution generation" of the design process, according to the identification of the design phases elaborated by Gero and Mc Neill (1998).

In the second part of the analysis the proposals discarded by the participants were assessed with the aim of determining whether the best option has been chosen from all their proposals and whether the environment in which they have worked could have some influence on the decision. In this case, because quantity and variety are factors that include all the proposals (selected and discarded), the analysis refers only to the factors novelty and quality. Hence, we have seen how the differences were significant in the case of quality, but in terms of novelty they were not noteworthy. Figure 7 shows how the best alternative in terms of quality was chosen in most cases in room B, whereas few wise choices were made in room A. Thus, it can be deduced that participants make a better choice of higher quality proposals in environment B than in environment A. Therefore, this does not mean that environment B helps to generate higher quality ideas, but rather that it helps to choose the best quality ideas from among those generated by the designer in the previous phase of idea generation. The positive effect of the relaxing environment would hence occur in the solution evaluation and solution selection phases, in line with Gero and Mc Neill (1998) definition of design phases.

These results point not only to a number of direct conclusions in absolute terms as to whether one environment helps to generate more creative concepts than another, but they also open up a debate on which environment is better in each conceptual design phase, accepting that conceptual design covers different diverging and converging phases (Gero & Mc Neill, 1998). This leads us to consider the possibility of creating environments that change according to the conceptual design phase instead of environments that remain static throughout the whole process.

### *4.1 Limitations of the study*

The study is limited to one case study with 18 participants, each solving three different problems. This results in a total of 54 items to carry out the statistical results. However, all participants had the same profile of final year students in Design Engineering. It would therefore be desirable to extend this sample with other participant profiles, such as established professional design engineers.

In addition to the professional profile, there are other factors associated with the individual that could be taken into consideration, such as the personality profile. It is known that the same stimulus can generate different emotional responses in individuals (Chulvi et al., 2020). In this study we have tried to limit this effect, for example by using unfamiliar music based on the selection by Kuan et al. (2017). However, it would also be interesting to replicate the study by selecting participants with different emotional profiles, in order to analyze whether there are substantial differences in their reactions to the stimuli studied.

## 5. Conclusion

This paper has reported a practical application within the field of Design Engineering regarding the effect of environment factors on the creativity of designers, which have been studied to date as isolated factors that affect the individual's creativity. Specifically, combinations of cold and warm colors with music have been analyzed, in order to create an arousing and a relaxing environment, together with the results of the practical design exercise.

One direct finding is that the environment with warm color and arousing music (A) yield better results in terms of variety. A strong direct correlation was seen, however, between the parameters quantity and variety. Therefore, as a first conclusion we can highlight that an arousing environment (warm light and arousing music) gives rise to a significantly greater variety of ideas than in a relaxing environment (cold light and relaxing music), which is positively correlated with the quantity of ideas.

Additionally, the influence of the environment on the selection of proposals was also seen, the conclusion being that in environment B significantly better proposals are chosen than in environment A in terms of quality.

By combining both conclusions a new scenario can be posited, in which the environment should not be static during all the phases of the conceptual design process, but should instead be able to vary. That is to say, a room with warm light and arousing music in the idea generation phase results in a greater variety of ideas, whereas a room with cold light and relaxing music leads to better quality solutions being chosen from among the previously generated proposals.

This new scenario is, in fact, a novel hypothesis that will have to be tested in a new practical study conducted in a variable environment with the aim of determining whether these conclusions are really fulfilled on varying the environments throughout the conceptual design process instead of performing it all in the same environment.

**Acknowledgements**

The research presented in this paper was funded by the Generalitat Valenciana Government (project ref. GV/2017/098) and the Universitat Jaume I (project ref.UJI-A2019-10).

**Disclosure of interest**

No potential competing interest was reported by the authors.

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