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The effect of nature on designers' creativity, according to their personality profile



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Abstract The aim of this work is to demonstrate whether natural environments, either real or simulated, tend to enhance designers' creativity, and whether the effects differ depending on their personality profile. Numerous studies have been conducted on the variables that shape the work environment and affect the designer's creativity, but few take into account the interaction between the work environment and the designer's personality profile. The aim of this study is to carry out a practical experiment in which a certain number of individuals solve conceptual design problems in different work environments, followed by an assessment of the creativity of the results. The results show higher values of creativity for both types of natural setting than in a neutral scenario. The personality of the designers determines whether the highest values are achieved in real or in artificial nature.

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1. Introduction

Creativity is one of the fundamental factors to be considered in the design of industrial products [1]. Within the design process, the initial phases are those that are most related to creativity, since their fuzzy nature means that the solutions adopted can be very varied, depending on how the different variables involved are developed. In this regard, numerous studies have been conducted that attempt to assess how the different variables of the creative process affect the creativity of the resulting design [2–10].

One of the main variables that can influence the creativity of a conceptual proposal for the design of a product is the working environment, this being understood as the physical and visible part of the immediate context in which the designer's work is carried out [2,4,11–15,9,16]. In contrast, those individuals or social contexts that might surround and/or affect the designer's work that have already been studied in previous research are not considered within this parameter [2,17–20].

Designers' work settings often have common characteristics, such as an open environment with neutral furniture and numerous items related to the practice of the profession [21–24]. However, the evolution of technology [25], in addition to the fact that the sketching work of the conceptual design phases is usually analogical, allows the work studio to be transferred to a natural environment in order to take advantage of the benefits that can be derived from it [26]. In this

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sense, some studies analyse in detail different elements of the creative workplace that influence creativity, considering certain factors related to natural environments [27,28]. Consequently, it is relevant to consider as a starting hypothesis (H_1) whether natural environments tend to enhance the designer's creativity.

In recent years, numerous companies in the technological field that focus their efforts on knowledge and creativity when solving problems have been implementing more recreational or user-friendly work environments in their workplaces to enable employees to feel more comfortable [29,30]. In fact, this characteristic has played a fundamental role in the communication of the company's own identity in order to differentiate itself from other competitors. For this reason, the present study attempts to approach the subject from the hypothesis (H_2) of whether a working environment that includes artificial nature enhances the designer's creativity in the same way as a real natural environment.

It is well known that the personality traits of individuals influence their reactions to a given stimulus. Consequently, it is reasonable to think that the nature of each individual and their personality profile could condition their creativity according to the workspace where they carry out their creative activity. Therefore, the hypothesis (H_3) is also posed as to whether the effect of working in a natural environment, either real or simulated, can influence the designer's creativity differently depending on his/her personality profile.

In order to study the hypotheses put forward, the aim of this work is to conduct a practical experiment in which a certain number of individuals solve conceptual design problems in different work environments: a real natural, a simulated natural and a neutral work environment. These conceptual proposals will be evaluated to quantify the degree of creativity achieved by means of the Moss metric [31], with the aim of being able to compare how it is influenced by the working environment. In addition, the study also aims to examine the personality profiles of the participants in the study (NEO-FFI) in order to determine how they are related to the influence of the working environment on creativity according to their personality.

2. Methods & materials

2.1. Participants

The experiment was carried out with the voluntary collaboration of 18 students from the last year of the Engineering Design degree – 6 men and 12 women aged between 19 and 27 years (mean age: 21.5) – with the intention of forming a sample that was as homogeneous as possible in terms of capabilities and abilities in the field of conceptual design. At the end of the experiment participants were rewarded with a voucher worth €5 that could be exchanged for reprographic material in the university copy shop. 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.

2.2. Task

The task consisted in solving three different creative problems in three different environments.

The first environment (real nature) is a landscaped outdoor area located on the University campus, with lawns, hedges and large trees, which isolates it from traffic (Fig. 1). The area also has outdoor benches and chairs, so that participants could choose between sitting on them or sitting on the floor.

The second environment (simulated nature) consists of a representation of the outdoor garden inside a building (Fig. 2). For this case the researchers fitted a 3×3 m room with artificial lawn and a large window taking up one of the side walls, which allowed the room to be lit by natural light. On the other walls a floor-to-ceiling mural was placed with a full-scale image of the outdoor garden, in order to simulate immersion in the garden itself. Likewise, a chair was placed inside the room, so that participants could also choose whether to sit on the lawn or on the chair.

The third environment (neutral) is made up of a normal lecture room, with a work table, a stool and bare walls (Fig. 3).



Fig. 1 Real nature: outdoor garden area.



Fig. 2 Simulated nature: artificial representation of the garden indoors.

The lecture room also had natural light, although to a lesser extent, and this was complemented with artificial white light.

Before starting the experiment, participants were provided with pencils and markers of various colours, a rubber and several sheets of paper. In addition, to be able to carry out the experiment correctly in environments A and B, they were given an 80x60 cm wooden board, and a pair of 51 mm bulldog clips to hold the sheets of paper on the board.

The following problems were proposed: new concepts for wardrobe organisers, food containers for taking food to university and organisers for drawing materials.

2.3. Procedure

Before starting to solve the problems, each student completes a printed NEO-FFI personality test. They are given as much time as they deem necessary to complete the test, the usual amount being no more than 15 or 20 min.

The student is then taken to the first environment with the first problem to solve. They must come up with as many ideas as they can in 20 min. They are then allowed another 10 min to select the one that they think is most innovative and illustrate it on a card.

In another session, the same student moves on to the second environment with the second problem (different from the first). As on the first day, they are asked to think of as many ideas as they can on the new topic and then have 10 min to develop the one which they consider best on a card.

During the last session, the student works in the third environment with a third problem (different from the previous ones). The process is the same as in the previous sessions.

The order of the environments and problems is combined in a different way for each user to prevent them from being able to exchange information about them.

At the end of the experiment, they are asked to complete a perception questionnaire.

2.4. NEO-Ffi

The NEO-FFI questionnaire, consisting of a reduced version of the revised NEO PI-R personality inventory, was selected

as the instrument to classify participants according to their personality [32]. This questionnaire allows a quick and global assessment of the five general dimensions of personality, without going into specific details of the facets of each of these dimensions. The five dimensions measured by the test are Neuroticism, Openness, Extroversion, Agreeableness and Conscientiousness, but for the present study only the first two have been taken into account, as they are considered the ones that can affect the reaction of each individual with respect to the environment. Neuroticism refers to the intensity with which each individual feels emotions, while Openness refers to how interested a person can be in the outside rather than the inside world.

The classification was carried out according to the percentile in which the score obtained on the dimension analysed is located. In the case of neuroticism, a person will be considered to have a very high neuroticism when their score is greater than the 75th percentile (Q4), high neuroticism when the percentile is between 51 and 75 (Q3), they have low neuroticism if their score is between the 26th and the 50th percentile (Q2), and they are considered to have very low neuroticism when the percentile is less than the 25th (Q1). In a similar way, in the case of openness, the same percentiles will be considered to classify them as being of high or low openness.

2.5. Questionnaire

At the end of the experiment, they are asked to complete a perception questionnaire like the one shown in Fig. 4. It includes questions about the different feelings in each of the three environments in which they have worked (real nature, simulated nature and neutral environment), as well as asking participants about their perceptions as regards which of the three locations they felt most comfortable in and which they were more creative in.

2.6. Solutions evaluation

The creativity of the solutions provided by the students was evaluated by means of the Moss metric [31], which is still



Fig. 3 Neutral environment: normal lecture room.






Student:	Age:				
	Rate your answer				
	Unpleasant 	Uncomfortable 	Indifferent 	Comfortable 	Very comfortable 
How did you feel in the real nature environment? (garden)					
How did you feel in the simulated nature environment? (laboratory)					
How did you feel in the lecture room?					
Which environment did you feel most comfortable in?	Real nature <input type="checkbox"/>		Simulated nature <input type="checkbox"/>		Neutral <input type="checkbox"/>
Which environment helped you find the best ideas?	Real nature <input type="checkbox"/>		Simulated nature <input type="checkbox"/>		Neutral <input type="checkbox"/>

Fig. 4 Perception questionnaire.

widely used and accepted by the scientific community today [33–35,6]. Moss used the combination of two factors to calculate the creativity of the product, one referring to its novelty (unusualness) and another referring to its usefulness (usefulness). This criterion is accepted by a large number of authors who deal with the subject of evaluating the creativity of products [5].

The usefulness variable is determined by comparing the degree to which the functional requirements of the product comply with a standard solution or the lecturer’s solution. The possible values vary from 0 to 3 depending on how successful the solution is at the functional level: 0 – does not fulfil the basic function; 1 – only fulfils the basic function; 2 – reaches the level of quality of the lecturer’s solution; 3 – the solution is better than the standard one at the functional level.

The unusualness variable is determined by the inverse probability that such an idea will emerge within a homogeneous group of solutions. As in the previous variable, the solutions are given scores between 0 and 3 according to the frequency of appearance of the concept: 0 – very common solution (> 10% of similar concepts); 1 – uncommon solution (10%, 5%); 2 – infrequent solution (< 5%); 3 – highly infrequent or original concepts (1%). Therefore, as it is a comparative

system, the rater must be familiar with the possible solutions that can be found and the frequency with which they are found. A key aspect in this respect is the fact that the same three design problems have been used by the research team for similar experiments, thus ensuring prior knowledge of the possible solutions that can be provided by individuals with a similar profile.

Finally, the degree of creativity of the product is calculated by multiplying the scores for novelty and usefulness, resulting in this case in a creativity score between 0 and 9.

2.7. Statistical analyses

All the statistical analyses were performed with the software SPSS, PASW Statistics version 23 (IBM Corporation).

To analyse the possible relationship between the personality profile and the environment with the creativity achieved, bivariate correlations (Spearman’s Rho coefficient) have been applied between the variable creativity (and its factors) and the variables neuroticism and openness.

In order to test whether there are any significant differences in the distributions of the variables between the environments considered in the study, the Kruskal-Wallis test was applied.

Significant differences were observed with $p < 0.05$. Analyses of Variance, ANOVAs (with Bonferroni coefficient in the post hoc when the Levene test showed critical levels > 0.05 , otherwise the Games-Howell coefficient) were applied to test for any significant differences between the mean values of the creativity variables, according to the environment.

To study possible differences in the distribution of the variable creativity (and their factors) depending on the personality and the environment, personality dimensions (neuroticism and openness) have been classified in 4 quartiles, depending on the percentile it is in.

The Kruskal-Wallis test has been applied to the variable creativity (and its components) as dependent variables, and the levels (quartiles) of variables neuroticism and openness as factors, for each environment.

3. Results

The 18 volunteers who participated in the study solved a total of 54 problems, examples of which are shown in Fig. 5.

3.1. NEO-FFI personality test

Table 1 shows the scores for the personality profiles of the participants in the experiment. As explained in the previous section, of the five dimensions measured by the questionnaire, only the two that may affect the individual's reaction with respect to the environment have been considered, namely, neuroticism and openness. Each of the two dimensions is classified in 4 quartiles, depending on the percentile it is in.

As it can be seen, all the volunteers who took part in the experiment are into the second or third quartile, both in neuroticism and openness. Moreover, they are not a really homogeneous sample of the population in terms of neuroticism or openness. In the first case, there are 11 subjects with high neuroticism compared to 7 in whom it is low, while in the case of openness, 14 volunteers have a high profile, while only 4 are low profile.

Table 1 Participants' personality rates.

Participant	Neuroticism		Openness	
	Percentile	Quartile	Percentile	Quartile
1	49	2	71	3
2	62	3	44	2
3	71	3	59	3
4	49	2	64	3
5	75	3	75	3
6	47	2	64	3
7	64	3	49	2
8	46	2	56	3
9	47	2	49	2
10	54	3	72	3
11	58	3	73	3
12	38	2	67	3
13	75	3	69	3
14	53	3	49	2
15	42	2	71	3
16	56	3	53	3
17	65	3	62	3
18	60	3	53	3

3.2. Creativity of the conceptual design

The design outcomes provided by the participants in the three environments analysed were rated according to their creativity using the Moss metric [31]. The results of the evaluation can be seen in Table 2.

The box plot in Fig. 6 shows the differences in the medians and the distributions of the scores for creativity depending on the setting. In this plot, it can be observed that the results for creativity are considerably lower in the case of the neutral environment with respect to both types of nature. The values obtained for the concepts devised in simulated nature are slightly higher than those for real nature.

The results of the Kruskal-Wallis test for creativity indicate that there is a significant difference in the distribution, $H(2, 54) = 13.658$, $p = .001$. This significant difference was found

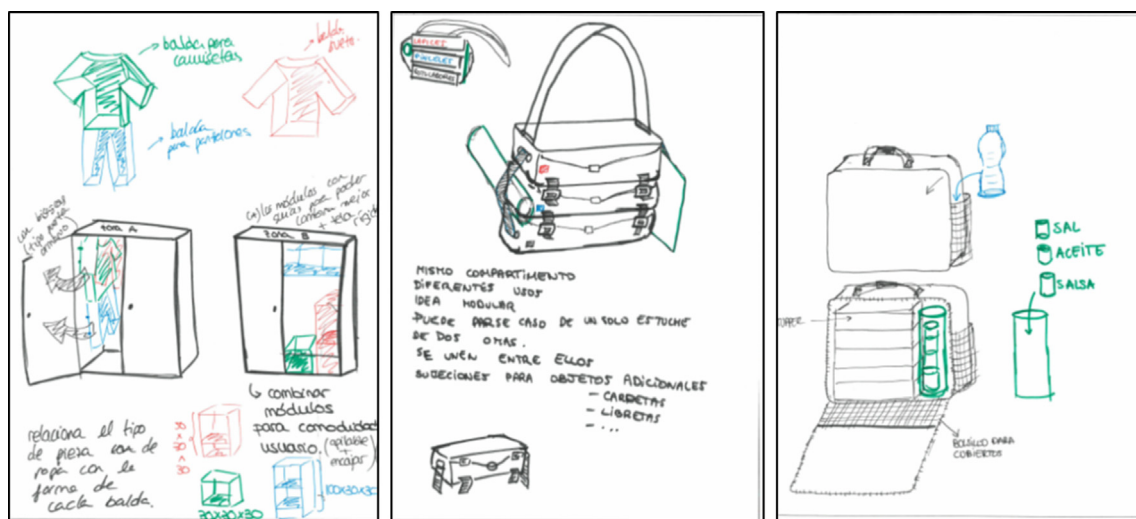


Fig. 5 Examples of solutions to the three problems posed.

Table 2 Results of the evaluation of creativity by environment using the Moss metric.

Participant	Neutral environment				Simulated nature				Real nature			
	Problem	Unusualness	Usefulness	Creativity	Problem	Unusualness	Usefulness	Creativity	Problem	Unusualness	Usefulness	Creativity
	1	2	0	1	0	3	1	2	2	1	2	2
2	3	0	2	0	1	3	2	6	2	1	2	2
3	1	0	2	0	2	2	1	2	3	0	2	0
4	2	0	2	0	3	1	1	1	1	0	2	0
5	3	2	1	2	1	0	2	0	2	3	0	0
6	1	0	2	0	2	2	2	4	3	3	2	6
7	2	1	1	1	3	3	2	6	1	1	2	2
8	3	3	1	3	1	3	3	9	2	3	1	3
9	1	0	2	0	2	2	2	4	3	3	2	6
10	2	3	0	0	3	1	2	2	1	1	1	1
11	3	2	2	4	1	2	1	2	2	2	1	2
12	1	0	2	0	2	1	1	1	3	2	2	4
13	2	0	2	0	3	2	2	4	1	1	2	2
14	3	0	1	0	1	3	2	6	2	1	1	1
15	1	2	2	4	2	2	1	2	3	3	2	6
16	2	1	2	2	3	2	2	4	1	1	2	2
17	3	0	1	0	1	3	3	9	2	2	1	2
18	1	0	1	0	2	1	1	1	3	0	2	0

between the neutral and the simulated nature environments ($p = .001$).

When we analyse separately the factors that compose the creativity, in Fig. 7 we can appreciate that medians and distributions of the values of unusualness according on the environment are similar to those presented in the final creativity results. Values are considerably lower in the case of the neutral environment regarding both natures and among them slightly higher in simulated nature. On the other hand, in the case of usefulness, the results were very similar in all three environments. This is also reflected in the Kruskal-Wallis test, where a significant difference was detected in the distribution of unusualness results, results $H(2, 54) = 9.709, p = .008$, while in the case of usefulness, no significant differences were detected between the environments.

If we analyse creativity results based on personality and environment, significant negative correlation is detected between creativity and neuroticism in real nature environment ($r_s = -0.640, p < .010$), this is, creativity decreases when the neuroticism has higher values.

In Fig. 8 it can be appreciated the different trends if we differentiate between high (Q3) or low (Q2) neuroticism. Thus, while people with low neuroticism obtain better results in real nature, people with high neuroticism present them in the simulated nature environment. In any case, the results obtained in the neutral environment show lower scores on creativity than the two types of nature.

In cases of low neuroticism, significant differences are found for creativity $H(2, 21) = 6.874, p = .032$. More specifically, there is a significant difference in its distribution between the neutral and real environments ($p = .032$). On the other hand, for high neuroticism the differences between creativity results have also been shown to be significant $H(2, 33) = 10.576, p = .005$, but in this case, the significant difference in their distribution is identified between the neutral and simulated environments ($p = .004$).

When analysing separately the factors that compose the creativity, correlations remain negative for real nature, but with lower values. Despite neither unusualness nor usefulness present significant correlation, it presents higher values in case of unusualness ($r_s = -0.432, p = .073$) than usefulness ($r_s = -0.198, p = .431$). Trend reflecting this can be seen in Fig. 9. While the results for usefulness still show no differences, unusualness does show two different trends depending on neuroticism. These trends are the same reflected in creativity: people with low neuroticism obtain better results in real nature and people with high neuroticism present them in the simulated nature environment. A significant difference is also detected in the distribution of the unusualness variable $H(2, 33) = 6.960, p = .031$, more specifically between the neutral and the simulated nature environments ($p = .029$).

With regard to openness, significant negative correlation is detected between creativity and openness, in simulated nature environment ($r_s = -0.591, p = .010$). In this environment, creativity decreases when openness has higher values. Fig. 10 also shows differences in the distribution of the results depending on whether the subjects display a low (Q2) or a high level (Q3) of openness. Here, it can be observed that people with low openness obtain better creative results in simulated nature, while for the results provided by participants with high openness there is no noticeable difference between real and simulated nature. In both cases the values of creativity are lower

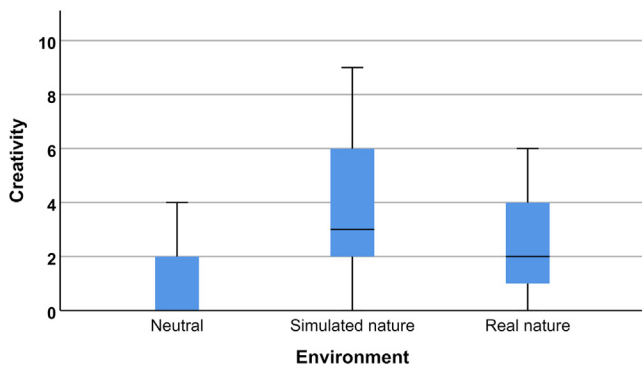


Fig. 6 Box plot of creativity depending on the environment.

in the neutral environment. Regarding the analysis of the results using the Kruskal-Wallis test, the participants with values in the Q2 percentile show a significant difference in the mean of creativity $H(2, 12) = 8.688, p = .013$, specifically between neutral and simulated nature ($p = .01$). No significant differences were detected between individuals with openness values in the Q3 percentile for creativity.

Regarding to the analysis of the factors that compose the creativity, it has been also detected negative significant correlation between unusualness and openness ($r_s = -0.632, p = .005$) in simulated nature environment. The Fig. 11 shows the box plots of the results of the unusualness and usefulness factors depending on the openness of the designers. Here, it can be seen that, for the unusualness, the results are higher in the simulated nature for people with low openness. This agrees with the Kruskal-Wallis tests, that points to significant difference in the results of unusualness $H(2, 12) = 8.260, p = .016$, between neutral and simulated nature ($p = .012$).

For usefulness, it can't be appreciated any trend from Fig. 11. Moreover, no significant differences were detected in any case.

3.3. Perception questionnaire

The last two columns of Table 3 indicate the environment in which participants expressed that they felt more comfortable and more creative. The cases in which the environment where they felt most comfortable or creative coincides with that in which they obtained the highest value in creativity are highlighted in bold. There are 9 matching cases out of 18 (50%), in which a higher value of creativity was achieved in the environment in which they felt more creative. As regards the environment in which they felt most comfortable, in 8 cases it coincided with the one in which they achieved the highest score on creativity (44%). The neutral environment was indicated on only one occasion as the one that made participants felt more comfortable, and was never mentioned as the one that made them feel more creative. The percentages in which participants chose each environment as the one that made them feel more comfortable and creative are shown in Fig. 12. On comparing the number of times, according to the personality profile, they obtained their best score for creativity in the environment in which they stated that they felt more creative, participants with low neuroticism (Q2) coincided 43% of times and those with high neuroticism (Q3) 54%. In the case of openness, there was a 37% coincidence for those with high openness (Q3) and 75% for those for whom it was low (Q2). Moreover, on relating the highest score for creativity with the environment in which they said they felt more comfortable, students with low neuroticism coincided 57% of times and 45% in the case of those with high neuroticism. In terms of

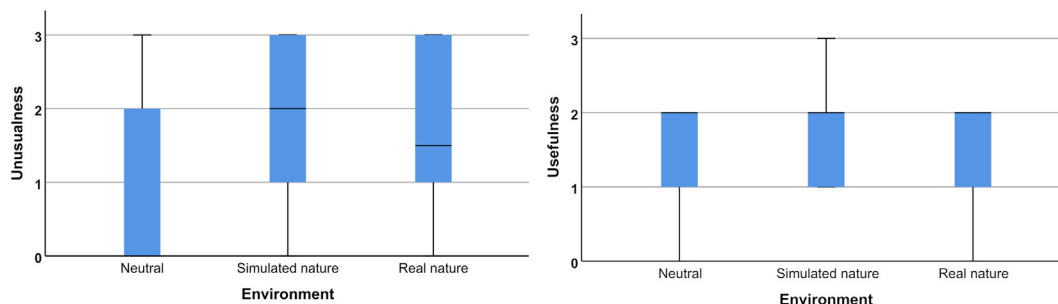


Fig. 7 Box plots of unusualness and usefulness depending on the environment.

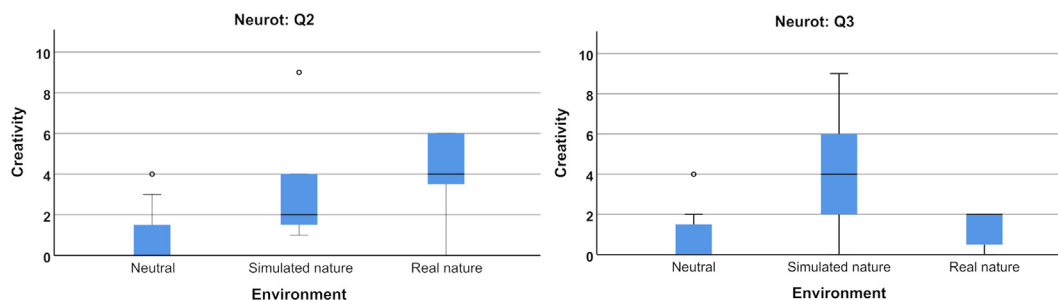


Fig. 8 Box plots of creativity depending on neuroticism.

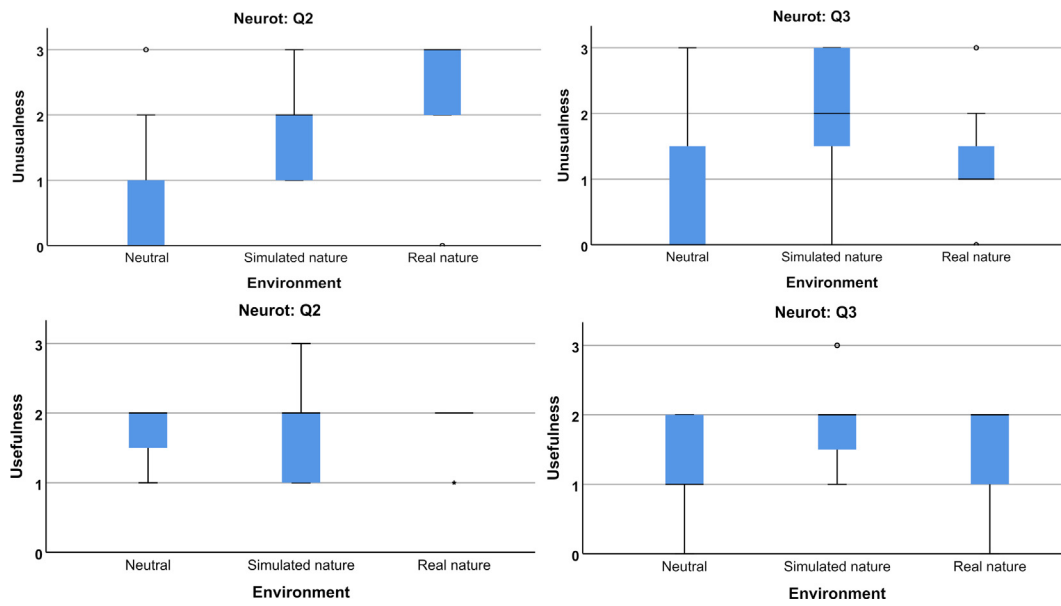


Fig. 9 Box plots of unusualness and usefulness factors depending on neuroticism.

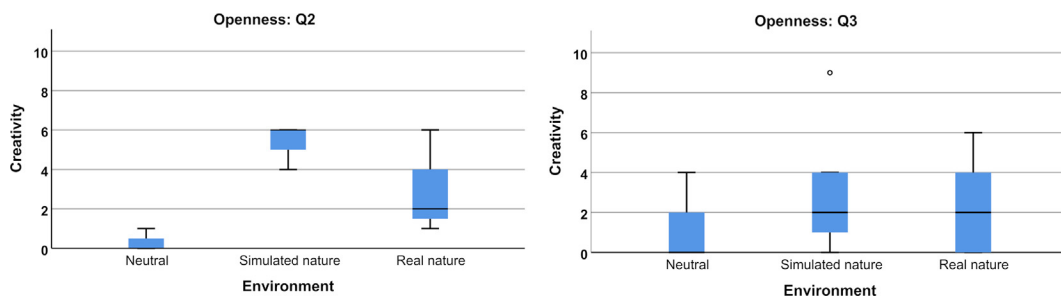


Fig. 10 Box plots of creativity depending on openness.

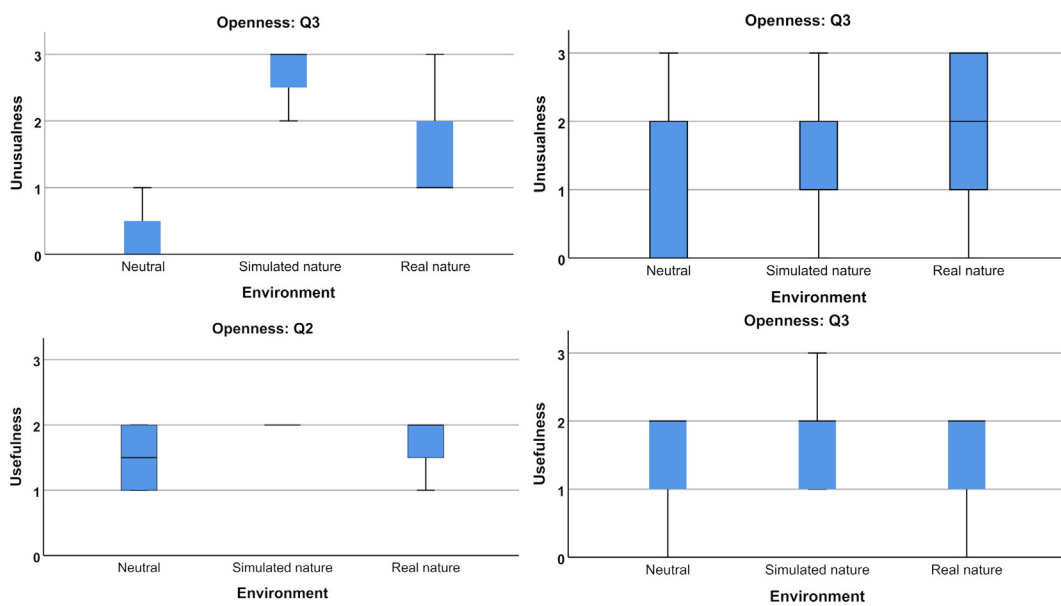


Fig. 11 Box plots of unusualness and usefulness variables depending on openness.

Table 3 Participants' perceptions in the experiment.

Participant	Feeling			Perceived as the most comfortable	Perceived as the most creative	Assessed as the most creative
	Neutral environment	Simulated nature	Real nature			
1	4	4	5	Real nature	Sim. nature	Real nature
2	3	4	5	Real nature	Real nature	Sim. Nature
3	4	5	2	Sim. nature	Sim. nature	Sim. Nature
4	3	3	5	Real nature	Real nature	Sim. Nature
5	3	4	5	Real nature	Real nature	Neutral
6	3	4	5	Real nature	Real nature	Real nature
7	4	5	5	Sim. nature	Sim. nature	Sim. Nature
8	4	2	5	Real nature	Real nature	Sim. Nature
9	2	4	4	Real nature	Sim. nature	Real nature
10	1	5	4	Sim. nature	Sim. nature	Sim. Nature
11	3	2	5	Real nature	Real nature	Neutral
12	4	5	3	Sim. nature	Sim. nature	Real nature
13	4	3	5	Real nature	Sim. nature	Sim. Nature
14	3	5	4	Sim. nature	Sim. nature	Sim. Nature
15	3	4	5	Real nature	Real nature	Real nature
16	3	4	5	Real nature	Sim. nature	Sim. Nature
17	4	3	4	Neutral	Real nature	Sim. Nature
18	2	4	5	Real nature	Real nature	Sim. Nature

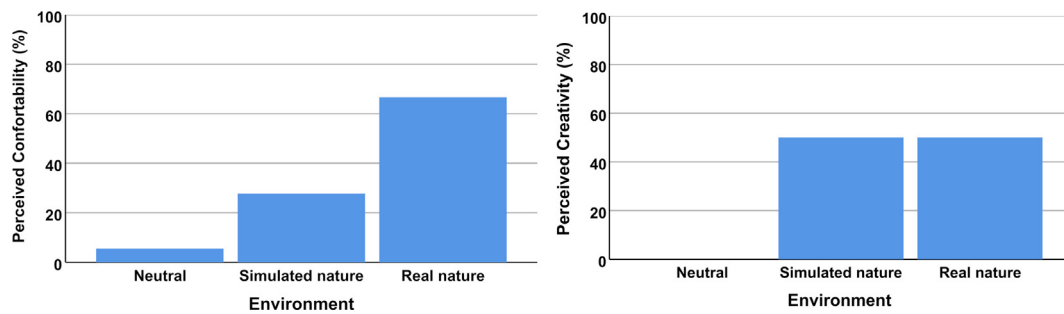


Fig. 12 Percentages of perceived creativity and comfortability.

openness, those with high openness coincided 37% of times, while those with low openness coincided 75% of times.

The results on how they felt in each of the three rooms follow the same pattern as the scores given by the participants to each environment, on a Likert scale, depending on how they felt: real nature (M = 4.50. SD = 0.841), simulated nature (M = 3.89. SD = 0.945), neutral environment (M = 3.17. SD = 0.841), which shows a preference for real nature, that is, the setting in which they felt most comfortable.

Going on to analyse the relationship between perception and personality, from the graphs in Fig. 13 it can be observed how a large majority of the population with low neuroticism worked more comfortably in real nature. However, while there is still a majority preference for the real-nature environment, there is not as much of a percentage difference in the case of people with high neuroticism. As for the feeling of creativity, although both populations are almost equally divided between real and simulated nature, people with low neuroticism scores tend more towards real nature, while those with high neuroticism tend to prefer simulated nature.

Regarding openness, most of the people with high scores on this parameter felt more comfortable working in real nature, while those with low scores on openness are divided equally

between real and simulated nature in terms of feeling more comfortable. People with high openness also reported feeling more creative working also in real nature, although not as much as in the case of comfort. Those with low openness, in contrast, for the most part stated that they feel more creative in simulated nature.

Nonetheless, in Fig. 14 it can be seen in which environment the designers achieved their most creative results. There, people with low neuroticism have their most creative results in the real nature environment, while the individuals with high neuroticism got their best creative results in the simulated nature. Regarding to openness, most of the designers, regardless if they have low or high openness, achieved their highest creative results in the simulated nature.

4. Discussion

Bearing in mind that the definition of creativity according to the Moss scale is the product of usefulness multiplied by unusualness, it is wise to analyse these two parameters first. In the case of usefulness it can be clearly seen that the values obtained in the three environments are very similar, yet not significant, and so it has to be deduced that the environment

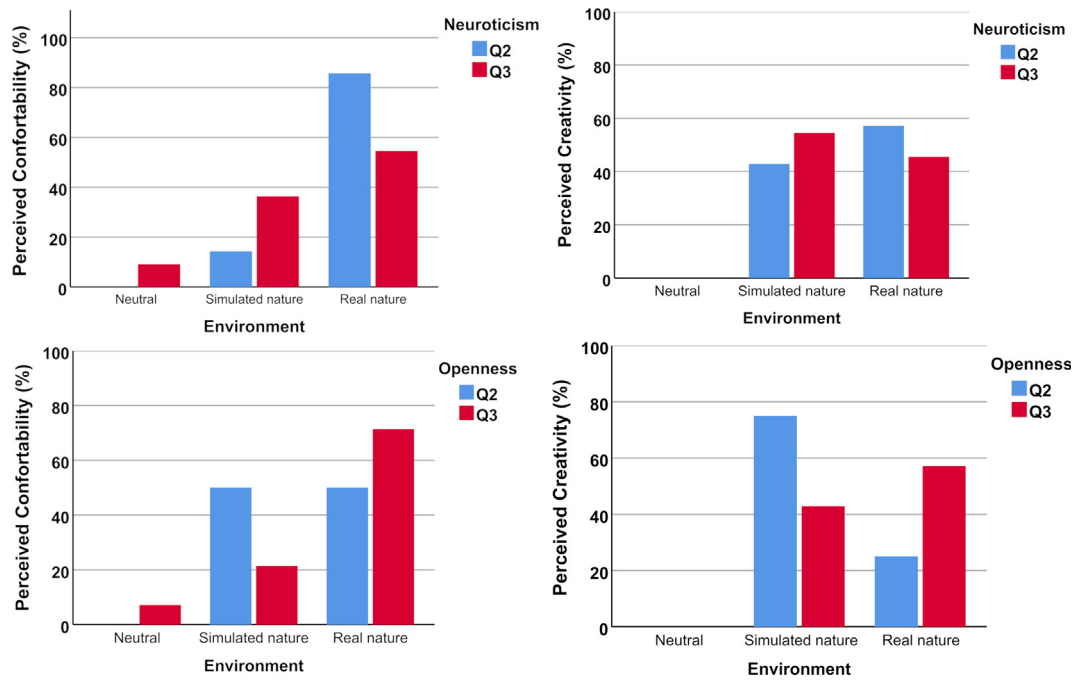


Fig. 13 Perceived creativity and comfortability depending on personality.

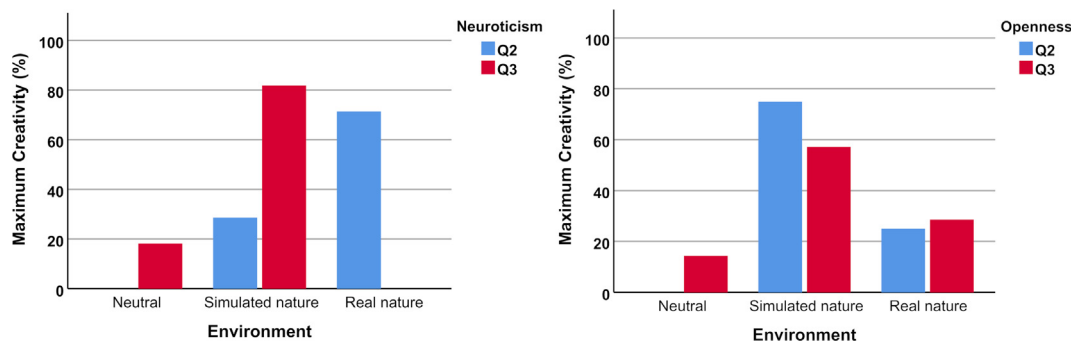


Fig. 14 Environment with maximum creativity achieved depending on personality.

in which the individual works does not affect the usefulness of the results. However, this may also have been influenced by the absence of a method. There are methods that make it necessary to stop to reflect and work on the design goals, and this is what makes the difference in the usefulness of the solutions [36]. In the absence of such a phase, perhaps the effect of the environment on usefulness is not perceived well, although it could exist if they were forced to devote more time to that point.

In any case, according to the results we have, all the differences in creativity that can be found are based exclusively on the difference in unusualness. If the graphs of the unusualness and creativity results are compared, we can observe that they present similar trends. In both it can be seen that the results of unusualness and creativity are considerably lower in the neutral environment. The highest values are seen in simulated nature, with little difference between those obtained in real nature. However, this difference is enough for the results were significant between the simulated nature and neutral

environments, but not so between the real nature and neutral environments. These results therefore need to be analysed in greater depth.

Accordingly, this study has examined whether the effects of this change of environment differ depending on the personality of the user who works immersed in it. Specifically, two factors have been considered: neuroticism and openness. At this point, it should be noted that, after analysing the personality of the participants, the sample was not found to be balanced in either case. In the case of neuroticism the difference in the population was not very high (7 low versus 11 high), but it was more notable in the case of openness, where only 4 participants have low values, while 14 have high values for openness. This could be because the participants are volunteers. It is therefore logical to think that people with an open personality profile will be more willing to collaborate in this type of activity.

If we divide the population according to the intensity with which each individual feels emotions, differentiating them

between low neuroticism and high neuroticism, we find the first difference. While both population groups obtain higher levels of creativity in either of the types of nature than in the neutral environment, it is seen that the low neuroticism population achieves more creative results in real nature, while the high neuroticism population obtains them in simulated nature. This difference could be due to the fact that people with higher neuroticism may take into account other factors that appear in an open space, and to which people with low neuroticism pay less attention, such as the possible presence of other people not related to the study. This could be a distraction for subjects with high neuroticism, since their thoughts may focus momentarily on what the passer-by might be thinking about them, something that should not worry or distract individuals with low neuroticism.

Similarly, we also find a difference between people with high and low openness. Initially, both groups also achieve higher levels of creativity in either of the types of nature than in the neutral environment. In this case, it is the population with low openness that achieves the best results in simulated nature, while individuals with high openness obtain the most creative results in real nature. However, the latter do not show a significant difference. That is, since people with greater openness are more open to the changes around them, they are not affected as significantly by the environment as people who are less open to change. These low openness individuals, in turn, despite being more creative due to the influence of a natural environment, achieve significantly better results in simulated nature, located indoors, possibly because it represents a minor change with respect to going outside to work.

Conversely, if we analyse users' perceptions, we see a clear division as to where they felt most creative: 50% in real nature and 50% in simulated nature. It could therefore be said that there is consensus regarding the fact that people are more creative in a natural environment, whether simulated or real, as opposed to a neutral environment, which is consistent with the results obtained. However, in terms of comfort, a large majority say they feel more comfortable in real nature, even though some of them feel more creative in the simulated version.

If we look at their neuroticism separately, it can be seen that, although the tendency of most individuals to say they feel more comfortable in real nature continues, this difference is far more pronounced in the case of people with low neuroticism than in those with high neuroticism, where there is not so much difference between the two types of nature, and one user even claimed to feel more comfortable in the neutral environment. This may also be due to the motives hypothesised above: these uncontrolled external factors that may disturb people with higher neuroticism and which make them feel less comfortable or creative and, indeed, lead them to achieve less creative results than in the simulated nature environment in which all the factors are more controlled.

As for the differentiation by openness, it can be seen that people with high openness perceive themselves as feeling mostly more comfortable and also more creative in the real nature setting, although the difference in terms of the results obtained for creativity were not found to be significant. Conversely, people with low openness did not show a clear predilection for either form of nature in terms of comfort, although they did state that they felt more creative in simulated nature, which was also observed in their results. There-

fore, it could be said that people who are open to change perceive the scenario that entails greater change as more positive, although that same facet of their personality does not affect these changes.

5. Conclusion

In the present work it has been proved, through a practical experiment, that working in natural environments enhances the creativity of the designer's results in the conceptual phase, as stated in H_1 . In addition, since both real and simulated environments have obtained better results in creative terms compared to the work carried out in a neutral lecture room, H_2 is confirmed.

However, on breaking down the creativity of the concepts into their two predefined factors, unusualness and usefulness, it can be seen how the usefulness parameter is practically unaffected by the environment, and thus the differences in creativity are directly due to the novelty of the results obtained.

In general terms, the difference between the real nature and the neutral environments is significant, yet it has been seen that this depends on the designer's personality (H_3). Specifically, it has been noted that individuals with high neuroticism achieve their most creative results in simulated nature, which coincides with the environment where they feel most creative, while individuals with low neuroticism obtain better results in real nature, also coinciding with the environment where they feel most creative.

Furthermore, people with low openness obtain more creative results in simulated nature, which is where they perceive themselves as more creative, while the population with high openness does not show any significant difference on varying the environment, that is, they adapt better to changes in the environment and are therefore affected by it to a lesser extent.

In terms of their perception of comfort, a large majority opted for real nature, regardless of the results, and no pattern has been detected that can relate the perception of comfort in an environment with the creativity of the results.

The limitation of the study would be given by the sample. As the subjects were volunteers, the desired homogeneity could not be achieved particularly in the case of openness. We can assume that people who are more open are more likely to collaborate in this type of study. For that reason, future work entails to increase the sample size, but making a previous selection of the personality profiles of the participants in order to ensure a homogenous distribution.

The results, firstly, endorse the theoretical studies which hold that the natural elements in the environment promote creativity in general terms. In addition, the study was framed in a specific practical application, Design Engineering. The results also defend the creation of indoor natural spaces, thus eliminating the need to work outside and allowing natural spaces to be available anywhere inside design studios.

Finally, having established that this effect on creativity is mostly due to improving the unusualness or novelty of the results allows us to theorise about the possible combination of design methodologies with different environments, with the aim of optimising the positive effects on the creativity of the results depending on the conceptual design phase that we are working on. This will obviously require further research to identify which of these stages creativity is fostered in and

at what level, and which method or typology of methods it is most effective to work with under these conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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