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Effects of continuous and discontinuous non-relevant stimulus on creativity

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KEYWORDS
Creativity; cognitive load; virtual reality; stimulus; environment

ABSTRACT

Innovation is made of different tasks from strategic positioning to the first phases of production. One of the main activities is the generation of ideas through different creativity phases. These creativity activities are carried out in numerous conditions and with different tools having more or less context and interactions. This study focuses on the influence of different non-relevant stimuli composing our environment on cognitive load and creativity. This experiment consists of two creativity tasks which consisted in providing answers to a given question using the visuo-spatial and audio-verbal area, with three stimulus appearance conditions: without, continuous, discontinuous. For the visuo-spatial task, participants have to illustrate their answers using an immersive drawing software. For the audio-verbal task, participants have to answer a question with a simple text editor software. Regarding the drawing task, results indicate that the discontinuous stimulus had decreased the number of ideas per participant. For the writing task, the stimulus had increased the intrinsic and extraneous cognitive load. This study reveals our creativity is under the influence of the different elements of our environment, the tool used and the task.

1. Introduction & related work

It is said that it is better to have a rich and stimulating environment in order to be creative, and sometimes that, conversely, it is better to have a simple environment. In order to provide answers on this point, we need to better understand the phenomena at play in creative tasks when task-unrelated stimuli are present in the environment. Creativity is usually defined as the ability to generate new concepts in line with a context in which they are realized (T. Lubart et al. 2015). Creativity can be mobilized in problem-solving tasks (Wang 2019) as in tasks of ideas generations with specific constraints, such as the alternate uses test (Guilford 1967). It is the result of complex cognitive activities influenced by various factors stemming from a sum of personal and social experiences (Ward and Kolomyts 2010). Amabile (1983b) has built a model gathering the cognitive factors affecting creativity. Even though the temporal, material and human components are essential (Amabile and Pratt 2016), some levers can regulate our creativity, for example, by affecting reasoning or problem-solving patterns (Amabile 1983a; T. I. Lubart and Sternberg 1995). Several works have focused on the understanding of the construction of ideas based on knowledge and the effects of fixations (Crilly 2015; Cassotti et al. 2016). Thus, these studies demonstrate that creativity is influenced by personal factors

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(called intrinsic) and external factors arising from the environment (call extraneous). Among the first, personal motivation will encourage us to solve the task, and cultural and social background will engage us more or less in the task (Zhang and Bartol 2010; Binnewies and Wörnlein 2011; Schepers and Van Den Berg 2007). However, the environment is also composed of elements, stimuli we do not control and which might be non-relevant for the creativity task. Several studies have contributed to build a taxonomy on how the environment and the stimuli it contains can impact on our creativity (Jett and George 2003; Mochi and Madjar 2018). Stimuli which are not linked to the creativity task can improve the idea generation by inspiring the participants, i.e. by let them associate their idea with the stimuli to generate new ideas (Goldschmidt and Smolkov 2006; Baird et al. 2012; Jett and George 2003). Non-task stimuli can also be a distraction for the participants, forcing them to make an inhibition effort to concentrate on their task. Finally, these stimuli can interrupt the participants, i.e. force them to stop the creativity task at a certain point and resume it. Current work about environments, especially in open spaces, lists numerous elements being able to interrupt people when working (Addas and Pinsonneault 2015; Tams et al. 2015). In most cases, interruptions are detrimental (Mochi and Madjar 2018). Some stimuli appear to be annoying during creativity and problem-solving tasks and contribute to reduced performance (Kasof 1997). On the one hand, an uncluttered, easy-to-understand environment can enhance creative performance (Kosmadoudi et al. 2013; Feeman, Wright, and Salmon 2018). On the other hand, some studies suggest that during some activities, a rich environment with many different stimuli may increase the amount of ideas produced, for example, in a task of sketching solutions for product design problems (Goldschmidt and Smolkov 2006). This paradox could be based on the fact that, depending on the characteristics of the irrelevant stimuli, it could have a positive inspirational effect, or a distracting effect, or it could interrupt the task. Studying the cognitive load attributed to the task versus that attributed to the environment and the use of tools could provide a better understanding of this phenomenon. Sweller began to link mental work load and the amount of production made by the participants of his experimentation. Although cognitive load measurement was initially used to understand and improve learning (Sweller 1994), it is also used in studies focused on problem-solving tasks (Sweller 1988) and creativity (Sweller 2009). The cognitive load can be split into three components (Sweller 1988; Paas et al. 2003): intrinsic, extraneous and germane. Intrinsic cognitive load is related to the presentation of the task (whether it requires learning new knowledge or not) and the level of skills and habits to solve it. Extraneous cognitive load is linked to a misrepresentation of the task or to the efforts needed to apprehend the different elements appearing in the environment. The heavier or more comprehensive the tool and the environment, the higher this cognitive load. Last, germane cognitive load is related to the response to the task to create new mental links and thus to produce new ideas. Unlike the extraneous cognitive load, it is higher when tools are easier to use.

According to intrinsic and extraneous cognitive load, we notice that environment elements can have a negative effect on creativity because of distraction (Paas and van Merriënboer 2020). On the opposite, the different elements of the environment can have inspiring and positive effects on creativity (Goldschmidt and Smolkov 2006). These elements have an influence on the cognitive load. That's why it is essential to use simple tools that offer the possibility to control the environment to be able to get inspiration without increasing too much cognitive load.

Virtual reality seems to be a great option by its ease of use (Feeman, Wright, and

Salmon 2018; Mille et al. 2020) or the inspiring possibilities (Yang et al. 2018; Fleury, Blanchard, and Richir 2021). In this regard, virtual reality appears to be a relevant tool to respond to the paradox above-mentioned paradox, as it allows the work environment to be controlled and thus adapted to the creative task. Thus, it can be used to assess the pertinence and impact of irrelevant stimuli in a creative task.

The reasons why some non-task stimuli have a positive impact on creativity and others have a negative impact are not clearly identified in the literature. As mentioned above, it seems that some stimuli can be inspiring, or necessitate mental workload to be inhibited, or other can interrupt the creative mental process. The main objective of the present study is to clarify the links between the stimuli characteristic and the consequences on creative activity. We assume that a stimulus, even subtle, can have an influence on personal experience and increase cognitive load. This increase will reduce creativity if we refer to Paas et al. (2003): the extra resources used to inhibit the environment will reduce the quantity and quality of ideas. We also think that the continuous or discontinuous nature of the stimulus will have an influence on creativity. A continuous stimulus will not interrupt the activity, while the scientific literature shows that a discontinuous stimulus breaks participant's thinking and reduce his creativity (Kasof 1997; Baird et al. 2012). We assume that the unpredictable nature the of the stimulus can strongly increase cognitive the load by making it more interruptive.

To study the impact of non-relevant stimuli and their nature on creativity and cognitive load, we designed two tasks using either audio-verbal or visual-spatial resources We have deliberately chosen two creativity tasks and types of stimuli that were as different as possible in order to arrive, to some extent, at a general discourse on the effects of irrelevant external stimuli on creativity. The two tasks were realized under three experimental conditions: without stimulus, continuous stimulus or discontinuous stimulus, interfering with the same resources (Baddeley and Broadbent 1983). We measured through questionnaires the evolution, according to the stimulus, of cognitive load.

2. Method

2.1. Participants

For this experiment, a sample group of 67 participants working or studying in the field of virtual reality was gathered. This group was composed of 20 women (30%) and 47 men (70%). The mean age was 25.31 years (sd = 6.59), for a maximum of 53 years old and a minimum of 18 years old.

2.2. Procedure

At the beginning, participants were invited to answer a first questionnaire collecting their age, sex and virtual reality skill level. During this experiment, two tasks were performed by the participants. Each task used different cognitive resources and was associated with a stimulus that interferes with the corresponding area (Baddeley and Broadbent 1983). We designed an audio-verbal task that we call 'writing task', and a visual-spatial task that we call '3D drawing task'. Each tack can be realized under three stimulus appearance conditions: continuous (the stimulus is always perceptible during the task), discontinuous (the stimulus is discontinuously perceptible during the task), without (no additional stimulus during the task). Participants had to execute one of the two tasks (drawing or writing) in one of the three conditions (without stimulus, discontinuous or continuous stimulus). Then, the questionnaire of Klepsch, Schmitz, and Seufert (2017) measuring cognitive load was administered. This sequence was repeated one more time but for the other task and in another stimulus condition. The order of presentation of the tasks and experimental conditions were counterbalanced. The objective of the study was not to compare the two types of task (audio-verbal and visuo-spatial), but to compare within these two tasks the three conditions of non-relevant stimuli (without, discontinuous, continuous). Before each creativity task, two minutes of training were given to participants to familiarize them with the tools. Each creativity task lasts for 5 min during participants are asked to suggest as many ideas as they can.

2.2.1. Writing task

The creative writing task was inspired by the work of Reiter-Palmon, Illies, and Kobe-Cross (2009). For this task, participant had to answer the following question 'What will be the consequences if we suddenly can no longer use our arms and legs?'. A text writing software (see Figure 1), was given to participants to record their textual ideas. Creativity in this task is not problem-solving, but based on generating creative ideas from among many possible answers that respond to the task and are not the result of simple linear reasoning, as in the alternate uses test (Guilford 1967). Participants usually give short answers, such as 'boxers would wear helmets instead of gloves and hit each other with their head'. The software allowed participants to formulate their answers using a mouse and a keyboard, on the left white part of the screen. After pressing *Enter* key or *Validate* button, the sentence was saved and appeared on the right grey part of the screen. It allowed participants to enter new answers until the end of the experiment. When the participants use this button, it counts for one idea. This task duration was 5 min. One minute before the end, a pop-up appeared to warn the participant there was only one minute left. Finally, at the end of the creative task, the software stopped by itself and saved the ongoing writing idea.

The stimulus, for the writing task, was a radio program broadcasted through two speakers placed in front of the participants. The program was an interview of Francis Groux, one of the co-founders of the comic book Angoulême Festival. This program was chosen because the language spoken was the same as the participants' and the subject matter was far from the theme of creativity task. For the continuous condition, the program was broadcasted entirely and without any interruptions during the creative session. For the discontinuous one, the program was randomly cut five times for one to three seconds. For the 'without stimulus' condition, the radio was not running.

2.3. 3D drawing task

Concerning the 3D drawing task, it was the same as Fleury et al. (2021) and quite similar to Goldschmidt and Smolkov (2006) (sketching ideas for improving a product) and Yang et al. (2018) (sketching innovative product in virtual reality). Participants were asked to answer the following question: '*The student's bag is too heavy, can you give solutions to make it more transportable?*'. To do this, an immersive drawing application was given to participants (see Figure 2).

Thanks to the virtual reality headset HTC Vive, participants were immersed in virtual white room. At its centre, a 3D model of backpack was placed on a pedestal. The backpack could be moved from the pedestal, using the grips of the controllers. On the right of the pedestal, a save button and a colour palette were disposed. A press on the save button recorded participant's drawing and reset the area to allow the participant to start a new idea. When the participants used this button, it counted for one idea. The colour palette lets choose a colour, a thickness, saturation of the line drawn by a controller. Each controller can be used as an independent brush and thus have a particular colour. By pushing the trigger of the controllers, the user can start drawing lines. When the backpack moves, the draw follows the movement. The duration of this task was 5 min. In the

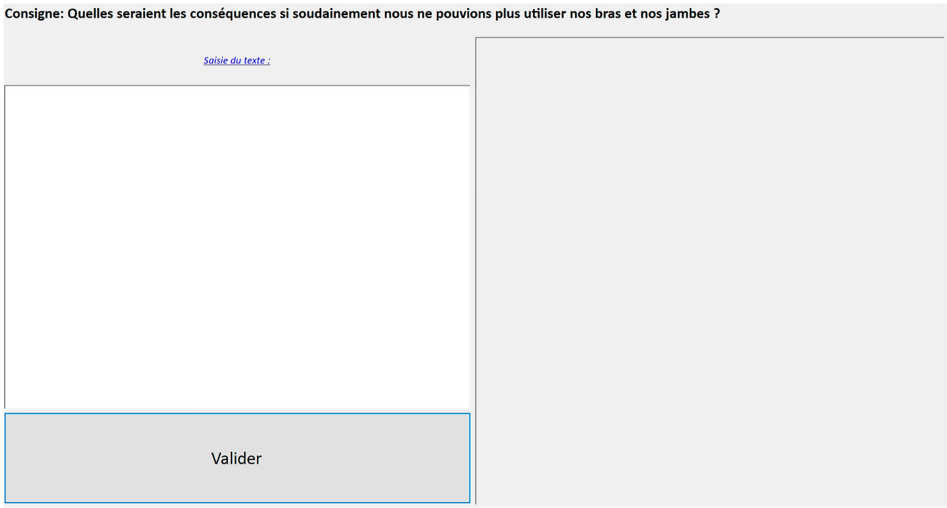

Figure 1. Screenshot of the tool used for the writing task.

condition with continuous stimuli, there was a blue light which moved in circles in front of the participant in the virtual environment. This stimulus was considered as continuous because it stayed in front of the participant and remained perceptible during all the tasks. In the condition with discontinuous stimulus, the blue light moved randomly in the virtual environment during the task. It was considered as a discontinuous stimulus because the light entered randomly on the visual field of the participants and left it in the same way during the activity. For the 'Without stimulus' condition, there was no blue light in the environment.

2.4. Measures

After each task, the cognitive load was measured through the questionnaire of Klepsch, Schmitz, and Seufert (2017). This questionnaire is composed of nine questions, using Likert's scale from 1 to 7, to measure independently intrinsic (two items), extraneous (three items) and germane (two items) cognitive loads.

Creativity was measured quantitatively: for each participant, the number of ideas produced was counted.

3. Results

This section is divided into two parts presenting the results of each task: writing then drawing.

3.1. Writing task

First, we tested the homoscedasticity (also called 'homogeneity of variances', assesses whether the variances of the groups are sufficiently equivalent to allow parametric tests) and normality of our data sample. The homoscedasticity is confirmed for the number of ideas per participant ($p = 0.588$), extraneous cognitive load ($p = 0.38$) and germane cognitive load ($p = 0.756$) depending on the distraction. On the opposite, the heteroscedasticity is confirmed for the intrinsic cognitive load ($p = 0.018$), depending on the distraction.

3.1.1. Analysis of idea production

We begin by analysing the impact of the stimulus on the number of ideas per participant. An analysis of variances depending on the condition did not reveal any statistically significant difference ($F(2; 60) = 0.371$; $p = 0.691$).

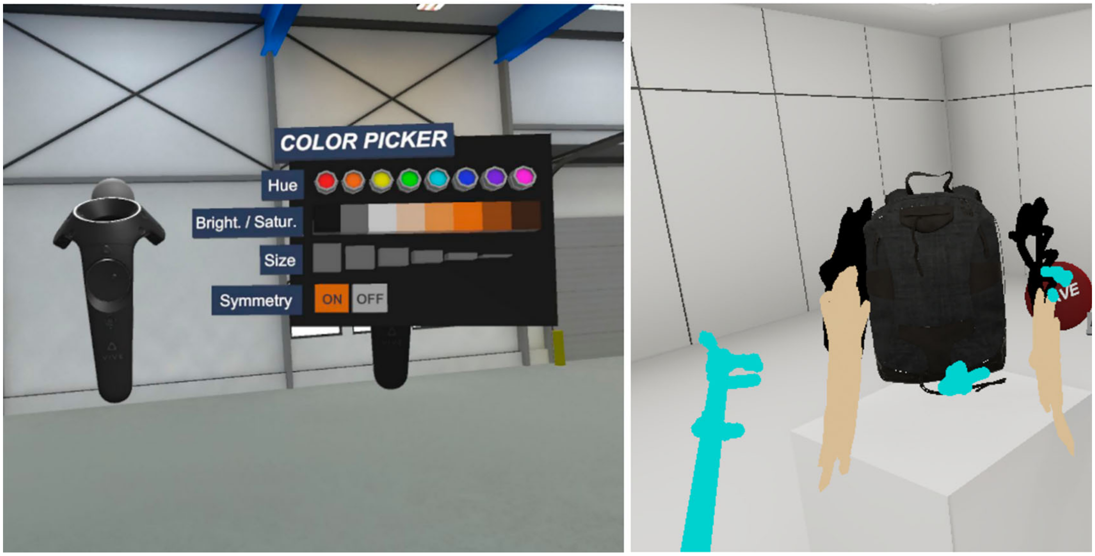

Figure 2. Screenshot of the 3D drawing tool.

3.1.2. Cognitive load analysis

Regarding the cognitive load induced by the stimulus, a Kruskal–Wallis non-parametric test revealed statistically significant difference for the intrinsic cognitive load ($\chi^2 = 19.775; p < 0.001$). A pairwise non-parametric comparison using Tukey and Kramer test revealed differences between the condition without stimulus and the other two (see Table 1). Figure 3 shows that the intrinsic cognitive load is higher when the stimulus is present in the environment.

An analysis of variances revealed statistically significant difference for the extraneous cognitive load ($F(2; 60) = 13.79$; $p < 0.001$). A pairwise comparison using T test revealed differences between the condition without stimulus and the other two (see Table 2). Figure 4 shows that the extraneous cognitive load is higher when the stimulus is present in the environment.

Table 1. Matrix of the pairwise comparisons for the intrinsic cognitive load of the writing task.

	Continuous	Discontinuous
Discontinuous	0.48	–
Without	0.006**	<0.001***

*p<0.05. ** p<0.01. *** p<0.001.

An analysis of variances did not reveal any statistically significant difference for the germane cognitive load ($F(2; 60) = 2.417$; $p = 0.09$).

3.2. Drawing task

To begin this analysis, we tested the homoscedasticity and normality of our data sample. The homoscedasticity is confirmed for the number of ideas per participant ($p = 0.522$), intrinsic ($p = 0.469$), extraneous ($p = 0.119$) and germane cognitive load ($p = 0.412$) depending of the distraction.

3.2.1. Analysis of idea production

First, we analysed the impact of the stimulus on the number of ideas per participant. An analysis of variances depending on the condition revealed a statistically significant difference ($F(2; 64) = 4.311$; $p = 0.018$). A pairwise comparison using T test revealed differences between the condition continuous stimulus and discontinuous stimulus (see Table 3). Figure 5 shows that the number of ideas per participant is lower when the stimulus is discontinuous in the environment.

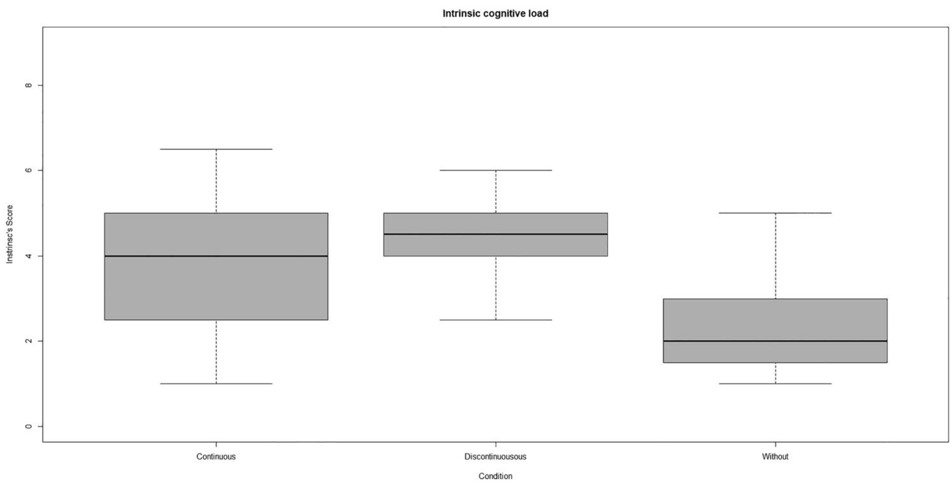

Figure 3. Boxplot of intrinsic cognitive load score depending on the condition for the writing task.

3.2.2. Cognitive load analysis

Regarding the cognitive load induced by the stimulus, a Kruskal–Wallis test did not reveal any statistically significant differences for the intrinsic cognitive load ($\chi^2 = 0.513$; $p = 0.773$) and extraneous ($\chi^2 = 1.527$; $p = 0.466$). An analysis of variances for the germane cognitive load depending on the condition did not reveal any statistically significant difference ($F(2; 64) = 0.048$; $p = 0.953$).

4. Discussion

We measured the impact of external stimuli, which compose our work environment, on creativity and cognitive load. We relied on a writing and a drawing task, in which participants had to propose ideas to solve a given problem.

For the drawing task, we observe that a discontinuous stimulus caused a reduction in the number of ideas per participant. It seems that the different stimulus's appearance in the visual field requires an effort. When the stimulus is continuous, a constant effort, but probably lower, must be made to inhibit it. But, when the stimulus is discontinuous, appearance and disappearance demand to participants to reproduce the same effort to ignore it. The reflection necessary for the participants to plan their actions is therefore interrupted each time the stimulus appears. These observations are consistent with those of Kasof (1997) and Baird et al. (2012), but allow to clarify that the interruptive nature of the stimuli seems to be a factor of being or not detrimental to creativity.

For the writing task, the presence of the stimulus increased intrinsic and extraneous cognitive loads. This increase indicates that taking the stimulus into account required extra effort. However, this extra effort did not result in a decrease of the number of ideas. This increase can also indicate that participants tried to use the stimulus as inspiration sources (Goldschmidt and Smolkov 2006). The radio broadcast was in the native language and could be easily interpreted by participants. Some of them have made a reference to the Angoulême Festival in their idea.

We can explain these differences by several factors linked to the task and also to the

Table 2. Matrix of the pairwise comparisons for the extraneous cognitive load of the writing task.

	Continuous	Discontinuous
Discontinuous	0.215	–
Without	$<0.001^{***}$	$<0.001^{***}$

$^{*}p<0.05$. $^{**}p<0.01$. $^{***}p<0.001$.

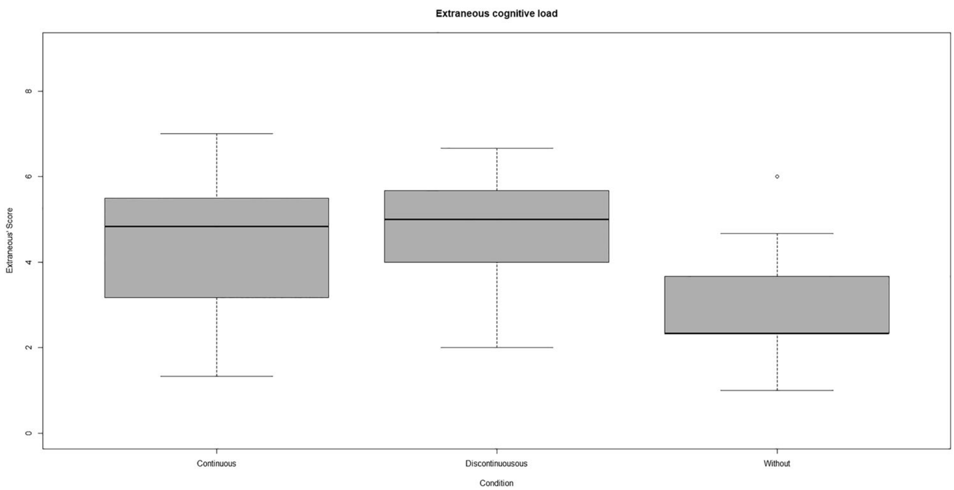

Figure 4. Boxplot of extraneous cognitive load score depending on the condition for the writing task.

stimulus. Without stimulus, the average number of ideas per participant is 5.52 for the drawing task and 10.86 for the writing task. The idea's realization time is quite different between the two tasks. So, we think the tools have an impact on the time to plan the actions needed to realize a new idea. The participants have to maintain their idea while they sketch it in virtual reality, but they do not have to maintain it in writing activity (or during a very short time) because writing an idea was very quick. Indeed, we believe that the appearance of the stimulus will briefly interrupt the participants' thinking for the planning of their actions, which is more disadvantageous for a tool that requires a longer planning time (i.e. the drawing tool). For the writing task, we think the habit of using text editing tools, especially in disrupted environments (e.g. transportation), allowed participants to remain focused on the creative task. In future research, it would be useful to explore the effects of other types of stimuli, such as music, which is likely to have an additional emotional impact. In addition, the virtual reality idea generation situation makes it possible to test an on-demand inspiration feature. Putting inspirational elements in the environment can potentially be distracting for the user, especially if these elements are animated. However, if users trigger the inspirational elements when they want to, then perhaps they can benefit from the positive effects without being disturbed. This will need to be investigated.

Table 3. Matrix of the pairwise comparisons for the number of ideas for the drawing task.

	Continuous	Discontinuous
Discontinuous	0.016*	–
Without	0.351	0.129

*$p<0.05$; **$p<0.01$; ***$p<0.001$.

5. Conclusion

This experiment shows that the different stimuli composing the environment have an impact on cognitive load and also on creativity. The tools, tasks or a simple stimulus (e.g. a bug, or a flicker) have more or less desirable consequences on creativity. For the drawing task, the appearance and disappearance of the stimulus required an additional effort that slowed down participants' creativity. Regarding to the cognitive load for the writing task, we notice that participants have in fact listened to the radio and tried to get inspired by it. We think the understandable nature of a stimulus has an impact on the way participants deal with it. In our experimentation, the stimuli have different

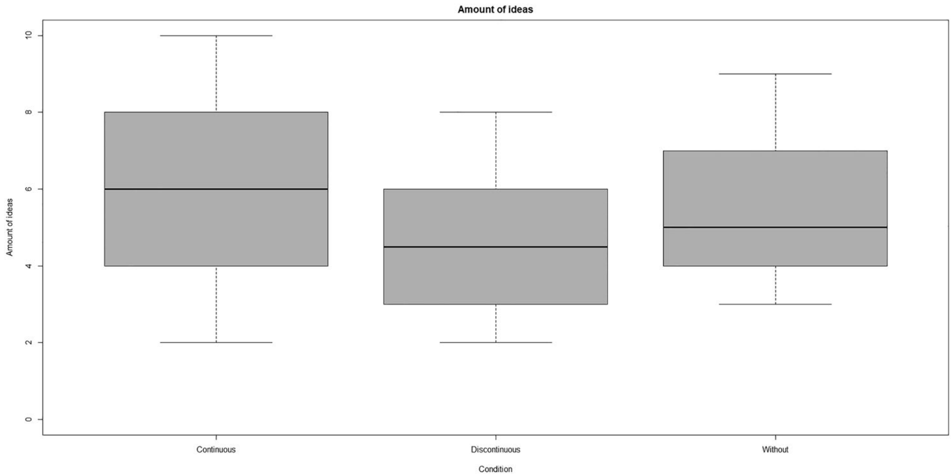

Figure 5. Boxplot of number of ideas per participant depending on the condition for the drawing task.

levels of interpretation. The stimulus of the drawing task leaves some room for interpretation and is perceived more as a disruptive element of the environment. Quite the opposite, by its intelligible characteristic, the stimulus of the writing task was used to bring new knowledge. However, this input of new knowledge in the environment increased extraneous cognitive load. In order to design efficient tools or environments dedicated to creativity, we need to understand how stimuli bring new knowledge and/or break creativity.

One of the difficulties revealed during the notation of ideas is linked to the perception of ideas realized in an immersive environment. This difficulty has resulted in a lack of understanding of some ideas. Due to the three-dimensional environment, the visual perspective of the author's idea is not always found during the evaluation and leads to different interpretations. It is essential to investigate in future works which tools and media could help to communicate the ideas represented in an immersive environment.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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