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Abstract. Humans perceive different objects, scenes or places using all their senses. Our sensory richness also plays an important role for creative activities. Humans also recall those sensory experiences in order to spark creativity, e.g. while writing a text. This paper presents a study with 100 students, divided in groups, that explores the effect of auditory and olfactory cues and their combination during a creative writing exercise. Our results provide useful insights suggesting that olfactory cues have an important role in the creative process of users and even when this type of cues are combined with auditory cues. We believe, that this type of modalities should gain more relevance on the development of creativity support tools and environments for supporting the creative writing process.

Keywords. Creativity Support Tools; Creativity; Olfaction; Odor; Sound; User studies; Creative Writing;

1 INTRODUCTION

Writing is among one of the top forms of human artistic expression [1]. Creative writing is also a central component to a range of different industries and disciplines (e.g. journalism, science fiction, advertisement, etc.) [2]. Even so the process of writing a text is often much unstructured, one can observe the following steps in a creation of a text: a writer starts with a prewriting, finishes the first draft, revises the draft, and then edits and finishes a final version of the work [1]. During this process, writers try to obtain their creativity from a very wide range of sources ranging from memories of dreams or television news reports, in a way in which they can imagine new characters or situations that can be included in their writings [3].

In our digital world 80% of our texts are created with the help of computer systems [4]. Therefore, different creativity support tools help people engage creatively with the world [5], and some researchers claim [6] that it is a challenge for human-computer interaction researchers and user interface designers to construct information technologies that support creativity. There are currently some possible solutions in creative writing tools to foster the creativity of writers. One example, is writing prompts [7,8] that

are simple phrases meant to help writers trigger their creativity and start writing fluently without losing their time with a "writer's block", not being able to write a single line of text. Shneiderman [9] argues that there's an effort for developing creativity support tools, which enable us to explore, discover, imagine, innovate, compose and collaborate. Even with decades of creativity research, there is no single, agreed upon methodology for evaluating how well a creativity support tools to aid the creativity of its users [10]. Creative workers use artificial stimuli as inspirational guides, e.g., listening to music while writing or looking at images while drawing.

Certainly, well-designed creative writing tools can help users in generating multiple levels of creativity during the process of writing, particularly tools that can also generate different stimuli [11].

Olfactory cues are well known to have a strong emotional effect on arousal level and task on arousal level and task performance have also been suspected but not well explored in the literature [11]. Among other researchers, Seo [12] states that even though we often perceive odours in the presence of various background sounds, there is limited knowledge about the effects of background sound on odour perception. Spence [13], has studied the effect of background noise on the sensory-discriminative aspects of taste/flavour perception and on people's hedonic responses to food and beverage items. He highlights the impact of background music and/or soundscapes on food and beverage perception/consumption on people's sensory-discriminative and hedonic responses.

Therefore, this paper presents the first study on the effects of different modalities (sound and smell) on the creative writing process. The core contribution of this research is a novel between-subjects study to discover patterns in the influence of smell and sound on the participants' creativity while using a word processor in different environments. The research described below makes two supporting contributions. First, we triangulate qualitative and quantitative data from different sources to assess creativity of users in different writing conditions, giving us useful insights to develop a novel prototype for supporting the creative writing process. Second, although research on creativity has thus largely occurred within areas such as psychology and neuroscience and HCI, we believe other areas of computer science can also contribute to this domain.

2 RELATED WORK

Researchers have investigated how to improve the creative writing *process* [14], e.g. by giving students the opportunity to interact with real readers of their work, showing that this could lead to an increased motivation to write. Advances in creative writing tools have been mostly made in very specific areas. Yannopoulos [15] proposed a symbolic language intended to express the content of films (motion pictures) much as notes provide a language for the writing of music, therefore bringing a new approach to the creative process of filmmaking. Goulet [16] focused on computer writing tools used during the production of documents in a professional setting. They report on a focus group conducted with professional writers, in which writers narrated their experiences using computer tools to write documents, describing their practices, pointing out the

most important problems they encountered, and analyzing their own needs. Based on this work, they describe LinguisTech, a reference website for helping language professionals. Keeping in mind that one goal of digital tools for creative writing is to help users produce greater quantities of writing, Coughlan and Johnson [17] present three perspectives on creative interaction that have emerged from four years of empirical and design research. They argue that creative interaction can be usefully viewed in terms of *Productive Interaction* – focused engagement on the development of a creative outcome; *Structural Interaction* – the development of the structures in which production occurs; and *Longitudinal Interaction* – the long-term development of resources and relationships that increase creative potential.

Perception of olfactory and auditory cues

Ho and Spence [18] investigate the differential effects of olfactory stimulation on dual-task performance under conditions of varying task difficulty. Their results provide the first empirical demonstration that olfactory stimulation can facilitate tactile performance, and highlight the potential modulatory role of task-difficulty in odour-induced task performance facilitation.

Some researchers, such as Xiang et al. [19] presented in their study a prototype system – Olfaction - that emits odour emoticons and it was applied in two contexts: online text chatting and voicemail receiving. Their results suggested that odour emoticons induced more chatting, and were easy to use, and helped participants to better perceive and convey emotions. Studies have been conducted with auditory cues in different areas such as consumer behaviours [20] and consumers' perception of food texture and quality [21].

Other studies were conducted to investigate the effect of visual cues on olfactory perception in humans [22]. Guest et al. [23], investigated whether similar auditory manipulations change people's perception of the roughness of abrasive surfaces and replicated the rubbing-hands manipulation of previous experimenters while participants rated either the perceived roughness or wetness of their hands. In these experiments, it was possible to demonstrate that auditory frequency manipulations can have an influence on the perceived tactile roughness and moistness of surfaces.

Creativity support tools

To properly investigate creativity, it is appropriate to adopt a variety of methods and perspectives to make it plausible and understanding. Creativity is a complex and multifaceted phenomenon [24] and includes discovery or invention of a significant idea, pattern, method, or device that gains recognition from accepted leaders in a field [25].

Over the last decades of creativity research there is no consensus on how to evaluate how well a Creativity Support Tool (CST) supports the creativity of its users [10]. As Joyce states [26] emerging computer-based tools can develop better and more creative solutions to the problems that we face in our days. Other researchers [27] considers that success during software development, despite of being a conceptually complex, knowledge intensive and cognitive activity, depends on the creativity of software engineers. Shneiderman [25] argues that it is a challenge to construct information technologies that support creativity and the goal of developing new CST can be obtained by building upon an adequate understanding of creative process. Also, the goal of CST is

to develop improved software and user interfaces that make users become more productive, and more innovative [6]. Creativity and motivation enhancement can easily be aligned with the design of high-quality human-computer interaction and creativity can be viewed as any process which results in a novel and useful product, as stated by [28]. Researchers have also targeted other stimuli to support creativity, such as the visual stimuli, images and text, increase both originality and diversity of ideas during brainstorming [29,30,31]. Other such as Gonçalves et al. [32], studied UI Zen-based themes, composed of sound and images, foster inspiration, focus and immersion on creative writing tasks.

In the next two sections, we will describe the evaluations of the different environments, including the methods, participants, procedures and results of each. All data taken from the experiment was made completely anonymous.

3 USER STUDY

We conducted a between-subjects experiment to investigate if olfactory or auditory cues affect peoples' creativity during a creative writing exercise. Since writing is part of everyday routine of our sample, the activity in this experiment involved writing a short story using Microsoft Word (MS Word) as the writing environment. We chose MS Word because the participants (high school students) were all familiar with.

3.1 Conditions

The writing activity was conducted under four different conditions: Neutral Environment (no cues); Smell Environment (cues alert/relax), Sound Environment (cues alert/relax) and Smell+ Sound (both cues, sound/smell combined).

Neutral Environment. Our baseline (*session 1, N=14*) without any cues.

Sound Environment. In this condition, we used two auditory cues: an alerting sound (*session 2, N= 17*) through which users might feel that they would be sitting in a cafe with the constant bustle of movement of people, machines and dishwashers, and a relaxing sound (*session 3, N=14*), achieved using a natural soundtrack featuring water, birds and foliage.

Smell Environment. We used two types of olfactory cues: an alerting smell (*session 6, N= 12*) which was achieved by the actual fragrance of hot coffee that was spread around the room, and a relaxing smell (*session 4, N=10*) for which we used a laurel fragrance.

Smell + Sound Environment. We used the combination of sound and smell in each condition – alert and relaxed. One group of students have smelled the real coffee and listen the sound of a café (*session 7, N=21*), and the other group of students smelled the relaxing fragrance and listen the sound of nature (*session 5, N=12*).

Smell Spread: To make sure that all students could smell the sense that was in the classroom, ten minutes before the session six and session seven started, we made coffee in the school's kitchen, and placed the coffee pot in the classroom, with doors and windows closed. To spread it we used a fan and small cups of coffee were placed next to

each computer in case participants wanted to smell it more during the writing. In session four and session five we spread olfactory laurel fragrances using air fresheners' room spray by Air Wick[1], that remains for up to one hour and is propelled by 100% filtered air. Participants were exposed to smell during the session. Sessions of the different olfactory cues were done on different days.

Audio: To play back the audio we used two sound columns of 2x10 Watt output power.

Since this was a study conducted in a school environment, including students that were minors of age, a protocol was setup between parents, school and researchers regarding all the data gathered, even if anonymous, in order not to raise any privacy or security issues.

3.2 Task

Students had to write a short story about an "imaginary path on an island" [7] [33] Therefore, map[2] (Figure 1) was handed out to all students before the activity. They were instructed to choose two points from the map, and through their own imagination and creativity they had to write a story about their path from a point A to point B. They had to initiate their writing from their own ideas. Participants were given 15 minutes as a time limit to complete the writing task in all conditions.

Fig. 1. Map used to trigger the writing task.

[1] http://www.airwick.us/products/room-sprays/
[2] All rights reserved to Sofia Vasconcelos http://frommadeiratomars.com/pt/

3.3 Participants

The study involved 100 students (45 female, 55 male), from the institution's population, aged between 15 and 19 years old (M=15.9; SD=0.94). They were recruited through the school's mailing list. All subjects were naïve to the experimental conditions. Everyone reported having a normal olfactory and auditory acuity.

3.4 Measures

We used the following measures for our experiment: Creative Behavior Inventory [34]; Flow Theory dimensions and Self-assessments; Creativity Support Index and Post-experiment interviews.

Creative Behaviour Inventory (CBI) is a psychometric tool to investigate ones past creative behaviour and activities [34]. The CBI was used to access the different creative levels of the participants. We used a subset of thirty items from the original CBI [34] [35], particularly the specific examples of creative activities such as: literature, miscellaneous, performing arts, science and music [36]. As Hocevar states [34], an item score was based on response category: zero points for never, one point for once, two points for twice, three points for 3-4 times and four points for more than five times. We classified subjects into two classes: subjects that had less than 30 points on the CBI as being *less creative*, and participants that had more than 30 points on the CBI as *highly creative* [10].

The Creativity Support Index (CSI) is a survey to assess a tool's creativity support which users provide ratings for six dimensions of creativity support: Enjoyment, Exploration, Expressiveness, Immersion, Results Worth Effort, and Collaboration [5].

We asked participants to self-rate their creativity [37], answering the question "*I consider myself a creative person*" ranking a seven-point Likert with the evidence scale for 1 (totally disagree) and 7 for (totally agree).

Another different approach to measuring creativity is the one of the Flow theory [38]. Csiksentmihalyi defines flow as "*a state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will continue to do it even at great cost, for the sheer sake of doing it*" [38]. As the author argues, we all experience flow from time to time and we recognize its characteristics. When we are *"in the flow"* we typically feel strong, alert, in effortless control, unselfconscious, and at the peak of our abilities. Therefore, we focused on the following Flow Theory dimensions: concentration, sense of control, losing track of time, and loss of self-consciousness. These dimensions were evaluated by the participants while ranking the following 7-point Likert scale questions: "*I felt very concentrated during this task*"; *"I was able to solve this task without any problem"; "I lost track of time during this task"; and "I lost my attention during this task*".

To access participants' mental well-being, they were asked to choose up to three adjectives from the following list: Surprised, Delighted, Laid back, Depressed, Pacific, Happy, Tired, Bored, Sad, Satisfied, Frustrated, Angry, Serious, Animated, Distressed, Creative, and Frightened.

Finally, we collected qualitative data from all users with a set of questions such as: *"Did you enjoyed to write in this condition and why?"; "This condition gave you more immersive and emotionally engaging experience and why?"; "This condition felt more natural to you to write and why?"; "In this condition you felt more creative and why?"; "Did you fell more relaxed and why?"; "Did you fell more stressed and why?"; "Is there any comment that you would like to add?"*, in order to know the participant's opinion about the whole experience.

3.5 Procedure

The experiment was conducted in a classroom in the secondary high school (Figure 2), during two weeks.

Fig. 2. Students from session 7, performing the study in the moment of the experience.

A preliminary evaluation was conducted with six participants to examine the feasibility and accuracy of the smell spread in the classroom. Three participants were in one classroom with the smell of coffee and the other three were in a classroom with the smell of laurel. For this purpose, we used a simple creative writing technique [36] that participants were presented with an image. They were asked to write a simple story during fifteen minutes. Following, participants were asked whether they could smell the odour during the writing task. The smell was already spread into the classroom as previously mentioned (*see 3.1 Conditions, Smell Spread*). Since participants reported that they smelled the odour, it was considered that the study may be conducted according the procedure.

In the main experiment, participants were brought to the classroom (Figure 2), previously prepared for it. The experiment was conducted in a classroom equipped with computers on desks, and the time requirement for each session, including pre-questionnaire, instructions, experiment and debriefing took over an hour.

When participants entered the classroom, they delivered the document with the experiment protocol and the authorization to participate, which was previous delivered to them. Before starting each session, it was asked if the smell bothered any of the participants. First, participants were requested to fill the Creative Behaviour Inventory [31], and to self-rate their creativity [33]. After filling the inventory, the writing task was explained. Then, when they finished the writing task, they had to fill the Creativity Support Index [3], together with the very short survey based on Flow Theory [35] and to select up to three adjectives from the list that was mentioned before. Lastly, we interviewed them.

4 RESULTS

To inquire the impact of olfactory and auditory cues on user's apparent and experienced creativity, we triangulated different data sources, such as behavioural data, users' verbal accounts during task execution, self-reports using psychometric scales of creativity and data from our exit interviews. We will refer to the creative writing conditions previously presented and shown in Table 1.

Table 1. Description of the creative writing conditions used.

Creative Writing Condition	***Session***	**N**
Baseline	Base	14
Sound Alert	SA	14
Sound Relax	SR	17
Smell Relax	SmR	10
Smell + Sound Relax	SmSR	12
Smell Alert	SmA	12
Smell + Sound Alert	SmSA	21

Are our samples equally creative?

Participants self-rated their creativity (M=4.85; SD= 1.17) in a seven-point Likert Scale before starting the experience. Results are shown in Tables 2 and 3.

Table 2. Frequency and percentages *"I consider myself a creative person"*.

Seven-point Likert scale	***Frequency***	***Percent***
1	0	0%
2	0	0%
3	11	11%
4	31	31%
5	32	32%
6	14	14%
7	12	12%
Total	100	100%

Table 3. Descriptive of self-assessment about creativity in each creative writing conditions.

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Mean	4.36	4.71	5.06	5.00	5.17	4.67	4.95
St. Deviation	.84	1.38	1.19	1.49	1.03	.88	1.24
Std. Error	.225	.370	.290	.471	.297	.256	.271
Minimum	3	3	3	3	3	3	3
Maximum	6	7	7	7	7	6	7

A chi-square test of independence was performed to examine the relation between students in each condition and their self-assessment of creativity. The relation between these variables was not significant, X (24) =17.992, p=.803. Therefore, there is no statistically significant association between participants and their self-assessment of creativity, i.e., students consider themselves creative persons.

Through Cronbach's alpha, the CBI inventory was found to be highly reliable (30 items; α= .84). Regardless of the self-report scale in the 30-item CBI that could capture a creative accomplishments and activities in past behaviours, our results suggest in terms of past creative actions that 42 students had more than 30 points on the CBI *("highly creative"*) and 58 students had less than 30 points on the CBI *("less creative"*). We compared the gender of the subjects with their creative level of the self-report scale in CBI to see if there were any difference between genders. On average, female participants reported greater creativity in past activities (M=30.78; SD=16.40) than male participants (M=25.86; SD=14.99). This difference was not statistically significant (t (98) = 1.57, p>.05). However, it did represent a small-sized effect r=.13.

We also compared the subjects in each condition (*session 1 to session 7*) and their creative level of the self-report scale in CBI. Some descriptive statistics are shown in Table 4.

Table 4. Average (SD) from CBI in each creative writing condition.

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
M (SD)	20.64 (12.73)	20.01 (14.93)	23.71 (9.50)	38.20 (15.55)	35.58 (14.40)	33.83 (23.26)	29.48 (13.38)

A chi-square test of independence was performed to examine the relation between the participants in each condition and their results in CBI (creativity in past activities). The relation between these variables was not significant, X (288) =296.04, p=.360. Therefore, there is no statistically significant association between participants and their creativity and all groups were equally creative in past activities.

Did olfactory or auditory cues lead to increased flow?

To access the participants' mental well-being, we asked them to select up to three adjectives from the following list: Surprised, Delighted, Laid back, Depressed, Pacific, Happy, Tired, Bored, Sad, Satisfied, Frustrated, Angry, Serious, Animated, Distressed, Creative and Frightened. Table 5 displays the percentages for each adjective, as selected by the participants on each creative writing environment.

We can see in Table 5 that Animated, Relaxed, Satisfied, Creative and Pacific were the most chosen adjectives.

A chi-square test of independence was performed to examine the relation between students and the adjectives selected in each creative writing condition. The relation between these variables was only significant for the adjective *"Tired"*, X (6) =20.490, p=.002. By looking at the data represented in Table 5, we can conclude that there is a statistically significant association between participants and their state of mental well-being in session one (*baseline*), session six (*smell alert*) and session seven (*smell + sound relax*);, suggesting that students felt somehow tired in these sessions.

Table 5. Results in percentages for the adjectives chosen by participants in each creative writing condition.

Adjectives/Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Distressed	-----	7.1	-------	-------	-----	-----	9.5
Animated	35.7	28.6	52.9	40.0	33.3	50.0	23.8
Satisfied	57.1	35.7	17.6	30.0	58.3	33.3	23.8
Bored	7.1	7.1	5.9	-------	-----	-----	4.8
Pacific	21.4	21.4	52.9	20.0	50.0	33.3	14.3
Relaxed	78.6	64.3	52.9	60.0	75.0	66.7	52.4
Creative	57.1	57.1	70.6	40.0	75.0	83.3	57.1
Astonished	21.4	7.1	17.6	-------	8.3	8.3	23.8
Serious	14.3	14.3	23.5	-------	-----	-----	14.3
Fear	-----	7.1	-------	-------	-----	-----	-----
Frustrated	-----	14.3	-------	10.0	-----	8.3	19
Happy	28.6	-------	29.4	20.0	16.7	8.3	28.6
Delighted	14.3	-------	-------	-------	-----	8.3	4.8
Tired	7.1	-------	-------	-------	-----	8.3	33.3
Angry	-----	-------	10.0	-------	-----	-----	-----
Sad	-----	-------	10.0	-------	-----	-----	-----
Depressed	-----	-------	10.0	-------	-----	-----	-----
TOTAL	*N=14*	*N=14*	*N=17*	*N=10*	*N=12*	*N=12*	*N=21*

Thus, when we asked about how they felt in the writing task, participants reported similar thoughts to the creative writing conditions in this case, e.g., "*I did not have much creativity, so I felt tired of writing."* [baseline, P12]; *"I got tired of writing and imagining the end of the story I was writing (...)"* [smell+sound relax, P10]; *"I did not feel like writing and I had no ideas to write."* [smell alert, P2].

Some statistical results are shown in Table 6, to test differences between each creative writing environment from the answers in the survey based on Flow Theory [35] dimensions and ranked by participants in a seven-point Likert scale.

Table 6. Average (SD) for Flow Dimensions in each creative writing condition.

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
(i) Concentration	4.64 (1.82)	5.50 (1.74)	4.47 (1.80)	4.00 (1.25)	5.25 (1.29)	5.25 (1.95)	5.00 (1.81)
(ii) Sense of Control	5.00 (1.75)	5.42 (1.60)	5.11 (1.69)	4.90 (1.85)	5.91 (.99)	5.17 (1.67)	4.90 (1.73)
(iii) Loss of self-consciousness	5.79 (1.37)	5.78 (1.93)	4.65 (2.19)	4.60 (1.89)	5.00 (1.70)	4.50 (2.28)	5.38 (1.69)
(iv) Lost Track of Time	3.79 (2.08)	2.71 (2.27)	3.35 (2.06)	3.50 (1.84)	2.41 (1.68)	2.67 (2.23)	3.47 (2.16)

A Skewness and Kurtosis and Kolmogorov-Smirnov test did not show a normal distribution of Flow Dimensions scores in each creative writing condition and, therefore, non-parametric tests were conducted. A Kruskal-Wallis test, showed that there was not a statistically significant difference in Concentration levels of participants' between the different creative writing conditions, H (6) = 8.36, p=.213 with a mean rank Concentration score of 46.21 for session 1 (baseline), 61.71 for session 2 (sound alert), 43.74 for session 3 (sound relax), 33.20 for session 4 (smell relax), 54.96 for session 5 (smell+sound relax), 57.88 for session 6 (smell alert) and 52.83 for session 7 (smell+sound alert). The Sense of Control level of participants was not significantly affected by the different sessions, H (6) = 3.192, p=.784 as well as the levels of Loss of Self-Consciousness, H (6) =7.724, p=.259 and the levels of Lost of Track Time, H (6) = 6.391, p=.381.

Yet, by looking at the Table 6, one can see that the *Lost Track of Time* dimension was not a significant issue for any of the environments we evaluated. The *Sense of Control*, *Loss of self-consciousness*, and *Concentration* dimensions, results were most consistent in all environments.

Qualitative data revealed that students in the Smell + Sound Environment (33.3%) felt more stressed and others claim that the noise interfered with their concentration. 7.1% of the users in the Neutral Environment felt stressed because they knew they were contributing to a study. In the Sound Environment 12.9% of the users felt more stressed as 18.8% in the Smell Environment. Participants in these environments felt pressure to write under a limited time, but both the smell of the coffee and the laurel relaxed them, and the same for the sound cues. For instance, e.g., *"I felt stressed about knowing that I am contributing to an investigation."* [baseline, P10]; *"Yes, I felt stressed, because I had a time limit to finish."* [sound relax, P13]; *"Yes, the fact of having a time limit left me stressed, but it did not stop me from expanding my imagination."* [sound alert, P14]; *"Yes a lot of pressure to write, however the smell of coffee allowed me to abstract a little."* [smell alert, P2].

Did olfactory or auditory cues lead to increased output?

Regarding the stories written and the data dispersion, results showed (Table 7) that the participants in the session 4 (smell relax) wrote an average of 412.6 words (SD=97.3), which contrasts with other creative writing conditions.

Table 7. Average (SD) for words written in each creative writing condition.

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Words Written	267.0 (132.1)	246.0 (90.23)	269.5 (105.7)	412.6 (97.3)	270.1 (90.0)	213.8 (79.7)	300.7 (79.6)

A Skewness and Kurtosis and Kolmogorov-Smirnov test did not show a normal distribution of words written in each creative writing condition and, therefore, non-parametric tests were conducted. A Kruskal-Wallis test, showed that there was a statistically significant difference between the words written by the participants' and the different creative writing conditions, H (6) = 20.449, p=.002. Mann-Whitney tests were used to follow up this finding with a correction at a .0083 level of significance, but we did not find statistically differences between sessions.

Did olfactory or auditory cues lead to increased CSI?

We used the CSI [3] as a way of evaluating how well each environment (neutral, smell, sound or smell + sound) supported the creativity of the participants. 100 students generated an average overall CSI score as shown in Table 8 for creative writing task in each environment. Tables 9, 10 and 11 show the average factor counts, average factor score, and average weighted factor score for each of the six factors on the CSI in each environment session.

Table 8. Overall CSI Score in each condition: Average (SD).

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Overall CSI Score	54.43 (15.77)	71.03 (21.09)	58.49 (18.88)	51.37 (17.30)	77.60 (15.97)	74.03 (14.92)	51.73 (21.89)

Table 9. CSI Avg. Factor Counts (SD): Sum of Results of Two Questions by Factor.

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Results Worth Effort	11.29 (2.76)	14.50 (5.27)	11.88 (4.40)	9.70 (4.92)	17.00 (2.31)	15.50 (3.24)	12.14 (5.00)
Exploration	10.71 (2.43)	13.40 (5.27)	11.47 (3.79)	10.50 (3.60)	15.10 (3.78)	13.60 (3.41)	10.86 (4.29)
Enjoyment	10.36 (4.57)	14.70 (4.45)	12.06 (4.58)	9.80 (4.78)	15.30 (3.97)	15.30 (4.16)	6.38 (5.69)
Expressiveness	9.64 (4.67)	12.90 (5.32)	11.35 (4.34)	10.90 (4.25)	15.30 (3.13)	13.70 (3.23)	11.43 (4.61)
Immersion	11.86 (5.67)	17.30 (3.06)	11.35 (3.89)	8.80 (3.68)	15.40 (4.50)	16.70 (4.16)	11.19 (6.03)
Collaboration	11.57 (3.34)	14.50 (5.42)	12.18 (4.23)	10.50 (3.60)	13.90 (5.02)	14.20 (3.33)	7.43 (4.23)

Table 10. Avg. Factor Score (SD).

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Results Worth Effort	2.14 (1.10)	2.40 (1.43)	1.94 (1.20)	2.70 (1.34)	2.40 (1.26)	2.60 (1.35)	2.24 (1.30)
Exploration	3.36 (1.15)	3.50 (1.08)	3.47 (1.46)	2.80 (0.92)	3.50 (1.08)	3.30 (1.16)	3.29 (1.15)
Enjoyment	2.00 (1.47)	1.10 (0.99)	2.18 (1.33)	2.30 (1.42)	2.20 (1.23)	1.10 (1.45)	1.71 (1.71)
Expressiveness	3.57 (1.60)	4.50 (0.53)	3.65 (1.22)	3.80 (1.14)	2.90 (1.66)	3.70 (1.25)	3.43 (1.57)
Immersion	1.71 (1.49)	2.40 (1.17)	2.18 (1.01)	2.00 (1.56)	2.20 (1.48)	2.40 (1.43)	2.90 (1.22)
Collaboration	2.21 (1.89)	1.10 (1.66)	1.59 (1.62)	1.40 (1.35)	1.80 (1.23)	1.90 (1.79)	1.43 (1.63)

Table 11. Avg. Weighted (SD).

Sessions	*Base*	*SA*	*SR*	*SmR*	*SmSR*	*SmA*	*SmSA*
Results Worth Effort	24.71 (14.96)	31.00 (15.61)	25.00 (21.95)	28.80 (22.58)	42.00 (23.72)	40.10 (25.31)	28.81 (19.18)
Exploration	35.71 (14.35)	45.50 (22.42)	40.59 (20.77)	28.00 (10.91)	52.60 (22.10)	45.90 (21.88)	36.71 (19.23)
Enjoyment	21.21 (20.36)	16.50 (18.45)	25.94 (15.95)	25.10 (17.43)	36.20 (27.60)	18.60 (26.50)	10.33 (15.63)
Expressiveness	35.29 (25.16)	58.90 (26.27)	43.65 (27.73)	40.20 (20.33)	43.90 (25.99)	49.50 (18.85)	40.10 (24.17)
Immersion	19.43 (17.91)	43.20 (25.02)	25.24 (15.76)	18.60 (21.13)	33.00 (25.96)	39.70 (27.23)	32.29 (22.27)
Collaboration	26.93 (23.07)	18.00 (31.45)	15.06 (13.81)	13.40 (14.52)	25.10 (19.89)	28.30 (26.60)	8.95 (11.42)

The Shapiro-Wilk test did not show a normal distribution of CSI scores and, therefore, non-parametric tests were conducted. The Kruskal-Wallis test showed that there was a statistically significant difference in CSI scores between the different creative writing conditions, H (6) = 24.046, p=.01 with a mean rank CSI score 39.21 for Base (baseline), 60.71 for SA (sound alert), 45.29 for SR (sound relax), 37.50 for SmR (smell relax), 73.42 for SmSR (smell+sound relax), 70.46 for SmA (smell alert) and 37.12 for SmSA (smell+sound alert). Mann-Whitney tests were used to follow up this finding. A correction was applied and so all effects are reported at a .0024 level of significance.

CSI scores in SA (Mdn=50.17) differ significantly from CSI scores in SmSR (Mdn=81.33), U=25.5, p=.002, r=-.59.

There was a statistically significant difference in CSI scores from students in SmR (*Mdn*=54.33) and SmSR (*Mdn*=81.33) *U*=12.0, *p*=.001, *r*=-.67. Also, CSI scores from SmR differ significantly from SmA (*Mdn*=77.17), *U*=12.0, *p*=.001, *r*=-.67.

CSI scores in SmSR (*Mdn*=81.33) were statistically different from CSI scores in SmSA (*Mdn*=50.33), *U*=41.5, *p*=.001, *r*=-.55.

Finally, CSI scores in SmA (*Mdn*=77.17), when compared with CSI scores in SmSA (*Mdn*=50.33), *U*=42.5, *p*=.001, *r*=-.55.

From the results, we can conclude that the combination of olfactory cues with auditory cues can significantly affect the level of support to the creative process of a digital creativity support tool, when compared to a condition that does not use any cue (olfactory or auditory). This holds true whether the cues are alerting or relaxing. Also, this is verified when there are only smell cues (alert or relax) in the creative writing task. However, when using only auditory cues, the results do not show any evidence of increased creative process support.

Triangulating the results with semi-structured interviews allowed us to support some of these results and observations. Students were curious to know what the writing task was, since none of the users had ever taken an experiment such as this one. In general, we observed that the participants were concentrated on the writing moment. It was clear that all participants felt somewhat creative during the experiment.

In the semi-structured interview, participants showed mixed feelings about how they felt creative in the creative writing conditions. 50% of students consider that they did feel more creative in the Neutral environment, 54.8% in the Sound Environment and 63.6% in the Smell + Sound Environment. 72.7% of the students in the Smell Environment considered themselves more creative in this creative writing condition.

90.9% of the participants enjoyed to write in the Smell Environment, expressing reasons such as: *"It made me relax, without any pressure."[*smell_relax_P2]; *"(...) because we were very excited and happy"* [smell_relax_P5]; *"(…) because I think it helps to have more ideas"* [smell_relax_P5]; *"It was interesting - at first I was anguished and then more relaxed."*[smell_relax_P10]; *"it made me want to work."*[smell_relax_P7]; *"it allowed me to get immersed in the activity and be very creative. Although I did not have enough time to finish my story, I managed to create a creative and funny story, while not respecting some rules of grammar*."[smell_alert_P9]; *"as the smell of coffee is comforting and makes it easier to express my ideas."*[smell_alert_P7]; *"(…) because it allows a better flow of writing.*"[smell_alert_P3]; *"I think that it stimulated my creativity, imposing it on the work"* [smell_alert_P8].

In the Neutral Environment 57.1% of participants enjoyed writing in this environment as much as the 57.6% users in the Smell + Sound Environment. 77.4% of students enjoyed to write in the Sound Environment, expressing *"(…) because I felt completely oblivious of what was happening around me and I was just concentrated on what I had to do."*[sound_relax_P11]; *"I was so focused writing that did not even notice the sounds around me."*[sound_relax_P12]; *"music gives a good environment for writing and is relaxing."*[sound_alert_P9]; *"(...) music has stimulated my creativity in writing"* [sound_alert_P3];

During the experience, we noted that participants were anxious and curious to know what they were supposed to do. In a qualitative way, we also observed them focused

and in absolute concentration during the writing task in all conditions. According to the interviews, some participants were deeply involved in the creative writing task.

5 DISCUSSION

This study aimed to explore which modalities, olfactory or auditory, were stronger triggers for creativity.

We identify that most of the students considered themselves creative persons, even though more than half of them were not usually engaged with creative activities, as reported by the CBI. These results indicate that the study was not biased by a highly critical self-assessment.

As stated by Csikszentmihalyi [35], every flow activity, whether they involved competition or any dimension of experience, had in common the sense of discovery, the creative feeling of transporting the person into a new reality. By giving a "writing challenge" we observed that students were immersed in the writing moment, and after they finished the activity, they felt creative, animated, relaxed and peaceful. This was especially evident during the smell and sound cues and during the combination of both (the smell + sound environment). From observation, in the Neutral Environment students were feeling more apathetic and they made more pauses in writing during the timeout. Although, through statistically analysis, we did not find significant results from the Flow Theory dimensions, from our qualitative data we noticed that sound cues could lead to lower levels of concentration. In addition, we noticed that they felt a little pressure towards writing with a time limitation, and this was probably the reason for the inexistence of substantial results in the Flow dimensions.

Triangulating the qualitative data from semi-structured interviews and results, indicates that 72.7% of students said they felt more creative in the Smell Environment, in contrast to other conditions that had higher values (50% in Neutral, 54.8% in Sound and 63.6% in Smell + Sound Environment) as well as that 90.9 % of students enjoyed writing in the Smell environment and 77.4% in the Sound environment.

CSI did show significant difference through statistical analysis, confirming the benefit of olfactory and sound stimuli during a writing task. It is also important to observe a decay on the CSI value for the combination of Alert smell+sound when compared to the single conditions (only smell or sound), suggesting that such combination overwhelmed the participants. Such disturbance is confirmed by the qualitative data results.

The different results from our study show a strong influence of smell and sound cues during a creative writing task and with a highlight on olfactory cues. Therefore, answering our main research question "*Which modality, olfactory or auditory, sparks stronger triggers for creativity?*". Such results become more relevant if we consider that previous research did not show any significant effect of odours on performance, as stated by Ho and Spence [17].

Our study suggests that olfactory cues should gain more relevance on the development of creativity support tools and environments. Novel smell dispensers [39] and

their integration on current portable media devices as well as the olfactory augmentation of multisensory work environments could improve and foster creative tasks but their combination with other stimuli must be designed carefully to avoid disturbance.

6 Conclusion

Creative writing is a constant activity in many sectors and professions in the modern world. Because of today's diversity of possible technological ways to write, designing a creative writing user interface is hard work. Sometimes it is difficult to find a tool that keeps users focused whilst eliminating some of the hard work. In this paper, we presented a study that addresses the use of different modalities such as smell and sound on the creative writing process of users to enhance creativity.

In the between-subject study, we tested the influence of smell and sound on the participant's creativity in a writing task measured by the Creativity Support Index. We have created two types of auditory and olfactory cues each: an alerting smell was created using the actual fragrance of hot coffee that was spread around the room in small cups. Regarding the alerting sound, users might feel that they would be sitting in a cafe with the constant bustle of movement of people, machines and dishwashers. As for a relaxing scent, we used the fragrance of laurel, and the sound mode used was a natural soundtrack with water, birds and foliage.

We investigated which cue could promote higher levels of creativity and mental well-being – as measured by a survey based on the dimensions of Flow Theory.

We compared four different environments (neutral, smell, sound and smell + sound) using MS Word as a word processor. From a creative perspective, and triangulating qualitative and the statistical results, it is suggested that users considered to feel more expressive and more creative during the writing task, especially in the Smell Environment.

We found out that participants considered that the smell allowed them more creative times, thus being one of the decisive factors to abstract and to become concentrated. Our results provide interesting information regarding the smell and sound cues modalities. At the same time, for the combination of smell and sound in each category, in semi-structured interviews participants gave emphasis to these conditions in the creative moment of the writing task.

A significant problem faced by interaction designers that are involved in multisensory interaction is the timing of each multisensory interaction (*when* to apply the multisensory stimulus). Writing prompts – among other techniques such as using images like a map – are sometimes used to kick start the creative process, when writing. In this research, we highlight the value of smell and sound cues as an alternative, more powerful means to kick-start that same process more effectively.

There are many aspects of this study that remain open for future investigation such as our results about creativity combined with different modalities. Measuring creativity is an important approach that will lead us to different impacts of specific creative writing tools. These tools can have features to increase the creativity of writers and contribute to unblock writer's block. In future work, we think it is important to intensify the

research on designing user interfaces that support creative writing and build novel tools that can be used by several people.

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