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# Towards Creative VR Workspaces: Investigating Effects of Room Size and Object Presence on Creativity


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## Abstract

Creativity is increasingly essential, especially as automation and artificial intelligence replace routine tasks. Previous work suggests that the physical environment, for example, room size and object presence, might influence our creativity. Virtual Reality (VR) enables working in any environment and thereby allows optimizing the environment to foster creativity. Previous research on creativity, however, did not systematically control room size and object presence. As their isolated effects are unclear, we explore the effects of room size and objects on creativity in VR. Participants completed an alternative uses task in small and large virtual rooms that were empty or filled with objects. We found that the presence of objects increases subjective creative performance but found no effects of room size or objects on objective creativity. We derive implications to enhance the subjective experience in creative VR workspaces and discuss that the effects of room size might be smaller than previously thought.



## CCS Concepts

• **Human-centered computing → Virtual reality**.

## Keywords

Creativity, Virtual Reality, Room Size, Environment

**ACM Reference Format:**

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## 1 Introduction

Creativity is a key aspect of professional life. Especially as routine tasks become increasingly automated through artificial intelligence, the value of creativity continues to grow. Previous research suggests that creativity might be influenced by the physical environment. Using photos of a large number of environments, McCoy and Evans asked participants to rate the environments' creativity potential [23]. They identified multiple factors that might increase creativity. Based on their pre-study, McCoy and Evans, compared a physical environment expected to increase creativity with another environment expected to decrease creativity [23]. They indeed found that the physical environment can increase creativity performance. Previous work also investigated the effects of environments' specific characteristics on creativity. Chan and Nokes-Malach assessed creativity in small and large rooms [5]. Based on an alternative uses task, they assume that larger physical spaces facilitate novelty and hinder the practicality of solutions.

Virtual reality (VR) devices have become significantly more powerful and accessible in recent years. Many efforts by companies such as Meta and Apple, recently entering the VR market with their Apple Vision Pro headset in 2024, indicate a technological shift regarding VR technology. Their uses extend to simulating reality and serving as devices for productivity tasks [11]. Thornhill-Miller and Dupont argue that VR is an underused tool for enhancing creativity, as it allows to control and modify the environment cost-effectively [32]. Strachan-Regan and Baumann, for example, found that small differences in room architecture, such as curved vs. rectangular rooms in VR, can increase creativity [31].

Previous work on the effects of different physical [5, 23] and virtual environments [7, 31] clearly shows that our surroundings can affect creativity. Previous work on the effects of physical environments is, however, limited by the challenge of isolating individual factors that influence creativity. The physical rooms compared by Chan and Nokes-Malach, for example, not only differed in size but also in terms of present objects, furniture, and light [5]. As shown by Strachan-Regan and Baumann, VR not only has great potential to increase the creativity of VR users but also to study an environment's effects with fewer logistical challenges [31]. Virtual environments could, therefore, be used to help design work environments that improve creativity [13]. However, to understand how VR environments can be used to influence creativity, the isolated roles of foundational factors of environmental design, such as room size and object presence in enhancing creativity need to be disentangled. VR not only offers fine-grained control over spatial




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and visual elements but also enables research that isolates specific design features, limiting the effect of confounding variables [20, 37].

We conducted a study in VR to systematically assess the effect of room size and object presence on creativity. Thirty-two participants completed an alternative uses task (AUT) in four rooms, which were either small (3m x 2.5m x 2.2m, W, L, H) or large (12m x 10m x 5m, W, L, H) and empty or filled with objects (Figure 1). Creativity was measured both objectively, using the AUT, and subjectively, through self-perceived creativity ratings. Our findings show that the presence of objects increases subjective creative performance, but no effects of room size or objects on objective creativity were found. These findings suggest that the spatial dimensions of virtual workspaces and creative environments might be less important than their interior design, as our results indicate that attention should be given to curating meaningful visual elements, which can enhance perceived creativity. While such features may not directly boost measurable creative output, they can positively influence subjective creative performance and motivation.

## 2 Related Work

In the following, we discuss previous work on creativity, clarifying terminology and introducing essential concepts. Additionally, we examine the influence of environmental factors on creativity as well as research mediums and methods for assessing creativity.

### 2.1 Creativity

Creativity is a complex concept that involves thinking of new products or ideas that are not only novel but also useful and relevant to their context [3]. Guilford [14] considered divergent thinking as one of the most relevant abilities regarding creativity. Divergent thinking is the ability to think of multiple solutions to a certain problem. He further elaborated on divergent thinking to comprise four measurable aspects: fluency, flexibility, elaboration, and originality. Guilford's work, therefore, provided a way to understand creativity through measurable components. While Amabile [2] explained creative thinking as a three-part process, consisting of: (1) the preparation phase, where individuals collect and recall relevant knowledge; (2) the response generation phase, where potential ideas are generated; and (3) the response validation phase, where the ideas are tested and assessed, and the most appropriate is chosen. The third phase is more internal, while in the first two phases, individuals are particularly influenced by their environment, with visual cues influencing idea generation [3]. Gustafsson [15] further distinguished creativity into personal and societal creativity. Personal creativity only has to be useful to the individual. While societal creativity serves a purpose in relation to current societal standards and is, therefore, better quantitatively measured.

### 2.2 Measuring Creativity

As creativity can be a complex and multifaceted construct, measuring it presents a significant challenge. Creativity is commonly assessed using divergent thinking tasks, such as the Alternative Uses Task [14], which measures creativity through fluency, flexibility, originality, and elaboration. Though popular in creativity research, these tests may only partially reflect real-world applications [15]. Such tests are better at measuring people's creative predisposition, but the results may not readily translate to everyday situations [8]. While objective assessments such as the AUT are useful for quantifying creative performance and testing hypotheses about cognitive processes, subjective methods may be better at highlighting participants motivation and creative engagement. Park et al. [27] showed that subjective creative assessments had high means and smaller variances with a moderately significant correlation to objective assessment methods. Combining subjective and objective assessments can, therefore, provide a more comprehensive view and understanding of creativity, measuring objective outcomes as well as the individual's perceived creative experience.

### 2.3 Creativity and the Environment

The interplay of environmental factors, such as interior design, on creativity will be discussed. McCoy and Evans [23] discovered that environmental factors, including room design, influence participants' creativity. A literature review by Meinel et al. [24] assessed different ways to design creativity-enhancing workspaces and came to a similar conclusion, citing the presence of plants, appealing sounds and smells, a window view, flexible furniture, as well and open offices that are adequately sized in combinations with spaces to relax without other people. Han et al. [16] further showed how the environment plays an important role in shaping user experiences, suggesting that large spaces can positively influence factors such as presence and enjoyment.

Through independent rating of the physical characteristics of different environments, [23] suggests that creative potential may be increased through spatial complexity, visual detail, natural views, the use of natural materials, sociopetal design, and cool colors. They suggest that big open spaces with visual complexity outperformed smaller spaces with lower visual complexity in creative tasks.

### 2.4 Creativity and Room Size

In comparing creativity in small and large rooms, Chan and Nokes-Malach [5] used the AUT to measure participants' divergent thinking. In a small room (2.4m × 3m × 2.4m, W, L, H), with participants seated directly in front of a wall heightening the effect of the room's small size, individuals generated more practical ideas. While a larger room (4.6m × 9.1m × 4.6m, W, L, H) led to more responses in the AUT (higher fluency) that were higher in originality, they hypothesized that the environment could prime concepts such as freedom or openness, with large open spaces leading to an open mind. Yet, the effect sizes were small and the effects regarding originality were only found in one of the two studies by Chan and Nokes-Malach [5]. In their second study, the large room had a significantly lower ceiling of 2.4m (vs. 4.6m in study 1) with equal length and width measurements to the first study. This may have negatively impacted creativity by disrupting the perceived proportionality of the space.

Chen et al. [6] investigated spatial sizes in VR and found that spaces with balanced room dimensions such as 8m × 8m × 4m (W, L, H) were most preferred by participants, while extreme ratios like 16m × 16m × 2m (W, L, H) were least preferred by participants. Further, visual complexity varied between the different rooms. Light color and brightness also differed, which were both shown to influence creativity [21]. de Groot [7] tried to replicate these findings in real environments and VR, and found larger room sizes to affect fluency, while not impacting originality positively.

Minas et al. [25] compared creative task performance in two virtual environments: a confined space where notes were placed on the walls and an open environment where the walls were removed, leaving the notes hovering in space. The larger setting resulted in increased creativity levels. This setting was not only a larger room but was also open to the nature around it. Therefore, the two conditions did not merely compare room size but rather small, confined spaces versus large spaces open to the outdoors, showing the sky and nature. An open beach environment in VR was shown to enhance creativity when compared to an enclosed laboratory setting in VR [19]. Views of nature through windows have also been shown to increase creativity in VR [29]. Research indicates that room size affects creativity [5, 7, 23], but the evidence is inconclusive, as confounding variables such as visual complexity may have influenced the studies overall.

## 2.5 Creativity and Visual Complexity and Object Presence

Visual complexity refers to the number and variety of objects and design elements within a room or environment that impact the environment's appearance, with an increase in visual detail leading to an increase in creativity [23]. In their study, Guegan et al. [13] showed that participants working in a "creative" room, designed with higher visual complexity, artistic elements, and the inclusion of plants, exhibited greater originality and elaboration compared to those in a standard office meeting room. They suggested that environmental cues primed participants to engage in more detailed and creative thinking about specific aspects of their surroundings, though this did not result in more ideas overall, aligning with the "path of least resistance" model as participants generate ideas that come easy to them, with visual stimulation acting as such. Guegan et al. [12] further supported this mechanism by showing through the Proteus effect that using creative avatars in virtual environments increased creativity.

The complexity of the environment also has to do with the arrangement and order of the objects, as disorderly rooms promote creative thinking compared to orderly rooms [34]. But literature specifically examining the effects of object presence or absence on creativity remains limited. Regarding objects, it is therefore unclear how variance in object count and room furnishing affect creativity. While higher complexity appears to lead to heightened creativity, the effects of empty rooms are unclear, being used interchangeably in some studies[5, 7].

While looking at room themes, Van Hooijdonk et al. [33] found that object-incongruent environments (e.g., thinking of creative uses for a book in a car garage) enhance creativity. This shows that the creative topic, as regards the room themes, can impact creative thinking, with topics unaligned with the current environment enhancing creativity. The study created different virtual environments, such as a library and a car workshop, while still accounting for possible confounding variables such as light, visual complexity, object presence, object arrangement, and room size. Virtual environments lend themselves to such studies as they allow the precise isolation of different variables, with VR allowing immersive experiences of such environments.

## 2.6 Device Comparisons in Creativity Research

While creativity research was originally conducted in real-world environments [5, 23], more recent research has employed different digital devices such as tablets, computers, and VR headsets. Studies examining these devices have shown mixed findings on how virtual environments displayed on various devices compare to each other, as well as how they compare to real-world settings. Guegan et al. [13] interactive PC-based first-person simulator, where participants could actively navigate a virtual room replica, performed equally with those in the real room regarding creativity.

Palanica et al. [26] reported similar increases in creativity between participants watching 3D videos of nature on a tablet to those using a VR headset. Ichimura [19] discovered that watching videos of nature in VR resulted in higher creativity scores than viewing the same content on a computer screen, suggesting that VR offers a more immersive experience. de Groot [7] further compared different VR environments with their real-life counterparts and found that VR neither enhanced nor diminished creative performance, further supporting the use of VR for creativity research.

While recent studies [31, 33] used VR to investigate environmental concepts, discussing their results as generalizable findings, not merely findings relevant to VR. Care must be taken when using VR to study creativity, as cybersickness has been shown to negatively impact creativity [9].

## 2.7 Summary

In conclusion, creativity can be influenced by the physical environment, while aspects such as room size and visual complexity may play a role [23]. With larger spaces being more conducive to creativity when comparing outside environments with indoor environments [19]. Furthermore, Guegan et al. [13] found that by creating spaces associated with creativity, originality and elaboration can be enhanced, without affecting subjective creativity. Yet this exploratory study does not shed light on the concrete variables that were responsible for the effects, such as lighting, visual complexity, room size, and theme, all of which differed between conditions.

In comparing room size, smaller rooms lead to increases in practicality, while larger rooms lead to more novel ideas as well as increased fluency, yet the effect sizes were small, and originality was only significantly altered in one of the two studies carried out by Chan and Nokes-Malach [5]. They also did not account for factors such as contextual cues (lecture hall vs. empty room), visual complexity [23], or light [21], which have all been shown to affect creativity. de Groot [7] found that VR environments perform equally with similar real-world environments, while increases in room size seemed to lead to increases in fluency but not originality or flexibility. While also not accounting for possible priming through a lecture hall as the large room and visual complexity of the different room types, these results differ from those of [5]. It is therefore unclear if larger room sizes lead to increases in creativity, and more specifically, which aspects of creativity. Furthermore, the

**Figure 1: Big Full environment (top left), Small Full environment (top right), Big Empty environment (bottom left), Small Empty environment (bottom right).**

specific effects of object presence on creativity, as well as potential interaction effects caused by room size, represent a gap in the current research.

## 3 Method

We conducted a study to investigate the effects of room size and object presence on creativity in VR. Participants completed an AUT to measure their creativity in small and big rooms that were either empty or filled with objects in virtual reality.

### 3.1 Study Design

We used a 2x2 repeated measures design with two independent variables: room size (small room vs. big room) and presence of objects (empty room vs. room filled with objects). Thus, we implemented four virtual environments to assess their effects on creativity. The dependent variables were objective creativity (AUT) [4], self-perceived creativity [13], presence (SUS) [30], and task load (raw NASA-TLX) [17, 18]. Participants completed the AUT in each of the rooms. To avoid sequencing effects, the order of the rooms was counterbalanced using a balanced Latin square design, while the sequence of words used for the AUT was kept the same for all participants.

### 3.2 Task and Measure

We used the AUT to assess creativity, a widely used and well-supported measure of divergent thinking [4]. It involves giving participants a prompt, usually an everyday item such as a "brick", they then try to come up with as many alternative uses for it as possible in a certain time frame. The AUT was administered in German, as the study was conducted in Germany. The words used were "Newspaper", "Cup", "Umbrella", "Match", "Brick", "Plastic bottle", "Tire", and "Pen" as they were used by Yin et al. [36]. The words were independently translated by two bilingual speakers, both native speakers of English and German. The translations were cross-checked for consistency, and any discrepancies were collaboratively discussed and resolved. Instructions were taken from [10] and slightly adapted and translated into German.

"The goal is to come up with as many alternative uses as possible for an everyday object that differs from its normal use. For example, a knife is typically used for cutting, but it could also be used as a screwdriver or a mirror. You will have two minutes per object. Try to think of as many alternative uses as possible that not only differ from the typical use but also from each other. Be creative with your ideas."

AUT response times range from 1 minute per item [31] to 4 minutes [5]. To balance the number of items per condition and minimize creative fatigue, a duration of 2 minutes per item was adopted, aligning with [19]. Participants were told to "be creative" to enhance creative performance [1]. Participants had two minutes to come up with as many alternative uses as possible for each word. They were allowed to finish a thought if the time ran out. Each condition consisted of two words. The order of the words used in the AUT was kept the same for all participants. The AUT answers were assessed using SemDis [28].

After each condition, subjective creativity, presence, and task load were measured. To assess participants' subjective creativity, we used the questionnaire proposed by Guegan et al. [13]. The questionnaire consists of the following three Likert items: "I had lots of ideas", "I had good quality ideas", and "This activity allowed me to be creative and imaginative". This assessment of subjective creative performance complements the objective quantitative results gathered in the AUT, as it can offer insights into the participants' personal creativity [15] and motivational state.

The Slater-Usoh-Olsen (SUS) Questionnaire [30], consisting of six items on 7-point scales, was used to assess participants' presence in the VR. In addition, we used the raw NASA-TLX [18] to determine participants' task load. The three questionnaires were administered in the following order: the self-perceived creativity questionnaire came first as it is the most relevant and short in length, followed by the presence questionnaire, which is close to the VR experience, and lastly, the NASA-TLX.

### 3.3 Apparatus

We used Unity (Version 2022.3.7f1) to implement the VR environments. For the VR experience, we used the Meta Quest 2 head-mounted Display, connected to a desktop PC running Unity (Intel i7-9750H, 16GB RAM, NVIDIA GeForce RTX 2060, Windows 10). Audio for the AUT was recorded using a DJI MIC mounted on the front of the headset.

Four virtual rooms were created in Unity. The small rooms measured 3m x 2.5m x 2.2m (L, W, H), equal to the small condition used by Chan and Nokes-Malach [5]. The big room's dimensions were 12m x 10m x 5m (L, W, H), the length and width being four times that of the small room. The layout was kept neutral, with white walls and ceilings. The floor was given a dark wood floorboard design in line with McCoy and Evans' [23] findings to add natural materials, which were shown to enhance creativity, besides also subjectively making the room more realistic. We conducted the study in a neutral laboratory room (see Figure 2).

In the virtual environment, the participants were seated on a chair against the wall of the longer side of the room facing inward towards a 2.2m grey door on the other side of the room, which assisted in giving proportional context to the room size. Their point of view is shown in Figure (1). The lighting was kept bright at 300lx with 5600K color temperature, staying consistent between the two room sizes. This was important as Lan et al. Lan et al. [21] found brightness and color temperature to affect creativity, two possibly confounding variables in the study by Chan and Nokes-Malach [5] regarding room size and creativity.

For conditions portraying objects, the small and large rooms were filled with different objects similar to those used by Guegan et al. [13], which appeared in a room that positively affected creativity compared to a meeting room. The interior consisted of a bookshelf filled with books, a desk with a chair, a plant, and an easel with a painting. The layout of these objects was kept the same in both room sizes to control for object placement. Consistent placement thus avoids possible differences in cognitive loads and perceptions of the objects. The objects were included to elicit increases in creativity [23] as compared to the empty conditions.

### 3.4 Procedure

We first informed participants that their participation was voluntary and that they had the right to withdraw from the study at any time without consequences. Afterwards, we asked them to provide informed consent by signing a consent form. They were then asked to sit on a chair, and the study procedure was explained to them. Here, the AUT was explained to them. Then, the external microphone recording was started, and the participants were given the VR headset and shown how to wear and adjust it to ensure a comfortable and secure fit.

**Figure 2: Study location, participants were seated on a chair during the study.**

After participants had put on the VR headset, the first condition started; they then had 90 seconds to get acquainted with the room before the AUT started. Subsequently, the next AUT item was orally presented by the researcher, with participants answering orally, with 2 minutes allocated per word. When the two words were completed, the participants stayed seated, took off the headsets, and were given a laptop to fill out the questionnaires, which consisted of the self-assessment of creativity, the SUS questionnaire, and the NASA-TLX.

The process was repeated for the other three conditions. To keep the time between conditions constant, the time to fill out the first questionnaire was measured and used for the other questionnaires ($M$ = 02:24, $SD$ = 00:43). Participants were instructed to fill out a demographic questionnaire after the four conditions were completed. They were subsequently debriefed, given opportunities to ask questions, and thanked for their participation. The study duration was about 45 minutes.

### 3.5 Participants

We recruited 32 participants for the study, with 17 identifying as male, 14 as female, and one participant identified as other. The age of the participants ranged from 19 to 35 ($M$ = 23.6, $SD$ = 3.27). Participants were recruited using the department's mailing list as well as through personal contacts. Students were compensated with one credit point if needed for their study program. Thirty-one participants were students at the University. Regarding the frequency of VR use, most ($n$ = 19) used VR "a few times per year", while three participants used VR "a few times per month" and 10 participants answered with "never".

## 4 Data Processing and Creativity Assessment

After the study was concluded the audio recordings were transcribed and subsequently deleted. As responses were collected orally, filler interactions or irrelevant comments, and comments unrelated to the AUT responses were omitted in the transcription process.

To rate the responses of the Alternative Uses Task, different options presented themselves. Human ratings are the more established method to date, but with promising findings regarding SemDis and its adaptation to the German language [28], along with the advantages of it being less time intensive and not requiring human raters which may also be prone to biases of their own. Therefore, semantic distance was chosen to rate creativity, hereinafter referred to as Creativity Score. For each participant and condition, an overall Creativity Score was obtained by summing the individual scores across all answers and averaging these sums. Through summing the answers given, both creative quality and quantity are accounted for [31]. The multilingual semantic model by Patterson et al. [28] (available under http://semdis.wlu.psu.edu/), where data can be uploaded and rated, was used. To further compare findings of Chan and Nokes-Malach [5] who found practicality to be higher in small rooms, this being a category that Semantic Distance cannot evaluate, practicality was measured using human raters, with instructions by Marko [22].

Two independent raters rated all the responses (*ICC* = 0.79) on a scale of 0 to 3, the final score being the average of the two raters' scores. Using practicality scores equal to 0, nonsensical answers were filtered out in line with [35]. After processing the data using SemDis, qualitative reviewing of the answers showed inconsistencies in the ratings. Therefore, in line with [5], novelty was measured using the same instructions and methods as the practicality ratings (*ICC* = 0.84).

## 5 Results

The results, including the questionnaire analysis and the results of the Alternative Uses Task, were processed using SPSS. All data was checked for outliers. No outliers were found, as assessed by examining studentized residuals for values greater than ±3. Sphericity was not tested as the within-subject factors are two categories per factor. Normality was assessed using the Shapiro-Wilk test on the studentized residuals ($p > .05$).

### 5.1 Objective Creativity

We used a two-way repeated measures ANOVA to analyze the mean semantic distance of the AUT (see Figure 3) to determine the effects on semantic distance. We found no statistically significant effect of room size ($F(1, 31) = 710$, $p = .406$, $\eta_p^2 = .02$) or object presence ($F(1, 31) = 0.78$, $p = .696$, $\eta_p^2 = .10$) on semantic distance. We also found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = 0.58$, $p = .453$, $\eta_p^2 = .02$) on semantic distance.

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on fluency. We found no significant effect of room size ($F(1, 31) = 529$, $p = .473$, $\eta_p^2 = .02$) or object ($F(1, 31) = 3.53$, $p = .070$, $\eta_p^2 = .10$) on fluency. We also found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = .80$, $p = .377$, $\eta_p^2 = .03$) on fluency.

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on practicality. We found no significant effect of room size ($F(1, 31) = 0.11$, $p = .918$,

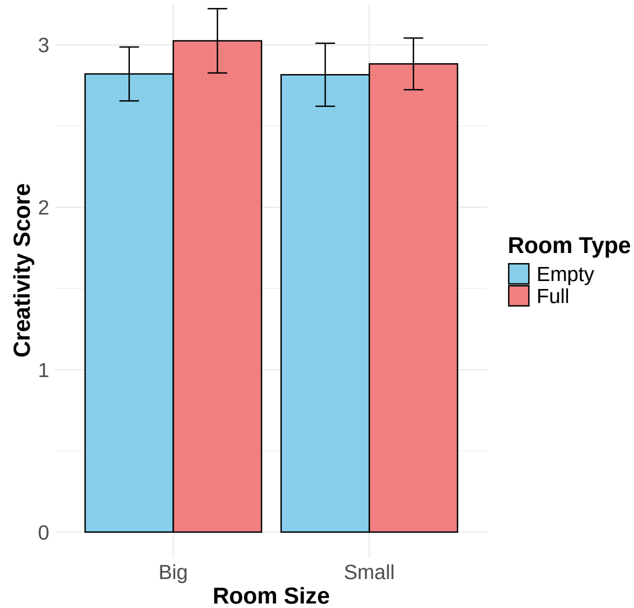


**Figure 3: Mean Creativity Score (i.e. semantic distance) across conditions. Error bars show the Standard Error.**

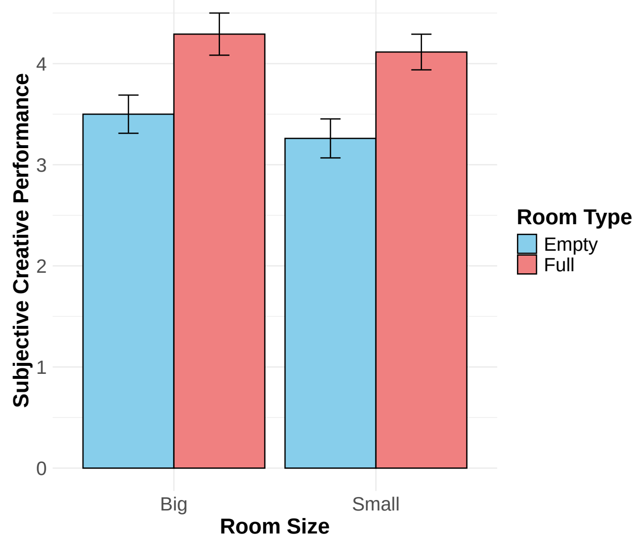


**Figure 4: Mean Subjective Creative Performance (SCP) across conditions. Error bars show the Standard Error.**

$\eta_p^2 = .00$) or object presence ($F(1, 31) = 2.53$, $p < .619$, $\eta_p^2 = .01$) on practicality. We also found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = .06$, $p = .809$, $\eta_p^2 = .00$) on practicality.

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on novelty. We found no significant effect of room size ($F(1, 31) = 1.00$, $p = .324$, $\eta_p^2 = .03$) or object presence ($F(1, 31) = 1.43$, $p = .241$, $\eta_p^2 = .04$) on novelty. We also found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = .02$, $p = .884$, $\eta_p^2 = .00$) on novelty.

## 5.2 Self-Perceived Creativity

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on self-perceived creativity (see Figure 4) measured using the self-perceived creativity questionnaire by Guegan et al. [13]. We found no significant effect of room size ($F(1, 31) = 1.46$, $p = .236$, $\eta_p^2 = .09$) on perceived creativity. The ANOVA, however, revealed a significant effect of object presence $F(1, 31) = 18.84$, $p < .001$, $\eta_p^2 = .13$ on perceived creativity. We found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = 0.42$, $p = .839$, $\eta_p^2 = .02$) on perceived creativity. The full room conditions resulted in the highest perceived creativity with the *Big Full* room resulting in the highest mean score ($M = 4.29$, $SD = 1.18$) and the *Small Full* room in the second highest mean score ($M = 4.11$, $SD = 1.00$). The *Big Empty* room resulted in the second lowest mean score ($M = 3.40$ ($SD = 1.07$) and the *Small Empty* room in the lowest mean score ($M = 3.26$ ($SD = 1.18$)).

Post-hoc paired t-tests revealed several significant differences in self-perceived creativity scores between Full and Empty conditions, with the *Small Full* condition compared to the *Big Empty* ($t = 2.64$, $p = .013$) and *Small Empty* conditions ($t = 3.80$, $p = .001$). Additionally, scores in the *Big Full* condition were significantly higher than those in the *Big Empty* ($t = -3.05$, $p = .005$) and *Small Empty* conditions ($t = 3.71$, $p = 0.001$). However, no significant differences were observed between the *Small Full* and *Big Full* conditions ($t = -0.80$, $p = .431$) or the *Big Empty* and *Small Empty* conditions ($t = 1.01$, $p = .321$).

## 5.3 Presence

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on participants' presence (see Figure 5) measured through the SUS [30]. We found no significant effect of room size ($F(1, 31) = 2.99$, $p = .094$, $\eta_p^2 = .09$) on presence. We, however, found a significant effect of object presence ($F(1, 31) = 30.64$, $p < .001$, $\eta_p^2 = .050$) on presence. We found no statistically significant two-way room size x object presence interaction effect ($F(1, 31) = 1.00$, $p = .326$, $\eta_p^2 = .03$) on presence.

The *Small Full* condition achieved the highest mean score of $M = 4.50$ ($SD = 1.13$) and *Big Full* followed closely with a mean score of $M = 4.11$ ($SD = 1.01$). The *Big Empty* condition had a mean score of $M = 3.57$ ($SD = 1.32$), while the *Small Empty* condition had a slightly higher mean score of $M = 3.70$ ($SD = 1.21$). Post hoc paired $t$-tests revealed several significant differences. The *Small Full* condition showed significantly higher scores compared to the *Big Empty* ($t = 4.47$, $p < 0.001$) and *Small Empty* conditions ($t = 4.89$, $p < 0.001$). Additionally, the *Big Full* condition scored significantly higher than the *Big Empty* ($t = -2.81$, $p = 0.009$) and *Small Empty* conditions ($t = 2.3$, $p = 0.029$). *Small Full* and *Big Full* conditions approached statistical significance ($t = 1.88$, $p = 0.070$), while *Big Empty* and *Small Empty* conditions also showed no significant differences ($t = -0.68$, $p = 0.499$).

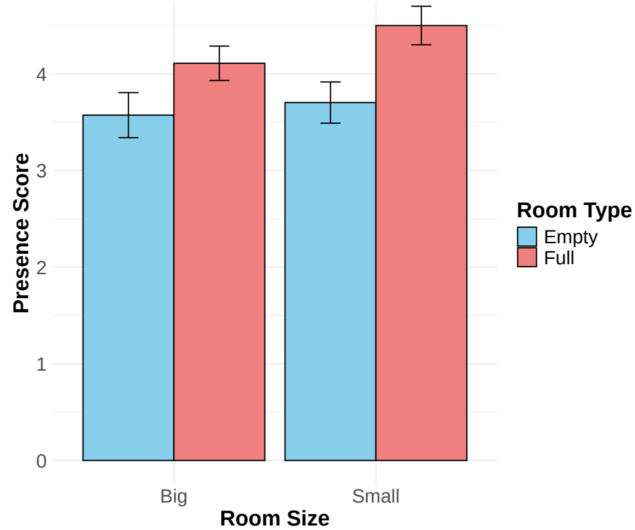


**Figure 5: Mean Presence Scores across conditions. Error bars show the Standard Error.**

## 5.4 Task Load

We used a two-way repeated measures ANOVA to determine the effects of room size and object presence on participants' task load measured through the raw NASA-TLX [17, 18]. Task Load was normally distributed ($p > .05$) except for the *Small Empty* condition ($p = .048$), as assessed by Shapiro-Wilk's test of normality on the studentized residuals. The main effect of room size showed no statistically significant difference in task load between trials, $F(1, 31) = .13$, $p = .719$, $\eta_p^2 = .09$. The main effect of object presence also showed no statistically significant difference in task load between trials, $F(1, 31) = 1.55$, $p < .696$, $\eta_p^2 = .01$. There was no statistically significant two-way interaction between room size and object presence, $F(1, 31) = .02$, $p = .899$, $\eta_p^2 = .00$.

## 5.5 Qualitative Feedback

Regarding the question "How did you experience the different rooms?" participants gave written responses at the end of the study. We used selective coding to categorize participants' responses into four categories, beginning with general impressions. We first conducted a review of all responses given in order to identify recurring themes and concepts and gain an overview of the material. Building on these insights, we developed a coding scheme consisting of four main categories: general feedback, object presence, room size, and room-specific feedback. We subsequently categorized each participant's response into these themes, combining similar responses and citing relevant impressions as well as divergent opinions on different subjects.

*5.5.1 General Feedback.* Participants were generally aware of the differences in room size and furniture, feeling the rooms were distinct yet sharing similarities. The rooms were described as "bland, office like, [and] generic" by one participant (P7). While the lighting was criticized as it didn't have a realistic point of origin (P25), further the lack of windows was negatively remarked (P2). Another critique being the shadow of the door being distracting (P6). While one subject (P26) said that they did not perceive a "... big difference because I think I was zoning out pretty quickly when I thought about the task."

*5.5.2 Object Presence Feedback.* The filled room conditions were largely mentioned positively, with participants often citing the furniture as a source of inspiration, six participants explicitly mentioning that it made ideation easier. One Participant (P23) mentioned how the plant inspired the "...application of a pen as something a potted plant might use to grow along." Five participants mentioned how the filled rooms made them feel more comfortable and it was also mentioned that the furniture enhanced realism (P23). While it was also expressed by two participants that the furniture was helpful to have something to focus on e.g. "I felt more comfortable in the rooms with objects, as I had something to look at while thinking" (P1) the opposite was expressed as well: "The rooms with furniture irritated me, and I was less creative and very much distracted by the things in the room [...] the rooms which were empty gave me more space to think and my imagination was better" (P11). Although four participants stated that empty rooms decreased their ability to think of new ideas. With words like "oppressive" (P14), "uncomfortable" (P22), "boring" (P29) for "unsettling" (P30) being used to describe the empty conditions.

*5.5.3 Room Size Feedback.* Large Rooms were viewed positively by multiple subjects, being seen as more open with a higher sense of freedom, saying they were more comfortable compared to their small counterparts (P26). However, some also mentioned the large rooms "...felt a bit more strange and unusual" (P17). Another participant mentioned that "room size did not really have an effect on how creative" they felt (P19). The Small Rooms were noted as being realistic and cozy by some, with one participant (P15) mentioning how they liked that it was similar to their workspace. But the small rooms were also remarked as being "cramped" (P27), "oppressive" (P14), "claustrophobic" (P2), "uncomfortable" (P4) and "restrictive" (P32).

*5.5.4 Room Specific Feedback.* The *Small Empty* room was mostly mentioned negatively, with participants saying they had no ideas (P9), it being "intimidating" (P10), "very uncomfortable and not very inspiring" (P22), "boring" (P29), "oppressive" (P14) and with one participant (P14) comparing it to a prison cell. While one participant described it as "strangely calming... [and]... inspiring due to its minimalism" (P25).

The *Small Full* room received almost exclusively positive comments, such as it giving more ideas, feeling more comfortable, "cozy" (P20), "best for creativity" (P25), "familiar" (P29), and "pleasant" (P31) also being used to describe it. The realism of the lighting being mentioned as less convincing in one instance (P25).

The *Big Empty* condition was remarked as being "unnatural" (P5), "difficult to think [in]" (P10), "oppressive, as if someone was about to walk through the door" (P18), "very surreal and unnatural" (P29), "frustrating" (P28) and "very empty" (P32). While it was also seen by others as "pleasant, not too big, fitting not too many distractions" (P31). And "...better than the *Small Empty* room" (P25).

The *Big Full* room was stated as helping with idea generation with the objects (P9), and as being "more comfortable and real than the empty big room, even though objects were weirdly placed in the middle of the room" (P13). It was also described as "open and free" (P14) and "very comfortable" (P26), though three subjects remarked the oddity of the location of the furniture in the middle of the room.

## 6 Discussion

While our study, in contrast to previous work, did not indicate effects of room size or object presence on objective creativity, significant results were found regarding subjective performance as well as presence. In the following, we discuss how our results relate to creative performance, task load, as well as presence, and reflect on the limitations of our experiment.

### 6.1 Creativity and Object Presence

Subjective creative performance increased with object presence. Participants felt more creative in rooms that contained objects, regardless of the room size. Object presence may, therefore, positively increase personal creativity. Helping participants come up with more creative solutions from their perspective also likely positively impacts creative motivation. While qualitative feedback showed that some participants felt inspired by the objects surrounding them, object presence did not affect objective creativity in the AUT. This is surprising as subjective creativity ratings increased in the filled rooms, but these subjective ratings did not carry over to objective performance. Interestingly, Guegan et al. [13] found their creativity-conducive environment to enhance objective creativity, while no differences in subjective creativity were found. This indicates that the link between how creative participants feel and how they perform remains ambiguous and may depend on additional factors. While McCoy and Evans [23] discuss visual complexity as a key environmental factor influencing creativity, the differences in the conditions may not be enough to elicit such effects. As even the filled condition was not visually complex, with white walls and ceiling creating a rather sterile environment, mentioned by McCoy and Evans [23] as negatively impacting creativity. Visual complexity may play a larger role regarding the overall design of a space rather than merely the presence or lack of objects.

Guegan et al. [13] found their creativity-conducive environment featured not just more objects but also greater visual complexity among other differences, with the room's design based on survey responses of what people perceive as ideal creative environments, with elements such as a window front with a view of nature possibly being a strong factor. While Van Hooijdonk et al. [33] also showed that specific environmental designs or objects influence thinking, they may shift thinking in a certain direction but not necessarily enhance it.

As the preferences and experiences reported via qualitative feedback differed, it may be concluded that both the empty and full conditions in this study helped individual participants differently. Some participants found the objects helpful in generating ideas, e.g., one participant mentioned using a pen as a climbing aid for plants, attributing the idea to the plant in the full room condition. Others reported the objects as visual clutter that were distracting, preferring the empty rooms in order to think more clearly. Surprisingly, objects did not affect the number of ideas generated per room, even though associations were made with the objects in the room. These findings indicate that object presence alone may not be sufficient to enhance objective creativity, with factors such as object type, placement, and overall room design potentially playing a significant role, which should be investigated in future work.

Designers of VR applications in domains such as ideation, brainstorming, education, or creative therapy may consider enhancing subjective user experience through environmental features like furnishing, decoration, or theming. Even if these features do not directly boost output quality, they may increase users' subjective experience and creative motivation. Moreover, given the variability in how individuals responded to object-rich versus minimal environments, flexibility and personalization should be central to XR workspace design. Allowing users to toggle between focused, minimalist settings and visually stimulating environments may accommodate a wider range of creative preferences and cognitive styles.

## 6.2 Creativity and Room Size

Regarding room size, no effects on objective or subjective creativity were found. These findings are contrary to the work by Chan and Nokes-Malach [5], who found that room size influenced novelty, practicality, and fluency. De Groot [7], in contrast to us, also found differences in fluency between small and large rooms. Instead, we did not find significant effects of room size on creativity, including novelty, practicality, and fluency. A possible explanation for these discrepancies is that the setups of previous studies did not fully control for other environmental factors. As previous work conducted their studies in real-world environments, for instance comparing a lecture hall to a small storage room [5], they were not able to account for confounding variables such as visual complexity [23] or lighting conditions [21]. Likewise, de Groot [7] did not control for these factors when comparing two different virtual rooms.

Moreover, the fact that this study found no such effects of room size or objective creativity regarding objects raises the possibility that other methodological factors, such as seating orientation, may have played a more significant role in the results of prior work. A key factor that differed between the studies was how participants experienced the size of the small room. While Chan and Nokes-Malach [5] as well as de Groot [7] chose small rooms that were identical in size (2.5m x 3m, W, L) to those of our study, the seating position in their rooms differed from ours. As we also investigated objects, we had participants sit against a wall looking into the room so that the entire room and its interior were in the participant's field of view. In contrast, Chan and Nokes-Malach [5] as well as de Groot [7] had participants sitting at a table up against a wall, which limited their spatial perception of the room to about 1m sight line to the next wall, compared to roughly 3m in our study. It could, therefore, be that room size may not play as important a role in creativity as orientation and seating arrangement, with a potential decrease in creativity if one is sitting up against a wall without windows, which have been shown to increase creativity [29].

While larger spaces seem to make a difference when nature is to be seen [19, 25], these environments were much bigger than even large indoor rooms, while also showing the sky and natural elements such as plants. Therefore, larger spaces leading to heightened creativity may have more to do with nature than the spatial dimensions. Further conclusions may, therefore, be that spatiality, especially indoors, may not play as significant a role in impacting creativity as previously assumed. Participants subjective experiences of the different room sizes further shed light on the topic as the lack of effect on room size may have to do with individual preferences regarding the topic, some participants favored the small room as it made them feel more comfortable, while others preferred the big room, viewing the small rooms as confining. Therefore, the ideal room size for creativity may be more individual.

## 6.3 Presence and Task Load

Regarding presence, no effects of room size were found. However, we found significant effects of object presence, with the participants reporting significantly higher presence for the full room. These results align with expectations as the full rooms were furnished in a realistic manner and made the rooms feel more real.

The absence of an effect of room size on presence appears to contrast with the in contrast to findings of Han et al. [16], who assessed spatial presence across 192 unique VR environments. They reported that users felt more present in panoramic environments (defined as spaces where one can see wide and far) compared to constrained environments. However, as the authors note, these panoramic environments also contained more virtual content. This suggests that the observed increase in presence may also be attributed to the presence of more objects. This interpretation is supported by our results, in which the presence of objects, rather than room size, significantly enhanced the sense of presence.

The NASA-TLX questionnaire assessed task load across the conditions and found no significant differences. This aligns with the overall findings on creativity, which similarly showed no notable differences between the conditions.

## 6.4 Limitations

This section addresses the possible limitations of the study. One limitation may be the motivation levels of the participants. As most subjects were recruited for points counting toward their degree, some participants may have lacked motivation, which is an important factor in creative performance [2].Additionally, the sample size consisted of only 32 participants. This is, however, comparable to previous study conducted in VR. For example, 35 participants took part in the study by Strachan-Regan and Baumann [31] and 24 participants in the study by Lan et al. [21]. Furthermore, we used a repeated measures design to increase statistical power resulting in 128 measures for each dependent variable. Nevertheless, the effects of the environmental impact on creativity generally appear to be marginal, and it may be necessary to use larger sample sizes to assess such aspects accurately. A further limitation may be the assessment method of the AUT results using SemDis, as this is a relatively new method for assessing creativity. However, to ensure reliability, our results were verified through human ratings of novelty, which showed consistent findings.

Furthermore, we cannot disregard that we only tested two levels of room size and two sets of objects. Further research is necessary to validate our findings beyond the tested room size levels, such as cathedrals, and across a broader range of present objects.

The AUT itself may present a further limitation in generalizability. The AUT is a widely used and validated method for quantitatively assessing divergent thinking, allowing for reliable comparisons across studies. Nevertheless, due to being physically passive, findings may not carry over to tasks that involve a greater level of interaction with the environment.

## 7 Conclusion

This paper investigated the effects of different room sizes and the presence of objects on creativity in VR. While we found no effects on objective creativity metrics, environments filled with objects increased subjective creative performance. This indicates that even when creative output does not objectively improve, users feel more creative when situated in virtual spaces filled with objects, as compared to clean, empty rooms. Our results further suggest that room size may not play such an important role in enhancing creativity as previously assumed, the effects often being found in correlation with outside environments and open spaces. This result is noteworthy, as prior studies assessed creativity based on subjective impressions of room arrangements, warranting further exploration into the reliability and influence of subjective metrics. Nevertheless, as the perception of work environments is shaped by multiple interrelated factors beyond room size and presence of objects, this study represents only an incremental step toward understanding how to design virtual spaces that foster creativity. Future research should explore how specific object types, wall distance, and interactivity contribute to both subjective and objective creativity. Additionally, understanding individual differences in environmental preference may help personalize virtual environments to further optimize creative potential in VR.

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