Real World Spaces and Creative Thinking

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ABSTRACT
Neuroscientists have comprehensively assessed how design can support creative thinking, most often in studies that detail the effects of a single physical factor. Creativity-linked design elements that have been identified include colour (surface and light), visual complexity, plants in view, natural light, visible wood grain, aesthetic factors, soundscapes, comfortable environmental control, audio and visual distractions, ceiling height, opportunities for movement, access to needed tools/task support, nonverbal messages sent by a space, and chance for cognitive restoration, for example (e.g., Batey et al., 2021; Studente et al., 2016; Weitbrecht et al., 2015). For the study reported here, multiple factors linked by previous research studies to enhanced creative performance were investigated simultaneously in real-world settings to determine their potential roles in creative thinking. Study participants first completed a task that assessed their individual creativity at a particular moment in time (Green et al., 2017). Then they categorized/described the components of the physical environment in which they did that task using the criteria noted above (e.g., surface colours). Findings confirmed many hypothesized consistencies between aspects of the physical environment previously identified as supporting creative thinking and the design of spaces where participants whose creativity test scores were among the highest 25% (the "higher scorers") completed the creativity task. Data from the higher scorers indicated that, compared with other participants, they were more likely to have answered the creativity test questions in spaces with, for example, plants in view, visible wood grain, possible natural lighting, nature sounds audible, surface colours with saturation and brightness levels that support cognitive work, comfortable environmental control, ceiling heights linked to enhanced creative performance, and that were perceived to support mental work.

Designers can apply the information derived by this study to develop environments that support creative thinking/problem solving and researchers generally can also use reported findings to better understand data collected at different study sites.

Keywords
Workplace design, Creative performance, Environmental psychology.

1 INTRODUCTION

Neuroscientists have comprehensively assessed how design can support creative thinking, most often in studies that detail the effects of a single physical factor. This study simultaneously probed multiple factors linked by previous research studies to enhanced creative performance via data gathered in real-world settings. Data collected indicate consistencies between aspects of the physical environment previously identified as supporting creative thinking and the design of spaces where participants thought most creatively.

For the purposes of this research, creativity was conceptualized as generating high quality, novel ideas related to the topic of concern (Sternberg, 2001). The focus of this study is individual creativity, not the creative performance of people working together.

2 CREATIVITY AND SPACE DESIGN – ABRIDGED LITERATURE REVIEW

Researchers consistently link particular physical environments to superior creative outcomes (e.g., Csikszentmihalyi, 1996; Sailer, 2011; Malinin, 2016). Mood, which is influenced by environmental design (e.g., Desmet, 2015), has also been tied to creative performance, with people in slightly energized, more positive moods generally thinking more creatively than people in neutral or more negative ones (e.g., Isen et al., 1985; Isen et al., 1987; Cote, 1999; Grawitch et al., 2003; Baas et al., 2008; Byron et al., 2010; Hennessey and Amabile, 2010). Sander et al. (2019) also directly relate environmental design that promotes more positive moods and enhanced creative performance. Veitch (2012) shares that working under preferred conditions can generate "a state of positive affect that in turn leads to benefits in the form of . . . increased creativity."

Byron and colleagues (2010) also associate experiencing environmental stressors to degraded creative performance; dealing with/understanding stressors consumes finite stocks of mental energy, leaving less available for other mental tasks, such as creative thinking.

Beyond the deleterious effects of environmental stressors on creative performance, other aspects of the physical environment have been linked to creative performance/achievement via objective neuroscience research using quantified, not impressionistic, measures. For example:

- Seeing *shades of green*, even very briefly, has been tied to enhanced creative performance (Lichtenfeld et al., 2012; Studente et al., 2016).
- *Colours* that are relatively *unsaturated but light* have been linked to viewer energy levels and moods consistent with creative performance (i.e., the positive, slightly energized moods described earlier in this document) (Valdez and Mehrabian, 1994; Martens, 2011).
- Viewing *moderate visual complexity* has been associated with enhanced creativity (McCoy and Evans, 2002; Ceylan et al., 2008; Vohs et al., 2013). Residential

environments designed by Frank Lloyd Wright generally have moderate visual complexity, for example (Vaughan and Ostwald, 2014).

- Being in *naturally lit* interior spaces has been related to higher levels of creativity (Meinel et al., 2017). Additional research ties experiencing natural light with lower stress levels (via its ability to influence circadian rhythms) (Boyce et al., 2003) and synchronization of circadian rhythms with location on Earth has been linked to better moods and cognitive performance generally (Beute and de Kort, 2014).
- Creativity is enhanced in *warmer* (say, 3000 K) but not cooler (around 4500 or 6000 K) *artificial light* (Weitbrecht et al., 2015; Abdullah et al., 2016). Slightly dimmer light levels (for example, 150 vs. 500 or 1500 lux) have also been linked to enhanced creative performance (Steidle and Werth, 2013).
- Wu et al. (2021), via data collected, in part, in makerspaces, learned that people are more likely to think creatively in *rounded, as opposed to more angular physical environments*. In more rounded environments corners, shapes, furniture, and other design elements, for example, are curved and in angular physical environments objects, etc., have sharper corners and are generally more rectilinear than curvilinear. In the curved environment noted by the Wu team, a round table was used while in the angular one the round table was replaced by one of the same size that was square, for instance.
- Wijesooriya and Brambilla (2021) associate *biophilic design* in general with enhanced creative performance. Use of natural materials is an important tenet of biophilic design. Looking at wood grain reduces human stress levels (Fell, 2010) and along with the use of other natural materials such as stone, has been tied to more creative thinking when compared to situations in which natural materials are absent (McCoy and Evans, 2002; Enso, 2020).
- Researchers report that performance on creative tasks has been positively affected by the presence of *green leafy plants* (e.g., Shibata and Suzuki, 2002; Studente et al., 2016; Hall and Knuth, 2019; Hahn et al., 2021).
- Having *views of nature through windows* has been tied to more creative thinking than when nature views are absent by McCoy and Evans (2002), Ceylan et al. (2008), Dul and Ceylan (2011), Loder and Smith (2013), and Van Rompay and Joi (2016). Research by groups such as Batey et al. (2021) indicates that the same boosts in creativity ensue when individuals look at *printed images (posters) of nature scenes*.
- Browning and Walker report on research linking hearing *nature soundscapes* to higher levels of creative thinking (2018).
- Consistent with the information on stressors noted earlier, *audio distractions* have been tied to *reduced creative performance* compared to conditions in which they were absent (Meinel et al., 2017). People are also less creative in spaces that are so quiet that sound levels approach silence (Burkus, 2017).
- Samani at al. (2015) and Thoring et al. (2019) generally relate the presence of *environmental distractions to degraded creative performance*.
- *Physical movement* and creativity have been positively associated, by, for example Rominger et al. (2020). Oppezzo and Schwartz (2014) had earlier tied walking (inside or outside, on a treadmill or not) to boosts in creative performance while walking and shortly after doing so; "Walking opens up the free flow of ideas, and it is a simple and robust solution to the goals of increasing creativity and increasing physical activity."

Muralo and Handel's 2022 findings echo those of Oppezzo and Schwartz. There is also evidence that people think more creatively while standing (Baker et al., 2018).

- *Higher ceilings* have been tied to enhanced creative performance (Meyers-Levy and Zhu, 2007). Meyers-Levy and Zhu compared creative thinking in spaces with 8-foot and 10-foot ceilings and recorded more creativity in the areas with 10-foot ceilings. Building on Meyers-Levy and Zhu's work, Zhu and Mehta (2017) report that "when the room ceiling is perceived to be relatively high (vs. low) it should enhance consumer creativity."
- Samani, Rasid, and Sofian (2015) and Martens (2011) directly link having comfortable amounts of *environmental control* to enhanced creative thinking. Veitch (2012) does as well, through control's effects on more positive moods.
- *Nonverbal messages* sent by the physical environment can boost creative performance (Fong, 2006; Martens, 2011) particularly when signal interpretation indicates support for the tasks-at-hand (McCoy, 2005; Dul and Ceylan, 2011; Dul and Ceylan, 2014; Thoring et al., 2019; Thoring et al., 2021).

The aspects of the physical environment linked to individual creative performance noted in this section were probed as potential supports for creative performance in real world environments; learning more about the physical environment's role in creative thinking was the goal of this study. There are additional environmental factors that have been tied to enhanced creative performance, but their presence in the participants' test-taking environment was not investigated; they are not mentioned in this brief literature review.

3 METHODOLOGY

Study participants completed an online survey in an indoor location of their choosing; it took approximately 10 minutes to answer all questions posed.

The administered survey had two major sections.

In the first section, study participants took an instantaneous test of creativity (an analogy completion exercise) detailed in Green et al. (2017). It determined their creative performance at a particular time, not their trait creativity more generally.

In the second section of the survey, participants answered a series of multiple-choice questions to provide information about the environment in which they completed the instantaneous creativity test mentioned in the last paragraph. Participants were asked about aspects of the places where they completed the instantaneous test of creativity such as colours present (surface and light), visual complexity, plants in view, presence of natural light, wood grain visibility, aesthetic factors, soundscapes experienced, incidence of comfortable environmental control, audio and visual distractions, ceiling height, opportunities for movement, access to needed tools/task support, nonverbal messages sent by the space, and chances for cognitive restoration. A projective question was used to collect information related to visual complexity and colour swatches embedded in the survey were utilized to study surface colours in place. Study participants were asked about their mood using the system developed by Desmet (2015).

The original research plan called for this survey to be completed in workspaces provided to participants at their employers' offices. The work-from-home requirements of the COVID-19

pandemic led to individuals answering all survey questions in alternate locations.

Study participants were recruited via social networks (for residential communities and undergraduate alumni groups, for instance) that the researchers are members of.

People participating in this study were required to answer all questions indoors and could not be designers.

Ultimately, after two rounds of survey administration, 70 completed surveys were available for analysis. These surveys met minimum criteria established by the researchers (answering all creativity test questions, correctly following the directions for the creativity test, and not answering the creativity questions in a predetermined sequence not related to the questions being asked (i.e., "pattern" answering)).

The environmental conditions present in the physical environments used by participants whose scores on the creativity test were in the top 25% of all participants tested as part of this project were compared to the conditions in the areas where the remainder of the study participants (i.e., all those not in the top 25%) answered the questions posed. Analyses completed included t-tests and ANOVAs (as appropriate), chi-square tests, and the calculation of percentages (for multiple choice options selected to describe physical parameters at test-taking locations in second section questions).

4 RESULTS

ANOVAs and t-tests (as appropriate) were conducted for numeric scores on the creativity test and each of the environmental conditions investigated. None of the ANOVAs conducted produced results that were statistically significant at the .05 level and few t-tests were significant at that level. Any tests completed with significant results are noted below.

In addition, chi-square tests were conducted comparing the answers to the multiple-choice questions related to conditions in which survey questions were answered of study participants in the higher and lower creativity test score groups.

The data collected indicated that many of the relationships that would be expected between environmental conditions and more creative performance were present:

- Participants whose creativity scores were among the top 25% (hereafter called "higher scorers") were more likely to be able to see green leafy plants as they took the test (47%) than people with lower scores (36%).
- Among the higher scorers, 59% indicated that the colours they could see on the surfaces around them as they took the test had the creativity supporting levels of saturation and brightness described in the research noted above, while 40% of the lower scorers reported this palette. When answering this surface colour question, study participants selected a response from three colour samples (two chromatic, one white) that were embedded in the survey question. When the data from those who selected the white option were eliminated, the chi-square test statistic was nearly statistically significant (3.64, p value = .056).
- Higher scorers on the creativity test were more likely to see wood grain as they worked

(88%) than people with lower scores (79%).

- The possibly that the test taking site would be lit by natural light if the sun was out was greater among higher scorers (100%) than among other participants (77%). A t-test showed this difference to be statistically significant (t=2.624, 2-tailed significance= .011) and a chi-square test with participants dichotomized into higher and lower scorers was nearly significant (2.39, p value = .12).
- Among the higher scorers, 27% could hear nature sounds as they answered survey questions, compared to 14% of the lower scorers. An ANOVA was nearly significant (F = 1.767, significance = .068). A chi-square test was statistically significant when study participants were dichotomized into higher and lower scorers (11.864, p value = .0184). Other acoustic response options provided were heating/air conditioning/fan in-operation noises, other people talking, something else, or no sounds at all.
- Higher scorers were more likely to perceive that they had control over their physical environments. Specifically, 100% of the higher scorers felt they could turn on or off the lights in the space where they were answering the survey questions. Also, 83% of the higher scorers could open or close a door to the room they were in (compared to 79% of lower scorers) and 65% of the higher scorers could open or close a window in the area where they were answering questions, while 68% of lower scorers could do so. If only the data from people in areas with windows are considered, 79% of the higher scorers could open or close a window while 72% of the lower scorers could do so.
- 12% of the higher scorers answered survey questions in a space with ceilings over 12 feet tall, while 8% of lower scorers did so. None of the higher scorers answered questions in a space with ceiling heights below 8 feet while 6% of lower scorers did. The results of the related ANOVA neared significance (F = 2.306, significance = .085).
- 87% of the higher scorers felt that the design of the space where they answered the creativity test questions would help them do some sort of mental work while 80% of the lower scorers did so.

The data related to several of the expected relationships between environmental conditions and creativity test scores were inconclusive:

- It was anticipated that test scores would be best in spaces with moderate visual complexity. 35% of the higher scorers answered test questions in spaces with moderate visual complexity while 37% of the lower scorers did so.
- 82% of the higher scorers could see a window to the outdoors as they answered the survey questions while 85% of the lower scorers could do this.
- Study participants were asked if they answered questions while working at a sit-stand desk as a proxy for opportunities to move and stand while working. Among the higher scorers, 12% worked at a sit-stand desk while 13% of lower scorers did.

Some data collected indicated relationships between scores on the creativity test and environmental conditions that were unexpected based on published research:

- For 71% of the higher scorers for whom natural light might potentially have been present, natural light was in place as questions were answered; natural light was present for 93% of the lower scorers for whom natural light might have been in place. A related chi-square test was significant (5.31, p value = .012). Information on time of survey completion was not collected, so it is possible that some of those for whom no natural

light was present answered survey questions after the sun had set.

- Among higher scorers who could see a window, 43% had a view mainly of nature (as opposed to buildings and other manmade things), while 60% among the lower scorers who could see a window had a view that was mainly of nature.
- Among higher scorers, surface colours were more likely to be warm for 53%, while this was true for 38% of the lower scorers. Research noted above indicates that seeing the colour green seems to enhance creative performance and this question on colour temperature was asked to probe test site colourscapes. Three response options were provided to study participants, warm, cool, and shades of white. 21% of lower scorers and 29% of higher scorers selected the shades of white option.
- When asked to report the colour of the light in the area where they were answering survey questions, 35% of the higher scorers indicated the light was warm while 60% of the lower scorers did so. This difference leads to a statistically significant chi-square test (3.84, p value = .0500) when the few people in each group (6% of higher scores and 8% of lower scorers) who could not decide if the light in the area was warm or cool were removed from the analysis.
- When asked to categorize lines present in the environment where they answered the creativity test questions, 100% of the higher scorers and 87% of the lower scorers described relatively more of those lines as straight as opposed to curving ones.
- Distractions were more likely to be an issue for higher scorers than lower scorers. Among higher scorers, 35% were distracted by something they could hear while answering survey questions while 15% of lower scorers were distracted by something audible. The chi-square test of this relationship was nearly significant (3.285, p value = .0700) as was the t-test (t = 1.771, 2-tailed significance = .081). In addition, among higher scorers, 31% were distracted by something that they could see while answering survey questions, while this was true of 11% of lower scorers. Again, statistical tests neared significance (chi-square = 3.643, p value = .056; t = 1.771, 2-tailed significance = .081).
- The moods of lower scorers were generally more positive than those of higher scorers. Among higher scorers, 74% categorized their mood as positive while 85% of those whose scores were lower on the creativity test did so.

Many of this study's findings are consistent with those of previous efforts to better understand the design of environments in which people are most likely to think creatively. All of the data collected do not align with those of previous studies, however. There are several potential reasons for this:

- Previous studies have generally only investigated one aspect of the environment and its relationship to creative thinking (with some notable exceptions such as Studente et al., 2016) while the effects of multiple factors were probed in this study.
- The sample size was relatively small.
- The online survey format used presented challenges when study participants were taking the survey on phones or other relatively small screened devices. This may have frustrated users and thereby degraded the quality of data collected.
- If study participants had provided photographs of the areas where they completed the survey, trained professionals could have directly coded environmental conditions present which might have enhanced the quality of the data set; as long as pictures sent were of

adequate acuity and included all environmental aspects of interest (e.g., if a window with a nature view was present, pictures sent would need to include that window, not cut off to the left or right of it).

- More creative individuals may have chosen to answer survey questions in different sorts of spaces than less creative people; they might have previously customized their work areas, etc., in ways not yet reported in the peer-reviewed literature and investigated in the course of this project.
- All data analysed were from people who answered all creativity test questions, correctly followed the directions for the creativity test, and did not "pattern" answer creativity test questions. Roughly half of all people who returned surveys met these criteria; environmental data from people who did not satisfy these criteria were not evaluated because of suspicions raised by pattern answering, etc. It is possible that the environmental conditions noted as unexpected for lower scorers (based on previously published research linking space design and creative performance) supported respondents' efforts to read directions, etc., and therefore boosted likelihood of inclusion in the data analysed, even if they can not be associated with elevated performance on the creativity test.

5 CONCLUSION

Findings confirmed many hypothesized consistencies between aspects of the physical environment previously identified as supporting creative thinking and the design of spaces where higher scorers completed the creativity task. Data from the higher scorers indicated that, compared with other participants, they were more likely to have answered the creativity test questions in spaces with, for example, plants in view, visible wood grain, possible natural light, nature sounds audible, surface colours with saturation and brightness levels that support creative work, comfortable environmental control, ceiling heights linked to enhanced creative performance, and that were perceived to support mental work.

This exploratory study produced multiple useful preliminary findings that can be further probed with a programme of future studies with larger sample sizes, an enhanced survey administration platform, etc. This investigation also established a protocol for studying links between creative thinking and design.

Administering a similar future survey in environments with conditions that are known to researchers but that are challenging for study participants to evaluate (for example, if surveys were completed in a workplace with known (to the researchers) ventilation rates or soundscape volumes) would allow additional factors to be evaluated as supporters of, or detractors from, elevated creative thinking.

Designers can apply the information derived by this study to develop environments that can be anticipated to support creative thinking and researchers generally can also use these findings to better understand data collected at different study sites.

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