INTERNATIONAL DESIGN CONFERENCE – DESIGN 2024
https://doi.org/10.1017/pds.2024.105

DESIGN 2024

Mediators of the relationship between physical indoor spaces and individual creativity

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Abstract

Workspaces can enhance the creativity of the designers that occupy them. Here, we review experimental studies of creative spaces to identify constructs that mediate (explain) the relationship between physical spaces and creative performance. Through a literature review of 8 journal articles comprising 13 experiments, we identify 14 constructs involving cognitive, affective and physiological components. Knowledge of these mediators can help researchers to formulate hypotheses, select control variables, and develop conceptual models and theories of creative spaces in design.

Keywords: design creativity, design theory, workspaces

1. Introduction

Workspaces have the potential to enhance the creative performance of the designers that occupy them, but little is known about *how* or *why* spaces cause changes in creative performance. Creativity can refer to the production of novel and effective ideas (Runco and Jaeger, 2012; Stein, 1953). Converging evidence from quantitative and qualitative methods supports the view that the physical properties of workspaces can influence creativity idea production (Martens, 2011; Meinel et al., 2017; Thoring, 2019). These include concrete aspects like furniture and the shape of a room and abstract qualities like the buzz and excitement that a room can elicit. The field could benefit from a unified explanatory theory for how spatial elements cause improvements in creative performance. Such a theory would facilitate the development of guidelines, methods, and tools to support workspace designers in the design of creativity-enhancing workspaces.

Recent research has laid the foundations for a causal theory of creative spaces, but there is a lack of knowledge about the mediators of the relationship between space and creativity, i.e., the constructs that explain how spaces relate to creative performance. Thoring et al. (2021) have put forward 10 propositions about such causal relations based on expert interviews, but the proposed explanatory mechanisms are not comprehensive and require further validation. This contribution is complemented by literature reviews that of empirical research about the associations between space and creativity, but which again stop short of examining the explanations for these effects (Lee and Lee, 2023; Martens, 2011; Meinel et al., 2017).

In this research, we sought to answer the question: "What are the mediators of the relationship between physical work environments and individual creativity?". The question was answered through a review and synthesis of experimental studies of creativity in physical spaces. The review addressed controlled experiments because they provide fine-grain manipulation of variables, allowing researchers to rule out alternative explanations and make causal claims about effects (Shadish et al., 2002). In this work, we

synthesise across 10 experiments that have identified relationships between some aspect of creative space (independent variables), creative outcomes (dependent variables) and mediating constructs.

2. Background: explanations for the relationship between spaces and creativity

2.1. Creative spaces

Creativity generally refers to the production of novel and effective (useful, valuable) ideas (Runco and Jaeger, 2012; Stein, 1953). According to the Four P model of creativity (Rhodes, 1961), the production of creative ideas involves four 'strands' or dimensions. Ideas are the 'product' of creativity, created by a 'person' carrying out a creative 'process' in a physical and social environment (the 'press').

Creative spaces are the physical structures and elements designed to facilitate creative work (Thoring et al., 2021). Creative spaces are situated within what Rhodes calls the press. Spaces can be considered at multiple scales, including individual products and items, interior spaces and arrangements of products, architecture, and neighbourhoods (Thoring, 2019). Spaces can also have concrete and abstract properties. For example, a space can provide seating through physical objects and a buzz or positive energy through decoration and product arrangements.

2.2. Causal propositions about the relationship between space and creativity

Thoring et al. (2021) have laid the groundwork for a causal theory of creativity spaces in the form of 10 propositions about the relationships between spatial constructs and creativity (Figure 1). Each proposition is derived from expert interviews and supported by empirical findings from the literature. Broadly, each proposition has three kinds of constructs: space, mediators, and creativity constructs.

- Spatial constructs are abstract properties of spaces that can be realised by combinations of spatial elements.
- Creativity constructs comprise a range of variables such as cognitive abilities, creative processes and creative outcomes.
- Mediators ('explanations' in Figure 1) are the pathway through which spatial constructs facilitate creativity.

Each proposition is a probabilistic causal chain, describing how spaces can increase the probability that a particular creative construct will occur. For example, bookshelves, libraries and writeable surfaces can provide 'sources'. This can facilitate 'new connections' or 'recombinations' that may increase flexibility or fluency of idea production, respectively (Proposition 1 (Thoring et al., 2021)).

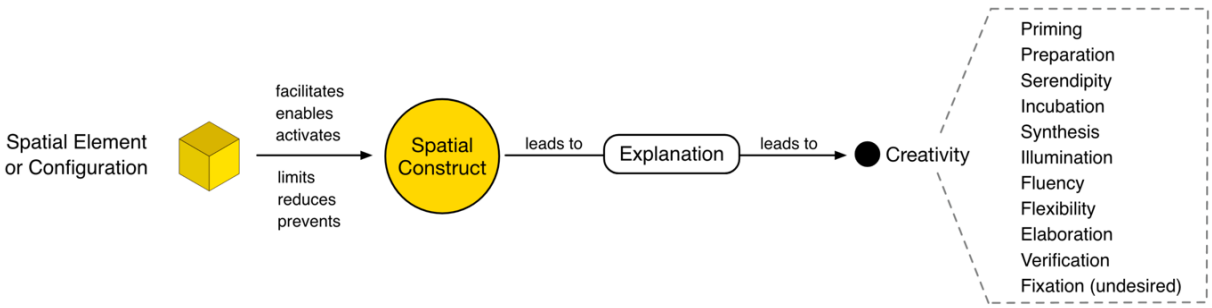

Figure 1. A generic proposition for a causal relation between space and creativity

The propositions lay the groundwork for a theory for predicting and explaining phenomena in creative spaces (see 'type IV' theories (Gregor, 2006)). The probabilistic causal relations provide a basis for prediction, and the explanatory mediators offer a basis for explanation. The explanations that have been put forward for the 10 propositions are adopted from empirical studies, including mindset priming (Sassenberg et al., 2017) and focused and diffused attention (Oakley, 2014). They provide a basis for

further research and hypothesis generation. Still, the explanatory constructs are not comprehensive, have yet to be validated empirically, and lack a unifying theoretical basis across the ten propositions, i.e., each proposition has different mediators drawn from different theories.

3. Methodology

Mediators were identified by compiling a list of experimental studies and analysing the sources. The goal was to identify mediators that have already been studied in empirical research. We took advantage of the collated articles in contemporary literature reviews (Lee and Lee, 2023; Meinel et al., 2017), which were relevant to creative spaces but had not focused on mediating constructs. Additional searches were carried out using keyword searches in Google Scholar, the Scopus database, and the AI-based search tool Elicit (https://elicit.com/).

Scope and inclusion criteria. The scope of the review is limited to experimental studies about physical environments, individual creativity, and objective measures of creative performance. Experiments were selected because they provide the best control over extraneous variables and thus are well-suited for making causal claims. Mediators were only included there was evidence of covariation between IV, mediator and DV or if the authors claimed a relationship exists. Physical environments include workspaces and learning environments, excluding digital screens and augmented or virtual reality environments. We exclude conceptual and mindset priming studies (Steidle and Werth, 2013 Exp. 1-3) as these primes are triggered by internally directed thought, rather than the properties of the environment. The search is constrained to individual creativity to facilitate an initial review but will be extended to group creativity in subsequent research. Objective performance includes creativity tasks but excludes, e.g., creative potential scales or subjective performance evaluations. Importantly, we do not assess the strength of the evidence for the mediators, as a quality assessment is far beyond the scope of this article (see Section 5.3).

Selected articles. A sample of 8 studies was compiled and reported in Table 1. The sample mostly overlapped with the experimental studies collated by Lee and Lee (2023), with the addition of one additional study (Ayuso Sanchez et al., 2018) identified through the unstructured searches.

Information extracted. We extracted the independent variables (IVs), creative tasks, and mediators tested in the experiment from the relevant articles.

Analysis. Mediators were inductively mapped against three construct classes which emerged during the review process. These were cognitive, affective, and physiological constructs.

4. Results

Table 1 provides an overview of eight journal articles comprising ten experiments that examine the mediators of space and creativity. The overview lists the source article and three characteristics of the studies. The independent variables (IVs) are elements of the spaces that were manipulated. The tasks refer to the creativity tasks that the participants completed. The 'mediators' column describes the construct that explains how the space influences creativity.

The studies investigate a variety of IVs, including room size (Chan and Nokes-Malach, 2016), the provision of light from daylight (Ayuso Sanchez et al., 2018; Stone and Irvine, 1994) and artificial lights (Lan et al., 2021), the presence of windows (Steidle and Werth, 2013), the angular or roundedness of rooms (Wu et al., 2021), the presence of plants (Ayuso Sanchez et al., 2018) and ambient noise (Mehta et al., 2012).

Creativity was measured using objective tests of performance. This predominantly involved tests of divergent thinking, such as the Remote Associates Task (RAT), where outcome measures included novelty and fluency (number of ideas generated). Some researchers also measured convergent thinking (Chan and Nokes-Malach, 2016; Wu et al., 2021) using the number of correct answers on, e.g., creative insight (A-Ha!) problems (Wu et al., 2021).

Table 1. Overview of the reviewed experimental studies, listing independent variables (IVs), tasks and proposed mediators.

Source	IVs	Creativity task	Mediator
[1](Ayuso Sanchez et al., 2018)	Daylight (from time of day) Greenery (from presence of plant)	Create mind maps of terms associated to a stimulus term	Activation of sympathetic nervous system Fatigue Subjective perception of workload
[2](Chan and Nokes-Malach, 2016)(Exps. 1-2)	Room size	AUT 'Shape Invention Task' (Figural Combination) RAT Letter series extrapolation	Direct priming Concept activation
[3](Lan et al., 2021)	Light temperate Light illumination	TTCT Spatial Insight Task AUT RAT	Mood (positive and negative affect)
[4](Mehta et al., 2012) (Exps. 2-4)	Noise: High (85 dB) Moderate (70 dB) Low (50 dB) No ambient noise	Idea generation (creative ideas for a new mattress) (Exp2) AUT (Exp3) Shoe-shine problem (Exp4)	Processing (dis)fluency Abstract thinking
[5](Shibata and Suzuki, 2004)	Room with: plant / book rack / no object Gender: male / female	Association task (generate up to 30 words associated to a given word)	Provision of Information Positive mood
[6](Steidle and Werth, 2013)(Exps. 4-6)	Brightness of direct light (exp. 4) Brightness of indirect light (exp. 5) Task (creative or analytical) (Exp. 6)	Creative insight problems (Exps. 4, 5 & 6). Logical reasoning problems (Exp. 6)	Perceived freedom from constraints
[7](Stone and Irvine, 1994)	Room (window or no) Window view (facing or perpendicular) Task (analytical, filing, creative)	20 items, details not reported	Stimulation Distractions
[8](Wu et al., 2021)	Angular or rounded professional work environments	AUT RAT	Approach motivation Avoidance motivation

Note: Numbers in square brackets [#] are used to correspond to the 'ref' column in Table 2. AUT = Alternative Uses Task. RAT = Remote Associates Task, TTCT = Torrance Test for Creative Thinking.

The mediators identified in the sample are defined in Table 2. Each mediator is associated with one of three classes that were derived inductively from the sample. Cognitive constructs (C) relate to the thought processes, cognitive abilities, or metacognitive judgements of the individual. Affective constructs (A) pertain to emotions, feelings, and mood. Physiological constructs relate to a person's bodily states and functions. Some constructs are primarily associated with a single class. Others, such as approach and avoidance motivation, involve cognitive, affective, and physiological aspects.

Table 2. Mediators of the influence of physical environments on creativity

Mediator	Definition	Explanation	Ref.	C	A	P
Abstract thinking	A measure of how abstractly people construe words or situations	Increased abstraction helps to avoid fixation, thereby improving creativity	[4]	x		
Direct priming	The goal directed search for resources in external space shares a common neural substrate with internal search	A sensitivity to free exploration leads a person to adopt a relaxed semantic search strategy that can lead to more distant and varied associations	[2]	x		
Distractions	Diversion of attention away from the task.	Not clearly specified	[7]	x		
Perceived freedom from constraints	A (potentially unconscious) feeling that one is not bound by constraints. "the subjective feeling that allows for risky and explorative processing."	Freedom of constraints elicits a global processing style, thinking about more abstract and remote associations	[6]	x		
Processing fluency	The subjective perception of how easily or quickly one can process information	Reduced processing fluency leads to more abstract thinking, allowing for more creative responses.	[4]	x		
Provision of information	Visual stimuli provide information to the viewer	Not clearly specified	[5]	x		
Stimulation	The opposite of distraction.	Not clearly specified	[6]	x		
Mood	Positive or negative affect (PANAS scale)	Not clearly specified	[5]		x	
	9-point semantic differential scale	Not clearly specified	[3]		x	
Sympathetic nervous system	The sympathetic nervous system releases hormones to increase heart rate	Not clearly specified	[1]			x
Feelings of fatigue	Subjective feelings of fatigue	Not clearly specified	[1]			x
Concept activation	The size of space evokes affective changes, e.g., confinement, freedom	The priming of a psychological state of openness or freedom induces information processing that is less constrained.	[2]	x	x	
Workload	Subjective perception of workload for a given task	Not clearly specified	[1]	x	x	
Approach motivation	The direction of behaviour towards positive stimuli	Improvement of cognitive flexibility by encouraging risk-taking, the breaking of contextual sets, restructuring and exploration behaviours, and the search for new responses and strategies	[8]	x	x	x
Avoidance motivation	The direction of behaviour away from negative stimuli	Avoidance motivation induces people to comply with rules and norms, focus on details, and seek out the optimal solution to a problem	[8]	x	x	x

Note: table ordered by class from most to least numerous, then alphabetically. C = cognitive, A = affective, P = physiological, E = evolutionary.

4.1. Cognitive mediators

Cognitive constructs are those that relate to the thought processes of the creative individual. Most of the mediators (11/14) involved some cognitive component, and half (7/14) were primarily cognitive, meaning they did not explicitly involve any affective or physiological components.

The cognitive mediators facilitate creativity by enhancing ideation-related cognitive processes. Examples include avoiding fixation, moving flexibly between ideas and finding remote associations in semantic knowledge.

One explanation for the relationship between spaces and creativity is the provision of information via visual stimuli. The 'provision of information' and 'stimulation' mediators are not clearly defined but appear to refer to enhancing creativity via visual stimuli. Visual stimuli can provide search cues for associative memory search processes (Nijstad and Sroebe, 2006) and facilitate analogical reasoning (Fu et al., 2013). Contrary to the positive effects of visual stimuli, excessive stimulation may cause 'distractions' and divert attention away from a creative task (Stone and Irvine, 1994). Although the mechanism for this effect is unclear, it could be enabled by extraneous processing and excessive cognitive load (Mayer and Fiorella, 2014).

Encouraging abstract thinking can help to overcome fixation effects and allow people to explore associations more broadly (Zahner et al., 2010). Abstract thinking can be triggered indirectly by ambient noise. Mehta et al. (2012) show that excessive ambient noise can lower idea fluency (a metacognitive judgement about one's ease and speed of idea production), which in turn causes people to engage in more abstract thinking. Dark environments are also said to encourage abstract thinking by inducing a feeling of freedom from constraints which results in a 'global processing style' that involves abstract thinking and the finding of remote associations (Steidle and Werth, 2013). These examples also show how multiple cognitive mediators can be chained together in serial, with metacognitive judgements causing abstract thought.

A third kind of mediator is the induction or 'priming' of cognitive states. Chan and Nokes-Malach (2016) investigate two riming effects. 'Direct priming' posits neurological commonalities between the externally directed search for resources in a physical space and the internally directed search through memory. Large environments afford the ability to move freely and explore. This then engages changes in semantic search strategies that involve greater exploration and can reach more semantically distant and varied associations. 'Concept activation' is the priming of affective states, which in turn have downstream effects on cognitive information processing. For example, large spaces may prime feelings of freedom or openness, which then induce less constrained information processing.

Approach and avoidance motivation are multi-faceted constructs that support cognitive flexibility. Approach motivation refers to an organism being energised by, or energised in the direction of, positive stimuli. Avoidance motivation is the opposite, the energisation of behaviour by, or away from, negative stimuli. Stimuli can be, e.g., objects or events, and positive or negative stimuli. Wu et al. (2021) apply these concepts to compare rounded workspaces (rounded shapes, lines, forms and furniture) to angular workspaces. They conclude that rounded workspaces are conducive to divergent creativity as they induce positive feelings such as harmony and low stress. This enhances creativity as people are encouraged to engage in behaviours that improve cognitive flexibility, such as taking risks, restructuring ideas, and exploring more broadly. In contrast, an angular work environment enhances convergent thinking through a similar but opposite mechanism.

Finally, reductions in self-perceived workload have been proposed as a mediator of creativity (Ayuso Sanchez et al., 2018), but the nature of this effect is not articulated.

4.2. Affective mediators

Affective constructs relate to experiences of feelings or emotions. Of the four constructs that involved affective aspects, mood (measured in two independent studies) was the only one that was primarily affective. The temperature and illumination of lights in a room (Lan et al., 2021) and the presence of plants (Shibata and Suzuki, 2004) have been said to improve mood and creativity in turn. However, the role of mood in enhancing creativity is not elaborated upon further.

Some mediators were hybrid cognitive and affective constructs. For example, Chan and Nokes-Malach (2016) note that 'concept activation' may involve affective changes such as the association of positive

valences to feelings of freedom. For perceived workload, (Ayuso Sanchez et al., 2018) used the NASA TLX questionnaire, which includes self-assessment of one's degree of frustration (Hart and Staveland, 1988). According to the Hierarchical Model of Approach-Avoidance Motivation (Elliot, 2006), approach and avoidance motivation are also partly based on affective factors.

4.3. Physiological mediators

Two of the mediators were primarily physiological constructs, meaning that they related to an individual's bodily state or function. Ayuso Sanchez et al. (2018) suggest that increased daylight in the workplace could improve creative performance via activation of the sympathetic nervous system (increased heart rate) and a reduction in feelings of fatigue. Fatigue was measured using the 'Jikaku-sho Shirabe' questionnaire (Tachi, 2003), which comprises 25 items across five factors: sleepiness, unstable feeling, unpleasantness, tiredness, and blurriness. Approach and avoidance motivation also involve 'neurobiological sensitivity' to positive or negative stimuli and so are partly rooted in human physiology.

5. Discussion

With the research reported in this article, we set out to answer the question: "What are the potential mediators of the relationship between creative spaces and cognition?". We did so to fill a gap in knowledge about the constructs that can provide explanations for the relationship between spaces and creativity. To address this question, we reviewed experimental studies in which elements of physical spaces are manipulated, and their influence on creative outcomes is measured. In a review of 8 journal articles comprising 10 experiments, we identified 14 constructs that have been investigated as mediators of creativity. The constructs were examined to show whether they involved cognitive, affective, or physiological aspects. The answer to the research question is illustrated in Figure 2, which shows the 14 potential mediators of the relationship between space and creativity, situated in the context of the generic causal propositions developed by Thoring et al. (2021) (Figure 1). 'Space' represents the collection of spatial elements manipulated in the experiments (Table 1). 'Creativity' refers to the creative outcomes measured in the experiments. The 'potential mediators' show the same fourteen mediators listed in Table 2.

In this discussion, we assess the findings in the context of the broader literature and discuss the near-term implications and applications of the work. Importantly, we qualify the findings in the context of some the limitations of the review and outline some next steps for developing a causal theory of creative spaces.

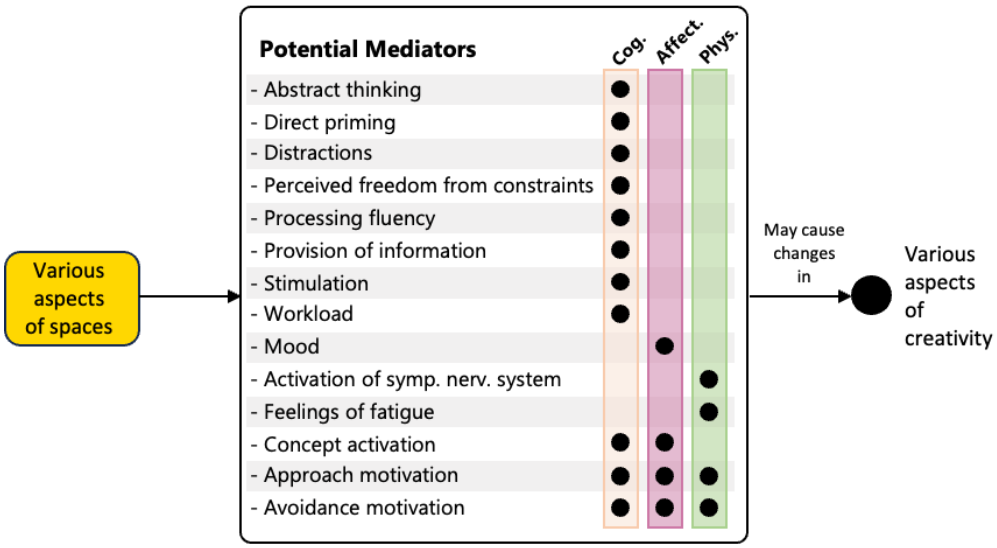

Figure 2. Fourteen potential mediators of the relationship between physical spaces and creativity, showing whether they involve cognitive, affective, or physiological aspects

5.1. Novelty and comparison with existing research

The list of mediators shown in Figure 2 is a novel contribution to research on creative spaces. It is the first look at the constructs that may mediate the relationship between physical spaces and creativity. Our work provides unique but complementary advances to previous research. First, our findings fill a gap in knowledge in prior literature reviews. Prior studies have examined the relationships between elements of physical spaces and creative outcome measures Field (Martens, 2011; Meinel et al., 2017), but have not examined the mediators of those relationships. Secondly, our findings provide a platform for unifying the ten causal propositions put forward by (Thoring et al., 2021). These propositions are currently independent but could be integrated into a cognitive, affective and psychological theory that accommodates multiple potential mediators.

The reviewed literature is also missing some important elements that prior works have captured. For example, the spatial elements in the reviewed studies in Table 1 (e.g., room size and light temperature) cover a narrow range of those that have been associated with creative outcomes (see: Martens, 2011; Meinel et al., 2017; Thoring, 2019). A second missing aspect of the reviewed studies is the breadth of creativity constructs that are measured. All 13 experiments measured the properties of ideas, such as novelty or utility. As introduced in Section 2.1, creativity can also be considered in the 'person' or 'process' dimensions (Rhodes, 1961). In design, for example, creativity is associated with cognitive ability (Campbell et al., 2023), i.e., the person dimension, and the heuristics and methods that a designer uses (Chulvi et al., 2012), i.e., the process dimension. Some studies in the reviewed literature address creative abilities or processes. For example, approach motivation is said to improve cognitive flexibility in various ways, including the search for alternative strategies (Wu et al., 2021). However, the experiment does not include any measures of the activities or strategies enacted by the participants.

5.2. Implications

Our findings have near-term implications for research on creative spaces and longer-term consequences for the development of a causal theory of creative spaces. In the near term, knowledge of the potential mediators of spaces and creativity can support experimental research by helping researchers control for extraneous variables. For example, if mood and feelings of fatigue mediate the relationship between space and creative performance, researchers may wish to control for these variables through pre-study participant filtering or covariate analyses. A second implication is that interventions can have an unexpected influence on outcomes via multiple mediators. For example, the provision of views via windows may provide information (Shibata and Suzuki, 2004) or stimulation (Stone and Irvine, 1994). However, if that window is also square or rectangular, with multiple intersecting lines creating sharp corners, it may also elicit avoidance motivation compared with a round window. Depending on the direction of effect from these independent variables, researchers may uncover compound benefits for creativity or may inadvertently introduce opposing effects.

The results also indicate show that some of the mediators are more developed than others. Some are poorly specified (see the 'explanation' column in Table 2), such as the role of the sympathetic nervous system in creative spaces. Others are more developed and relatively more complex. For example, it has been shown that processing fluency and abstract thinking have a complex but overall beneficial relationship in the context of creative spaces. This implies that in some cases, single mediators may need to be broken down into more complex systems of interconnected constructs.

In the longer term, the list of mediators can set the stage for the development of a causal theory of creative spaces. The findings show that the relationship between space and creativity is likely multi-faceted and complex. Mere 'lists' of mediators will not be sufficient to capture these interactions. Rather, a causal theory of creative spaces may need to accommodate interactions between cognitive, affective, and physiological systems.

5.3. Limitations and future work

The review presented here provides a first look at creative space mediators but has limitations that could be overcome with further research. First, the mediators assembled here are not a comprehensive list of all constructs that could explain the relationship between spaces and creativity. Our review is limited to

experimental studies that explicitly examine creative space mediators. More mediators could be identified through exploratory, hypothesis-generating research using a variety of qualitative and quantitative methods.
Secondly, we emphasise that we have not performed a quality assessment on the sample. The mediators shown in Table 2 and Figure 2 are those which researchers have measured using controlled experiments, but we have not assessed the validity of the claims about the role of these constructs as true, causal explanations for the relationship between space and creativity. Until such an assessment has been conducted, we urge researchers and practitioners not to be cautious when making inferences about the role of these constructs in creative spaces.
Third, we note that our mapping of constructs to the three classes of cognition, affect, and physiology has not been validated. Indeed, there are likely other ways to conceptualise these constructs (see Figure 3 in Moosavian (2022) for an example in the domain of aesthetic experience).

6. Conclusions

To develop a causal, explanatory theory of creative spaces, there is a need to establish the constructs that mediate (explain) the performance between spaces and creativity. To this end, we synthesised findings from controlled experiments to identify 14 constructs that mediate the relationship between physical indoor spaces and creative ideas (Figure 2). We conclude that the relationship between spaces and creativity is likely mediated by a complex set of cognitive, affective, and physiological constructs.
In the near term, the work can support researchers in reasoning about extraneous variables and selecting control variables. Further research is required to broaden the literature sample, assess the quality of the claims made in the source articles, and combine the findings with knowledge about design processes and activities. In the future, a causal theory of creative spaces that includes these mediators could help designers to create spaces that fulfil the creative needs, desires, and capabilities of their occupants, contributing to a more creative and productive society.

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