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Introduction

1 This paper confronts and summarises some reflections from a Ph.D. project (Canepa, 2019) predominantly focused on the exploration of the nebulous dimension of architectural atmospheres. This scientific research path provided an unprecedented opportunity to test an interdisciplinary approach, aimed at integrating artistic and theoretical considerations about architectonic space with quantitative, reproducible methods, purposely designed to assess the real emotional responses of subjects to spatial conditions. Our objective was to analyse atmospheric dynamics with two interrelated academic disciplines: architecture and neuroscience. More recently, these two disciplines have started to interact, both in the combination of their theories and through experiment-based investigations.

2 In short, we can define the atmospheric dimension as the domain where the experiential vocation of architecture takes place, that which rises from the physical nature of the built environment to subsequently transcend it. Atmosphere, in fact, concerns both the measurable field of the physical parameters of the built environment and the evanescent one of personal feelings. As a whole, atmosphere behaves as the sign impressed on our senses and our intellect by the experience of architectonic space. Even if the atmospheric aura is not instantly perceivable, we cannot separate architecture from it. "Whether people are fully conscious of this or not, they actually

derive *countenance* and *sustenance* from the atmosphere of the things they live in or with. They are rooted in them just as a plant is in the soil in which it is planted" (Wright, 1954, as cited in Pfeiffer, 2010, p. 350). The primary goal of our study was to understand the core meaning and the mechanisms of action of architectural atmospheric perception (Pallasmaa, 2014). Afterwards, a digression into the cognitive neuroscience field came from an attempt to explore new topics, useful in resolving architecture's atmospheric enigma.

3 Inside the lexical scope of the architectural discipline, *atmosphere* initially seems to be a familiar, comprehensible, and harmless word. However, by exploring its profound, intimate meaning, it reveals itself to be uncertain, ambiguous, and unintelligible. *Atmosphere* is "a state that is hardly defined not because it is rare and unusual but, on the contrary, because it is as omnipresent – even though at times unnoticed – as the emotive situation" (Griffero, 2010, 2014, p. 1). By analysing the origin and evolution of this term, its mysterious and vague character emerges on three different levels: in its semantic, ontological, and epistemic sense (Rauh, 2017). Atmosphere is a complex phenomenon because it is invisible, intangible, elusive, without physical limits, unstable, instinctive, highly subjective, and often described through metaphors. Essentially, atmosphere is an orphan – by inherent inertia – of a precise identity. Many authors have written about the impalpable nature of the atmospheric concept. One of the first to express this notion was Mark Wigley in his seminal article of 1998, which has become, over time, the cornerstone of atmospheric-domain investigation. "Atmosphere escapes the discourse about it. By definition, it lacks definition. It is precisely that which escapes analysis. Any specific proposal for constructing atmosphere, no matter how changeable or indeterminate, is no longer atmospheric" (p. 27). However, the difficulty, if not even the impossibility, of resolving the atmospheric issue is equal to the urgency of finding a clear and – if possible, scientifically grounded – understanding.

4 At least in the last two decades, investigations about atmosphere, aimed at comprehending, experimenting, and visually representing its expressive qualities, have been drawing unprecedented attention. From the end of the 20th century, some scholars have even identified an 'atmospheric turn' (Soeteng, 1998, as cited in Griffero, 2010, 2014, p. 3). The architecture community has significantly delayed its entrance into this current, multidisciplinary discussion about atmospheric dynamics, unlike some other fields of academic research, such as aesthetics and phenomenology, which have already considered the atmospheric problem in the design process at different scales (from urban planning to design products). Therefore, our work intended to explore the atmospheric issue from an independent, architectural perspective, by studying the topic throughout the sensory-emotional filter of the perceiving subject located in the built environment.

5 From a methodological point of view, our research is organised into five main operating phases.

Phase One: A definition problem

6 Our primary reflection was to produce a more precise definition of atmosphere in order to clarify the boundaries of our research domain: what is architectural atmosphere? Or, perhaps more saliently, does it make any sense to ask about the meaning of

atmosphere, whilst it seemingly avoids any stipulative definition? The belief in a positive response encouraged our group to go beyond the identification of a simple definition, searching – paradoxically – for an objective and scientific definition. Therefore, we established a univocal semantic explanation, with the aim of formalising a concept that had been defined, until now, mainly through metaphors and 'ineffable' expressions [1]. The first necessary step concerned the etymology of the word *atmosphere* and its evolution. Afterwards, we mapped the whole taxonomy of semantic declinations that are recognised by architecture. In other words, we have tried to answer the questions: what is atmosphere for architects? What has its significance been throughout the history of architecture?

7 Although the word *atmosphere* is derived from two Greek terms [2], it does not belong to the ancient Greek's lexicon. Originally coined in Flemish (the compound word *dampcloot*), the Latin neologism *atmosphaera* (created in 1608 by the Dutch astronomer Willebrord Snellius, translating his compatriot Simon Stevin's cosmographical writings) diffused into European languages from the middle of the 17th century (Martin, 2015, p. 44). Intended in its literal meaning of 'vapour-ball', the term was especially present in cosmological and meteorological essays. However, during the 19th century, a more figurative interpretation of this meteorological term bloomed. With the Romantic age, the word *atmosphere* assumed new cultural inflections, becoming a semantic medium capable of describing intersubjective relations of varied nature (social, psychological, sentimental, and ethical), not only between two or more individuals, but also between an individual and their physical surroundings. "And yet Romantic atmospheres destabilised [the] modern dichotomy of literal reference versus illusory figuration. They were sensory structures of communicable feeling, at once somatic and ideal, aesthetic and material, affective and conceptual" (Ford, 2018, p. 20). This composite semantic evolution is the result of a very complex and non-linear genealogy (Riedel, 2019, p. 56-88). As time went by, some semantic meanings disappeared: "with advances in scientific knowledge about the human body, the term 'atmosphere' became", for example, "largely obsolete as a medical term by the early 19th century" (p. 87). In the present day, the contamination between the literal meaning and the figurative allusion is complete: the flexible nature of the expression *atmosphere*, a refined balance between specialist and indeterminate, has fostered the dispersion of that term among the different branches of human knowledge. Many disciplines have developed specific meanings, resulting from their own procedural perspectives. Indeed, we find distinct and autonomous explanations of the atmospheric concept in several fields, such as physics, meteorology, acoustics, law, medicine, philosophy, literature, cinema and theatre, music, art and, finally, architecture.

8 Nowadays, the atmospheric approach represents a nerve element both for the design practice and for the critical comprehension of architectural subject matter. Despite this, its semantic spectrum struggles with determining its own boundaries. It is not easy to clarify when the atmospheric topic started to circulate in the architectural domain. As Harry Francis Mallgrave (2018, p. 121) outlines in his reconstruction of the word's evolution, it is likely that the first architect to introduce the word *atmosphere*, within a work pertinent to the architectural discipline, was the German Gottfried Semper in 1860. According to Mallgrave, at the beginning of the 20th century, the term *atmosphere* became "relatively common in a few design circles" (*ibid.*), but later disappeared into anesthetising oblivion, from the middle of the century. Atmospheric

sensitivity rose again after some decades thanks to the aesthetic awakening promoted by Gernot Böhme, founder of the *Neue Ästhetik* (1991, 1993, 1998, 2001, 2006, 2013, 2017). From our point of view, it seems that the vocable *atmosphere* has continued to be present within the expressive background of designers, just transforming its own appearance (replaced by synonyms and foreign substitutes [3]), but never contextualised in a precise and shared way.

9 In the most renowned Italian architecture encyclopaedias and dictionaries, there is no trace of the word *atmosphere* (Portoghesi, 1968; Pevsner, Fleming & Honour, 1966, 1992), not even in its techno-physical inflection. Conversely, atmospheric influence emerges from the lexicon spontaneously used by certain architects and affects the linguistic register of some contemporary magazines (Romano, 1941; Albini, 1954; Bucci, 2005). Free to not respect a restrictive semantic boundary, the atmospheric element extends within the vast landscape of admitted interpretations, progressively acquiring a rising autonomy. A demonstrative example of that trend is the critical design column *Meteorology*, edited by Philippe Rahm and hosted, for the whole of 2018, in the magazine *Domus*, directed by Michele De Lucchi. Here, developed in a specific domain (an original synthesis of physiology, thermodynamics, and climatology), atmosphere surges ahead as a founding act of the architectural discipline:

> architecture is basically the design of the atmosphere. […] Rather than reasoning in terms of grid, structure, symmetry and form, we must learn to reason in terms of convection, conduction, emissivity and effusiveness. Rather than working in brick, concrete, steel or wood, we have to work with light, heat, shade or moisture (Rahm, 2018, no. 1020, p. 107).

10 Architecture's domain, grounded in its autonomy, but at the same time deeply influenced by external stimuli, has gathered an undefined miscellany of semantic meanings around the atmospheric topic. Within this incoherent network of interpretations, we are able to recognise a wide spectrum of expressive variations, some more accepted and employed than others. In summary, the totality of definitions about architectural atmosphere admits at least eleven categories of sense:

1. atmosphere as *an environmental-control condition* (that is an artificial microclimatic bubble, able to influence the psychophysical comfort of individuals through the manipulation of thermic, hygrometric, and physical-chemical factors in the composition of indoor air);
2. atmosphere as *a meteorological staging* (that is a scenic design procedure, working together with the light and the phenomena proper of the Earth's atmosphere, such as clouds, hazes, air flows, or lightning);
3. atmosphere as *an aesthetical-decorative quality* (found in the external covering of the architectural object or, more appropriately, in its decorative apparatus, independent from surrounding environmental conditions);
4. atmosphere as *the innate and distinctive identity of the place* (that is the *genius loci*, commonly interpreted as the 'spirit of the place');
5. atmosphere as *the collective imaginary* (the outcome of the *Zeitgeist*, the 'spirit of the age', that rises as the vehicle of values typical of a community: social, ideological, political, and holy values);
6. atmosphere as *a metaphor* (linked to the integrative power of words and imagination, capable of evoking a missing physical presence or of delineating particular qualities that transcend the domain of concrete and material);

7. atmosphere as *the constitutive character* (that is an expressly designed identity, able to confer an explicit and unequivocal appearance to a specific space, drawing an emotional, sentimental, social, ideological, moral, or spiritual connotation);
8. atmosphere as *the aura* (that is the inherent trait of authenticity and uniqueness emerging from the architectonic work);
9. atmosphere as *a collector of memories* (linked to the personal past, a synthesis of intimate experiences lived and subconscious associations);
10. atmosphere as *a perceptive experience* (that is the perceptive tension among the architectonical features of a place and the subjective sensitivity of the individual immersed in that spatial domain);
11. atmosphere as a *mood* (that is the emotional tonality radiated by the surroundings and attuned to the temporary state of mind or feeling of whoever stays in that space).

Phase Two: Background matter

11 Having analysed the atmospheric question within the usual disciplinary confines of architecture, we had to tackle a delicate issue: we crossed the disciplinary boundaries and prepared an appropriate critical and theoretical background that would enable a clear understanding, by the architecture community, of neuroscientific aspects within the context of architectural atmosphere. Many disciplines, over the centuries, influenced the interpretation of architecture, opening innovative possibilities of theoretical and experimental investigation. Our decision of having a confrontation with the neuroscientific culture is due to the purpose of observing the architectural experience through new insights, even if preliminary and not complete. The exploratory study illustrated below is only the first step towards more neuroscientifically grounded tests. Neuroscience is our starting speculative premise: the approach to this discipline is mediated by phenomenological, behavioural, and aesthetic theses.

12 The contribution of neuroscience is crucial in examining sensorial, emotive, and cognitive mechanisms in perceptual dynamics. Neuroscience inquiries into mental functions (in other words, the processes arranging mental activity, including memory, imagination, thought, reasoning, and motor planning), studying the anatomy and physiology of the nervous system from a strictly biological perspective. In the last decades, thanks to the introduction of advanced techniques of neurophysiological analysis and neuroimaging, neuroscience has seen a great expansion, turning into the core of many interdisciplinary research projects. Nevertheless, until now, its application in the design field has been scarce. Therefore, before testing the results of a possible interrelation between architecture and neuroscience, there are some initial and fundamental issues that must first be deliberated. Primarily, why should and how might neuroscience be useful in the practice of architecture?

13 New, experimental hypotheses on human experience in the built environment have the potential to provide the design process with a renovated, scientific rigour, which is necessary for many scholars. Currently, highly developed techniques of neurophysiology and neuroimaging are available. Their combination with more familiar procedures for the design activity (*i.e.* the virtual reality simulation) could foster the evolution of the study of how people perceive, imagine, and interpret textures, colours, distances, proportions, that is to say the totality of physical,

sensorial, and material properties that define a room or an urban landscape. Architecture and neuroscience were separate branches of knowledge until we acquired the awareness that the human brain develops in a continuous condition of adaptation to the variations of surrounding physical space. The involvement of architecture was, at that point, inevitable. In the last ten years, the architecture community has begun, with ever-increasing enthusiasm, to advocate the utilisation of neuroscientific research. Among others, Harry Francis Mallgrave (2010, 2013a, 2013b, 2018) and Juhani Pallasmaa (2013, 2015, 2018), academics who have dedicated themselves for a long time to the history and critique of architecture within the canonical boundaries of the discipline, have promoted the propagation of neuroscientific education for designers and architecture students.

14 On account of their differences, architects and neuroscientists have to assume complementary roles in this interdisciplinary discussion. On the one hand, the neuroscientific side is encouraged to inform architects about how design choices impact perceptual mechanisms; on the other, designers have to formulate appropriate questions, to which neuroscientists can apply their powerful analytical instruments. In other words, architects are needed to clarify problems, to translate them into valid and accurate questions, and to present them to neuroscientists, who then have to find answers [4]. A fundamental operation is identifying what we want to supervise and what we want to measure; most of all, we have to clarify the aim of this exercise of interdisciplinary collaboration. The preliminary step in determining the scope of research is – undoubtedly – a task for architects. The architect has to focus and formalise a theory that will be tested by experiment. It is not, and should not be, the prerogative of neuroscientists to produce architectonical theories. They should only be called to provide concepts and methods to the architectural community, useful for their integration into new theoretical presuppositions on spatial perception. As designers, the most dangerous mistake would be to insist on confirmations from experimental data on that which is a priori assumed.

15 Dealing with neuroscientific subject matter as non-specialist scholars, highlighting benefits and limitations of a neuroscientific approach to architectural research, and summarising a compendium of the main neuroscientific contributions, which have already been developed in the academic literature of aesthetics and architecture, have been preliminary considerations, essential in analysing and framing the proper investigation domain where we have contextualised this research project. This kind of investigation background is not familiar within the architecture community. This is why creating it has been so fundamental: we have provided it with the opportunity to validate and defend itself. This having been achieved, we were then able to undertake the next phase of our study: the finalising of an original architectural hypothesis (the personal definition of the atmospheric phenomenon), with which we have tried to match limited numbers of specifically chosen neuroscientific models. We were interested in evaluating the existence of a neurobiological basis of atmospheric perception that would underscore the importance of the physiological origin of spatial interactions, conscious of the need of moderating the neuroscientific initiative and relying on exploratory studies – not yet supported by neurophysiological measures.

Phase Three: The hypothesis

16 Once the widespread network of interpretations of atmosphere moulded by the architecture community was examined, this research project chose to work with the category of atmosphere as a *perceptive experience*. This is our starting hypothesis. Through its inherent spatial presence, architectural action instils an emotional potential in the physical environment, shaping the ground for architectural atmospheric perception. In this multisensory and multimodal condition, we suppose that the human being internalises and simulates some of the features of built space.

17 Thus, the term *atmosphere* defines a state of resonance and identification (sensorimotor, emotive, and cognitive) between an individual and their surrounding built space. This interpretative horizon, inspired by phenomenological and embodied cognition theories, compares itself with some principles developed by modern cognitive neuroscience. The premise is that "an atmosphere is not simply a space but a combination of space and activity – something produced by the people within the space" (Thibaud, 2014, p. 71). Atmosphere originates from the contact, immersive and absolute, of the perceiving subject with the architectonic landscape, exciting their emotional responsivity and influencing their cognitive abilities. In the exchange of impulses and reactions between the body-brain unit and the physical environment, there is a bidirectional and mutual influence.

> In summary, the brain controls our behavior, and genes control the blueprint for the design and structure of the brain, but the environment can modulate the function of genes and, ultimately, the structure of our brain. Changes in the environment change the brain and therefore can change our behavior (Cage, 2009, p. XIV).

Somatosensory information detected by exteroceptive sensory systems (*i.e.* the skin) and proprioceptive ones (*i.e.* the muscles) joins the information registered from the peripersonal and extrapersonal space (including visual, acoustic, and olfactory stimuli). The activation of remembered emotional and motor patterns, and mental representations modifiable by experience trigger perceptual mechanisms that decode every external spatial event. As highlighted by Richard Neutra:

> [...] through the process of respiration the organism is chemically so united with its environment that the two can be separated only in the abstract way in which we separate the water of two tributaries which have flowed together into a common river bed. Organisms are immersed to fusion in their chemical as well as their social setting; *they literally live on and in one another* (1954, p. 12).

18 Consequently, we hypothesised that the human body might establish an empathic link with the surrounding built environment, interiorly simulating some architectural features such as form, proportion, rhythm, materials, light and shade, temperature, and sounds [5]. This experience would allow the perceiver to intuitively comprehend their immediate surroundings. Namely, the atmosphere contributes to activate and define the empathic connection between an animate subject (the individual) and an inanimate object (their architectural environment). Thus, atmosphere becomes the *empathic medium* of the architectonic object. This empathising experience has been analysed, by this study, through the interpretative filter provided by the *Embodied Simulation Theory* (Gallese, 2005; Freedberg & Gallese, 2007; Gallese & Sinigaglia, 2011). The supposed neural correlates of this functional process are the mirror neurons. They prove to be able to translate the sensorial qualities of an observed object, or an

observed action, into motor programmes for interacting with those objects. Every architectonic landscape, by its atmospheric epiphanies, likely resonates with the subpersonal components of the individual and, consequently, is internalised as a subjective experience. Establishing a connection with a building, a room, or an architectural element might imply, therefore, a spontaneous simulation of the motor acts and emotions evoked by those spaces and those objects (Gallese, 2015, p. XIII). Subsequently, we supposed that the architectural scene sets up an *atmospheric continuum*, the substrate of sensorial, motor, and emotional reactions that influence the behaviour and the mood of the individuals interacting with that environment.

19 In short, we have outlined a neuroscientific theoretical background for organising the atmospheric phenomenon in architecture. There are five critical elements of this personal interpretation:

1. the multisensory and synesthetic nature of perceptual processes;
2. the prerequisites of the *Embodiment Theory*, which emphasise the role of the corporeal self;
3. the emotional nature of the architecture experience;
4. the hypothesis of neurophysiological empathy;
5. neural mirroring mechanisms.

This integration with theories of neurobiological origin emerges not to reinforce the conceptual and cerebral component of the architectural activity, but to promote the centrality of the body in architectural perception. Using this knowledge, we now have an architectonical theory about atmospheric perception. This precise definition of the concept of atmosphere might be included in a dictionary of architecture, so as to fill the existing gap.

Phase Four: The testing challenge

20 The challenge that this study posed was to confirm – using experimental methodology – the validity of the architectonical theory that we have here assumed about atmosphere. In other words, we wondered if it is possible to scientifically evaluate and map architectural atmospheric perception, determining which architectural features principally ignite atmospheric tension, on the basis of emotional sensitivity. In order to answer this question and, thus, to better understand the relationship between architecture and neuroscience, we designed and undertook an experiment. We proposed to verify the existence of an empathic reaction in subjects put in contact with architectural settings, loaded with variable arrangements of atmospheric tension. The aim was to determine if this supposed empathic performance is shared among subjects and gradable as a model in architectural theory – according to the scientific principle of objectivity and replicability. Even though we had previously defined atmospheric dynamics as a state of resonance and identification (sensorimotor, emotive, and cognitive) between an individual and their physical surroundings, the focus of our experiment was specifically to study this phenomenon at the emotive level. That is, we attempted to measure ‘our feelings’ for architecture by those emotions that we hypothesised would be capable of orchestrating the *atmospheric continuum*.

Participants

21 We took a homogeneous sample of 205 adults, of mixed sex (83 males and 122 females), of the same age range (20-35 years) and the same sociocultural milieu (they were, in fact, almost all students, scholars, or professionals working in the architectural design field), as summed up by Table 1. The subjects had no history of psychiatric or neurological illness. All candidates were naïve to the purpose of the experiment and they gave written informed consent before participation. The experimental protocol was approved by the ethics committee of the University of Genoa and carried out in agreement with legal requirements and international norms (Declaration of Helsinki, 1964).

Table 1: Participants characteristics (no. = 205): mean values ± standard deviation

Participants no. (%)	**Males**	**Females**	**Total**
	83 (40.49)	122 (59.51)	205 (100.00)
Age (min. 20 – max. 35)	24.84 ± 3.26	23.34 ± 2.39	23.95 ± 2.86
B-IRI score (min. 16 – max. 80)	52.04 ± 6.16	55.98 ± 7.00	54.38 ± 6.93

Experimental procedures

22 Prior to the primary experimentation, we examined our subjects using a brief form of the *Interpersonal Reactivity Index*, called B-IRI (Ingoglia, Lo Coco & Albiero, 2016), in order to evaluate their disposition to empathic responsiveness. Thereafter, every candidate interacted with twenty-one digital project settings – that is, with twenty-one three-dimensional models simulated in virtual reality (VR). Participants were asked to enter and walk in a 1:1 wooden construction (the physical set-up for experimental sessions that we named the 'atmospheres box'), wearing a VR headset (model: *Oculus Rift*) equipped with a touch controller (see Figures 1, 2, 3).

Figure 1: The 'atmospheres box' that hosted all experimental sessions

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Figure 2: Inside the 'atmospheres box', during a VR testing session

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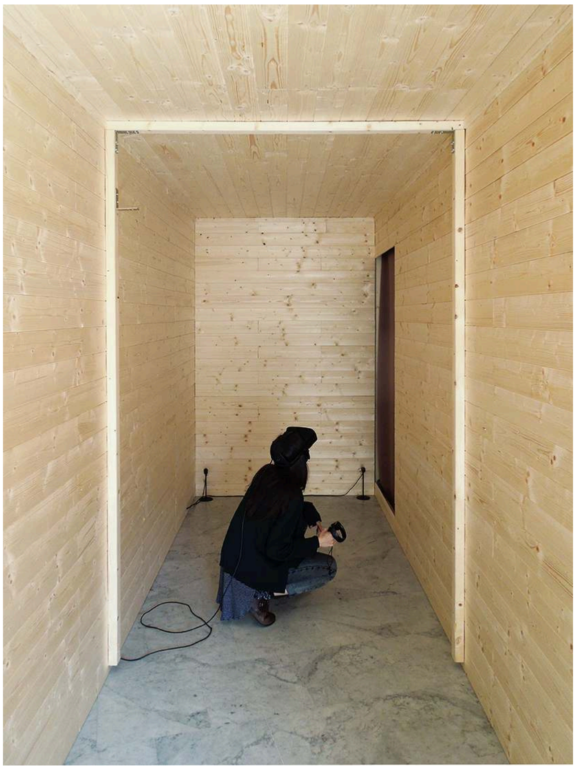
Figure 3: Inside the 'atmospheres box', during a VR testing session



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23 The preferred case study was the spatial unit of the corridor, chosen for several reasons:

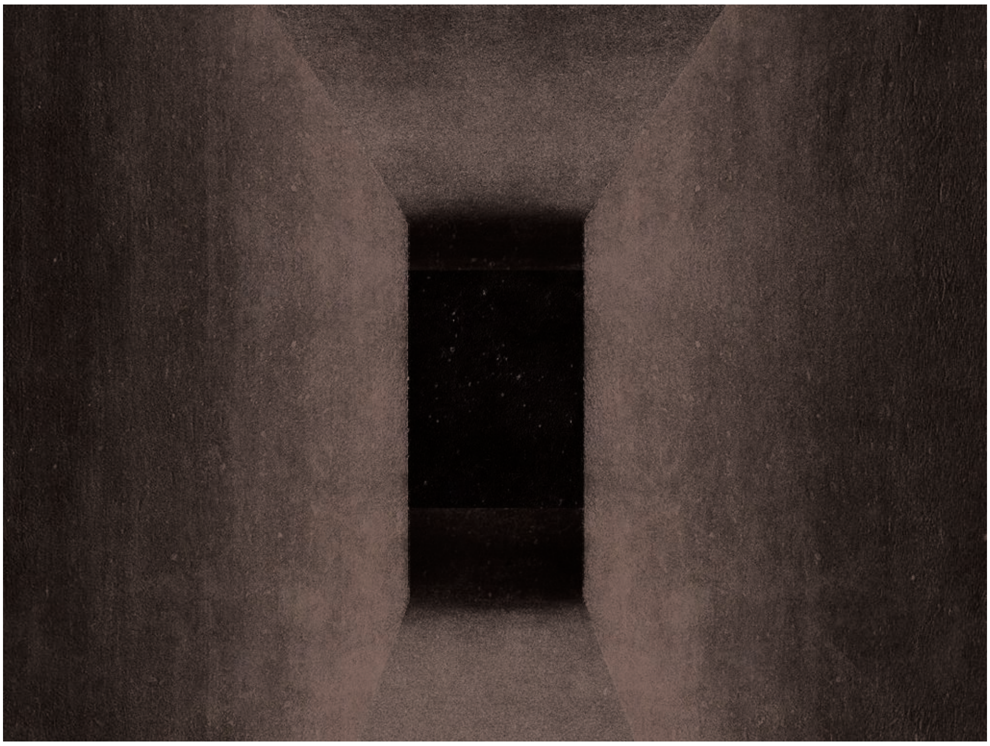
- the corridor is a primary unit of architectural construction;
- Rem Koolhaas defines the corridor as one of the fifteen fundamental elements of architecture (2014);
- it is a universally accepted distributive structure;
- it is a global building element, able to delimit physical space into a whole and independent form;
- it is used as a system of control, connection, direction, and movement;
- it can manage and organise void;
- it is based on an essential constituent anatomy (*i.e.* walls, floor, roof, accesses, and even windows);
- there are a lot of design variables that can be combined in its definition (*i.e.* dimensions, proportions, surface treatment, colours, and light conditions);
- it is an architectural setting strongly characterised in terms of emotional responses (in the collective imaginary corridors are often lonely, dark, risky, or interminable passages);
- it is a spatial paradigm that has already been studied from psychological and functional perspectives, especially in the case of patients with cognitive impairment;
- and, finally, the corridor is restrictively regulated by building code standards.

24 In our experiment, the baseline corridor (BC) was typical of a private residential building, at 1.20 metres wide and 2.70 metres tall, with smooth finished concrete walls,

floor, and ceiling (cf. Figure 4). The choice of concrete depended on multiple considerations:

- its aesthetic properties (such as its colour gradation, texture, and porosity) are noticeably perceivable;
- its monomaterial and monochromatic essence helps to configure the most uniform possible spatial domain, without relevant interfering elements that may have impeded the experiment with aggravating stimuli;
- and, we supposed, additionally, that a concrete corridor would not belong to the imaginary and memories of the participants and, thus, be freer from preconceptions shaped by personal lived-experience.

Figure 4: Corridors library – Baseline: Study sketch of the standard corridor



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25 We inflected this baseline unit (BC) with five categories of design parameters, obtaining twenty-one digital settings overall (the baseline plus twenty variations on the theme). The following were our five design categories:

- V1. Variation of plan layout;
- V2. Variation of section;
- V3. Variation of horizontal surfaces (floor) treatment;
- V4. Variation of vertical surfaces (walls) treatment;
- V5. Variation of light and shade layout.

Each category was composed of four subcategories (see Table 2 for details). For every setting, we changed just one potentially atmospheric design variable, because we wanted to be sure that the altered emotional responses of the subject to spatial conditions were actually due to that specific remodelling [see Figures 5-6-7-8-9]. The selection of architectural variables chosen for the experiment was intentionally wide and heterogeneous: we aimed to prepare a settings library capable of summarizing the main types of ‘generators of atmosphere’, frequently mentioned by architects and scholars that propose a phenomenological approach within the architectural design field. As Alberto Pérez-Gómez underlines:

> it is obvious that multiple factors contribute to the creation of atmospheres, among them forms and their geometries, the dimensions and proportions so familiar to architects. But equally and often more important are colors and textures of surfaces, the weight and the origin of materials, the care or lack of detailed execution, and the characteristics of varying sorts of light (2016, p. 31).

The experimental protocol imposed several limitations; as a strategy for simplifying the experiment development, we preferred to examine only those features that can be visually perceivable, even if we are perfectly aware that atmospheric perception is founded on multisensory and synesthetic mechanisms. Furthermore, prior to our actual experiment, we performed a pre-test in order to verify the architectural variables chosen. In this preliminary phase, we analysed forty virtual architectural settings, but we decided to halve this quantity and not overwhelm the attention of participants.

Table 2: Corridors library

BC	**Baseline** Standard element (width: 1.20 metres; height: 2.70 metres; length: 10.00 metres)	
V1	**Category V1** Variation of plan layout	
	Subcategory **V1.1**	Standard layout with doubled length (length: 20.00 metres)
	Subcategory **V1.2**	“L” layout with right-turn
	Subcategory **V1.3**	“T” layout with dead-end
	Subcategory **V1.4**	“C” layout with right-turn
V2	**Category V2** Variation of section	
	Subcategory **V2.1**	Rectangular section with doubled height (height: 5.40 metres)
	Subcategory **V2.2**	Rectangular section with increased width (width: 5.40 metres)
	Subcategory **V2.3**	Trapezoidal section with internally-inclined walls (angle: 3° with respect to vertical)
	Subcategory **V2.4**	Trapezoidal section with externally-inclined walls (angle: 3° with respect to vertical)
V3	**Category V3** Variation of horizontal surfaces (floor) treatment	
	Subcategory **V3.1**	Blue coloured flooring
	Subcategory **V3.2**	Red coloured flooring
	Subcategory **V3.3**	Yellow coloured flooring
	Subcategory **V3.4**	Wood-panelled flooring
V4	**Category V4** Variation of vertical surfaces (walls) treatment	
	Subcategory **V4.1**	Blue coloured walls
	Subcategory **V4.2**	Red coloured walls
	Subcategory **V4.3**	Yellow coloured walls
	Subcategory **V4.4**	Wood-panelled walls
V5	**Category V5** Variation of light and shade layout	
	Subcategory **V5.1**	Zenithal and scattered natural lighting, directly introduced into the corridor room
	Subcategory **V5.2**	Right-side and scattered natural lighting, directly introduced into the corridor room
	Subcategory **V5.3**	Right-side and delimited natural lighting, directly introduced into the corridor room
	Subcategory **V5.4**	Symmetrical arrangement of natural light point sources, placed along lateral walls of the corridor room

Figure 5: Corridors library – Category V1 'Variation of plan layout': Study sketch of the case 1.4 ('C' layout with right-turn)

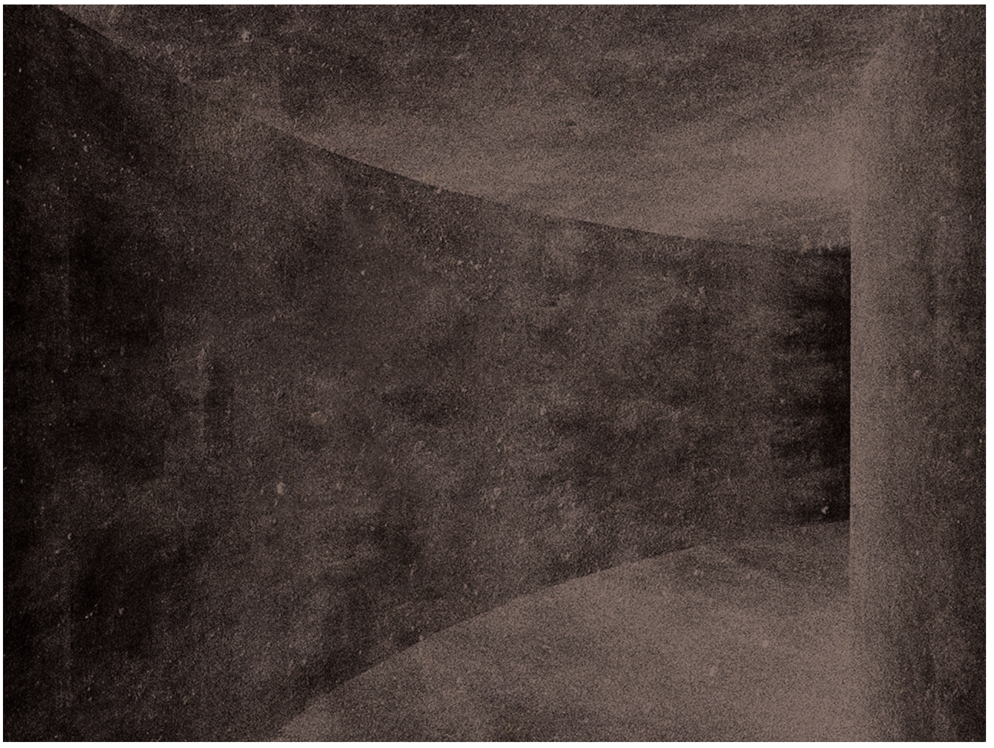

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Figure 6: Corridors library – Category V2 'Variation of section layout': Study sketch of the case 2.4 (trapezoidal section with externally-inclined walls)

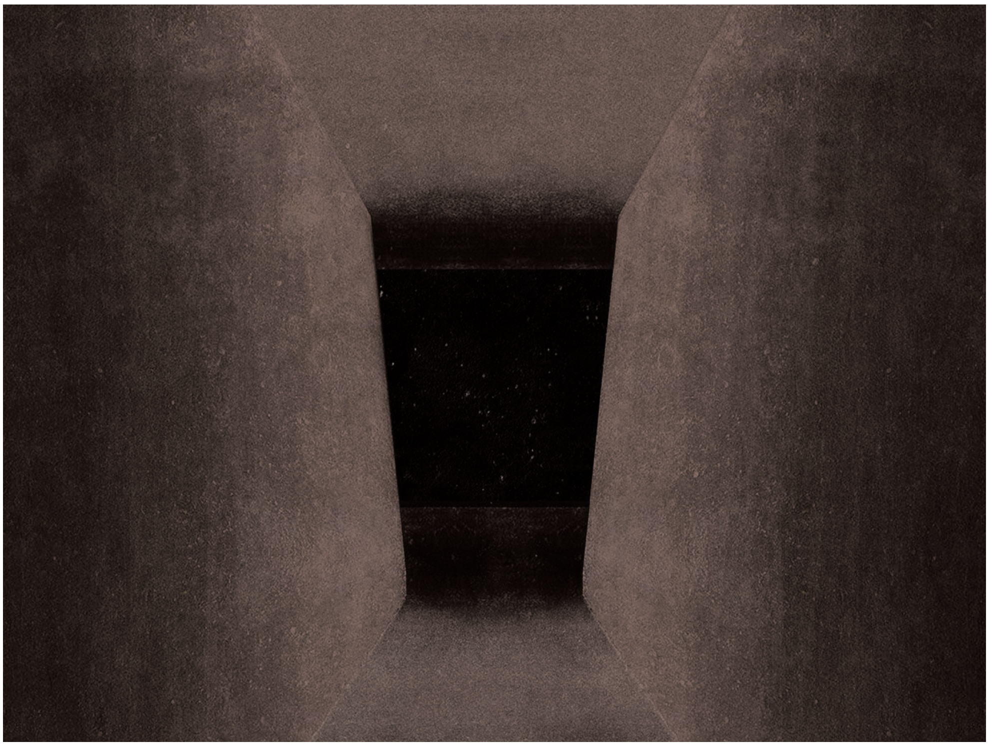

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Figure 7: Corridors library – Category V3 'Variation of horizontal surfaces (floor) treatment': Study sketch of the case 3.4 (wood-panelled flooring)

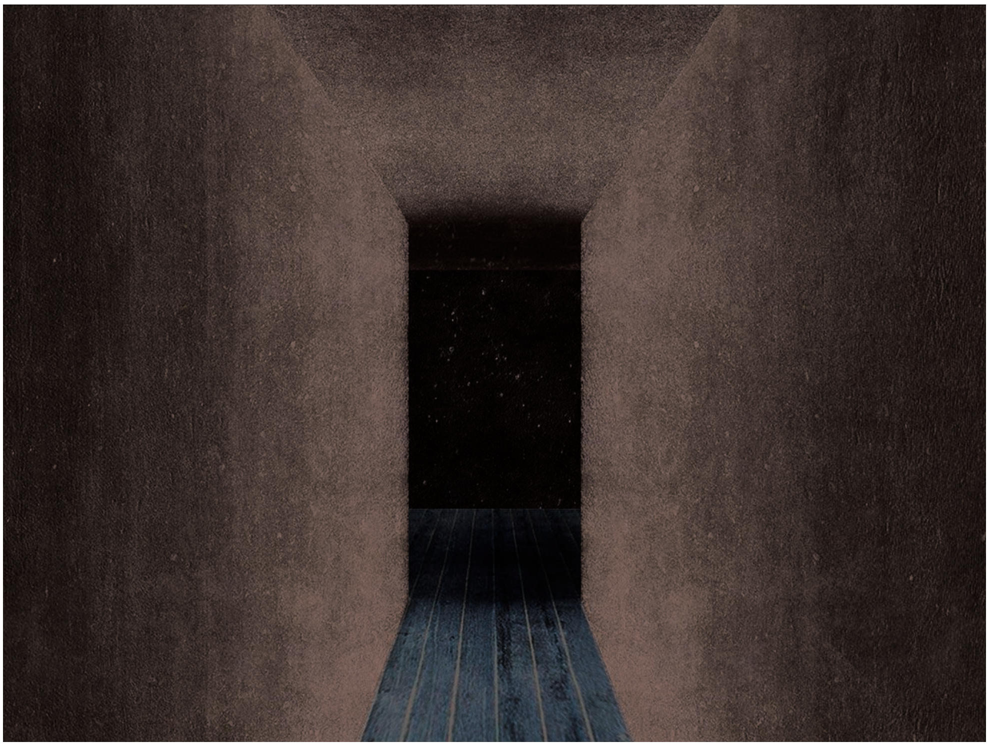

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Figure 8: Corridors library – Category V4 'Variation of vertical surfaces (walls) treatment': Study sketch of the case 4.4 (wood-panelled walls)

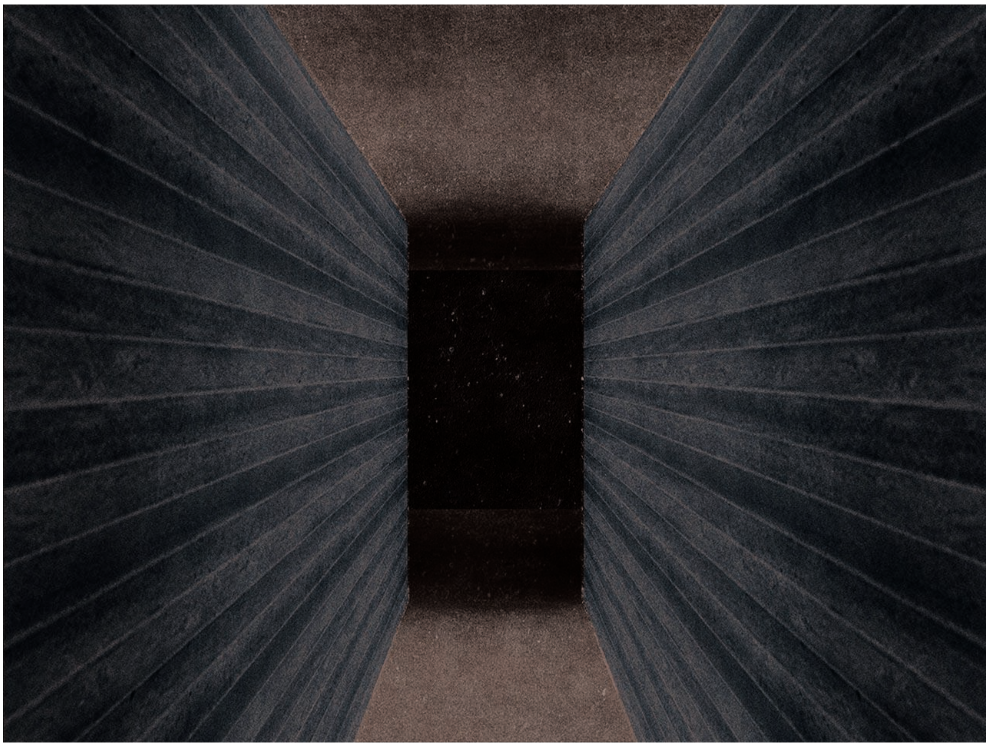

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Figure 9: Corridors library – Category V5 ‘Variation of light and shade layout’: Study sketch of the case 5.1 (zenithal and scattered lighting, directly introduced into the corridor room)

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26 The twenty-one corridors were presented in a random order. Every VR simulation lasted, at most, sixty seconds. Immediately after a virtual immersion into a different corridor was completed, the candidates were instructed to fill out a self-report questionnaire. The questions rated the subjective measure of the atmospheric emotive component, using a visual analogue scale (VAS), based on two parameters: the *emotional arousal* and the *hedonic valence* elicited by each corridor. The *arousal* indicator describes the intensity of the felt emotional state, whereas *valence* codes events as emotionally positive or negative. These queries allowed us to collect objective data on subjects’ reactions on corridors. More specifically, in the first part of the questionnaire, we asked the participants how much the corridor aroused them (they could choose a score from 1 to 9, as illustrated in Table 3); and, in the second section, we requested how pleasant or unpleasant (considering ‘pleasant’ something causing a feeling of happiness or pleasure, and ‘unpleasant’ something disagreeable) the corridor appeared to them (the scoring range was again from 1 – ‘extremely unpleasant’ to 9 – ‘exceptionally pleasant’, as illustrated in Table 4).

Table 3: Questionnaire form: self-report measure of arousal, using a visual analogue scale (VAS) that rates a score from 1 to 9

The corridor arouses me...

1……2……3……4……5……6……7……8……9

a little ………………………………………………… ⇨ much

Table 4: Questionnaire form: self-report measure of emotional valence, using a visual analogue scale (VAS) that rates a score from 1 to 9

The corridor appears to me...

1……2……3……4……5……6……7……8……9

unpleasant ………………………………………… ⇨ pleasant

Statistical analysis

27 Arousal and valence scores ranged from 1 (lowly arousing and extremely unpleasant) to 9 (highly arousing and exceptionally pleasant). Since, except the baseline corridor (BC), all the five categories of design alteration (V1, V2, V3, V4, V5) were composed by four subcategories, a mean of the arousal and valence scores was computed for each category. Then, for *arousal,* the resulting scores were recoded into three segments: ‘high arousal’: scores ≥ 6; ‘no arousal’: scores = 5; ‘low arousal’: scores ≤ 4. The same procedure of computing mean scores and recoding them was applied to *valence* scores: ‘pleasant’: scores ≥ 6; ‘neutral’: scores = 5; ‘unpleasant’: scores ≤ 4. Finally, we obtained the variation by score category cross tabulations. Correlations analysis between *B-IRI score* and *arousal* and *valence ratings* were also performed. Statistical analysis was conducted using SPSS 22.0 software. P-values of 0.05 were considered as threshold for statistical significance. The full matrix of gathered data, used for the statistical correlations, is illustrated in Table 5. Self-report data were tabulated observing three parameters: arousal, valence, and B-IRI scores.

Table 5: Full matrix correlating arousal, valence and B-IRI scores

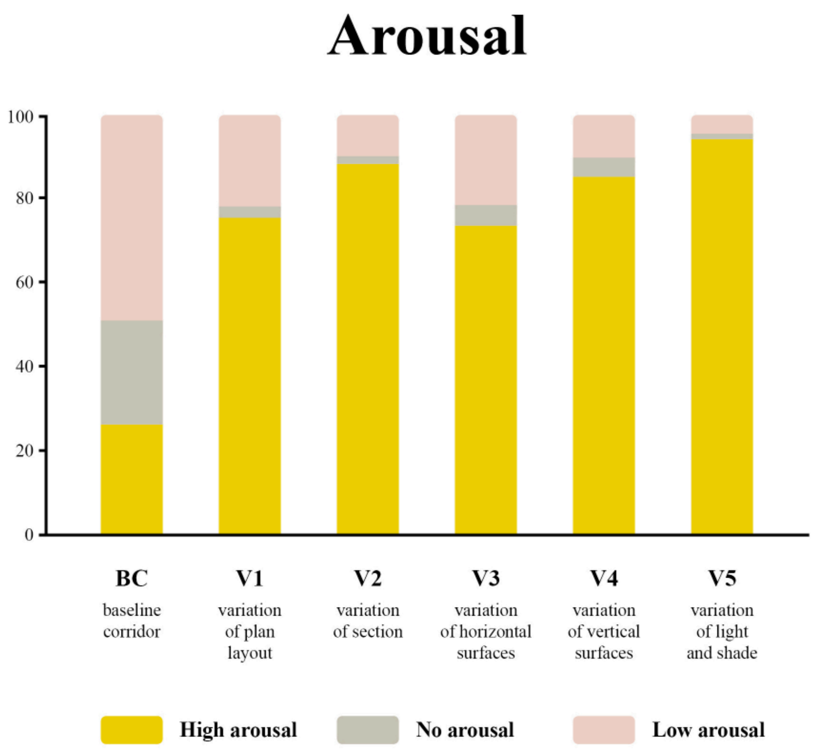
Results

28 Regarding *arousal*, all categories of design variation (V1, V2, V3, V4, V5) evoked higher levels of arousal in comparison with the BC (p always < 0.05) (see details in Table 6; cf. Figure 10). These differences remained significant, even when age, sex, and B-IRI score entered the analysis as covariates.

Table 6: Number of subjects that rated the corridors stimuli as high, low, or no arousing

AROUSAL	BC baseline	V1 category	V2 category	V3 category	V4 category	V5 category
High arousal no. (%)	55 (26.83)	156 (76.10)	182 (88.78)	152 (74.15)	176 (85.85)	194 (94.64)
No arousal no. (%)	50 (24.39)	5 (2.44)	4 (1.95)	10 (4.88)	9 (4.39)	3 (1.46)
Low arousal no. (%)	100 (48.78)	44 (21.46)	19 (9.27)	43 (20.97)	20 (9.76)	8 (3.90)

Figure 10: Number of subjects, expressed in percentage, who rated the corridors stimuli as high, low, or no arousing



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29 Regarding *valence*, the BC was the architectural setting considered to be the most neutral, since the statistical analysis showed this percentage to be significantly higher than the percentage of neutral evaluation assigned to each of the other corridor variations (p always < 0.05). All of the design categories, except V1 (variation of plan layout), were found to be significantly more pleasant than the BC (p always < 0.05). In particular, V5 (variation of light and shade layout) was evaluated as being the most pleasant; in decreasing order of valence score, we arranged V3 (variation of horizontal surfaces treatment), followed by V4 (variation of vertical surfaces treatment) and V2 (variation of section), which were equally considered more pleasant than V1; this last category was the only one that actually did not differ from the BC. Furthermore, V1 and V2 were rated as the most unpleasant by participants (see details in Table 7; cf. Figure 11). As for arousal, all the noticed differences remained significant, even when age, sex, and B-IRI score entered the analysis as covariates. According to the Shapiro-Wilk statistical test, *B-IRI scores* were normally distributed (cf. Figure 12).

Table 7: Number of subjects that rated the corridors stimuli as pleasant, unpleasant, or neutral

VALENCE	BC baseline	V1 category	V2 category	V3 category	V4 category	V5 category
Pleasant no. (%)	57 (27.80)	60 (29.27)	89 (43.41)	145 (70.73)	116 (56.59)	186 (90.73)
Neutral no. (%)	65 (31.71)	21 (10.24)	18 (8.78)	16 (7.81)	13 (6.34)	6 (2.93)
Unpleasant no. (%)	83 (40.49)	124 (60.49)	98 (47.81)	44 (21.46)	76 (37.07)	13 (6.34)

Figure 11: Number of subjects, expressed in percentage, who rated the corridors stimuli as pleasant, unpleasant, or neutral

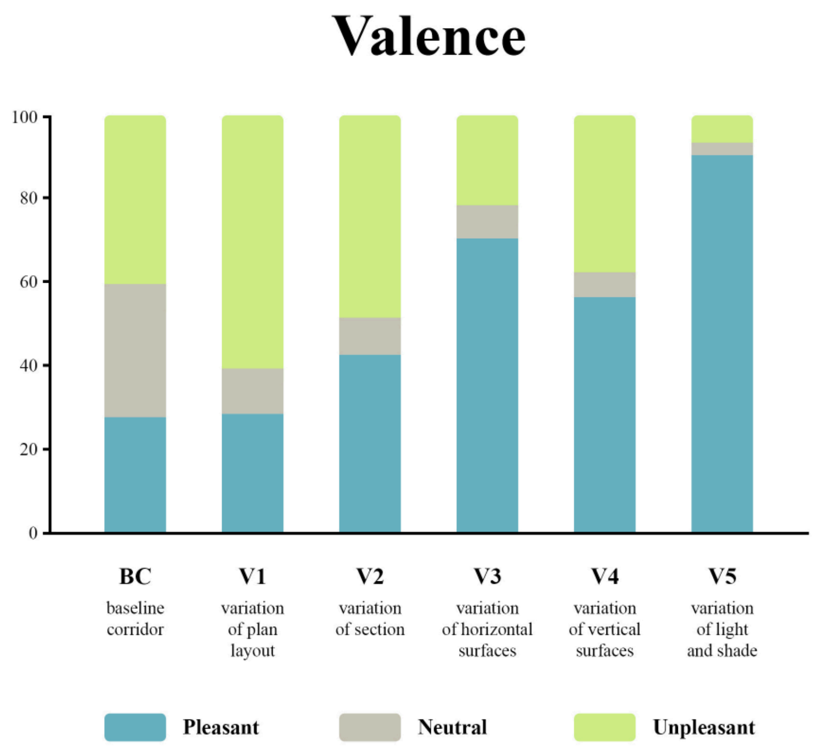
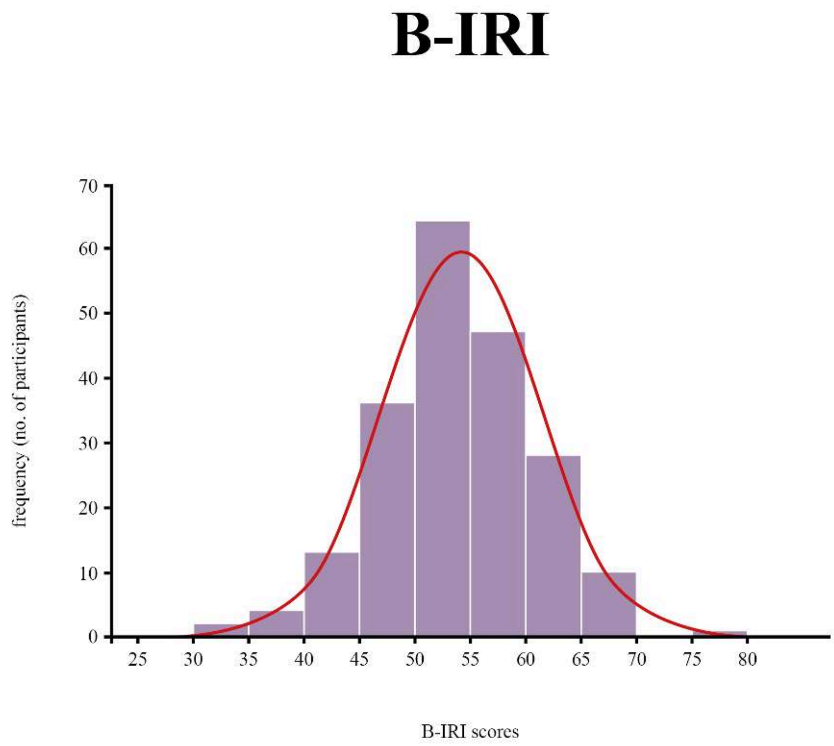
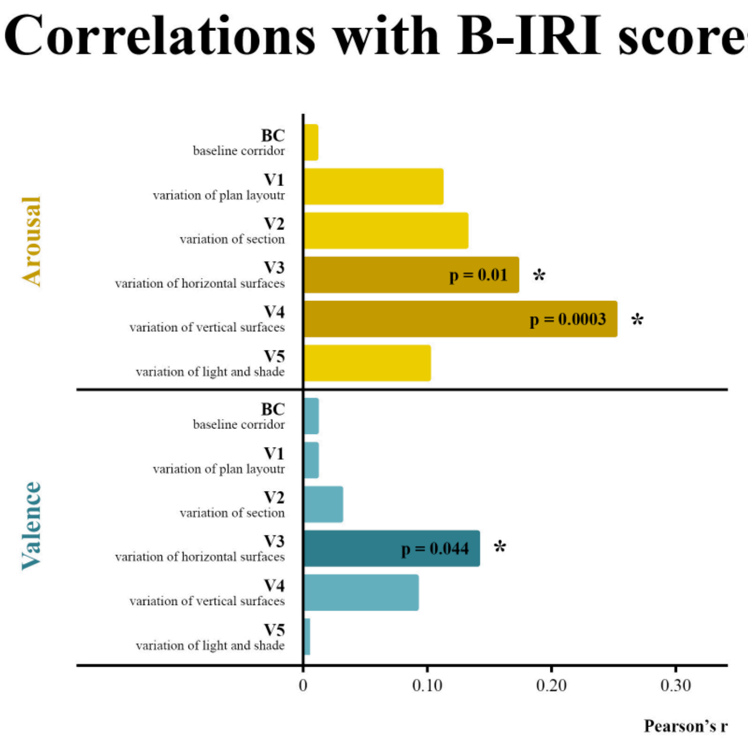


Figure 12: Histogram representing B-IRI scores distribution



30 With reference to *arousal*, the *correlation analysis* determined significant positive correlations between B-IRI scores and V3 (variation of horizontal surfaces treatment) and V4 (variation of vertical surfaces treatment) arousal ratings (V3: $p = 0.01$, $r^2 = 0.03$, $r = 0.17$; V4: $p = 0.0003$, $r^2 = 0.06$, $r = 0.25$) (Figure 13). These results showed that the more subjects were interpersonally empathic, the higher was their activation in terms of arousal when they observed corridors distinguished by colour and/or material alterations.

Figure 13: Correlation analysis between B-IRI scores and arousal and valence ratings



Asterisks indicate statistically significant correlations

31 With reference to *valence*, significant positive correlations were found between B-IRI scores and V3 (variation of horizontal surfaces treatment) valence ratings (V3: $p = 0.044$, $r^2 = 0.02$, $r = 0.14$), meaning that the more subjects were interpersonally empathic, the more pleasant they evaluated V3 corridors. No significant correlations were detected between B-IRI values and valence scoring of the other categories of design variations (p always > 0.05), even if a trend similar to that one mapped within subcategory V3 was recognisable in V4 corridors (cf. Figure 13).

Phase Five: Interpretation of experimental results

32 With the aim to address which are the most relevant parameters for our definition of atmosphere, as the *empathic medium* of the architectural organism, we analysed the statistically significant correlation observed in specific design categories between the B-IRI values and those of arousal (V3 and V4) and valence (above all, V3). In the case of coloured and/or materially altered settings (V3 and V4 corridors), in fact, we found that there was a direct correlation between the B-IRI index scores and the arousal and valence readings of our participants (cf. Figure 13). It seems, therefore, that there is a clear correspondence between the supposed individual ability to empathise with another person's experience, to sense other people's emotions, and their potential empathic reaction in response to particular configurations of the architectural setting. More people are empathetic with that which is similar to them (*i.e.* other animate subjects), and more they can establish an empathic link with those inanimate objects that normally compose their physical domain of movement and interaction, if colours

and material patterns interfere with the overall architectural arrangement. In other words, chromatic and material design elements offer a dynamic spectrum of perceptual variability, capable of interplaying with the empathic sensibility of the perceiver and reverberating in their emotive responses.

33 Completely different is the case of category V5, namely that which worked with the manipulation of light and shade: it was, unequivocally, the most arousing and pleasant set of arrangements on the level of the emotive effect, exactly as we expected. However, V5 corridors did not report a statistically significant correlation with the measure of dispositional empathy. This kind of reaction to light might be ascribed to the fact that its power of emotional excitability is so strong that it can influence the perceiving abilities of the subject, regardless of their empathic disposition to emotional resonance. Thus, the consequences of lighting design activity might transcend the personal domain of emotional predisposition and, eliciting a perceptual saturation, manage substantial reactions from the point of view of arousal and valence.

34 There is an additional interesting reflection concerning the BC. It seems to approach effectively an acceptable condition of neutrality, since – as it was always presented to participants in a random order, mixed with its alterations – it was able to activate subjects in terms of arousal significantly less than each of the other architectural settings. So, it appeared to fulfil the criteria of control, useful to analysing the different emotional responses of subjects to spatial configurations. Undoubtedly, it was not the most neutral paradigm overall, but we could opt for it as a satisfying reference point. We might wonder how can we improve our baseline element, searching for a condition of emotive neutrality, namely a condition of absence of emotional reaction.

Conclusions

35 The significance and worth of the experiment performed does not wholly lie in the single and partial results obtained, but rather in its entire process and approach. It suggests that there is a genuine opportunity for and benefit to studying atmospheric perception (as an expression of architectural experience *tout court*) using scientific methodology. The attempt to adopt a rigorous experimental approach, even if it is not strictly of a neuroscientific nature (as hypothesised in the theoretical objectives) because supported by self-report analyses on emotions, partially integrates the atmospheric condition in its linguistic vulnerability. There is, in fact, an apparently insurmountable discrepancy between the possibility of living an atmospheric experience and the ability to communicate and describe it. In the future, to further develop the conclusions of this prototypical study, we – architects and neuroscientists alike – should contemplate validating gathered experimental results by neurophysiology and/or functional neuroimaging techniques.

36 At the moment, we are firmly confident that atmospheric qualities, examined through both a phenomenographic and experimental approach, could provide a fundamental contribution to architecture process, being synergically involved in the design activity together with physical constituent elements and programmatic tools. Atmospheres become the overriding research instrument useful to understanding how we ‘feel’ architecture by our emotions and to exploring the meaning of experiencing the architectonic essence of built space.

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NOTES

1. The adjective *ineffable* is a reference to the famous notion invented by Le Corbusier, 'l'espace indicible' (1946).

2. ἀτμός ('vapour') + σφαῖρα ('ball', 'sphere').

3. The founding idea of architectural atmosphere is embedded in many of its synonyms and foreign equivalents. We highlight *air*, *ambiance*, *lived space*, *mood*, *temperament*, *feeling*, *attunement*, *Stimmung*, *milieu* or more uncommon variants such as *Umwelt* (German, literally 'environment'), *in-between*, and *ki* (a Japanese concept that literally alludes to the image of the steam rising from cooked rice, but also figuratively to the life energy of a place). In our research, we chose to exclusively employ the term *atmosphere*.

4. This topic emerged in the panel entitled *Advances in Measuring Scientific Studies*, held during the *2018 Academy of Neuroscience for Architecture (ANFA) Conference*. La Jolla, CA: Salk Institute for Biological Studies. September 20, 2018. Invited discussants: Zakaria Djebbara, David Kirsh, Upali Nanda, and Giovanni Vecchiato. Facilitator: Eduardo Macagno (ANFA Board).

5. That is to say the so called 'generators of atmosphere' (Böhme, 2001; 2013). See also the well-known Zumthor's stream of consciousness (Zumthor, 2006).

ABSTRACTS

What is architectural atmosphere? To answer this question, we propose a paradox: a precise definition of the inherently vague and ambiguous concept of atmosphere that satisfies, as so far as possible, scientific criteria and methodology. We suggest that the term *atmosphere*, understood in an architectural context, defines a state of resonance and identification (sensorimotor, emotive, and cognitive) between an individual and their surrounding built space. Human beings can empathise with inanimate rooms when they interiorly establish an embodied simulation of certain architectural features. Thus, atmospheres might be determined, mapped, and measured through quantitative methods tracing emotional, cognitive, and neurophysiological responses of individuals to spatial conditions.
The exploratory study illustrated attempts to test this hypothesis, by undertaking an experiment informed by phenomenological and embodied cognition theories. We analysed the spatial unit of the corridor, altered in twenty-one variations. We modified one potentially atmospheric parameter at a time, and collected emotional responses of participants. Subjects interacted with immersive virtual-reality settings. Our findings demonstrate that an experimental approach is applicable to evaluating atmospheric perception and suggest which architectural features seem to interplay with the empathic sensibility of the perceiver (*i.e.* colours and material patterns) and which ones do not (*i.e.* lighting qualities).

Qu’est-ce que l’atmosphère architecturale ? Pour répondre à cette question, nous proposons un paradoxe : pour un thème intrinsèquement vague et ambigu, nous avons forgé une définition exacte, obéissant autant que possible à des critères scientifiques. Nous avons décidé que le mot *atmosphère* indique un état de résonance et d’identification (sensorimoteur, émotionnel et cognitif) entre un individu et l’espace construit qui l’entoure. Les sujets humains peuvent établir un contact empathique avec l’espace inanimé lorsqu’ils déclenchent intérieurement une simulation incarnée avec certaines caractéristiques architecturales. L’atmosphère peut donc être définie, numérisée et mesurée grâce à des méthodes quantitatives capables de détecter les réponses émotionnelles, cognitives et neurophysiologiques d’individus aux configurations spatiales.
L'étude exploratoire présentée tente de vérifier cette hypothèse en réalisant une expérience scientifique éclairée par les théories phénoménologiques et les théories de la cognition incarnée. Nous avons analysé l'unité spatiale du couloir en le modifiant en vingt-et-une variations. Nous avons modifié un paramètre atmosphérique potentiel à la fois, et nous avons recueilli les réponses émotionnelles des participants. Les sujets ont interagi avec des modèles tridimensionnels simulés dans la réalité virtuelle. Nos résultats démontrent que l'approche expérimentale est applicable pour évaluer la perception atmosphérique et nous suggèrent les caractéristiques architecturales qui semblent interagir avec la sensibilité empathique du percepteur (par exemple les couleurs et les matériaux) et celles qui ne le font pas (par exemple l'illumination).

INDEX

Keywords: atmospheric perception, architectural experience, cognitive neuroscience, semantic definition, emotional responses, embodiment, empathy, experimental evidence, virtual reality, corridor
Mots-clés: perception atmosphérique, expérience architecturale, neurosciences cognitives, définition sémantique, réponses émotionnelles, cognition incarnée, empathie, preuves expérimentales, réalité virtuelle, couloir

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