Cogn Process
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ABSTRACTS

Abstracts and authors of the *9th International Conference on Spatial Cognition: Segmentation and Binding in Spatial Cognition* (ICSC 2024)

1. Abstracts of Keynotes

KEYNOTE 1:

Information and meaning

Federico Faggin

In 1948 Shannon published a seminal paper that gave birth to information theory. To measure "information" it is only necessary to recognize the symbols, irrespective of their meaning. However, the purpose of information for us is to carry meaning. If a symbol has no meaning there is no information. This theory brought information into the materialistic worldview that has come to dominate science and society. Recently, large language models like ChatGPT and Gemini, are generative artificial intelligence programs that allow us to ask questions and have answers that at times are more meaningful than those we could get from a well-read human being. Are we then machines like the computers that run Gemini? The author will explain how training a computer with neural networks can create programs that appear intelligent. Surprisingly, this explanation requires a new theory of consciousness and free will that restores to the universe and to us the meaning and purpose that materialism stripped away.

KEYNOTE 2:

Orienting of attention and spatial cognition

Michael Posner

University Oregon, United States

Humans orient to their sensory world through foveation of target location or through covert shifts of attention. Orienting provides primacy to the selected location and in humans improves the precision of discrimination and increases the opportunity for segmentation and binding. All of these functions are mediated by common brain networks that include frontal, parietal and subcortical areas. Covert orienting can serve to prioritize processing the target even increasing its subjective intensity and its acuity. Cells exist that can conjoin features without attention, but reporting the conjunction appears to require orienting to it. An understanding of the pathways that connect attention networks to memory networks may allow us to enhance orienting and thus improve spatial cognition.

KEYNOTE 3:

Towards neuroadaptive navigation assistance to reduce spatial de-skilling

Sara Irina Fabrikant

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Maps have been invaluable navigation aids for millenia and thus critical for human survival. Increasing popularity of and dependence on current smart navigation technology, however, has shown to divert our attention from the environment and influence innate spatial abilities. To mitigate this, I propose neuroadaptive mobile maps that respond in real-time to navigators' cognitive task demands and visuo-spatial attention needs. In doing so, responsive displays may not only help us to maintain navigation efficiency, but more importantly, to also scaffold spatial learning. The proposed responsive navigation solution must strike the appropriate balance between welcomed mobility efficiency gains while limiting human spatial deskilling. Leveraging neuroadaptive cartography, we can ensure to remain effective navigators, empowered to explore the world with confidence.

KEYNOTE 4:

How are segmentation and binding computed and represented in the brain?

Christoph von der Malsburg

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As the Gestalt Psychologists observed a hundred years ago, our brain has the ability to extract from the sensory input as well as represent to

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SYMPOSIUM 1: Submission 87

Associative learning in peripersonal space: Fear responses are acquired in hand-centered coordinates

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Space coding affects perception of stimuli associated to negative valence: threatening stimuli presented within the peripersonal space (PPS) speed up behavioral responses compared to non-threatening events. However, it remains unclear whether the association between stimulus and its negative valence is acquired in a body-part centered reference system, a main feature of the PPS coding. Here we tested the hypothesis that this associative learning takes place in hand-centered coordinates and can therefore remap to other positions in space, according to hand displacement. We used a Pavlovian fear-learning paradigm to associate a visual stimulus, *vertically projected on a table* (light circle, the conditioned stimulus, hereafter CS) with an aversive stimulus (an electrocutaneous shock) applied on the right hand only when the CS was displayed close (CS+, *2 cm from the index finger*), but not far from the hand (CS-, *30 cm away*). Measuring the skin conductance response (SCR), we observed a successful learning of the negative value of the CS+, with a higher anticipatory fear response associated to it. Noteworthy, when participants kept their hand in a novel position, higher SCR was observed for visual stimuli displayed close to this new position, which was far from the hand during the conditioning phase and never associated to the aversive stimulus. By revealing a hand-centred (re)mapping of the conditioning effect, we provide support to the possibility of establishing associative learning in hand-centered coordinates. We suggest that the threatening valence of an object also depends on its basic spatial relationship with our body.

SYMPOSIUM 2: General abstract

Spatial cognition, neuroscience, and architecture: A conversation about the impact of built environments on cognition and emotion

Convenors: Giovanni Vecchiato[1] & Nicola Bruno[2]

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We aim to initiate a conversation about the impact of built environments on human cognition and emotion. Architects and art historians have long assumed that the built features of interiors constrain not only the practical use of a space but also its impact on users' mental states and psychological well-being. The symposium will focus on such aspects and on the interplay of peripersonal space (PPS), defined as the multisensory representation of the space around the body that enables interaction, and extrapersonal space (EPS). The proposed talks will provide different perspectives, varying among academic disciplines and professional backgrounds. We will reconcile different concepts of space by identifying a common root in the concept of affordance, thus by considering a moving person exposed to different possibilities of experience at changing spatial locations, strictly depending on individual distributed patterns of perception and behavior. An example of such observer-environment relation is provided by the macro-affordance effect, producing a facilitation effect for the execution of walking-related actions in response to modification of the EPS. It reflects an implicit coding of spatial features of the environmental layout and observer–environment relationships, preferentially guiding a walking-related exploration of the built environment. We argue that the built environment transcends static states and representations, thus comprising a multitude of complex signals relevant to human cognition. Accordingly, the symposium will explore how architectural rhythms may foster neural entrainment, which affects working memory and perception, analyzing how real-world architectural configurations impact the interplay between the brain, body, and surroundings. In such an interplay, we will contribute with a theoretical and empirical framework forstudying architectural atmospheres' role on first impressions of space, integrating self-report assessments and neurophysiological measurements. We will then examine PPS's neural and computational mechanisms in humans, along with its primary functions and properties, thus showing its dynamic nature and optimization for body-environment interactions. We will explore the reciprocal relationship between PPS and social interactions, emphasizing its involvement in social cognition and susceptibility to social modulation. We will further explore such top-down influences on the PPS boundary by testing how the alteration of cognitive states produced by variations of architectural forms impact our space of interaction. The relationship between EPS and PPS could have a social ground, possibly depending on the individual architectural experience. Next, moving between lab-based investigations and large naturalistic datasets, we will show how the results from an empirical virtual reality study using brain, body, and behavioral measures informed a 'real world' replication using a longitudinal dataset that investigated the relationship between academic performance and the size of the rooms the assessments were conducted within. We will present several examples of how to translate neuroscientific research into architectural design and how such environmental changes affect human behavior. Ultimately, contributions will foster our understanding of the mutual and intimate relationship between body and space and immersive and interactive technologies as tools for architectural design.

SYMPOSIUM 2: Submission 28

Shared rhythms between the brain and the environment

Zakaria Djebbara

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While moving through our built environment, the omnipresent patterns on the floor and wall become enacted and thus discharged as rhythms in the visual field. Such rhythmic stimuli are known to have an entraining effect on neural populations. Neural entrainment is the alignment of intrinsic brain oscillations with external rhythmic cues, and is known to affect cognitive processes, such as working memory and perception, by altering neural dynamics. We argue here that the built environment transcends static states, representations, and isolated variables, but instead comprise ongoing interconnected signals that foster resonance that affects working memory and perception. By conceiving our interaction with space as rhythmic, it changes how we analyze space relative to the human body and brain. Analyzing space should thus occurs through analyses that reveal entrainment, cross-frequency coupling, and phase resetting. In this study, we take advantage of the sensitivity to environmental rhythms, such as recurring architectural structures, to impact perception and working memory. Our analysis examines how real-world architectural configurations impact neural dynamics, cognitive functions, and behavior, underscoring the integral role of everyday rhythms in shaping the interplay between the brain, body, and surroundings.

SYMPOSIUM 2: Submission 56

The macro-affordance effect: Characteristics, neural correlates and role in the built environment

Giorgia Committeri & Annalisa Tosoni

University G. d'Annunzio of Chieti-Pescara, Italy

The original Gibsonian notion of affordance was inspired by real-time interactions between animals and their extended natural environment. Using an incidental priming paradigm based on repeated presentation of pictures of a virtual reality environment framed from different distances from the observer, we have described a behavioral facilitation effect for the execution of a footstep action, taken as proxy of walking, in response to distant vs. near objects/locations in the extrapersonal space (EPS). Based on the parallelism with the well-known "micro-affordance" effect within the peri-personal space (PPS), the effect has been referred to as "macro-affordance" effect. Later works have shown that the effect is implicitly activated and preferentially guided by the framing distance of the environmental layout rather than by distance of isolated objects in the environment. More recently, we found that the effect (a) generalizes to pictures of real-world scenes in which distance is not metrically manipulated, (b) is guided by both spatial (far vs. near distance) and semantic (built vs. natural environments) aspects and (c) is not associated with "micro-affordance" within the same individuals, in line with the dissociable nature of PPS and EPS. Finally, neurophysiological studies that we conducted through Transcranial Magnetic Stimulation (TMS) and electroencephalography (EEG), demonstrated that the effect is instantiated within foot-related sensory-motor and dorso-medial parietal regions, through mechanisms of motor anticipation and subsequent prediction error. The whole findings suggest that the "macro affordance" effect can be conceived as a measure of preferential body-space interaction for the walking-related exploration of the large-scale, built environment.

SYMPOSIUM 2: Submission 67

Exploring emotional and neurophysiological responses to architectural atmospheres

Elisabetta Canepa[1], Martina Putzolu[2], Edoardo Poratelli[3], Zakaria Djebbara[5], Kutay Güler[6], Luca Andrighetto[4], Anna Fassio[2], Bob Condia[7], Andrea Jelic[8], Laura Avanzino[2], Valter Scelsi[1]

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Background: Since our actions are spatially situated and emotionally driven, first impressions are crucial to extract information from our surroundings. Atmosphere is what we immediately and overall feel before focusing on details. Although multidisciplinary research on architectural atmospheres is expanding, how we experience atmospheres—via our bodies—remains indefinite. *Aim*: Through the interplay of architecture, psychology, and physiology, we explore the priming potential of architectural atmospheres on our first impressions of space. *Methods*: Participants (n=40) walked through four virtual-reality iterations where a corridor connected an empty room to an exhibition space. The starting and ending rooms never changed, whereas the corridor's light varied: dark, blue, amber, and bright. By integrating self-reports with physiological measures (heart rate and skin conductance), we investigated whether and, if so, how the corridor's atmosphere primed participants' impressions of the subsequent room. Before the virtual-reality test, a 5-minute resting-state electroencephalogram recorded participants' functional brain networks, and questionnaires analyzed their emotional intelligence, personality, and empathy traits. *Expected results*: First, we hypothesize the dark corridor has the most priming effects, thus replicating a previous experiment. Second, we expect connectivity indexes of various resting-state networks (e.g., salience, visual, and parietooccipital) to correlate to self-reported impressions of the ending room and heart-rate and skin-conductance behaviors. Third, we foresee correlations among individual characteristics, neurophysiological correlates, and atmospheric responsiveness (conscious and nonconscious). *Conclusions*: Atmosphere exists and primes our lives—even when moving through a corridor. This work intents to provide evidence-informed insights into how design features affect our emotions and first impressions.

SYMPOSIUM 2: Submission 68

From laboratory to real world: The impact of built environment scale in controlled and naturalistic settings

Isabella Bower

University of South Australia, Australia

Understanding brain activity and behavioural outcomes linked to built environment exposure is important, as it may affect underlying cognitive processes. This presentation explores the role of interior built environment scale on cognitive performance by exploring the results from a lab-based investigation and large naturalistic dataset. In the first study, 66 participants were exposed to indoor rooms of various scales using virtual reality and indoor environmental quality monitoring, while using electroencephalography to record neural responses. Our results showed enlarged room scale increased power spectral density across the beta bandwidth, frontal midline power in the gamma bandwidth, and enhanced theta connectivity across the left temporoparietal region and right frontal region. Given the link between high-frequency oscillatory activity and higher order cognitive tasks, a follow-up study was conducted to test the results in a real-world setting with a cognitive task. The second study used historical data of 15,400 higher-education students' examination scores and measurements of the rooms where the assessments were conducted within. Using a linear mixed model and accounting for students' coursework performance, the results indicated examination performance was reduced in rooms with elevated ceiling heights. Combined, the results from these two studies help us understand the role of interior built environment scale on brain activity and cognitive performance. Importantly, the findings provide evidence of how the scale of the buildings we occupy affects brain activity and our ability to perform tasks, suggesting we may be able to optimise cognitive functioning through building design, which could lead to major benefits for society.

SYMPOSIUM 2: Submission 85

The impact of architectural experience on interaction possibilities

Giorgia Guerra[1], Nicola Bruno[1], Giovanni Vecchiato[2]

[1]Department of Medicine and Surgery, University of Parma, Italy; [2]Institute of Neuroscience, National Research Council (CNR), Italy

It has been demonstrated that architectural space, experienced through a virtual reality promenade, elicits a motor potential exerting an early effect on the processing of body expression. Capitalizing on these results, we investigate how perception of interaction possibilities are influenced by the manipulation of architectural features. Specifically, we aim to clarify the role of the extrapersonal space representation in shaping human interactive experiences and social cognition. To this aim, we analyze how changes in architectural features influence the plasticity of peripersonal space (PPS). Participants experience a virtual reality promenade through architectural spaces varying in sidewalls distance, as well as ceiling and windows height. Simultaneously, they performed an audio-tactile interaction task in which they were asked to respond as fast as possible to tactile stimulation applied to the trunk, while task-irrelevant auditory stimuli approach the same body part. The distance within which multisensory facilitation of reaction times occurs can be taken as a proxy of PPS boundaries. Moreover, the presentation of an avatar within such architectural spaces serves to explore the social role of architecture on the plasticity of PPS. We also test potential effects of cognitive expertise and professional training. Using high density electroencephalography we investigate the neural correlates underlying PPS' mapping in social and non-social conditions within changing architectures. We spend most of our time in architectural environments, engaging in numerous physical and social activities. Thus, our work could provide guidelines for designing interior spaces optimized for social interactions.

SYMPOSIUM 2: Submission 102

The built environment through the lens of psychophysics

Sergei Gepshtein

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Designers of the built environment seek to deepen their understanding of human perception and behavior. The scientific method offers one manner of achieving that through the means demonstrated in psychology, cognitive science, and neurosciences. Adopting this approach to design is gaining momentum, opening new avenues for the application of established scientific concepts and methods. Significantly, the interaction with design alters the science, too, by triggering new scientific questions. I will address two such questions, in which psychophysics plays a central role. The first question concerns the structure of the "space" of the built environment: the apparent void that dwells between material objects. This space is organized in terms of specific possibilities of perception and action, and not by distance metrics used in physics and cosmology. I will show how rethinking the classical psychophysical theme of contrast sensitivity helps to understand and represent this structure, in a way that is new to both design and science. The second question concerns architectural proportion. Traditionally central to architectural thought, this theme was later marginalized because of the unclear motivation for choice of specific proportions and the lack of detailed understanding of their effects. By reframing this question scientifically we alert the designer to the fact that only those proportional relations matter for experience that can be distinguished by perceptual systems. The capability for making such distinctions depends on the viewing distance and the angle of observation. These basic notions have been neglected by prior research of proportion in both science and design.

SYMPOSIUM 2: Submission 109

Multisensory environments and their implications for design

Isabella Pasqualini

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Spatial interactions within the human environment, influenced by design, have the potential to subjectively shape perception, behaviour, mood, and well-being. While designers often rely on their intuition to generate design concepts, the vast potential of understanding the environmental influence on mental states and behaviour can significantly enhance and uplift design practice. Bodily self-consciousness builds the foundation of human experience through self-identification with and self-location within the boundaries of one's body. Past investigations conducted with virtual interiors have shown that perspective and depth sensations impact bodily self consciousness and, in turn, are mediated by multisensory space (Pasqualini et al., 2012; 2013; 2018). Further studies confirmed the relevance of multisensory space on architectural perception involving geometrical, atmospheric, or social parameters. Integrating our findings from the Lab into a hybrid research process merging neurocognitive studies with art and design practice, we aim to validate our initial hypothesis regarding the profound implications of cultural influences on environmental perception. Background emotions, such as familiarity, identity, and safety, are deeply rooted in the cultural context, not only the spatial and social design layout. Moreover, mood, as a specific, momentaneous, and subjective expression of self, seems to be a significant indicator. Our artistic research aims to challenge the idea of a universal design approach to spatial cognition, emphasizing the need for a contemporary interdisciplinary approach to design practice through empirical science to maximise inclusion, for instance, in terms of healthy ageing and neurodiversity.

SYMPOSIUM 2: Submission 138

Designing and evaluating architectural experiences

Tommaso Bertoni[1], Federica Sanchez[2], Ashwanth Ramkumar[2], Elena Giancarli[1,2], Anna Custo[1,3,4], Manuel André Bottiglieri[2], Cristian Catania[2], Andrea Serino[1,5]

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Architecture design often relies on implicit knowledge of how the brain represents space. Some multidisciplinary projects have attempted to link cognitive neuroscience and architecture. This work demonstrates that it is possible to apply brain function mechanisms to design architectural spaces and study human experiences within them. For a large furniture exhibition (Salone del Mobile, Milan), architects from a company in Milan proposed a novel exhibition pavilion layout design. Unlike the traditional grid-based layout with horizontal-vertical axes, the proposed design was more natural, ecological, and landmark-based. We hypothesized that this novel design would facilitate an easier, more enjoyable, and less stressful visit, enhancing memory and navigation of the exhibits. To test this, we conducted a virtual reality-based experiment where participants explored two

5. List of Authors

For each author reference is made to the type of contribution (KEYNOTE, SYMPOSIUM, TALKS, POSTERS) and to the submission number.