idea

investigating design in architecture
2023 edition

edited by
Gaia Leandri

foreword by
Angelo Schenone

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Full Papers

2

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This meeting stemmed out from studies, investigations and PhD lectures, in particular:

- 2022, Departamento de Expresión Gráfica Arquitectónica, Universitat Politècnica de València (UPV) and Dipartimento di Neuroscienze, Riabilitazione, Oftalmologia, Genetica e Scienze Materno Infantili (DINOGMI), Università degli Studi di Genova (UNIGE): Gaia Leandri, PhD thesis *Freehand digital drawing: a boost to creative design the observer's eye and the draftsman's brain*;
- 2022, Dipartimento Architettura e Design (DAD), Università degli Studi di Genova (UNIGE), lectures to PhD students in Architecture, Design, Digital Humanities and Neuroscience;
- 2023, Post Doc Consolidator Scolarship: *Ideazione dell'immagine e neurofisiologia: l'apporto creativo e gli strumenti per la comunicazione visiva*, Dipartimento Architettura e Design (DAD), Project Supervisor: Prof. Ruggero Torti; Research Fellow: Dr. Gaia Leandri.

The promoting committee is composed by professors, lecturers, PhD students and researchers from Italy, Spain, the US and the UK:

Angelo Schenone, Marco Testa (DINOGMI, Unige); Maria Linda Falcidieno, Andrea Giachetta, Gaia Leandri, Linda Buondonno, Elisabetta Canepa (DAD, Unige); Francisco Juan-Vidal, Susana Iñarra Abad (UPV); David Sunnucks (Queen Mary University of London).

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Neural correlates of object and spatial visual cognitive styles.
Psychological and electroencephalographic assessment

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1. Context

The research proposal is part of the Ph.D. research developed by Linda Buondonno, tutored by Prof. A. Giachetta, and it's designed together with Arch. Ph.D. Gaia Leandri, Prof. Angelo Schenone, Prof. Massimo Leandri, Prof. Manila Vannucci and Prof. Carlo Chiorri. The aim of the study is to find out how mental images and digital tools for design work together. The study we propose represents a multidisciplinary collaboration that expands the methodology of the case study presented in the previous section, following a neurological methodology validated through the research conducted by Ph.D. Gaia Leandri, Prof. Angelo Schenone and Prof. Massimo Leandri. We seek insight into the neural correlates of different visual cognitive styles using electroencephalography. We believe this can be a forerunner approach for future research on the design process, that can benefit from both the contributions of psychological research and neurophysiology methodology. Hypotheses, details of the methodology, and expected results will be discussed. To date, we are completing Phase 1 of the study.

2. Introduction

The results of a previous study suggested that the use of digital tools during a design task may affect the cognitive and emotional processes implied by the task. Here we extend the research investigating the associations between the visual cognitive styles of expert architects and their cerebral activity during the performance of a design task aimed to simulate a design process as it happens when using BIM software.

1.1 Visual cognitive styles and visualization abilities

Mental imagery is the human ability to experience the perception of some object, event, or situation in the absence of the corresponding visual input (Kosslyn, 1999).

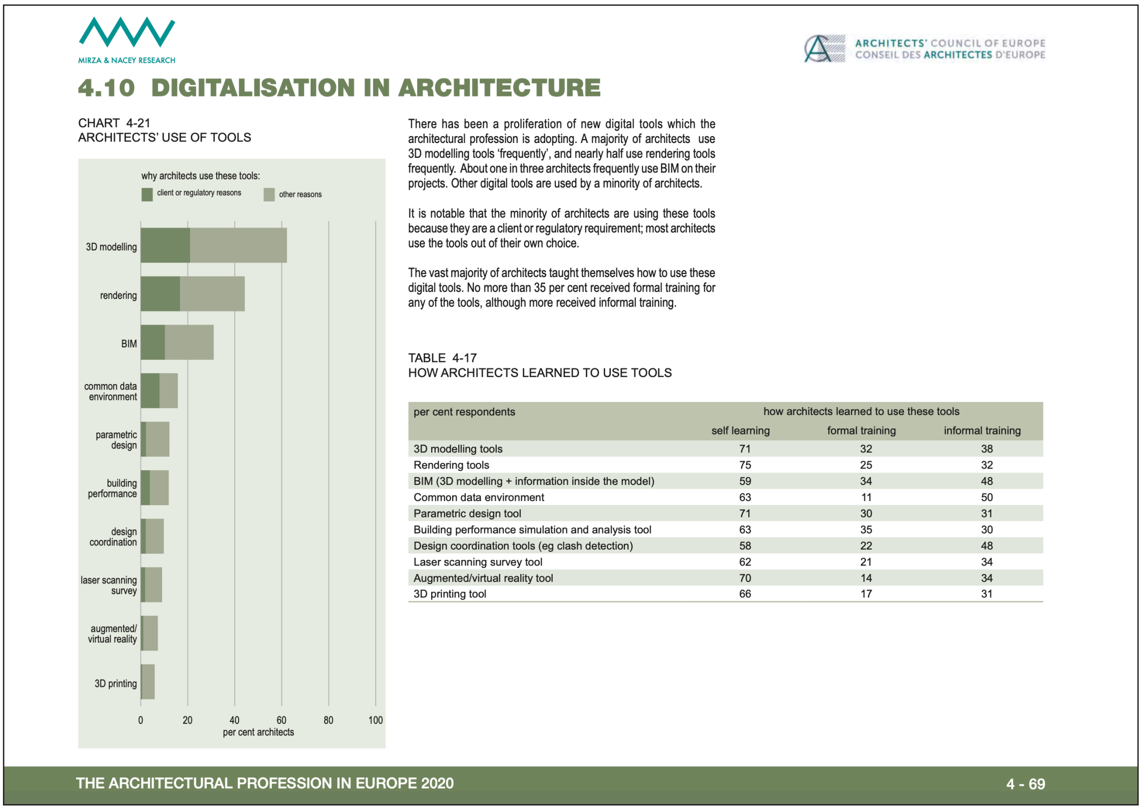
People used to be thought to process information about their environment either through what they heard or what they saw. More recent research (Kosslyn *et al.*, 2001), thanks to the advances in neuroscience, demonstrated that there are two distinct pathways in the brain, dorsal and ventral, which correspond to two different visual abilities. The ventral pathway process correlates to “object” visual ability, namely, the cognitive capacity to process visual information in terms of shape, color, and texture. The dorsal pathway process corresponds to the “spatial” visualization ability, namely, the cognitive capacity to process information about spatial relations, positions of objects in space, and to perform spatial transformations. While the ability is the cognitive capacity per se of performing a specific task, the same dissociation between object and spatial has been demonstrated in connection with visual cognitive styles. Kozhevnikov (2007) suggested that cognitive styles represent heuristics an individual uses to process information about his or her environment; they are stable in time, and develop as the result of long-term external factors. Kozhevnikov et al. (2013) found that object visualization (ability and style) was associated with artistic creativity, while spatial visualization (ability and style) was associated with scientific creativity; considering the three types of domain-specific creativity that overcame the unitary creativity construct.

Architects are expected to have both strong spatial abilities and an «understanding of design components in terms of both scientific aspects and artistic aspects» (Cho, 2017).

1.2 BIM software

Building Information Modelling (BIM) is a methodology for design development in AEC Industry. It allows the creation of virtual models that contain multi-disciplinary data that can be managed by different stakeholders.

Due to the numerous benefits in terms of time, cost, and manpower, during project construction, BIM has widely been utilized by architects, engineers, individuals, and businesses in the AEC industry not only in every step of the design process, but also in operation, maintenance, and even demolition of the physical products of the process (Rafsanjani & Nabizadeh, 2023). ACE, in *The architectural profession in Europe 2020,* *a sector study*, reports that around 30% of architects in Europe already implemented BIM in their practice, and Autodesk forecasts an increasing trend of BIM users (Dodge Data Analytics, 2021) (Figg.1,2).


MIRZA & NACEY RESEARCH

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4.10 DIGITALISATION IN ARCHITECTURE

CHART 4-21
ARCHITECTS' USE OF TOOLS

There has been a proliferation of new digital tools which the architectural profession is adopting. A majority of architects use 3D modelling tools 'frequently', and nearly half use rendering tools frequently. About one in three architects frequently use BIM on their projects. Other digital tools are used by a minority of architects.

It is notable that the minority of architects are using these tools because they are a client or regulatory requirement; most architects use the tools out of their own choice.

The vast majority of architects taught themselves how to use these digital tools. No more than 35 per cent received formal training for any of the tools, although more received informal training.

TABLE 4-17
HOW ARCHITECTS LEARNED TO USE TOOLS

per cent respondents	how architects learned to use these tools		
	self learning	formal training	informal training
3D modelling tools	71	32	38
Rendering tools	75	25	32
BIM (3D modelling + information inside the model)	59	34	48
Common data environment	63	11	50
Parametric design tool	71	30	31
Building performance simulation and analysis tool	63	35	30
Design coordination tools (eg clash detection)	58	22	48
Laser scanning survey tool	62	21	34
Augmented/virtual reality tool	70	14	34
3D printing tool	66	17	31

THE ARCHITECTURAL PROFESSION IN EUROPE 2020 4 - 69

Figure 1 - ACE (2021). *The architectural profession in Europe 2020*, a sector study. Research commissioned by: The Architects' Council of Europe.

This would also happen in response to regulatory requirements that almost everywhere are increasingly asking AEC professionals to implement BIM in their practice. «The move towards [BIM] integration appears to be leading to oversimplified buildings, lower fees, and shorter design schedules rather than to the quest for the perfect jewel of a project. It is, therefore, necessary to question what this revolution strives to accomplish» (Oppenheimer, 2009).

Since BIM constitutes a transformational methodology in the architectural design process, its implications on different levels should be investigated to reach a balance between the tool's power and the designer's will. There is plenty of literature, mainly in the field of engineering and construction, that demonstrates the advantages of BIM implementation in terms of costs and efficiency, but research so far does not cover the implications of BIM use on the design process on a cognitive level. To create such complex models, BIM software is provided with a demanding interface that "asks" users to give a lot of inputs of various kinds. Construction elements are categorized and organized into "families" and building form is developable through a very rigid and diagrammatic series of inputs, determining a process comparable to a sum of predefined parts. Although this could facilitate the process of building modeling, for someone it could represent a strain on the consolidated processes or a constraint on students' developing processes and competences.

1.3 Electroencephalography (EEG)

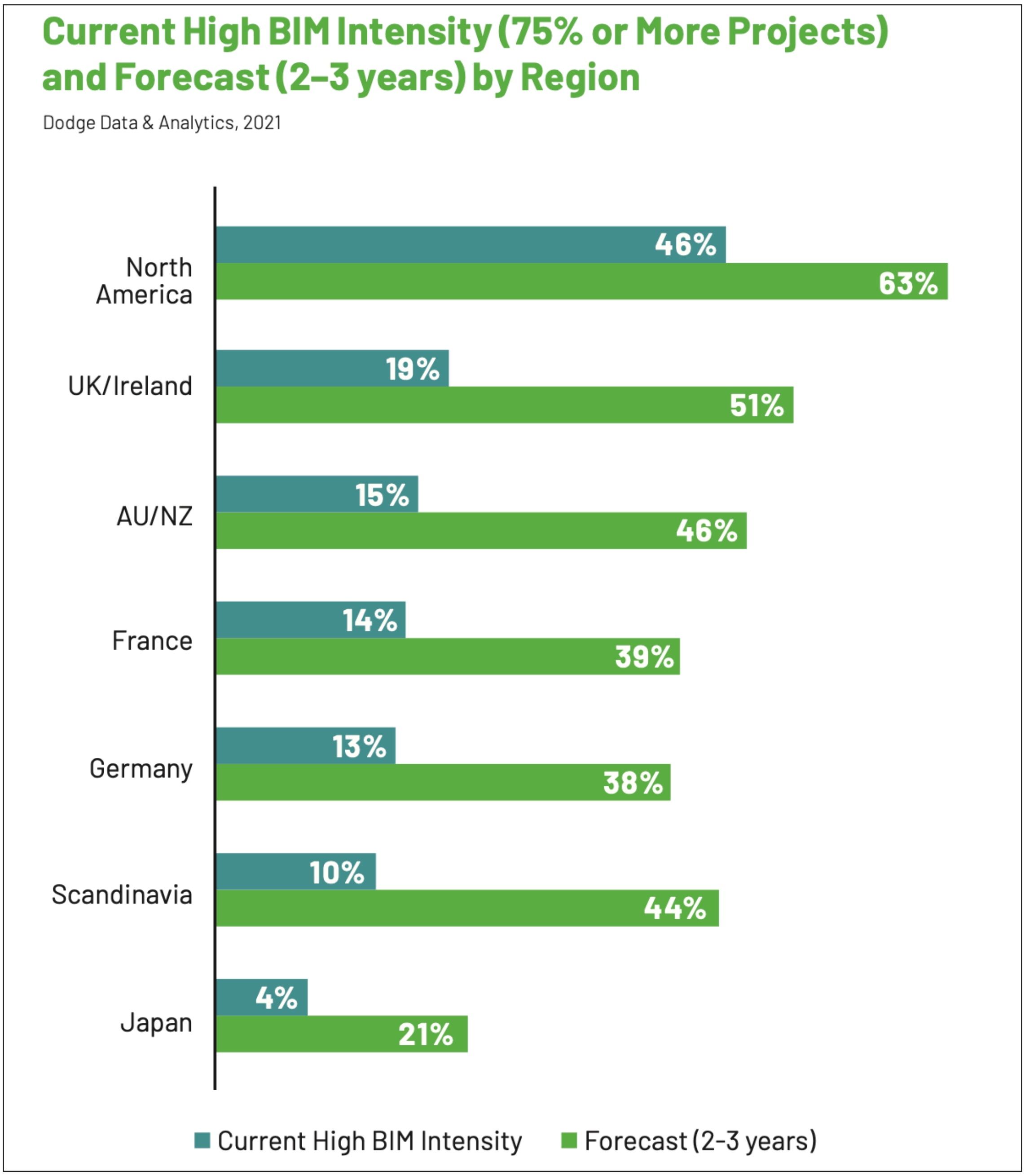

Figure 2 - Dodge Data Analytics (2021). SmartMarket report for Autodesk.

The electroencephalographic (EEG) recording from the scalp is an innocuous procedure and provides instrumental evidence of the activity of brain cortical areas that are somehow influenced, among other factors, by the cognitive or emotional status of the participant. In order to detect subtle changes in such activity, it is paramount to increase by several orders of magnitude the signal-to-noise ratio of the recording.

The most efficient method that can provide immediately understandable results with simple mathematics performed by any computer is the averaging. This is based upon the principle that if we perform a longitudinal operation of mean, those parts of the signal that are time and phase linked to an event will be enhanced, whereas those parts that occur randomly will cancel out. In our case, we propose to explore the EEG activity which is synchronous to the movement of clicking the mouse to select an image on the screen.

The average obtained as a consequence of such movement is called 'movement-related cortical potential', or MRCP. It is possible, by storing the digitized EEG in a continuous memory loop of appropriate length, to recall the EEG occurring before a definite event (in this case, the click). So it is possible to explore the cortical activity that eventually leads to the motor command for clicking.

This activity may arise in several parts of the cortex, according to the responsible cognitive process, called praxis. In neuropsychology, praxis is defined as the ability to perform skilled or learned complex movements finalized to a definite aim (Kriegstein & Brust, 2013).

All our actions are performed in response to inner thoughts or stimuli from the environment; from these early steps, the will of movement is born and the motor plan, the core of the praxis, forms up. So, in the recent past, a series of experiments were devised to understand praxis. When asked to perform cognitively demanding tasks, the investigated participants produced cortical activity approximately 3 seconds before the actual movement. Such activity was localised both in the prefrontal and also in the posteriorly situated parietal area. It could be demonstrated that such activity was specific to complex praxic actions (Bozzacchi *et al.*, 2015; Wheaton *et al.*, 2005). Interestingly, the very early activity that occurred in the prefrontal areas was modulated by an emotional expectancy state.

Tackling the subject of the present proposal, we hypothesise that complex cognitive activities like those employed in architectural designing could influence the characteristics of MRCP linked to the movement mouse clicking necessary to operate the selection of images.

2. Aim

We aim to understand if architects with different visual cognitive styles (object or spatial) show differences in their cerebral activity during a task aimed to simulate a design process, as it happens when using BIM software. Based upon the general aim described in the previous paragraphs, the aim of the EEG recordings will be 1) to assess the intra- and inter-participant reliability of the procedure, 2) to identify the MRCP parameters influenced by different cognitive or emotional statuses, and 3) to quantify possible differences between participant groups or tasks.

3. Method

3.1 Participants and procedure

PHASE I- Psychological pre-test

20 expert architects (from 9 to 30 years of professional activity) were recruited. We asked them to complete a schedule in which we asked for personal (age, sex, education) and professional information (years of professional experience, main activities carried out, proficiency in the use of different software for design).

In the same session, we administered them three different psychometric instruments to assess cognitive styles and visual ability: the Object Spatial Imagery Verbal Questionnaire, the Vividness of Visual Imagery Questionnaire, and the Paper Folding Test (see Materials section). At the end of Phase 1 we expect to be able to identify 2 groups of 4 architects, composed –Group A– by the architects that resulted as “object visualizers” and –Group B– by the “spatial visualizers”.

Object-Spatial Imagery and Verbal Questionnaire (OSIVQ)

The OSIVQ is a self-report instrument to assess individuals' visual (object and spatial) as well as verbal cognitive style dimensions (Blazhenkova & Kozhevnikov, 2009). The OSIVQ comprises 45 items that participants are asked to rate on a 5-point agreement scale (‘5’ indicating absolute agreement with the statement and ‘1’ indicating total disagreement). .

Vividness of Visual Imagery Questionnaire (VVIQ)

The VVIQ is a self-report instrument assessing vividness and brightness of individuals' imagery (Marks, 1973). Participants are asked to rate from 5 to 1 (from ‘no image at all’ to ‘perfectly clear image’, respectively) the vividness of the evoked visual images by a list of 16 items.

Paper Folding Test

According to (Ekstrom & Harman, 1976) the PFT measures spatial visualization ability, which reflects the ability to apprehend, encode, and mentally manipulate abstract spatial forms. The test comprises 2 series of 10 items, each representing a square piece of paper that undergoes two- or three-folds and a punch through all its layers. The participants are asked to select one correct drawing among five drawings, which depicts how the paper would look when fully opened. They have 3 min to complete the test.

PHASE II - Electroencephalographic (EEG) recording

EEG related to 100-200 movements will be recorded in each session. Each participant will repeat the same recording in identical conditions at least three times to assess intra-participant repeatability. Each click will trigger the memory storage of 3500 ms before and 500 ms after the click. Consequently, the participants will be asked to click the mouse at intervals not shorter than 5000 ms. Recordings acquired at shorter intervals will be discarded.

A piezoelectric sensor will be attached to the left mouse button. Each time the participant presses the button to select an image, a synchronizing signal is sent to the EEG recording apparatus for MRCP averaging. The EEG will be recorded from 3 derivations according to the international 10-20 system (C3-Au1, C4Au1, and Cz-Au1).

The EEG signal will be amplified with bandpass of 0.1-2000 Hz) and digitized with an analog to digital converter (NI PCIe-6320, X Series Multifunction DAQ, 16 Bit, 250KS/s sampling rate by National Instruments, Austin, Texas). Signal storing and analysis (averaging and cross-correlation among samples) will be performed with dedicated applications developed in LabView2019© language. Analysis of the MRCP components will be performed in accordance with the methods already proposed by Leandri *et al.* (2021). The components of interest for this work are N-150, P-40, N+30, P+120, N+300. Their latencies, amplitudes, and areas will be assessed as principal parameters. For each session, an averaging will be produced. Once a set of repeatable recordings has been identified, the average of the single averages, or grand-average, will also be calculated to identify a common trend. Descriptive statistics and Student’s t-test will be used where needed, with a p value < 0.01 set as significance level. The Shapiro–Wilk test will be used to assess normality of the distribution of the data when needed.

Task

Participants, both from Group A and Group B, will receive a design brief with some information on the site, the budget, and a list of a few client requests. The project will have to be developed through a series of "guide sheets" that the architect can scroll through one after the other on a computer. Each sheet has a word indicating the theme to which they are asked to respond by choosing among given options, in the form of icons, numbers, or diagrams. (See examples below).

We claim that this task simulates the condition of modeling in the BIM environment, corresponding to a more abstract spatial reasoning comparable to the spatial cognitive ability.

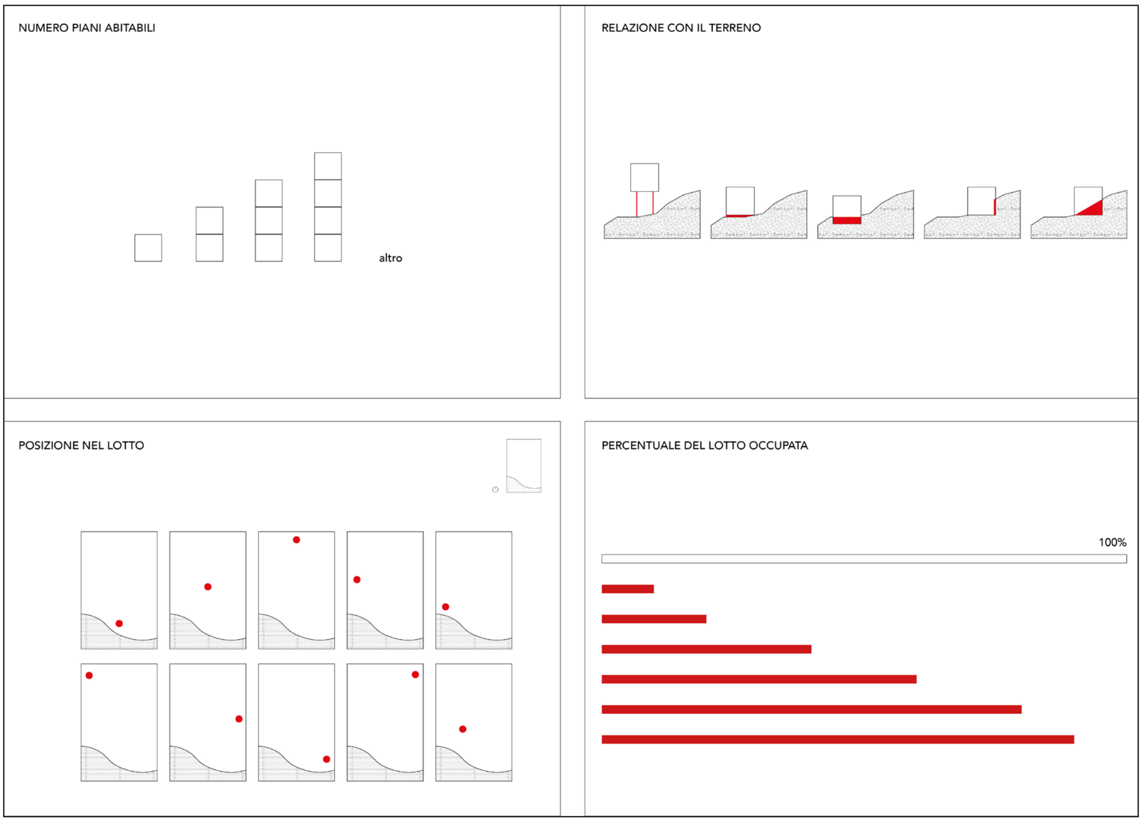

Figure 3 - Examples of "guide sheets" trhough which the project has to be developed. Clockwise: Number of floors, relation with the soil, percentage of lot occupied, position in the lot. Diagrams by L. Buondonno.

4. Attended results and implications

We expect to find some differences in the recorded signals during the task. If those differences could be traced back to the different cognitive styles of the participants, object visualizers or spatial visualizers, it could be a relevant result that adds insight on the user interface and adaptability of human-computer interaction.

Software designers could be interested in such results to target the improvement of their products towards a cognitive visual style-oriented approach.

Such results could also address the strategies of architectural education towards more personalized didactic activities, especially those involving BIM, but also digital tools that imply abstract spatial reasoning in general.

If differences in the recorded signals are not appreciable, it could mean that the task does not trigger different reactions depending on the cognitive visual style, but other correlations could be found with years of professional experience, age, or other personal information.

This study is also significant for the validation and replicability of a method that can contribute to shedding some light on typically understudied processes in design research.

Figure 4 - The first test of the experiment at the laboratory of the University of Genoa (DINOGMI). Picture by M. Leandri.

References

Blazhenkova, O., Kozhevnikov, M. (2009). The new object-spatial-verbal cognitive style model: Theory and measurement. *Applied Cognitive Psychology*, 23(5), 638–663. DOI: https://doi.org/10.1002/acp.1473 (open access).

Bozzacchi, C., Spinelli, D., Pitzalis, S., Giusti, M. A., Di Russo, F. (2015). I know what I will see: Action-specific motor preparation activity in a passive observation task. *Social Cognitive and Affective Neuroscience*, 10(6), 783–789. DOI: https://doi.org/10.1093/scan/nsu115 (open access).

Cho, J. Y. (2017). An investigation of design studio performance in relation to creativity, spatial ability, and visual cognitive style. *Elsevier Enhanced Reader*. DOI: https://doi.org/10.1016/j.tsc.2016.11.006 (open access).

Ekstrom, R. B., Harman, H. H. (1976). *Manual for kit of factor-referenced cognitive tests*. Educational testing service.

Kosslyn, S. M. (1999). *Le immagini nella mente: Creare e utilizzare immagini nel cervello*. Firenze: Giunti Editore.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience*, 2(9), Article 9. DOI: https://doi.org/10.1038/35090055 (open access).

Kozhevnikov, M. (2007). Cognitive styles in the context of modern psychology: Toward an integrated framework of cognitive style. *Psychological Bulletin*, 133(3), 464–481. DOI: https://doi.org/10.1037/0033-2909.133.3.464 (open access).

Kozhevnikov, M., Kozhevnikov, M., Yu, C. J., Blazhenkova, O. (2013). Creativity, visualization abilities, and visual cognitive style. *British Journal of Educational Psychology*, 83(2), 196–209. DOI: https://doi.org/10.1111/bjep.12013 (open access).

Kriegstein, A. R., Brust, J. C. M. (2013). Appendix B *The Neurological Examination of the Patient*. In E. Kandel, Schwartz, J. H., T. M. Jessell, S. A. Siegelbaum, A. J. Hudspeth (Eds.), *Principles of Neural Science* (Fifth Edition, pp. 1533–1549). New York: Mac Graw Hill.

Leandri, G., Schenone, A., & Leandri, M. (2021). Detection of movement related cortical potentials in freehand drawing on digital tablet. *Journal of Neuroscience Methods*, 360, 109231. DOI: https://doi.org/10.1016/j.jneumeth.2021.109231 (open access).

Marks, D. F. (1973). Visual Imagery Differences in the Recall of Pictures. *British Journal of Psychology*, 64(1), 17–24. DOI: https://doi.org/10.1111/j.2044-8295.1973.tb01322.x (open access).

Oppenheimer, N. (2009). An Enthusiastic Sceptic. *Architectural Design*, 79(2), 100–105. DOI: https://doi.org/10.1002/ad.862 (open access).

Rafsanjani, H. N., & Nabizadeh, A. H. (2023). Towards digital architecture, engineering, and construction (AEC) industry through virtual design and construction (VDC) and digital twin. *Energy and Built Environment*, 4(2), 169–178. DOI: https://doi.org/10.1016/j.enbenv.2021.10.004 (open access).

Wheaton, L. A., Shibasaki, H., & Hallett, M. (2005). Temporal activation pattern of parietal and premotor areas related to praxis movements. *Clinical Neurophysiology*, 116(5), 1201–1212. DOI: https://doi.org/10.1016/j.clinph.2005.01.001 (open access).