idea

investigating design in architecture
2023 edition

edited by
Gaia Leandri

foreword by
Angelo Schenone

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Full Papers

2

Conference Proceedings
IDEA – Investigating Design in Architecture
2023 Edition
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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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Angelo Schenone, Marco Testa, Lucio Marinelli
(DINOGMI)

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INDEX

Foreword

This book is a collection of papers presented at the first workshop on Investigating Design in Architecture (IDEA ‘23). Aim of the event is to promote an interchange of ideas and expertise from several sources to tackle the issue of architecture and design on one side and neuroscience and psychology on the other. This meeting is a unique opportunity to define scientifically sound experimental bases to the mental process of design, craft creation and the perception of architectural spaces and forms. Different from the unilateral approach of neuroarchitecture, where the object of investigation is the well-being of the user, in IDEA ’23 the main interest shifts towards the relationship between the author, architect or designer, and the project, a notion well expressed in the words “Investigating design”, suggesting that it is the design process itself that is the object of investigation. This is a prospective project based on a joint PhD program awarded by the Department of Graphic Expression in Architecture University of València, and the departments of Neurosciences, Rehabilitation, Ophthalmology, Genetic and Maternal and Infantile Sciences (DiNOGMI) and Architecture and Design (dAD), University of Genova.

The topic of the program, conducted by Dr. Gaia Leandri, was focused on the cerebral activity of the designer according to the method used to lay down the project. At the end of the doctoral path, Dr. Leandri presented a thesis entitled “Freehand digital drawing: a boost to creative design. The observer’s eye and the draftsman’s brain”. Since then, further research has been carried out, and is still being developed, with the essential and very active collaboration of the dAD, University of Genova, where lectures have been held to students and seminars organized for discussing and planning future interdisciplinary projects. In the course of these meetings, a rather widespread interest was discovered from various sources which went from local and international Ph.D. students in architecture and neuroscience to academics of both fields. Therefore, a promoting committee was established, formed by professors, lecturers, PhD students and researchers from Italy, Spain, the US and the UK (A. Schenone, M. Testa (DINOGMI, Unige); N. Casiddu, E. Bistagnino, M.L. Falcidieno, A. Giachetta, G. Leandri, L. Buondonno, E. Canepa (dAD, Unige); F. Juan-Vidal, S. Iñarra Abad (UPV); D. Sunnucks (Queen Mary University of London), and it was decided to send a call to present papers for this first symposium.

The response has been encouraging, since more than 20 papers have been accepted for publication, a token of the interest arisen by this topic. We may now foresee that the future meetings, that hopefully will be planned, may further increase the number of scientific contributions to this interesting subject.

A. Schenone

Part I - Body, Mind, Emotions

Anatomy, Neuroscience, Psychology, Creativity

Keywords

Design process
Visual stimulation
Neuroscience
Movement
Stimuli
Anatomy
Drawing
Neuroarchitecture

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

Linda Buondonno, Gaia Leandri, Manila Vannucci,
Carlo Chiorri, Andrea Giachetta

Università degli Studi di Genova
Università degli Studi di Firenze

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).

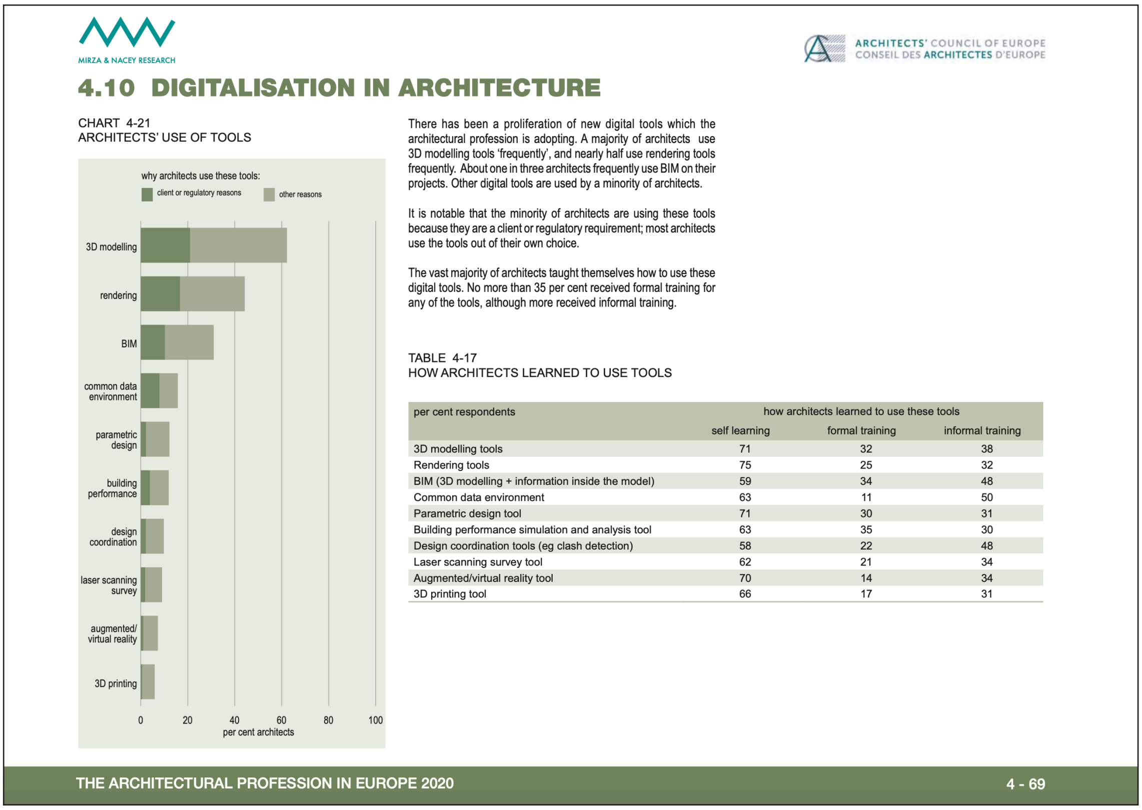
People used to be thought to process information about their environment either through what they heard or what they saw. More recent research (Kosslyn *et al.*, 2001), thanks to the advances in neuroscience, demonstrated that there are two distinct pathways in the brain, dorsal and ventral, which correspond 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

ARCHITECTS' COUNCIL OF EUROPE
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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)

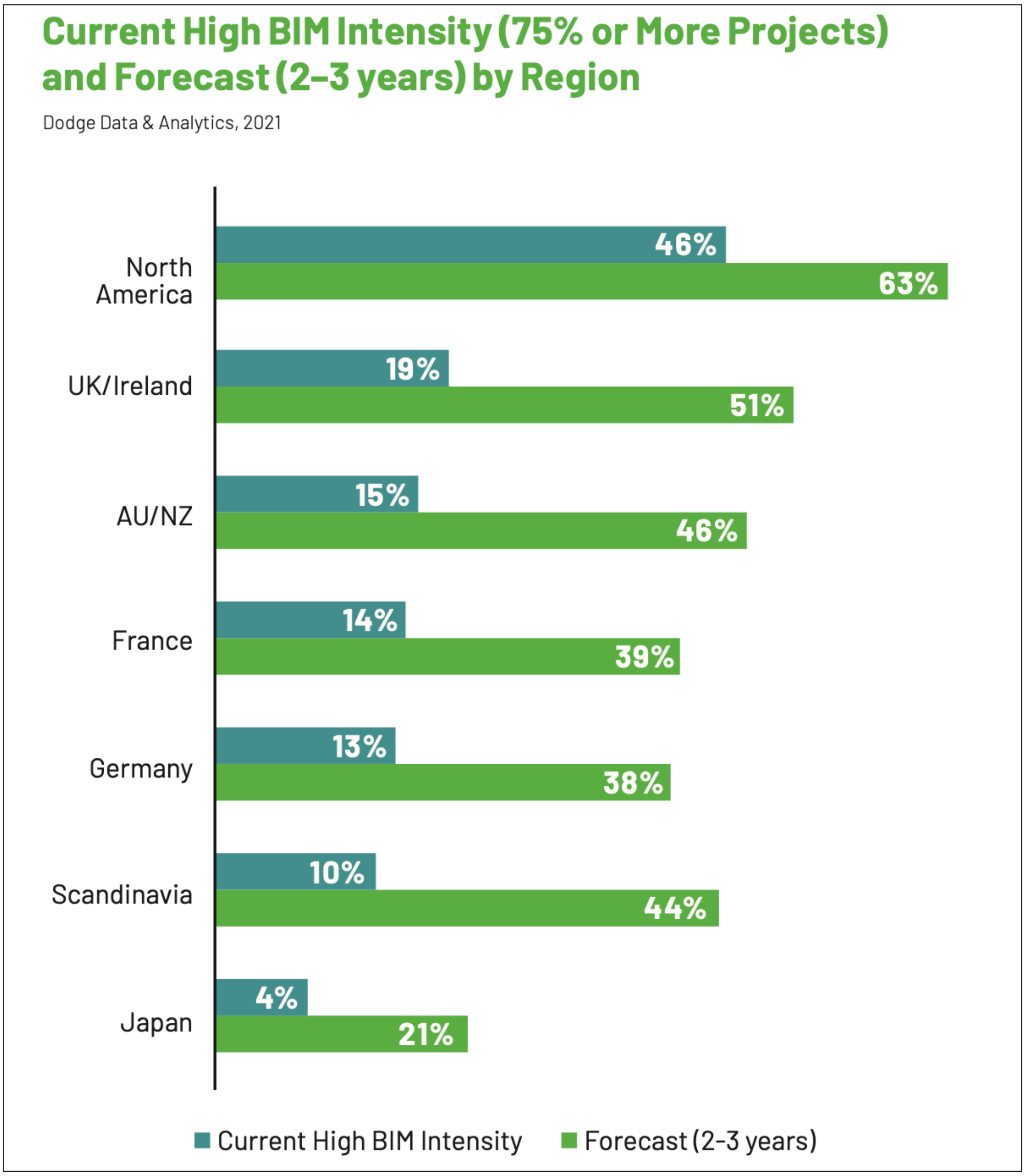

Figure 2 - Dodge Data Analytics (2021). SmartMarket report for Autodesk.

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.

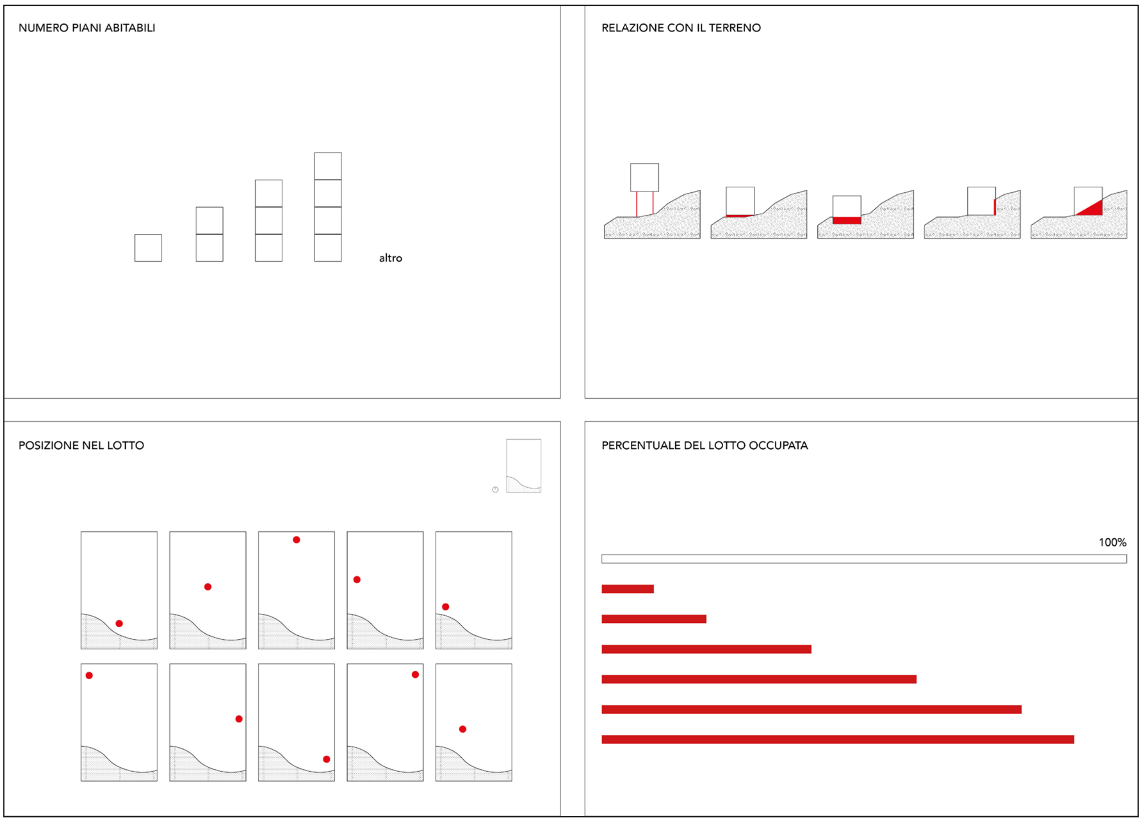

Figure 3 - Examples of "guide sheets" trhough which the project has to be developed. Clockwise: Number of floors, relation with the soil, percentage of lot occupied, position in the lot. Diagrams by L. Buondonno.

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.

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Scene perception of urban projects from architects and non-expert population: their verbal and visual responses[1]

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Abstract

Public spaces in cities are essential elements for the proper functioning of a community. Most of the designs of these spaces are valued by experts in the field. However, this assessment may be biased and may only respond to some of society that has this expert training in architecture and construction. This was the aim of the present experimental study: to analyse the differences in the verbal and visual responses of *architects* and *non-architects* to the visualisation of renderings of public space projects.

To this end, 39 architects and 36 non-architects viewed renderings while their verbal (subjective assessment of the environment) and visual (time of fixation to the compositional elements of the image) responses were collected. The verbal response was quantified by means of a questionnaire of adjectives previously acquired by differential semantics, while the visual response was measured by means of an eye tracking device. The results show differences in the verbal response, but not in the visual response. Therefore, the expert training condition may be influencing the occurrence of this difference. The results may be of interest to professionals in the sector.

1. Introduction

Public spaces in cities are essential and determining elements for the functioning of a community (Mehta, 2014). For this reason, in recent decades, there has been a growing interest in finding out how these spaces

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[1] This work was supported by the Ministry of Economics and Competitiveness of Spain (Project TIN2013-45736-R). The second author of this work is supported by the Ministry of Education of Spain (FPU19/03531).

influence the quality of life of citizens (Lloyd & Auld, 2003; Marcus & Francis, 1998; Schmidt & Németh, 2010).

The most economical way to analyse the individual's response to the environment is through the visualisation of images and the completion of self-reported questionnaires, being one of the usual procedures to follow in this type of study (Granié, et al., 2014; Lis & Iwankowski, 2021).

A very widespread technique for working with questionnaires has been differential semantics, which investigates the attitudes held towards different words. It is available for measuring the affective meaning of concepts developed by Osgood, Suci and Tannenbaum (1957). Among its possible fields of application are environmental studies, as it has been widely used to find out preferences in the urban environment (Kinoshita et al, 2006; Llinares, Page & Llinares, 2013). However, more and more researchers, such as McManis *et al.* (2001), are including measures of the nervous system and other physiological processes in their studies to complement these self-reported measurements. To this end, eye-tracking is postulated as one of the most powerful techniques for collecting the user's unconscious response through objective metrics (Casado-Aranda, Sánchez-Fernández & Ibáñez-Zapata, 2020). Eye-tracking is a technique that allows us to follow the path of the gaze during the visual exploration that humans make of their environment, distinguishing between microsaccade and fixation movements. Among others, it has been widely used to analyse the perception of images among the population with Autism Spectrum Disorder when these visual scenes present humanising elements (Frost-Karlsson *et al.*, 2019). This type of work has been based on the assertion that eye movement fixation is related to the attention of the observer (Kiefer *et al.*, 2017). In this regard, it is important to note that the way in which images are processed and valued is highly conditioned by prior experience and information (Gegenfurtner, Lehtinen & Säljö, 2011). Thus, studies such as Vogt and Magnussen's (2007) showed that artists and non-artists employed different image viewing strategies: it shows that *artists* spent more time scanning structural and abstract features, while *non-artists* focused on objects and human features.

More recent studies in the field of design and construction have also obtained consistent results where *architects* and *non-architects* show different perceptions of the environment (Ghomeshi & Jusan, 2013; Llinares & Iñarra, 2014; Montañana, Llinares & Navarro, 2013; Šafárová et al., 2019; Yazdanfar, Heidari & Aghajari, 2015). However, all of them have focused on the aesthetic and subjective valuation of the environment.

This methodology shows a main limitation: the measurement of self-reported appraisal is a metric that provides too partial data on the subject, focusing only on the purely cognitive aspect. In order to shed light on this question, it is necessary to look at another aspect of the person, such as the more physiological aspect. In this sense, it seems necessary to answer two questions: is the cognitive and physiological response different for *architects* and *non-architects*, and is there a relationship between the two responses? The aim of this study is to answer these questions. To this end, it aims to analyse: (1) the differences in verbal and visual responses between *architects* and *non-architects* and (2) the possible relationships between the two responses for each group of people. To this end, data were collected on the verbal response (subjective perception of the observer) and the visual response (visual tours undertaken) in the process of evaluating urban projects. To measure both responses, the differential semantic-based questionnaire technique and the eye-tracking technique were used, respectively.

2. Methodology

To address the objective, research work was carried out in an experimental context where the visual and verbal response of each participant to the presentation of 3 randomised stimuli out of 27 possible stimuli was collected. The study involved 75 subjects, aged between 20 and 40 years (50.67% were men and 49.33% were women). Of the total number of participants, 39 were architects and 36 were distributed among other professions not related to building or architectural design.

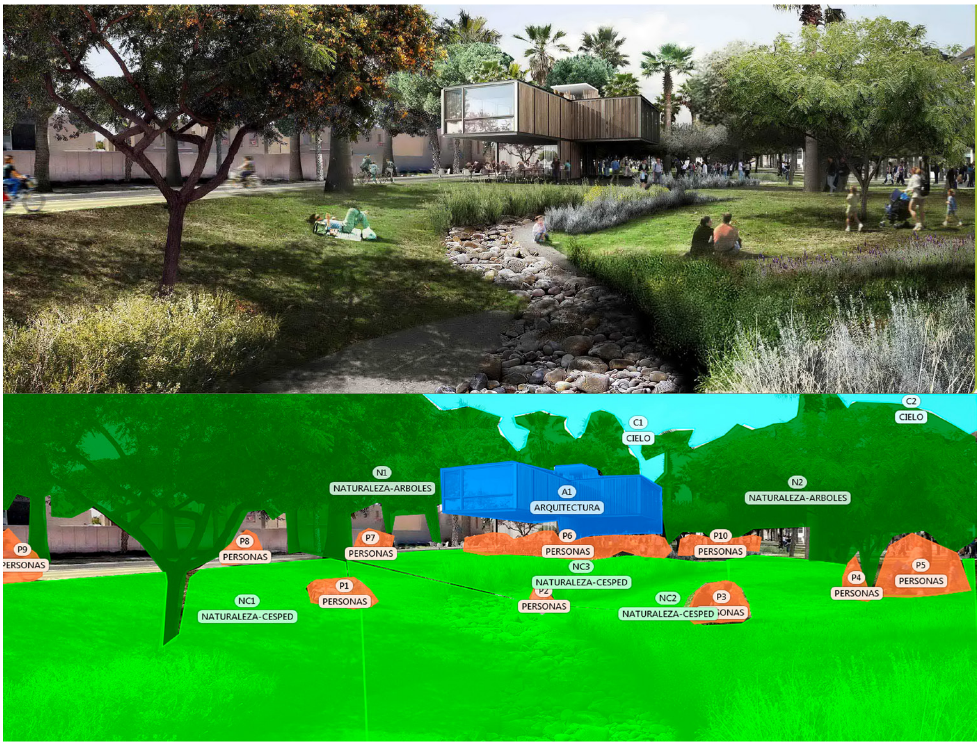

Figure 1 - Example of a stimulus (upper image) and its CE delimitation (lower image). Benicasim Boulevard. Castellón. Project/Image: Iñaki Alday.

2.1 Stimuli

A set of 27 renders of public spaces made up the group of stimuli presented. All the selected images had their compositional elements (CE) calibrated: nature -Trees or Lawn-, people, architecture, urban furniture, ground and sky (Fig.1). In this way, the conditioned perception that can be produced by the disproportionate combination of these different elements is reduced.

2.2 Recording responses

The following sequence was used to collect the response: First, the user, without giving any indication, visualised the image while the visual response was collected (duration of approximately 30 seconds). Then, the participant was instructed to rate the images through a questionnaire, which was used to collect his or her verbal response (duration of approximately 17 minutes). The metric for each response is then specified.

Verbal response. Each visualisation was assessed on the basis of 6 affective factors (Llinares & Iñarra, 2014): (1) Tranquility, Well-being, Harmony, (2) Innovative, Futuristic, Fashionable, (3) Happy, Warmth, Colourful, (4) Nostalgic, Romantic, (5) Functionality and (6) Monumentality, Huge and Luxury. A 5-point likert scale (from -2 to 2) was used: totally disagree, disagree, neutral, agree, totally agree.

Visual response. For each visualisation, data were collected on the time in seconds of the Total Fixation Duration (TFD) to the different ECs. For this purpose, an eye tracking device by Tobii TX300 eye tracker (https://www.tobii.com/) was used. Figure 1 shows an example of the delineation of the CEs in one of the stimuli used.

2.3 Statistical analysis

The data collected were processed using IBM SPSS v.16.0 (https://www.ibm.com/es-es), testing for normality using the Kolmogorov-Smirnov test and assuming significance at a p-value <.005.

The results showed that the data did not follow a normal distribution, so non-parametric tests were applied for analysis.

3. Results

The verbal and visual responses to the renderings were grouped according to the participant's background (*architects* or *non-architects*).

The data obtained were processed for statistical analysis, leading to the following results.

3.1 Comparison of visual and verbal response between *architects* and *non-architects*

To compare the visual and verbal response between architects and non-architects, the Mann-Whitney test was applied. The results are shown in Figure 2. The emotional impressions that show significant differences between *architects* and *non-architects* are nostalgic-romantic and functional. For the nostalgic-romantic impression, the ratings are higher among *architects*, contrary to the functional impression where the values are higher among *non-architects*. In any case, all the levels of evaluation obtained were considered, with the innovative evaluation being the best rated for all the renders in both groups. *Architects* and *non-architects* also coincide in evaluating the nostalgia and romanticism factor with lower scores. In addition, it is important to note that *non-architects* give more extreme scores. The results for the TFD variable show that there are no significant differences between *architects* and *non-architects*.

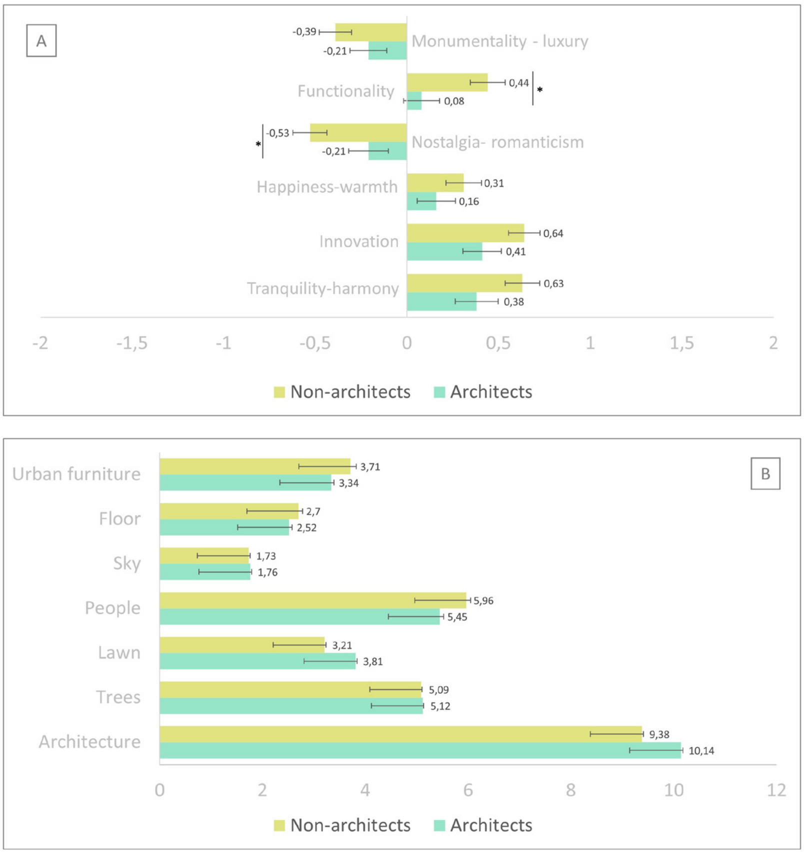

Figure 2 - Comparison of verbal (A) and visual (B) response means between *architects* and *non-architects*. The asterisk indicates significant differences (p < .005).

3.2 Relationship between visual and verbal response in *architects* and *non-architects*

In order to find out the correlations between the visual and verbal response of *architects* and *non-architects*, the Pearson correlation test was applied. The results are shown in Figure 3. Among *architects* there seem to be relationships between what is observed and what is positively valued. Thus, the more they looked at trees, the more they expressed a sense of well-being, happiness and nostalgia. In turn, higher scores for innovation and monumentality correlate with more time spent looking at areas of architecture. Architects also show negatively significant correlations of the happiness rating with sky viewing, the monumentality rating with fixation on people and street furniture and, finally, the nostalgia rating with street furniture.

On the other hand, in the fixations of *non-architects*, there are not so many relationships between what they look at and what they express. We only found negative relationships between the observation of trees and the impression of nostalgia and between the observation of street furniture and the impression of monumentality.

NON ARCHITECTS — Total Fixation Duration

affective factors	ARCHITECTURE	TREES	LAWN	PEOPLE	SKY	FLOOR	U.FURNITURE
TRANQUILITY, WELL-BEING	-0,071	0,167	0,085	-0,136	-0,084	0,001	0,037
INNOVATIVE, FUTURISTIC	0,096	-0,007	-0,035	-0,071	0,112	-0,147	0,060
HAPPY, WARMTH	-0,043	0,117	0,154	0,109	-0,120	-0,191	-0,071
NOSTALGIC, ROMANTIC	-0,168	-0,661	-0,143	-0,149	0,003	-0,054	0,075
FUNCTIONALITY	-0,002	-0,119	-0,019	0,102	-0,076	0,179	-0,071
MONUMENTALITY	0,119	-0,093	0,000	0,020	0,181	0,000	-0,357

ARCHITECTS — Total Fixation Duration

affective factors	ARCHITECTURE	TREES	LAWN	PEOPLE	SKY	FLOOR	U.FURNITURE
TRANQUILITY, WELL-BEING	-0,130	0,268	0,083	-0,049	-0,071	-0,086	-0,073
INNOVATIVE, FUTURISTIC	0,298	0,022	0,111	-0,075	0,069	-0,116	-0,056
HAPPY, WARMTH	-0,062	0,277	0,114	0,073	-0,235	-0,156	-0,035
NOSTALGIC, ROMANTIC	-0,183	0,249	-0,067	-0,060	-0,096	-0,014	-0,268
FUNCTIONALITY	0,003	0,047	0,011	-0,098	0,010	0,196	0,058
MONUMENTALITY	0,331	-0,148	-0,109	-0,253	0,175	-0,103	-0,332

Figure 3 - Summary of Pearson's correlation coefficients between verbal and visual response in non-architects (top box) and architects (bottom box). Red and yellow indicate significant negative and positive correlations (p < .005), respectively.

4. Discussion and conclusion

Although the spaces are built with the aim of meeting the needs of the population as a whole, the aesthetic component of the designs is based largely on the criteria of the specialist. In this sense, it is necessary to know whether these criteria are representative of the user population.

This study attempts to address this problem by analysing the processing of urban rendering images by *architects* and *non-architects*. Analyses indicate that professional training may affect verbal response, but not visual response. Non-experts use a different categorisation scheme (Devlin, 1990), making more extreme verbal responses. This may be because, unlike architects, they do not have training that allows them to be more accurate and realistic with their assessments. As for the visual response, there are no differences between the two groups, which is consistent with other studies in which there were only visual differences between the groups that had a task associated with the visualisation of the image and those that did not (Vu, Larson & Chandler, 2008). This may be due to the fact that the way we look is a more biological aspect, so that, if no explicit cue is given, people follow common visual patterns to process an image.

Thus, it can be concluded that it is necessary to address both responses together, as they provide different information on the behaviour that architectural and non-architectural experts have before viewing a rendering. This can help to find effective design and assessment processes that enable the creation of user-centred spaces, expanding the methods available for public participation in urban planning (Hemmersam *et al.*, 2015). The results are of interest to the urban planning sector as it allows the designer to consider inclusive projects based on common physiological metrics.

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Art and rehabilitation. Movement clues in signs and image structures as facilitators in paediatric motor rehabilitation processes[1]

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Abstract

Aesthetic experience has made it possible to understand that our brain does not remain indifferent to the beauty of certain images. When faced with a work of art, it is activated by influencing our visual, emotional and motor perception. The characteristics of certain artistic representations and practices are so "beautiful" that they are included in the medical field as part of various therapeutic practices. This essay addresses the issue of the use of artwork in psychomotor rehabilitation activities for developmental age subjects with tetraparesis and hemiparesis. With respect to this objective, the study methodology was divided into a phase of identifying the cognitive skills of subjects with severe and moderate tetraparesis and moderate haemiparesis. We then went on to identify the graphic and compositional signs accessible to the target group examined and to verify their effectiveness in terms of motor stimulation thanks to the contribution of the medical staff of the Department of Physical Medicine and Rehabilitation of the Giannina Gaslini Paediatric Institute in Genoa.

The outcome of this research phase was the elaboration of guidelines able to support therapists in the selection of works of art to be submitted to the patient also through the use of technological instruments functional to interaction.project, animations were developed showing a possible digital interaction between the child with tetraparesis and hemiparesis. The results obtained were presented and evaluated by the doctors of the Department of Physical Medicine and Rehabilitation of the Gaslini Pediatric Institute in Genoa.

[1] All the results were reviewed and judged by the medical team of the Department of Physical Medicine and Rehabilitation of the Giannina Gaslini Paediatric Institute in Genoa.

1. The perception of the human being in front of art

According to Semir Zeki, neuroaesthetics was not born to say what beauty is but seeks to understand more about how the brain works. This discipline investigates the brain mechanisms responsible for what we experience when we observe artistic representations such as a work of pictorial art, a musical performance or mathematical formulas and theorems (Savino and De Clemente 2020). The ultimate aim of this discipline is to find scientific answers to questions that have always been asked by humanistic researches, particularly those related to the field of aesthetics. Why does art induce aesthetic pleasure? Why are we attracted to some works while we consider others uninteresting or even ugly? And above all, why is art considered a universal phenomenon that always maintains certain constants, even across millennia and continents?

The search for these answers has prompted neuroscientists to investigate the innate and instinctive brain processes underlying perceptual experience by studying the neurons that respond specifically to external stimuli that can be traced back to the observation of a static image or to particular body or head movements made by other subjects (Craighero, 2017). These neurons, discovered by Giacomo Rizzolatti in 1992, are called “mirror neurons”. Subsequent studies, thanks to the contribution of Vittorio Gallese, then highlighted the activation of mirror neurons and the cortical motor system during the observation of a work of art, producing responses of physical and emotional perceptual well-being. Art, with its aesthetic engagement and involvement of the imagination given by sensory activation and the evocation of emotions, leads to cognitive stimulation that can trigger psychological and physiological responses in social behaviour, directly linked to the state of health and well-being.

And it is precisely with reference to these issues that the hypothesis was born to verify the rehabilitative potential of the empathic and dynamic qualities of certain artistic images in the context of motor rehabilitation processes.

What can be the benefits, in terms of movement induction, determined by the “vision” and therefore the “understanding” of the gesture that has traced a certain type of image?

Thanks also to the support of the medical staff of the Department of Physical Medicine and Rehabilitation of the Giannina Gaslini Paediatric Institute in Genoa, a research project has been launched aimed at outlining a methodological proposal for the selection of visual artefacts functional to motor rehabilitation in the age of development, with particular reference to cases of hemiparesis and tetraparesis.

In order to correctly identify the works of art useful for facilitating the rehabilitation activity for the above-mentioned pathologies, the characteristics of the cases of children with severe and moderate tetraparesis and those for children with moderate hemiparesis were analysed at first, then the appreciable visual and graphic characteristics were investigated outlining guidelines and finally examples of pictorial works of art were identified with which the child could relate and interact in order to carry out psychomotor rehabilitation.

Referring to the literature relating to the description of motor impairment in the different degrees of paresis, the main limitations of movement and related motor stimulation actions were identified.

1.1 Tetraparesis

The limitations induced by tetraparesis concern the area of movement of the four limbs and a general impairment of the latter. It consists of difficulty in acquiring antigravity skills, poverty of movement, poor modulation of movement according to the task, stereotypy of movement; severe impairment with hypertone present in all body districts; moderate impairment, with hypertone: a) in all body districts; b) in the distal districts; in all parts of the body, non-homogeneous impairment It is characterised by a considerable poverty of movement, and the inability to acquire antigravity skills and to correctly maintain postures with a high centre of gravity.

The child is unable to critically evaluate information from the context around him and to adapt and modulate his responses according to external demands. The child is forced to 'suffer' external sensory stimuli, as he is only able to interact with the environment with a limited repertoire of movements, he learns to constantly listen and respond to reduced types of information, reinforcing an increasingly closed and stereotyped circuit. These difficulties in interacting with the environment are common in the child with severe tetraparesis and in any framework with poor movement.

In the case of severe tetraparesis, the objectives of rehabilitation work do not involve the acquisition of antigravity skills, but rather aim to achieve the physical and psychological well-being of the child and their carers.

The primary objective is undoubtedly to improve the child's quality of life as much as possible. The child with moderate tetrapathy is able to adapt more easily to problems posed by the environment, modifying his or her response according to sensory experience and the characteristics of the problem to be addressed. Problem solving may be more difficult in the intermediate sitting posture where the child, having a smaller base of support, needs greater stability/mobility of the trunk, or in the standing posture, where greater control of the oscillations of the body axis is required.

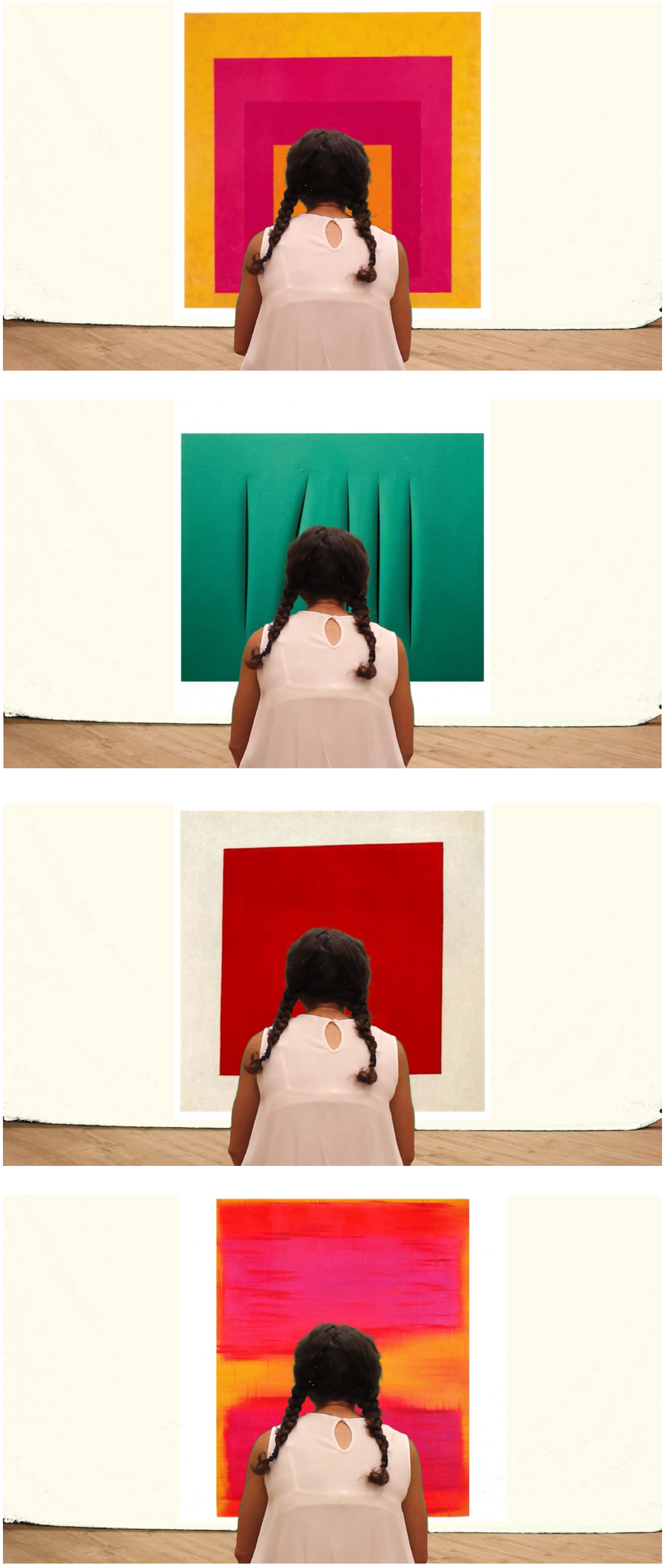
The child's transition from one posture to another is conditioned by his ability to move stably against gravity, using information coming mainly from the visual, labyrinthine and tactile-proprioceptive channels.

The latter is indispensable in making him understand where he is at a given moment and in what relation he is to his surroundings. In order to adapt his motor behaviour to these situations, his knowledge of the environment is crucial. In cases of moderate tetraparesis, the objectives may include the acquisition of good postural autonomy and functional movement in an upright position, although naturally, the prognosis project will be differentiated, following the careful evaluation of each child's potential. It is very important to allow the child to experience the different postural situations involving verticalisation at an early stage, even when he/she does not yet have all the necessary prerequisites to deal with it independently (Giannoni and Zerbino, 2000). Furthermore, according to *Recommendations for the rehabilitation of children with infantile cerebral palsy*, (Simfer; Sinpia, 2013, p. 19), haemiplegic children mainly present strabismus (71%), refractive defects (88%) and visual field alterations (64%); in tetraplegia, the neuro-ophthalmological profile is more severe, with impairment of all components, ophthalmological (98%), oculomotor (100%) and perceptual (visual acuity reduction in 98% of cases). With all this in mind, it was possible to proceed with the hypothesis of which works and with which interaction these children could enjoy art in their therapy.

For cases of severe tetraparesis with very reduced or completely absent movement abilities and very high percentages of associated severe visual impairment, therefore, the solutions will aim to achieve a perception of psycho-cognitive well-being in the child. For this reason, works of art that involve the exclusive use of colour have been identified as useful in pursuing this objective.

For children with severe tetraparesis, preference is given to those works in which the composition must be very simple, based on a purely two-dimensional construction without alluding to perspective references that would complicate perception, any reference to figurativism is absent but what must be contemplated is colour, colour is form and space as the concentration of the emotional sphere of the artist and of those who go to perceive the painting, the origin of the positive emotions derived from the use of colour with contrasting chromatic combinations, not too vibrant, bright and sunny to avoid inducing disturbances in perception and the stimulation of gloomy and disquieting scenarios.

Colour becomes the work's internal light source, there is no play of light and dark, but the exclusive use of uniform backgrounds along the surface (Figg.1-4).



Figures 1,2,3,4 - From top: Photomontages, Josef Albers, Squares with orange, red, burgundy, light orange, c. 1960; Lucio Fontana, Spatial Concept, 1968; Kazimir Malevich, Red square, 1915; Mark Rotchko 1960 ca. Images by the author.

The treatment is different for the child with moderate tetraparesis, for whom movement is not impeded but present and must be stimulated through autonomous play initiatives or with the support of the parent and or the therapist. These children need to be stimulated to activate movement by selecting and proposing works of art that are able to convey the desire to move and explore space and at the same time are easy to understand. The works of art identified present completely different characteristics to those reported for the previous case study.

The composition must be built on dynamic lines that favour construction lines converging at least at one point, this means that the use of perspective, of depth that induces the exploration of space, must be clear and evident. The presence of the horizon line is recommended, not only because it is an element that often recurs in children's representations as an abstract subdivision between sky and earth, but if it is placed at eye level in a perspective space it guarantees better immersion in the work on the part of the observer. The elements present must be easily distinguishable and in small quantities to avoid visual crowding. Each subject present must contribute to the construction of spatial depth through different solutions. The colour should be light and bright, favouring visible colour contrasts and not too vibrant which could cause spasms in the child, uniform backgrounds, shades and transparencies may be present but always if they contribute to creating effects of perspective and depth (Fig.5). The guidelines for children with hemiparesis have been analysed in more detail due to the complexity of childhood tetraparesis.

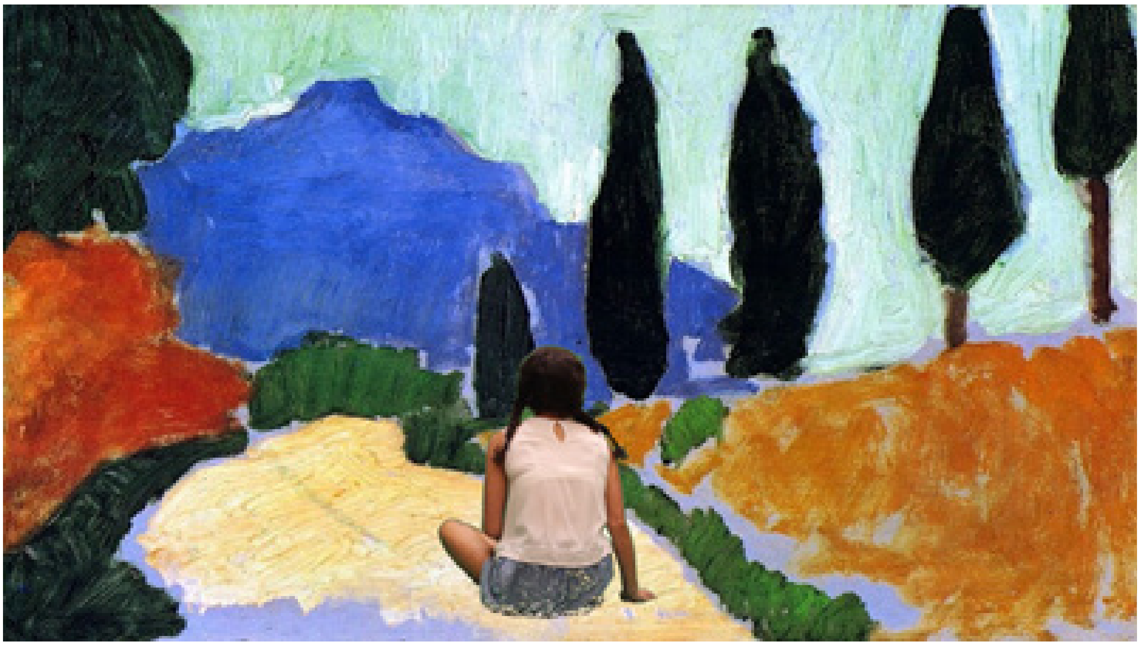


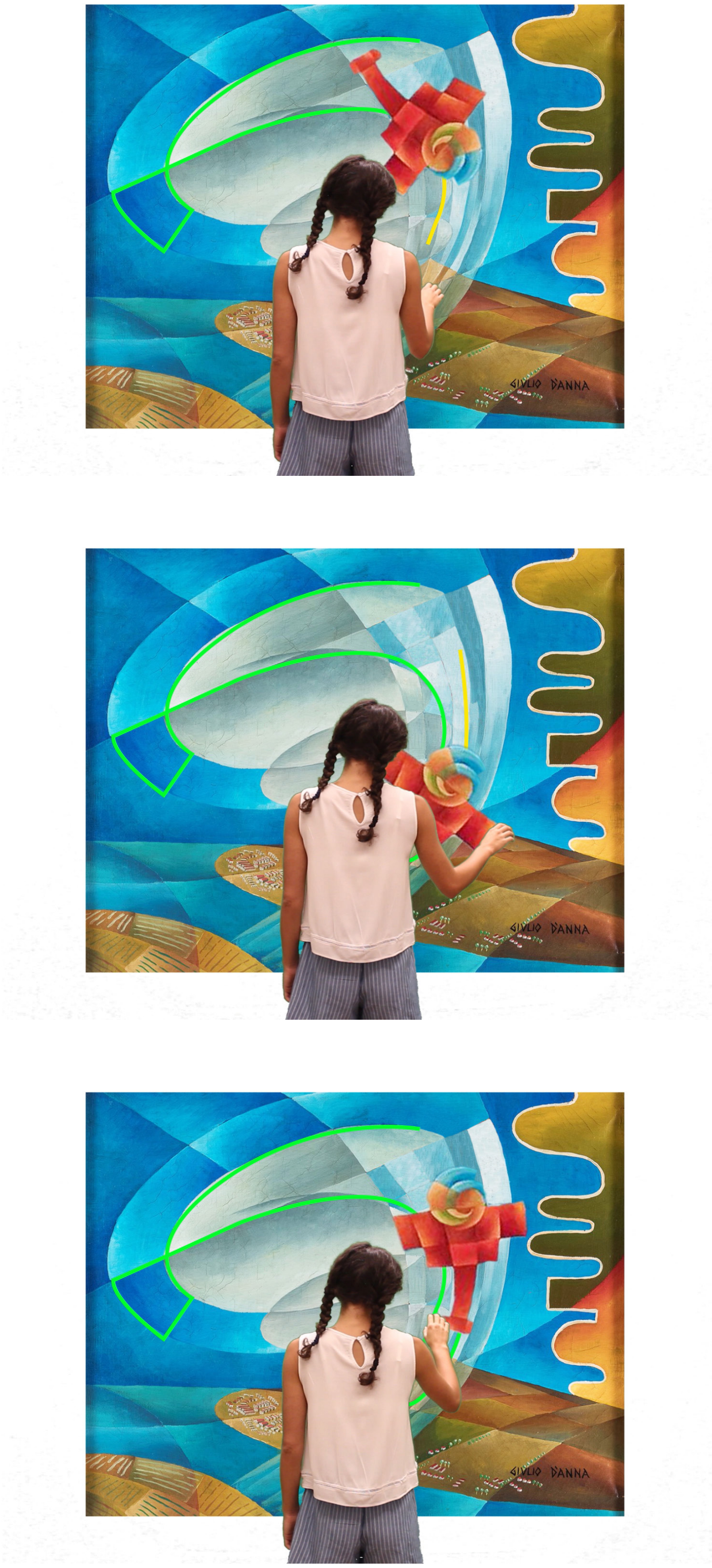
Figure 5 - Photomontage, André Derain, Cypress, 1907. Image by the author.

1.2 Hemiparesis

It is not considered as a single syndrome, but rather a collection of different clinical pictures, depending on the pathogenesis and the time of onset. Apparently it is a simple pathological form, but in reality it presents some complex aspects; in addition to the posturokinetic problem, other perceptual, linguistic and cognitive-affective disorders are frequent. Since a child with hemiparesis is capable of reaching the various neurodevelopmental milestones on his own, the ultimate goal of any project must aim at the quality of the functional repertoire and not only at the conquest of abilities that the child achieves even without help. The characteristics of the haemiplegic child are poor movements, predominantly at one hemilateral; side asymmetry; greater impairment to the upper limb in babies born at term and to the lower limb in preterm infants; excessive tonic recruitment especially at the distal limbs; perceptual sensory disturbances; neuropsychological disorders; possible seizures (Giannoni & Zerbino, 2000). In these children, movement is present in different ways; each case will have different difficulties in the gestures of their limbs. For this reason, there is a case study of a hemiparetic child who has difficulties in the precision and fluidity of gesture of the upper limb and a second case study of a child with problems in bimanual and symmetrical coordination of gesture. Consequently, the aim is to select the work and propose a way of interacting with it that can stimulate and help the child in refining these aspects just mentioned. For the first case, interaction was proposed with the work of art created by Giulio D'Anna in the Second Futurism (1930), the title being *Volo sull'Etna*. The compositional characteristics of this painting were studied, which were necessary for the hemiparetic children with whom an attempt was made to refine the precision and fluidity of the gesture. The interaction begins with an initial prolonged moment of analysis of the work with the support of the therapist to better understand what is represented and what emotions and feelings it conveys. Then we move onto the digital interaction during which the aeroplane moves along the painting's guidelines and the child has to follow the trajectory correctly (Fig.6) after having thought about the interactive activity, a prototype video of the interaction between the work and the child was created (Figg.7-9).

In the last case study of moderate hemiparesis there is a need on the part of the child to improve the bimanuality and symmetry of the gesture. It is important to provide the child with hemiparesis with early experiences of bilateral use of the two upper limbs, and in children with milder impairment, greater control is sought, with activity of the paretic limb only or of both, of the approaching and grasping behaviours, also implemented in different postures and on different planes.

Figure 6 - Outline, Giulio D'Anna, Flight over Etna, 1930. Image by the author.



Figures 7,8,9 - Photomontage, Giulio D’Anna, Flight over Etna, 1930. Image by the author.

For this last study, the work considered is called *Composition II in Red, Blue and Yellow* created by Piet Mondrian in 1930. The work is composed of perfectly symmetrical coloured geometric shapes. Thanks to this structure, it is possible to design a rehabilitation system to stimulate bimanual work between the two upper limbs.

The child placed in front of the digital canvas has a screen with the opaque geometric figures that serve as guidelines to facilitate the activity with the geometric shapes to be used to compose the work to the side, and the original artwork that the child must reproduce on the canvas to the side. The child after analysing the scene has the possibility of choosing one geometric figure at a time, after selecting it it appears in the centre of the screen in full colour, not opaque, at which point the child can begin the interaction through the bimanual gesture coordinated with the other (Fig.10).

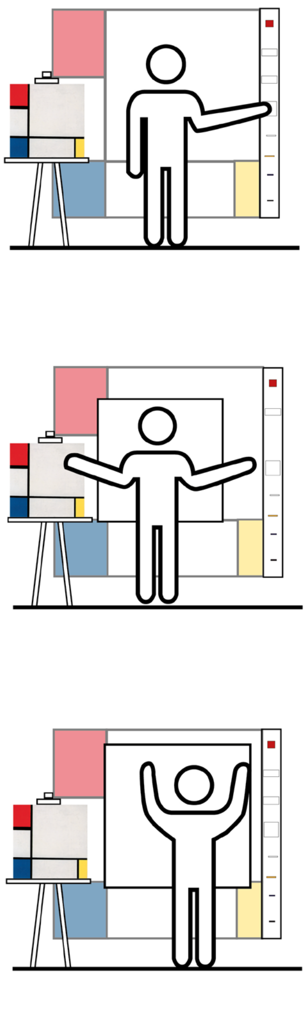


Figure 10 - Scheme, Piet Mondrian, Composition II in Red, Blue and Yellow, 1930. Image by the author.

The shape can be enlarged, shrunk, once the correct proportions have been identified, it must be placed in the right area of the surface. A small vocabulary of gestures indicating the actions that can be performed has also been developed (Fig.11). After thinking about the interactive activity, a prototype video of the interaction between the work and the child was created (Fig.12-15).

As in the case of tetraparesis, guidelines were outlined and summarised in Fig. 16 and Fig. 17.

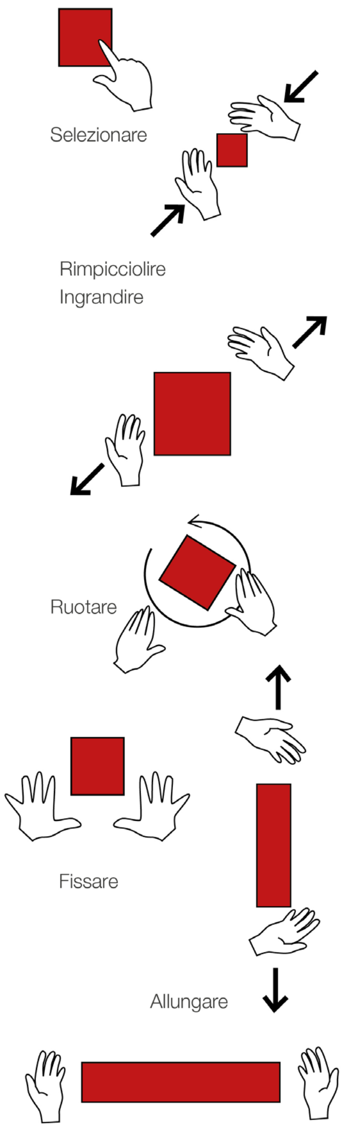
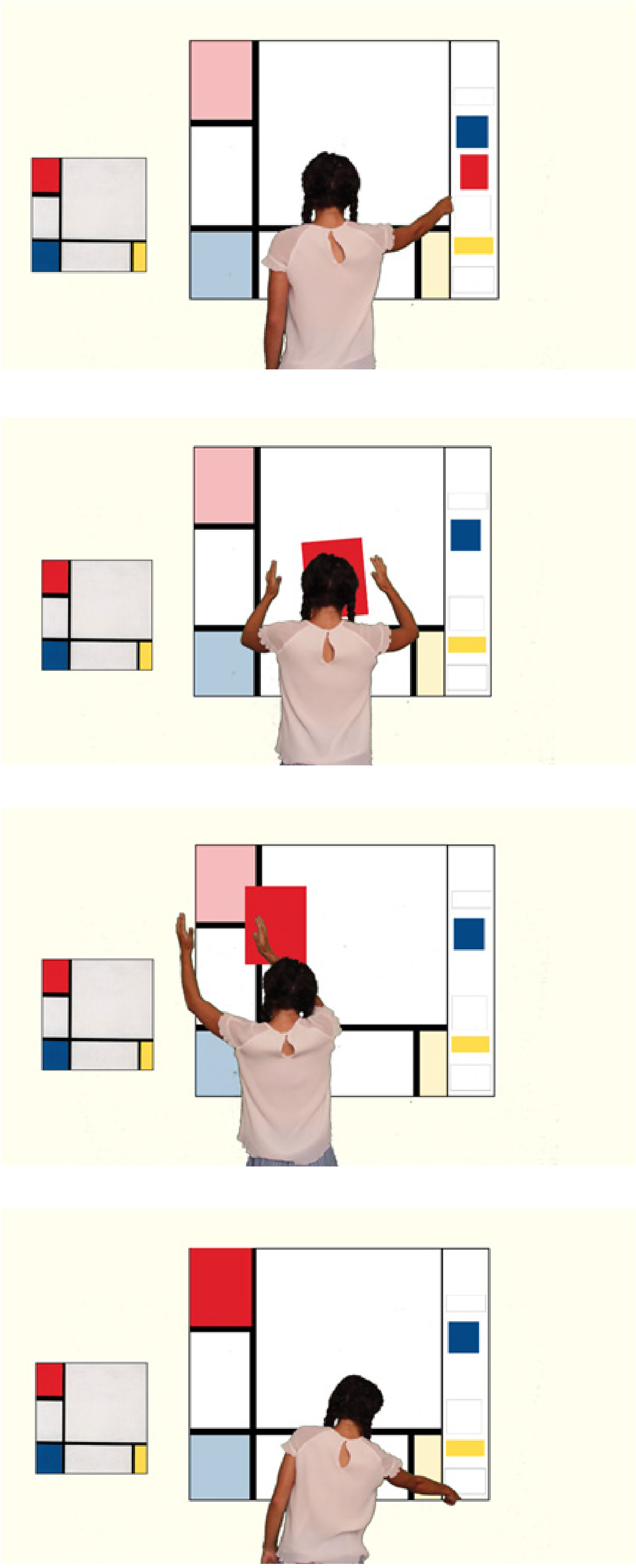


Figure 11 - Vocabulary of gestures. Image by the author.



Figures 12, 13, 14, 15 - Photomontage, Piet Mondrian, Composition II in Red, Blue and Yellow, 1930. Images by the author.

Figure 16 - Artwork Guidelines, case study 1. Image by the author.

Figure 17 - Artwork Guidelines, case study 2. Image by the author.

These primordial selection principles that only take into account the composition, elements, form and colour of the artwork might be suitable for some children and for many others not. In these cases, the work of art is not always accessible and usable for children.

On the other hand, it would probably be impossible to find individual solutions that suit every patient's needs. What can be done, and what has been implemented in this thesis, is to identify a certain type of target, a certain pathology, for which more specific criteria can be established that look precisely at the problems and needs of that problem under consideration. In this way, these principles make it possible to identify a certain number of works of art that present characteristics that may prove useful in therapeutic practice for that type of target.

In this set of works, however, there will be representations that present similar compositions, elements, signs, conception of space, colours and use of light but with different levels of complexity, which the therapist will only then be able to make a final, more specific selection of the most suitable works with reference to the severity of the pathology, limitations, strengths, age and interests of the child. The therapist will be able to select a number of works and then let the child choose which one to use for the activity.

Art can be accessible and usable by everyone as long as multidisciplinary teams are involved to find solutions to facilitate and enable the encounter between the two.

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Electroencephalogram in freehand and CAD drawing discloses different cognitive involvement

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Abstract

Thanks to technological evolution, in the course of the years, the mechanical reproduction of Walter Benjamin has been integrated with the mechanical creation. Architectural projects can be completed from the start with little human involvement. Artificial intelligence and CAD ready made blocks are tokens of pervading mechanization dulling the mind.

The concerns raised by few when decades ago the CAD was born, are even more justified and shared today. Since our mind has roots based in the neurobiology of relationship life, it is conceivable that creativity could be boosted by movement reactions to sensory afferents, as in freehand drawing. On the other hand, reducing physical activity would inhibit such performance. This paper reviewes some recent experimental evidence from our laboratory, based on electroencephalography, suggesting that freehand drawing is associated with much higher cognitive activity than CAD. This may be the first promising step in investigating the effect of various methods of drawing and modelling architecture may have on the crafter's mind.

1. Mechanical reproduction and mechanical creation

In 1935 Walter Benjamin wrote his essay on "The Work of Art in the Age of Mechanical Reproduction" (Benjamin, 2019). At that time photography had progressed enough to be widely affordable and reliable, so that documentation of the real world by images and reproduction of artworks were commonplace in newspapers, journals and books. He argued that mechanical reproduction fundamentally changes the nature of art and the way in which it is experienced. His work still continues to be relevant, as we grapple with the ongoing effects of digital technology on the production and dissemination of art.

The field of architectural design is one of the most permeated and influenced by the advent of new technologies. Computer Aided Design (CAD) has replaced hand work in most steps of the entire process, and quite often even the first project phase is adapted to the available features of the software. One of the most recent advances in the digital world is the development of artificial intelligence (AI); once reserved to very few research centres, has now become within the reach of architects around the world as almost common use. AI can be used to enhance the design process itself, by enabling architects to quickly generate and test a range of design options based on various criteria and constraints (Castro Pena, Carballal, Rodríguez-Fernández, Santos, & Romero, 2021) (Fig.1). For example, generative design algorithms can be used to automatically generate multiple design options based on input parameters such as site conditions, programmatic requirements, and environmental factors. The mechanical reproduction tackled by Benjamin is now bound to be transformed into a mechanical creation. We are now reaching a point where the entire process of architectural design can be started and perfected without human intervention.

Figure 1 - Design options generated by a free AI image generator. Image by the author.

2. Cognitive science and the sensorimotor activity

The technological race seems to make us forget that the mind is not an entirely abstract process, but is based upon biology and behavioural interrelation with the environment and the self. This is the approach of embodiment in cognitive science, based mainly upon the clues provided by progress in neuroscience. According to that, our bodily experiences and movements provide firm ground to our mental processes, adding meaning and effectiveness (Varela *et al.*, 1993).

Embodied cognition is shaped by our sensory and motor systems, and consequently cannot be gained by a machine. What is more, embodied experience is something that some authors claim to be essential to the end of designing architecture. Pallasmaa, in his two main essays, *The thinking hand* and *The eyes of the skin* (Pallasmaa, 2009, 2012), asserts the paramount importance of an approach in enjoying and designing architecture not only with the sight, but with all our senses, mainly with touch and movements of the hand.

The hand with its fine touch and proprioceptive sensations and with the immense creative potential is considered as if it may have a mind of its own. It is common experience of any artist that movement, and movement of the hand in particular, is an essential part of creation and inspiration for the advancement of their deed. With the hand the artist communicates with the outside world, shapes it and receives a feedback nurturing further inspiration.

The process of continuous sensorimotor interaction between the human and material object of a creative act is theorised in enactivism (Thompson, 2010), a position in the cognitive science born in the 90s of the last century with the aim to emphasize the shaping activity upon the world. The general idea of embodiment and the means to gain it by enacting the environment, have strong links with the astounding progress in neuroscience during the whole last century, when anatomical and functional details of the nervous system have been discovered shedding light on cognitive neural mechanisms (Stewart *et al.*, 2014) with a particular attention to the hand, as means of cognition (Hutto and Myin, 2013, p.46). It is interesting how the importance of the hand both as an explorative and creative instrument had formally been claimed since the first presocratic phylosophers (Diels, 1974). The current mechanistic trend dwarfs the motor active role of the designer, whose work is limited to inputting some data into a computer. The machine acts as a curtain which prevents communication, hence cognition, between the designer and the object. It may be argued, at this point, that the object cannot be considered any more as a work of art, because there is no transferring the spirit of the crafter into it, and embodiment is lacking

(Berndtson, 1960). Psychology and philosophy are now taking hint from the most recent advancements in neuroscience, and appealing theories are being built upon them. It may be difficult to find the way in the maze of new ideas and speculations, and to filter the hard evidence based upon experimental results from further theorisations, whose basis are less scientifically rigorous.

The aim of this essay is to discuss how electroencephalography, the most widely used technique for non-invasive exploration of the cortical functions, may provide evidence about the effect that automatisation has on creativity in architectural design. To that end, the results of three experiments from our laboratory are reported, where two drawing techniques, the freehand and the CAD, are matched, demonstrating a larger cognitive involvement of the former.

3. The discovery of the brain cortex functions

Localisation of function is one of the mainstays of modern neuroscience, allowing to establish a precise relationship between cause and effect in nervous diseases. In short, the idea is that motor, sensory and cognitive functions have a definite parent structure or cortical area within the brain. The most known scholar who worked extensively along this line of thought was John Hughlings Jackson (York & Steinberg, 2007).

In the in the second half of the XIX century he founded the bases of modern neurology by studying epileptic patients and correlating symptoms with brain lesions found at autopsy. He was able to prove with scientific rigour some of the hypotheses that the science of phrenology had started to assert a few decades before just on empirical grounds.

Jackson went so far as to prove that aphasia, disturbance of the language cognitive function, was due to a lesion of a definite area of the brain cortex. These discoveries opened the route to investigations and speculations on the link between cognitive functions and brain cortical areas.

Neuropsychology is the branch that now is dedicated to such a study. At the time of Jackson, the methods to correlate function with localisation were elementary: observation of neurological signs/symptoms on one side and autopsy on the other. In our time non-invasive exploration of the entire nervous system is available with several techniques, and a much more detailed map of the nervous functions can be traced and changes in cognitive functions linked to contingent situations can be documented.

So, we are approaching to understand the influence that perception of the outer world has on our brain and what are its reactions to that. Nevertheless, though evolved, the available methodology has limits, that often are ignored because of the enthusiasm to push the boundaries of our knowledge into utopia.

4. Electricity the language of neurons

The aim of the nervous system is to transmit information, and this is done by electric pulses. The main functional component of the nervous system is the neuron, a biological cell surrounded by an excitable membrane. In its resting state, the membrane has properties that keep the inside of the cell at a negative electrical potential relative to the outside at approximately -80 mV. When the cell needs to transmit information the membrane changes its state from resting to excited by reversing the electric potential difference, which now turns to positive inside and negative outside (Hodgkin & Huxley, 1952). This change of polarity lasts only a few milliseconds and travels across the excitable membrane of the neurons at speeds varying from 80 to 0.5 meters per second. The foundations of our thoughts, emotions, actions, lie all in the tiny electric currents generated by neurons in the brain sending pulses to other neurons, in a complex network. The generated electric field can be detected by any electrode placed at some distance, with voltage inversely proportional to its distance from the source. The voltage produced by only one neuron, seen by the far away electrode, is extremely small, fractions of microvolts, and cannot be recorded from the surface of the body. However, when hundreds or thousands of neurons are activated in a restricted period of time, the electric fields may be of sufficient phase concordance for an effective summation to provide a potential large enough to be detected from the skin surface. This way, clusters of neurons in the cerebral cortex that are rhythmically activated in a synchronous manner can generate the activity detected at scalp level; this is commonly known as the electroencephalogram (EEG) (Fig.2).

The EEG only reflects the spontaneous activation of cortical neurons, unrelated to perception of any external stimulus. However, according to inner conditions, like mental engagement, attention, emotion, the EEG may show different characteristics. Also, in presence of disease, there may be alterations which loosely suggest the location of altered function.

Thanks to progress in signal analysis, the EEG may now provide much more complete information than when it was first used approximately one century ago, and significant changes can be detected in normal volunteers performing tasks that involve higher cognitive functions, like creativity (Srinivasan, 2007).

We may identify several major advantages for the use of EEG in studying the neuronal function.

First, the EEG is a passive technique, completely innocuous and can be repeated many times for any length of time. In this sense, it is ideal to test conditions that vary in intervals of hours or days. Second, it is extremely accurate in time, with a definition only depending on the equipment used, and that can easily be of the order of the millisecond. Third, even long recordings from several electrodes, or channels, take a comparatively little digital storage space. Fourth, digitalisation of the signal is easy and accurate.

Fifth, the signal can be analysed in the time and frequency domain with a number of programming languages, like Matlab © or Labview ©, just to quote the most known (Figg.2,3).

Sixth, the recording sessions have a negligible cost. Seventh, the EEG is the direct recording of the neuronal language, with no intermediary process interfering with interpretation of data.

5. The EEG related with external and inner events: the evoked and event related potentials

The EEG can detect cortical activity not only spontaneous but also related to external stimuli. However, the number of cortical neurons that are recruited in response to an external stimulus is so small that their electrical potentials cannot be recognised from the background electrical activity arising from other neurons discharging spontaneously.

The statistical technique of averaging comes to help if the stimulus can be repeated several times. Based on the fact that the receiving cortical neurons discharge always at the same time and with the same modality after each stimulus, it is possible to summate the EEG responses, so that the stimulus synchronous events will be enhanced, whilst those not linked to the stimulus will cancel out. Dividing the sum by the number of replications completes the process of averaging and restores the original amplitude of the EEG response. The result is of immediate comprehension, has the advantage of not altering the original waveform and is very easily computed with little signal processing, either by hardware or software.

These responses to external stimuli are called evoked potentials (EPs) and can be elicited by tactile, proprioceptive, visual or auditory stimuli. It is remarkable that the EEG responses to these stimuli are localised upon definite areas, and that those components occurring immediately after the stimulus and which reflect the first arrival on the cortex are independent from the mental status of the subject. Also, they maintain definite characteristics according to the type and intensity of the stimuli. In addition to the EPs, there are EEG events that are still synchronous with the stimuli but occur later in the time domain and are not linked to the stimulus characteristics. Also, the locations from which they are recorded are less definite and, most importantly, these responses are strongly influenced by the cognitive state of the subjects. Attention is determinant in modulating their amplitude and latency. These late responses are called event related potentials (ERPs), signifying that they occur in relation, or loose connection, to the stimulus, and their features are more linked to the subject's state of mind than to the stimulus properties. For such reason these are also called endogenous potentials, signifying that they are more related to the self than to the outside world, where the stimulus originates.

Because of their dependency on the inner status of the subject, objective control on the conditions in which they are recorded is very limited. As the ERPs are modulated by attention and other cognitive or emotional statuses, these are widely used to ascertain their sensitivity and specificity to tasks involving various psychological challenges. In order to obtain reliable data from investigations with ERPs, it is necessary that the experiments are performed under rigorously controlled conditions, and are run by experts in the field. Unfortunately this is not always so, and many studies reporting results allegedly classified as significant, cannot be accepted as scientific evidence. Popular issues that have been investigated by this method are connected to the reaction to beautiful/ugly images, to facial recognition, to pleasant/unpleasant situations, to creativity. Despite the extensive literature on the matter, few definite results have been attained.

6. Backward EEG reveals movement preparation

The storage capacity of electronics has made real a neuroscientist's dream: what happens to our brain before action? Is there a planning? How long before, and where? (Deecke, 2014).

Similarly to what happens with the EPs and ERPs, it is conceivable that the number of neurons involved in a definite motor activity is small, hence there is the need to use averaging as well. A backward averaging can be performed by continuously recording the EEG and a trigger signal related to the movement, and a reasonably long time interval can be analysed to extract movement related potentials (MRPs), the neuronal activity occurring before each movement.

It has been demonstrated that each single movement is preceded by cortical activity up to three seconds before it, with several components related to excitation of different cortical areas. The MRPs are influenced by strength and velocity of the movement and by the cognitive state of the subject.

7. The EEG during freehand and mouse CAD drawing

Recording the EEG, in particular the ERPs and MRPs has so far provided a large amount of information about possible correlations with several cognitive states that have been induced with dedicated tasks.

Even for MRPs, it is to be noted that there is no definitive evidence linking characteristic potentials with a given condition. For example, there is no ERP or MRP specifically related to vision of beauty, or well being, or abstract thought. The only information that can be gathered by these experiments is that it is possible to compare the EEG potentials between two or more different task conditions. Of course the cognitive or emotional state is determined by the task design, so the result is always very much contingent to the situation.

It is noteworthy that very little information has so far been gathered with the EEG performed during actual, natural movements while drawing, either in the freehand mode, or, as architects mostly use, by mouse and CAD. A comparison of the two is relevant to the current issue of creativity in architectural design. Because of the almost completely digitised process, the freehand design, rich in movements, has been set apart in favour of CAD. Such trend has raised concerns by many authors as to the lack of creativity that these new procedures may induce (Pallasmaa, 2009; Scheer, 2014).

In our laboratory a series of experiments has been dedicated to the EEG recording during natural freehand and CAD drawing movements; a visual summary of their results is depicted in Figure 3. One first experiment (Leandri, Schenone, & Leandri, 2021) was aimed at setting up and testing a reliable equipment and procedure to record the EEG synchronised with the start of each drawing stroke, without hampering the freedom of movement. Also, the experiment compared the EEG related to meaningful movements, tracing over a figure in freehand drawing, to meaningless movements of the pen.

Because of the natural movements, the rhythm of strokes was faster than the usual single and well spaced movements studied in most of the previous research. So, only the time interval of 800 ms before the stimulus and 800 ms after it were studied. It was found that the EEG activity before movement was definitely larger in the meaningful freehand drawing than in the meaningless strokes. The activity after stroke, was instead, at least in the first 100 ms, similar in the two conditions.

The activity before movement constitutes the pre-motion part of the movement related EEG recording (MRP) and is connected to the supplementary motor, premotor and primary motor cortical activity of the frontal lobe (Fig.5), those areas planning movement and sending orders to actuate it.

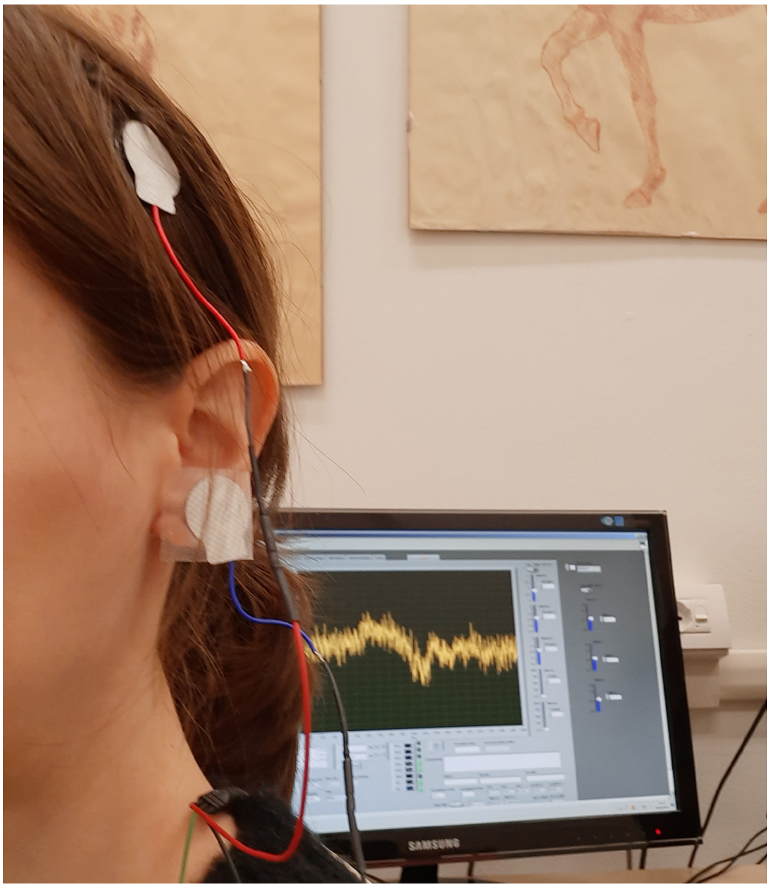

Figure 2 - Signal coming from the electrodes (EEG) is diplayed in realtime on screen. Picture by M. Leandri.

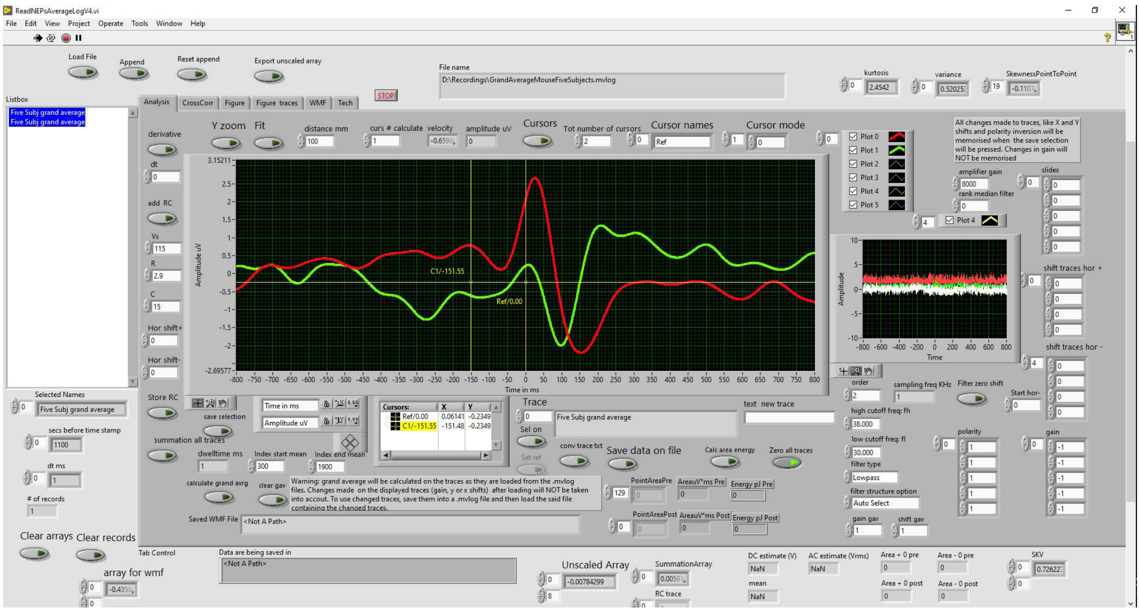

Figure 3 - After recording, the EEG is processed by averaging time epochs synchronised with the pen contact or button pressing trigger signal (0 on X axis). The results of pen (red trace) and mouse (green trace) movements are quite different. Image by the author.

The activity after movement is the post-motion part of the MRP and is due to the sensory afferents coming from the hand and activating the sensory parietal cortex (Gerloff et al., 1997). This post-motion part can be assimilated to EPs (within 100ms after movement) and to ERPs (later events). The difference in the pre-motion MRP between the two conditions in drawing suggests that at activity at the frontal cortex in preparation of each stroke involves a larger number of neurons if the movement is meaningful. On the other hand, the similitude between the two conditions in the early post-motion part (EPs) is in favour of a similar amount of sensory afferents evoked by each movement. It may be concluded that the mechanical part of the movement, independent from its saliency, is similar and not influenced by cognitive status. Because the freehand drawing had been done with a digital tablet and pen, all data of pen movements could be accurately collected. Velocity and extent of movement were recorded at each stroke, and no significant difference could be detected between the two modalities, a clue supporting the hypothesis that it was the saliency of the gesture and not the different kinetics that was responsible for the results.

The second experiment (Leandri, 2022) was then performed comparing freehand with CAD drawing, assuming, as a working hypothesis, that CAD drawing would be less demanding on the cognitive system of the participant and provide results similar to those of the not-salient task (simple meaningless pen tapping and stroking) of the first experiment. The hypothesis could be confirmed by a larger EEG amplitude in freehand than in CAD drawing,

A third experiment (Leandri, Iñarra Abad, Juan Vidal, & Leandri, 2022) was focused on the post-motion components, that is those linked to the sensory input from proprioceptors of the hand, could demonstrate that some later components of the ERP linked to cognitive processing were indeed larger in freehand movements.

In conclusion, these three experiments demonstrate that CAD drawing has much less cognitive involvement in movement preparation and in processing the sensory proprioceptive feed-back than the freehand movements. A visual simplified summary of the three experiments is depicted in Figure 4.

The traces are the average of recordings from one subject who performed the two drawing tasks. The upper trace, in red, was obtained during freehand drawing on tablet and pen.

The lower trace, in green, was the recording during CAD drawing with mouse. The Movement Related Potential (MRP) is constituted by several components that in temporal sequence are deemed to be the reflection of the idea of movement, formed in the supplementary motor area between -800 and -400 ms before movement, then the planning of movement from the prefrontal area, between -400 and -100 ms, and finally the direct motor commands from the primary motor area between -100 and 0 ms. The resulting movement, taking place at time 0 (vertical dashed line in bold) stimulates the proprioceptors and touch receptors of the hand causing a sensory afferent volley to reach the primary sensory cortex. Its activity is the one taking place between 0 and 100 ms after movement, whose components constitute the early and intermediate Evoked Potentials (EPs), linked to stimulus features.

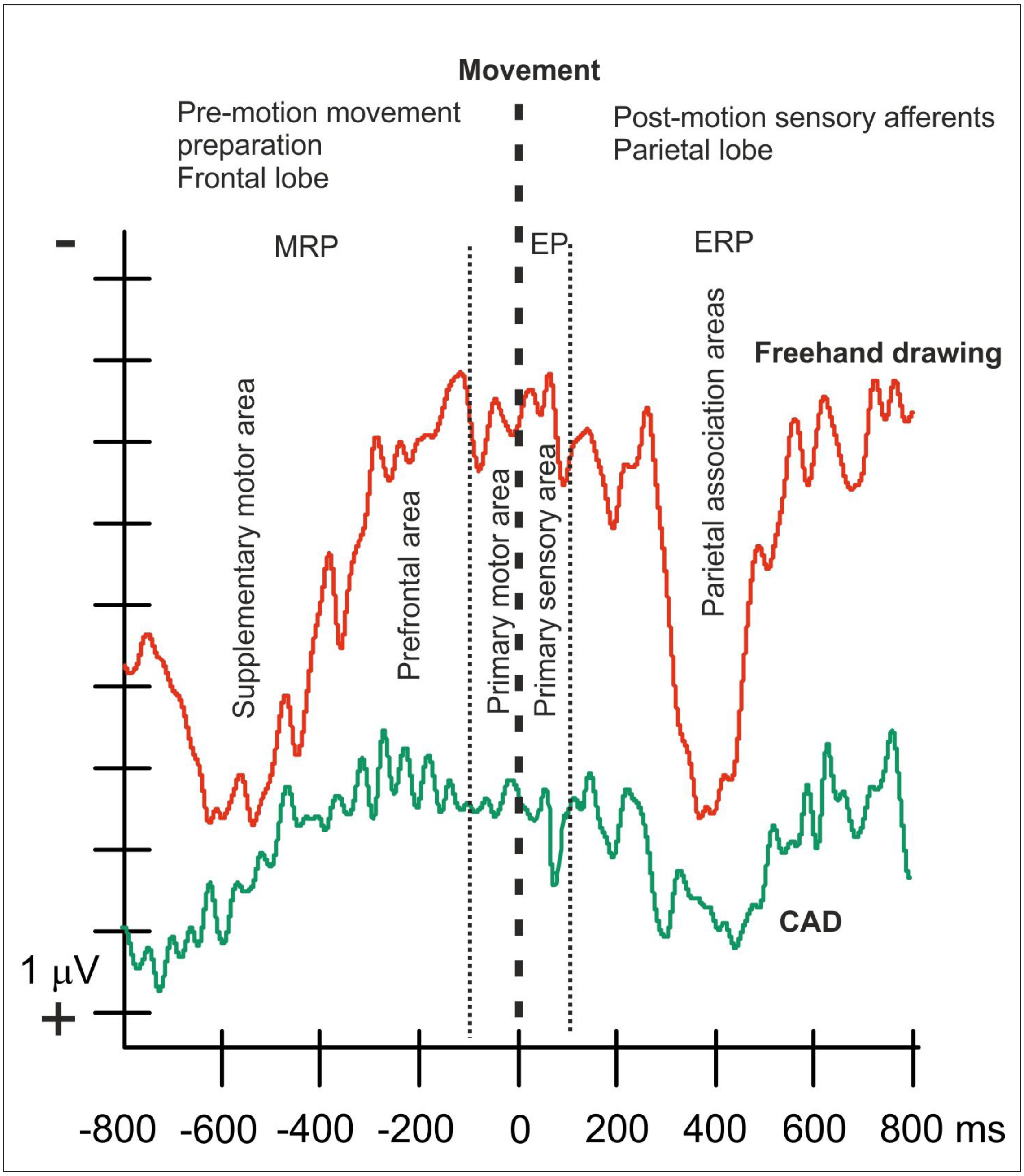

Figure 4 - an example of the results obtained in the 3 experiments showing differences both before and after movement. Image by the author.

Later on the sensory afferents undergo further processing by the association areas of the parietal cortex, recorded as Event Related Potentials (ERPs). This is a complex activity adding cognitive properties to perception and also fostering new ideas about the next movement. This area is connected to the frontal motor areas, especially the supplementary motor area, which will start a new cycle of brain activity, beginning about -800 ms before the next movement. The two dotted vertical lines mark the -100 and +100 ms time.

The activity within these two boundaries comes from the primary motor and sensory cortical areas, whose neurons are in direct connection with the peripheral muscle effectors and the sensory receptors.

These neurons are arranged in a somatotopic fashion shaped as motor and sensory homunculi (Penfield and Boldrey, 1937). It is to note that the MRP amplitude is much larger in the case of freehand drawing indicating the recruitment of a far larger number of neurons in those areas thought to be the cradle of creativity.

The sensory side of the EEG in the interval 0-100 ms is very similar between the two conditions, suggesting that the sensory receptors have been activated in a similar manner by a similar kinematic process, whereas the cognitive components of the ERP are much larger in the case of freehand drawing. So, even on the sensory side, the movements of the freehand drawing, though they are of the same extent as the CAD, excite a far larger number of neurons, a possible token of cognitive involvement.

8. Implications on creativity

The reported investigations on natural movements during drawing suggest that the cortical neuronal pools reflecting cognitive involvement (mainly indicated by their timing relative to movement) are much more active in freeehand drawing. The obvious question is if this behaviour may be linked to creativity, an essential property for original and agreeable design in architecture. As discussed earlier, there is no such feature of the EEG which can directly be related to a specific mental faculty as creativity. Nevertheless, it is possible to construct an hypothetical circuit that involves both sensory and motor functions and that could provide the basis for creativity. If this hypothesis could be deemed correct, then it would be reasonable to infer that a strong reduction of the sensory and motor activity of the hand, as it happens in CAD drawing, would also dwarf creativity. The circuit is depicted in its essentials in Figure 5, and it is based upon several, independent observations on EEG, positron emission tomography (PET), functional magnetic resonance imaging (fNMRi) (Fink, Benedek, Grabner, Staudt, & Neubauer, 2007).

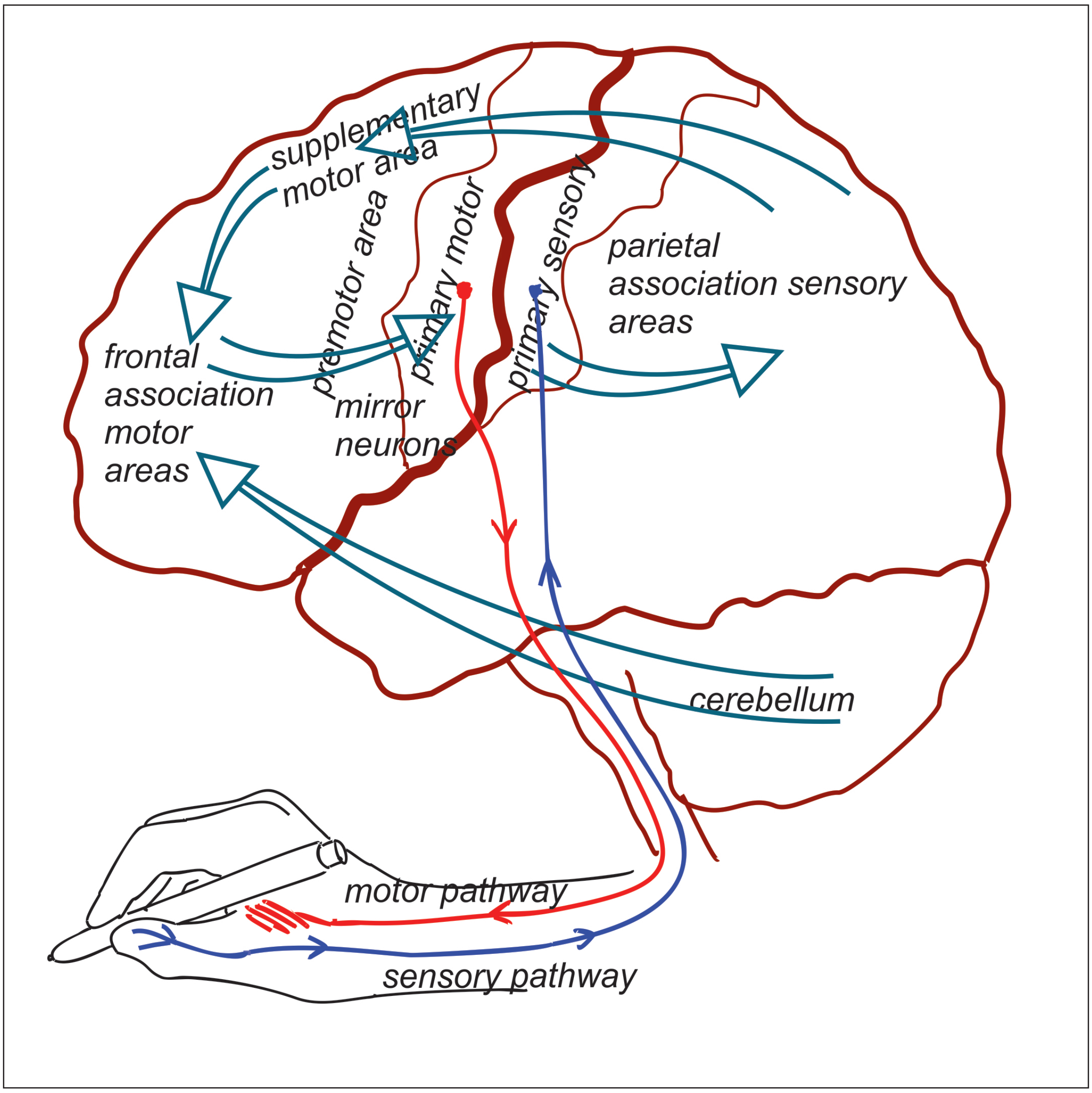

Figure 5 - The hypothetic creativity circuit, based upon separate investigations on cognitive features of cortical areas. The actual working of this functional loop can only be inferred, but has never been demonstrated in its entirety. Drawing by the author.

The circuit is formed by sensory, or post-rolandic, and by motor, or pre-rolandic, cortical areas. It could be named the creativity circuit and consists of several cortical areas of the brain, plus other motor structures. The first area involved is the primary sensory, which receives the sensory input from proprioceptive receptors of the hand, performs some elementary processing and sends them to the posterior parietal lobe (Di Russo et al., 2017), where starts preparation to movement. The parietal lobe sends this processed information to the supplementary motor area in the frontal lobe, a site pivotal to creative thinking preliminary to consequent actions (Shibasaki, 2012).

Then a more focused motor planning can be formulated in the prefrontal cortex paralleling the activation of the parietal lobe (Wheaton, Shibasaki, & Hallett, 2005). Aside to the above events, it is thought that the family of mirror neurons may contribute to creativity. These are double functional sensory-motor neurons located in the frontal lobe (Matheson and Kenett, 2020). Lastly, the cerebellum, until recently deemed to only control movements, has been found to give rise to creative thoughts (Buckner, 2013). Activation of the creativity circuit can be performed through several modalities but the most important is due to the sensory proprioceptive afferents from receptors of the hand.

9. Conclusive remarks

Electroencephalography supports the idea that freehand drawing may foster new creative ideas in architectural design. The accurate time definition of EEG allows to identify the stages and temporal sequence of activation of the cortical areas constituting the hypothetical creativity circuit.

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Assessing architecture students' "in the moment creativity" and emotive response during design tasks

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Abstract

> «It remains the case that the design process can be learned chiefly through practice and is very difficult to teach well. It is extremely difficult to understand without actually doing it. For all our empirical science and lofty philosophy we still seem remarkably dependent on our experience to interpret and make sense of more systematically acquired data...
> [D]esign is a form of thinking, and thinking is a skill. Skills can be developed.»
> (Bryan Lawson, 2006:303.)

This experiment seeks the physiological response, understood as the anatomic nervous system, to architectural design-related tasks between second year (new to their architectural education) and fifth year architecture students (at the end of their education).

By issuing the same stimuli to early and experienced students, we reveal emotive or stress responses and discover any such discrepancies that coincide with a Kansas State pedagogical experience in design.

The design tasks will be of two forms: 1) a creativity test in the style of the "Panamericana" Creativity Test; and 2) an iterative test utilizing a repetitive system that requires varied solutions to the same formal inquiry.

Consequently, our experiment emphasizes not the definitive results of the creativity tasks but rather the biological changes (arousal) experienced when the participants are exposed to specific design tasks that include: two creativity tests and a process of four iteration tasks. The tasks will be recorded using the BioGraph Infiniti System's temperature-measuring tool, Galvanic Skin Response (GSR), Electromyography (EMG).

We expect to find a specific signature with a difference in amplitude when the subject exhibits arousal and enters a creative frame of mind. Because fifth years have more experience in design thinking, the tasks will

present themselves as more enjoyable rather than challenging, causing fifth years to enter a creative frame of mind more quickly than second years.

1. Introduction

> «Perhaps more important, their reported life histories revealed that neither parent pushed their children toward a particular career, but let them nurture their calling as a life project of their own making. Such pronounced inner liberty led MacKinnon to state, "The very personality of the potentially creative student is almost ideally suited to self-instruction." As a warning against likely objections from educators, he continued, "We will not create our able students in the image of the highly creative if we always insist upon their being well-rounded." That creative individuals are unlikely to be "well-rounded" countered the conventional pedagogical foundation of the liberal arts, and by extension could seem to imply a single-minded focus on one discipline at the debilitating expense of other life skills, but in fact it heightens their ability to find a bridge between their inner vision and the missions they undertake with heroic drive.»
>
> (Serraino, 2016: 232)

Teaching architecture, like all professions is particular. The purpose of an architectural education is to teach students to think like an architect (Schön, 1984). Thinking like an architect is "reflection in action", a way of knowing in a cognitive and pre-reflective context understood generally as expertise. This vital role in the design education requires certain levels of creativity (divergent thinking) and an iterative process that initiates problems among alternative approaches within similar criteria (Serraino, 2016). These skills of thinking and perceiving vary from student to student and from one design professional to another. This experiment aims to link the findings of E.A.

Carroll's basis of "In the Moment Creativity" (ITMC) (Carroll *et al*, 2009; Carroll and Latulipe, 2012) and Donald Schön's research regarding "Reflection in Action" (Schön, 1984). Using ITMC (evaluation through direct measurement of biological response) and "Reflection in Action" (discovery through observation) allows us to combine two distinct methodologies, that of Donald Schön and Erin A. Carroll, in order to analyze architecture students' overall response to a design task (Fig.1). Though the students' capabilities are important, our project tests the emotional arousal of the designers' active stimuli during specific creative and iterative tasks. What has been discovered is the clear distinction between feelings and emotions (Solomon, 1973). Feelings have been categorized as the mental perception of an experience; whereas emotions are the biological response to arousal; a phenomenon beyond our control (Solomon, 1973). By testing this precognitive reactions, we are using the BioGraph Infiniti System's temperature-measuring tool, Galvanic Skin Response (GSR), and Electromyography (EMG) to collect data for a better understanding of an architecture student's stress response to the design tasks. In this model, tests will conclude the correlation between the students' maturity as they progress through their architectural education and the change in arousal during specific design tasks.

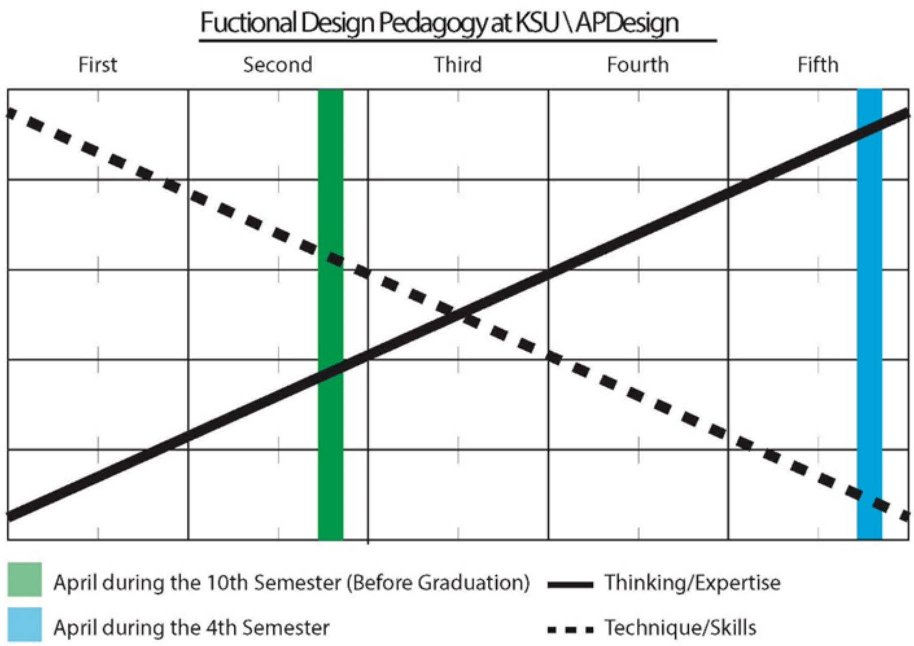


Figure 1 - This diagram demonstrates the basic pedagogical framework of architectural education at Kansas State University's Department of Architecture. Architecture as a profession is known as a practice. One learns Architectural design by doing. In analogy to other activities where body knowledge is fundamental – music, athletics, surgery, painting, etc. – young students of architecture must begin with the tools of their profession: drawing, building models and mastering software. If the X-axis is the time of a student progressing through their academic career, the Y-axis is the curriculum devoted to the accusation of professional skills, or the critical thinking Schön calls "thinking like an architect". Understand then that skills must come first, from first to fifth year the Technique/Skills emphasis decreases as the students begin to master the basic talents of representation. The line of Thinking/Expertise is an ascending line recognizing that young students begin by learning the vocabulary of architecture – history, formal critique, structures, building machinery, etc. – towards conversant students in their final year. This learning to walk before you can run correlates also with the demand of creativity that one has some mastery of the medium in which they create. A beginning musician cannot improvise Jazz.
Nor can the simultaneous exchange between the hand in representational task and the mind seeking a concept that makes up thinking like an architect be obtained by the unskilled.

2. Background

2.1 Measuring creativity

It was William James who first suggested the connection between bodily reactions and emotional experiences (Natsoulas, 1988). There is a significant amount of work studying the physiological manifestations of creativity. The position of this research synthesizes a relationship between creativity and cortical arousal (Picard, 1997). In other words, high alpha-wave amplitude represents low cortical arousal. In his review of physiological creativity research, Martindale (Picard, 1997) reports on relationships between cortical arousal and creativity. The link between cortical arousal and amplitude is described as the higher the amplitude, the lower the cortical arousal. Highly creative people are able to defocus and focus their attention instantaneously, meaning, because they are more creative, their brain does not have to stimulate high cortical arousal. On the other hand, those with lower levels of creativity, try harder during specific creativity tasks, so their arousal levels are higher (Martindale, 1999). This study also found that highly creative people had significantly lower cortical arousal than less creative people during creative inspiration but not during creative elaboration – so this result was highly dependent on the stage of the creative process (Carroll and Latulipe, 2012).

Rather than test all dimensions of creativity, which has not been possible thus far, divergence tests do not expose the individual's full range of creativity. From Martindale's work, it is evident that there is some relationship between creativity and cortical arousal, but the inconsistencies and lack of statistical significance are concerning. It seems highly possible that the relationship between creativity and cortical arousal is confounded across several variables: the "creative activity" being studied, the method of classifying people's creativity level, the stage of creative activity being measured and participant priming (Carroll *et al*, 2009; Martindale, 1999). Since there is a relationship between ones nervous system and creative tasks we expect to see various states of arousal in architecture students.

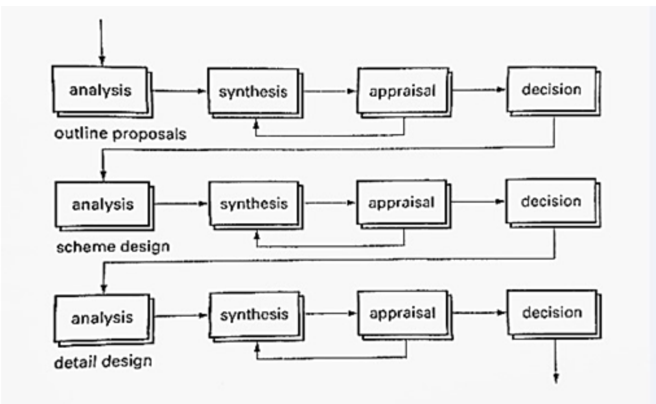
2.2 In The Moment Creativity (ITMC)

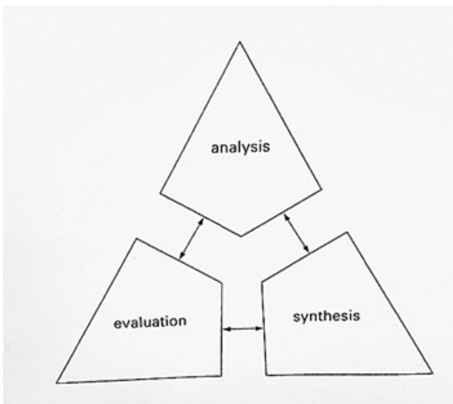
Architectural education has two levels of arousal we hope to measure in developing designers: first, a general emotive response to the stress of being asked to be creative or solve a problem of form; second, when doing so is there a legible emotive state that coincides with being creative? In the second case, we find the work of Carroll to be descriptive of an iterative frame of mind (Carroll *et al*, 2009). "In the moment creativity" is described as a method for detecting a correlation of creativity based on personal, temporal experience, rather than a quantified metric of all of creativity. We want some level of assurance that a time segment identified by a participant, as being a highly creative experience, was in fact the user experiencing an interval in which something specific happened- a creativity correlate (Carroll & Latulipe, 2012). ITMC suggests the schema designers are looking for. ITMC gives a name and critical structure to the mental shift of attention (phenomenon) designers regularly know as being creative (Carroll & Latulipe, 2012). In Carroll's application of ITMC, in order to self-report ITMC, participants used a custom video player application that allowed them to retrospectively identify time periods experienced as creative. Though Carroll makes a valid point regarding interrupting the current experiment, when taking into account the number of iterations in our experiment (four iterations, each with a five-minute completion period) as well as four incubation periods (one minute after each iteration), the iteration task requires 24 minutes to complete.

Because of the extent of the iteration task, we opted to directly ask the participants at the end of each iteration at what point they felt the most creative in order to negate any potential artifact due to the inability to remember the past events.

Our motivation for having participants self-report retrospectively was because concurrent self-reporting would distract from the creative activity (Carroll & Latulipe, 2012). By incorporating both the biofeedback and the self-reporting methodologies, we are able to acquire a scientific basis (biofeedback) as well as an alternative method to support the science: self-reporting; a method proven to hold validity in experiments (Carroll & Latulipe, 2012).

2.3 Iteration





Figures 2,3 - Left: The Markus/Maver design process map of iteration (Lawson). Right: Triangulating the three elements required for the design process- a more accurate representation of the relationship of iteration (ref. Lawson)

Iteration is generally understood as a method of repetition. A process, that seeks by its own recurrence and computational procedure, to be the means of obtaining successively closer approximations towards the desired solution of a problem. Iteration (also called looping) is the process by which a specified task undergoes constant evaluation and manipulation to achieve, or even exceed, the desired outcome. The process of iteration circulates around a similar goal rather than following a linear path. However, the process to obtain the end goal is not necessarily valued at the time of production. Lawson depicts four different maps of iterative design processes, each coming to the same conclusion: at any point of the design process, one can "loop" back to a previous step for further analysis or detailed evaluation. For Lawson the Markus and Maver Map is the closest depiction of the design process (Fig.2). However, this process, though detailed, is too precise in the step-by-step decision sequence.

For architectural design a more accurate depiction is that of the triangulated relationship between analysis, evaluation, and synthesis (Fig.3), rather than a "firm route" as proposed by Markus and Maver (Lawson, 2016). Chuslip estimates that iteration of design tasks accounted for one-third to two-thirds of the total development time of a project.

Therefore, iteration so conceived is incorporated in this exploration alongside creativity, because in architecture, iteration is the fundamental thinking (a skill developed through education) of the design process (Lawson, 2016). The fact that the execution of iteration is obvious (Chuslip and Jin, 2004), meaning the evidence of iteration is easily testable and measurable, allows the experiment to be more accurate. On the other hand, iteration of cognitive activities or mental iteration is less explicit because it occurs at the cognitive level inside designers' minds, which is why our overall understanding of the design implication iteration remains limited (Jin and Chuslip, 2006). Dorst and Cross applied observation from their protocol studies to the co-evolution model and found that creative design seems more to be a matter of developing and refining both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between problem-space and solutionspace (Jin and Chuslip, 2006).

3. Experiment

Our experiment derives itself from the work of Berkeley's Institute of Personality Assessment and Research, an experiment conducted in 1958-59, which gathered 40 of the top architects of their time to participate in a series of tests to discover the architects' level of creativity. Our research purposes aim to test the changes in physiological arousal between two groups of architecture students (2nd and 5th years), with varying backgrounds in design and levels of creativity. To further emphasize, we are not concerned with how creative the student is and have no previous knowledge of the students' creative abilities or success in their architectural design studio. The dual design tasks involve a series of iterative drawings and a creativity test based on the Architectural Aptitude Test used in Berkeley's study, similar to the modern Panamericana Creativity Test. Using BioGraph Infiniti equipment, subject's biological responses will be recorded. First a researcher will discuss, using a script, with the subject what the experiment requires of them.

In sequence of procedure, participants begin by reviewing and have the option of signing a consent agreement. If the participant decides to continue with the experiment, then a pre-experiment interview evaluates the subject's interest in sketching and their general psychological state pre-experiment.

Following, participants will take the Keirsey Bates Temperament Sorter, a personality test similar to the Meyers Briggs Temperament Sorter, as described in "The Creative Architect" taking note of the Berkeley's correlation between the personality types of thinking like an architect and the statistical results produced at the end of the experiment (Serraino, 2016). During the test, to discard the subject's self-assessment, three questions will be presented at the end of the iteration task.

The questions are: during which iteration did you feel you were the most creative? At which point did you feel the ease of designing ('in the moment creativity')? Do you think you think you ever fell out of creativity? At the end of the fourth iteration, the general question of "which iteration do you feel you were the most creative? Please rank them from least to most creative", will be proposed.

Based on the self-reports and the sensory recordings, we will be able to compare when and at which task, the participant demonstrated "in the moment creativity."

4. Methods

4.1 Process

We began configuring the experiment by running a series of pilot studies among our research team. Taking the idea of an iterative basis, the experiment is structured to elicit "thinking like an architect." The experiment is two-fold; two creativity tasks and four iteration tasks. The number of iterations was decided on how many "tries" it would take for the subjects to recognize changes in their design decisions until they reached a desired design. Two iterations did not provide the repetition required for the iterative process, so we ran a test using three iterations.

Once the team had been run through the same number of tasks, the agreed upon number was four iterations. Three iterations started the ITMC process, but in order to maximize creativity, we decided four iterations would best confirm our hypothesis. The two creativity tasks will bookend the iteration tasks to act as warm ups and cool downs for the experiment.

The length for each of these tasks was decided on what we perceived would be the subjects' level of interest in the tasks as well as a concern with the subject's initial readings. To regulate this time, we decided to make the creativity test 6 minutes. As we ran the test runs, anything less than 6 minutes did not provide substantial time to complete the task. The four iteration tasks are presented consecutively requiring 5 minutes for each iteration to complete.

4.2 Room arrangment

For the experiment, two separate rooms are chosen; one for conducting the pre experiment interview, and the other is designated for the primary experiment. The subject is directed into the first room positioned 10 feet away from the experiment room.

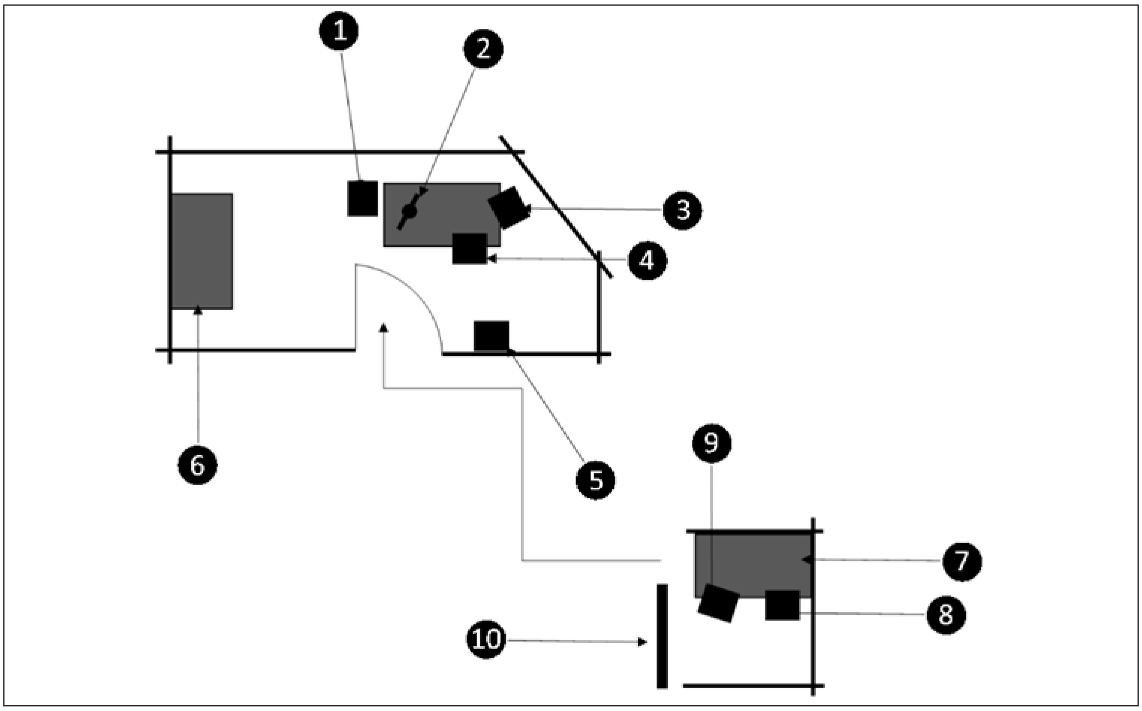


Figure 4 - 1. Technician chair; 2. Computer with Infiniti system; 3. Narrator chair; 4. Subject chair; 5. Stand for subjects' belongings; 6. Table for our belongings; 7. Table for Pre-Experiment interview; 8. Subject chair; 9. Administer chair; 10. Movable partition wall. Image by the author.

A small partition wall is rolled to enclose the subject and the pre-experiment proctor into the space. Once the subject has completed the pre-experiment interview and the Keirsey Bates Temperament Sorter, they are then walked into the primary experiment room, a much larger room with a door to enter and exit through. There, two alternate operators sit the subject at a table in the middle of the room. Upon completing the experiment, the subject is free to exit the door in which they entered. The room arrangement is portrayed in Figure 4.

4.3 Participants

The participants were selected based off volunteers. The 38 total subjects made the conscious decision to participate in our experiment; again, we have no previous knowledge of their creative abilities.

18 participants comprise the second-year architect students group; while 20 participants make up the fifth-year architect students. Both the second and fifth-years will participate in identical experiments; this was ensured using a script we wrote specifically to reduce any inconsistencies. In the pre-experiment interview, the participants are asked a series of questions to better gauge how comfortable they are with sketching and design tasks in general: How comfortable are you sketching with a pencil? On a scale from 1-10, how confident are you in your sketching abilities?

4.4 Materials

The creativity test is our design based on the Pan-Americana School of Art and Design's Creativity Test. The creativity task will be performed as an initial warmup for the designer and then be repeated in the end of the experiment as a cooldown. This test is chosen because it allows continuous creative thinking for the experiments time period of 6 minutes. The page is composed of 9 squares containing a pair of lines within each square. The goal of the creativity test is to have the student continuously involved in divergent thinking (originality of their answers). The last portion of the experiment includes an iteration task of our own design that will be given 4 times each lasting 5 minutes requiring the subjects to create an architectural form from three given shapes: cube, pyramid, and plane. A GoPro will record the experiment beginning when the subject enters the room until they leave the room.

4.5 Tools

TThe data is collected using the BioGraph Infiniti System equipped with a temperature-measuring tool, Galvanic Skin Response (GSR), and

Electromyography (EMG). The EMG tests muscle tension and compression. By applying three EMG nodes, one above each eyebrow and the third in the center of the forehead, we can measure the visual impact the amygdala, the part of the brain that controls all emotional arousal, has on the way the design tasks modulate the participants' facial expression. The GSR tool measures sweat conductivity produced by the participant. The readings provided detect the participant's level of stress and arousal during cognitive tasks. Based on the peaks during testing, we will be able to accurately determine at which points the participants exhibit levels of arousal.

Biofeedback tools are essential in specifying the types of arousal; those of fear or pleasure. Both are products of arousal, but fear shows up on one end of the spectrum, which produces adrenaline (the blood retracts and goes to the core). On the other end is pleasure, which produces dopamine when the blood extracts to the tips of the veins. The temperature-measuring tool differentiates between just that: fear and pleasure. Upon an increase in temperature, the participant exhibits pleasure. When on the other hand, a decrease in the temperature demonstrates fear. Using the GSR, EMG, and temperature-measuring devices is the only method to measure the body's response to the tasks that the test subjects will undergo.

4.6 Tools

Participants will be seated comfortably in a fixed seat in front of a large table. Participants will be asked to place their non-dominant hand in a place that will be comfortable without disrupting the drawing process. They will then be asked to minimize movements of the non-dominant hand and limbs during the experiment. The test will begin after a baseline period of two minutes. In the pre-experiment interview, the Meyers Briggs Personality Test will be given to the participant. By the end of The Meyers Brigg, four letters are assigned to the test-taker.

These four letters allocate the four general categories (Introvert or Extrovert, Intuitive or Sensing, Feeling or Thinking, Perceiving or Judging) that then further match up to one of the 16 personality types and provide background on the participant for the experiment administrator. After, the participants will engage in a creativity test, like the *Panamericana test*. The next task tests iteration (also known as looping). 4 iterations will be given to the participant. After the iteration test, the administrator will ask the participant how they felt during the task: At which point did you feel you were the most creative? The key is to pinpoint, through self-evaluation and the data of the biofeedback, when and for how long the architecture student was experiencing "ITMC".

The outlined procedure is as follows:

Figure 5 - Illustration of the sequence of the drawing tasks. After participants have comfortably seated themselves and the facilitator has gathered the baseline a cover will be removed to display the creativity test. Participants will attempt to fill out as many nodes in a 15- minute time period. The trial ends and the participant will drop their drawing tool. The image will be removed to reveal a fixation area. The second task begins when a cover is removed from an image beyond the drawing region.
The participant will be asked to replicate the image as best as possible beginning from the large forms, then progressing into the details. Again, the task ends at 15 minutes where the participant will drop their drawing tool. The final trial begins after another stabilization period displaying a third image. The participant will be asked to design a bench and locate it in the drawing. The period ends when the participant completes the image or when 15 minutes has passed. Image by the author.

4.7 Ratings of the stimuli[1]

Three judges will evaluate the results from each task. Additionally, each participant will be asked to take part in a post-experiment interview to evaluate when in their design task, they felt they were being creative.

[1] All under works/ not yet tested

Additionally, they will measure on a scale of 1 to +10 on how creative they were at each of their previously selected points.

Level of expertise, creativity, and emotional content will be compared, scored, and evaluated.

4.8 Recordings

Along with the machines for administering the biological responses to the stimuli, throughout the test?) have them circle on a piece of paper, their emotional state and when they felt they were being the most creative. Self-reporting has proven to be an accurate method for recording data.

Humans are more successful at short-term memory when the event happened within the last ten seconds as opposed something that occurred 30 minutes prior. By comparing the self-reports to the data, we will be able to pin point more accurately when the participant was most aroused (out of fear or pleasure). A post-experiment with the experiment director and the participant will also be conducted to playback the footage of the experiment.

5. Results

We concerned ourselves with the biological reactions recorded from the biofeedback machine. These readings align themselves with the same subjects from figures 1a and 1b. The orange line aligns with the second-year students who exhibits a creative personality; blue is a fifth year students with the architect personality type.

On the other spectrum, the yellow path represents a second year who is the opposite of the architect type; likewise, the grey line is a fifth year with the same personality type. Among the same years, the second year who demonstrates creative tendencies enter a creative frame of mind more quickly than the second year without that inherent trait.

When basing the data on our initial hypothesis, fifth year enter a creative frame of mind slightly quicker than the participants with less experience. Although this is what we hoped to discover, we were surprised to find the dramatic differences are apparent in the personality realm.

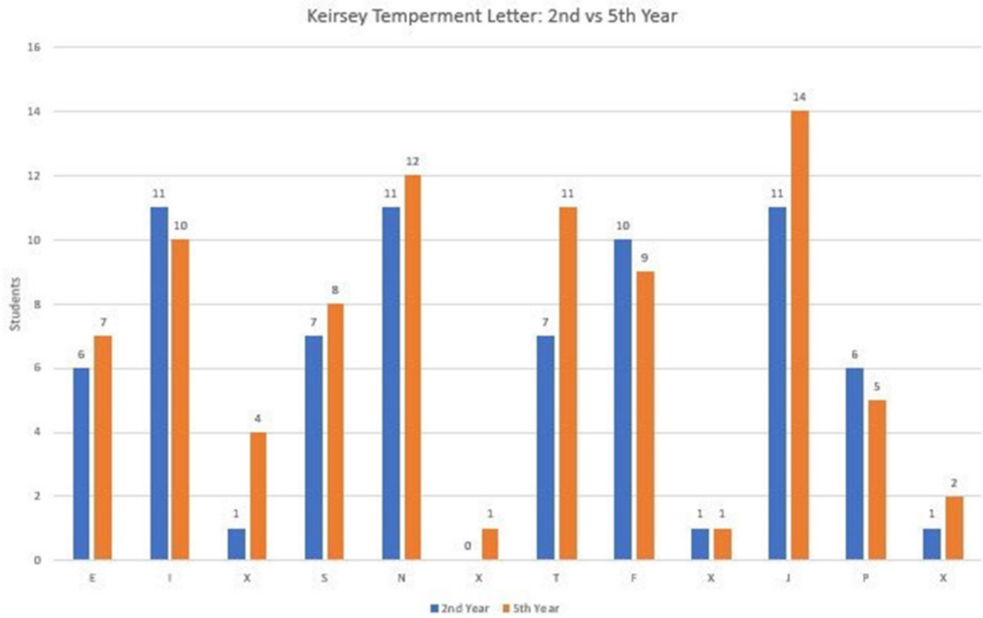


Figure 6 - Represents the number of fifth-year students (orange bar) versus second-year students (blue bar) who possess the specific letters found in the Kiersey Bates Temperament Sorter. We are most interested in the S versus N (Sensing or Intuitive) because it exhibits the preference to the think based on concrete facts and details (sensing) or to pursue an idea based on one's "gut" inquiry and thinking in a bigger picture context (intuitive). This innate ability to use one's intuition is unique and most associated with the "architect" personality type. Between the eighteen second and twenty, fifth year temperament results, there is no significant difference, but among the opposite types (for example S and N) the difference is rather distinct. To further demonstrate, the analogue data of the drawings the participants selected as the time they felt the most creative amongst the four iteration tasks as well as their final creativity task of the experiment (the nine boxes). Image by the author.

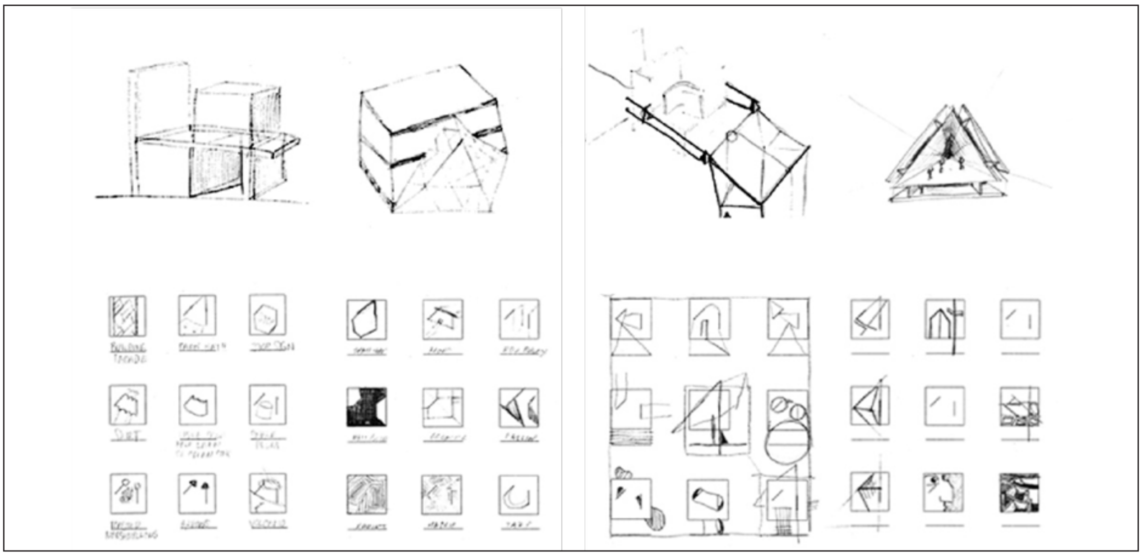


Figure 7 - The drawings above are 4 subject's drawings in response to the iterative task (the top row) and the creativity task (bottom row). Image by the author.

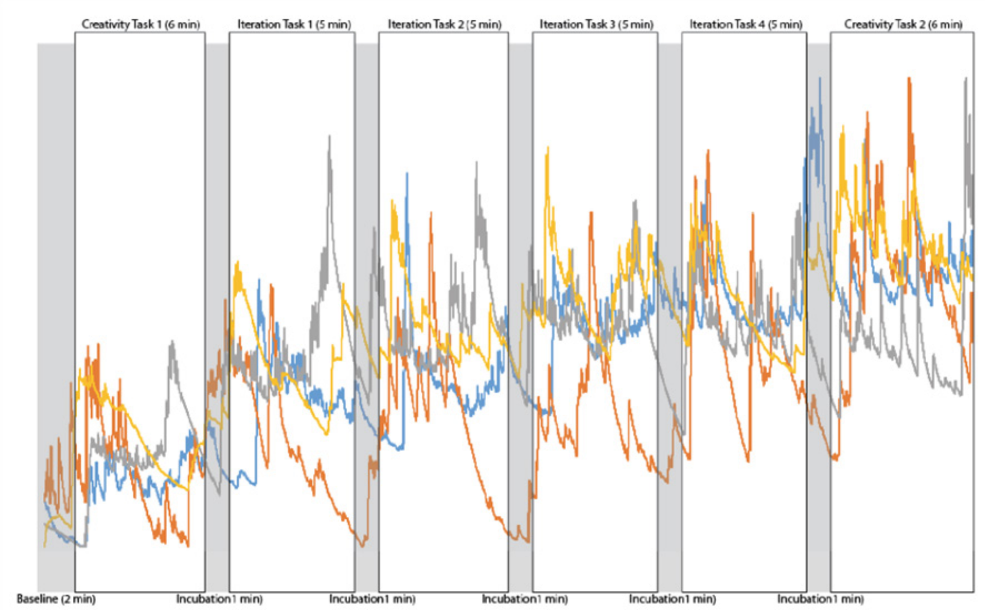


Figure 8 - The drawing tasks elicited a creative mentality. These are the physical results. When presented with the iteration task and the creativity task, second and fifth year students approached the tasks differently, but upon further analysis, the differences appear in their creations. These four subjects were selected as the second and fifth-year students who fit the "architect" personality type (the two sets to the left of the dividing line) and the second and fifth-year who closely resembled the opposite of the "architect" personality type (ESFJ) found to the right of the dividing line. Though only four subjects represent the broader pool of subjects, this trend appears amongst the other twenty-four participants. From left to right, the images depict the design tasks of a second-year architecture with the personality type of the INFJ; a fifth-year architecture student with the INTP personality type; a second-year architecture student with the personality type of ISFJ; a fifth-year architecture student with the personality type of the ESTJ. Image by the author.

6. Summary and conclusion

Observations during experimentation bear out that arousal significantly reduces when subjects enter the focused frame of mind we associate with designing, especially evident in the INTP type. Inspection of the data shows qualitative differences between second and fifth-year students, and between temperaments. We think a generalized additive model and statistical analysis will find a signature or stereotypic signal indicating ITMC. We are currently testing selfproclaimed "non-creative persons" as a control group. Our data suggests that tutorial experience in design studios produces quicker access into the creative frame of mind. However, initial analyses suggest that temperament may be more important than this tutorial experience, which will have broad implication for architectural design pedagogy. This research has led us to become familiar of the impact external stimuli has on an architecture student who has had 2-5 years of education in the field. Though the stimulus in this case was specific design tasks, this research has the potential to develop into in-situ experiments. Architecture has the power to evoke emotions within the viewer. With that being said, our “in the moment” creativity experiment opens up the opportunity to the participant’s physiological response to the stimuli of actual architectural structures.

7. Discussion

Another purpose of this study is to explore implications of the sketching in the architectural curriculum and how it could assist future designers and architects. If engagement with the world (i.e. sketching) is crucial for creative cognition in that it conveys emotion through physical bodily knowledge, then sketching should become a fundamental aspect of the profession, in that it is the artistic expression of the architect.

Future studies could compare the emotional content of drawing to the emotional content involved in the observation of drawings. If architecture possesses empathetic stimuli, do the drawings or caricatures of these built objects possess them as well, and does that relate to the creation of them. Additionally, the results may influence the curriculum.

5th year students may display a lack of confidence in drawing or reduced drawing accuracy because of the dominance of digital production in many architecture curriculums. Similarly, we are curious if we can translate the same testing to practicing architects. Will experience level expose a varied result? Do all architects naturally enter this flow state?

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The Drawing Hand

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Abstract

The hand is the main biological tool that permits interrelationship between the self and the exterior world. Since the dawn of man, it has been used for all creative activities, with wondrous effects in the world of the art and technology. In the last decades, its role has been dwarfed because of mechanistic substitutes. With the reduced use of the hand, also the mind that commands it is less exerted and less involved in the life of relationship. A more limited use of the hand also means less awareness of movement and less tactile information from the outside. In short, there is a lack of embodied experience, which, on turn, may limit the divergent thinking needed for creative thoughts. This paper, after an introduction on the role of the hand in art and creative thought, briefly reviews the complex anatomy of the hand which is at the basis of the range of movements and features which make it much more than a simple mechanical contrivance.

1. Introduction

Architects and architectural theorists have a long tradition in blending the object of their creation with the image, biology and mind of humans. Anthropomorphism has been a common theme in architecture throughout history, one of the earliest and most famous examples being the Great Sphinx of Giza in Egypt. But perhaps the most renowned image referring to anthropomorphism is the Vitruvian man, a representation of the ideal human form, often used as a symbol of the Renaissance's emphasis on humanism and the importance of individual achievement (Drake, 2003).

The proportions and measurements depicted in the drawing have been used to study the human body and to design architecture, tools, furniture, and other objects that are optimized for human use. The Renaissance's emphasis on humanism brought a wide interest in the relationship between architecture and the human body, mainly on a basis of bodily proportions.

Such viewpoints are now rejected, but the importance of a strict connection between the architectural craft and human anatomy, physiology and cognition has never been forsaken. This is what Juani Pallasmaa calls the embodied experience (Pallasmaa, 2012), and which should be sought in designing architecture. The built environment should be perceived by the user not only through sight, but with a holistic approach, involving all other senses, most of all touch. A no less important consideration about architecture is the perspective of its crafter. According to the same author (Pallasmaa, 2009), even in this case all senses should contribute to the birth of ideas, and most of all, the hand movements performed in drawing should stimulate creativity. This latter notion was not new in the art world as we may find it clearly and repeatedly expressed in the "Il Libro dell'Arte," or "The Craftsman's Handbook," which is considered one of the most important treatises on art from the Middle Ages written in Italian, by the painter Cennino Cennini. He wrote that by constantly drawing, the artist brain will produce new and better ideas (Thompson, 1933). The notion of the hand as a physical instrument of creation, and also as the source of new ideas is still little considered in the architectural world. The new and appealing field of “neuroarchitecture” makes reference to the psychological effects that the built environment has on the user (Wang *et al.*, 2022), with no or very limited attention to the neural mechanisms underpinning the design process. The aim of the present paper is to briefly investigate this neglected view and report the physiological mechanisms and the functional anatomy supporting the essential role of the crafter’s hand. This issue is felt to be particularly relevant in the current times, as digitalisation of the design process in all its steps, for the first time in the human history, has almost completely ruled out the use of the hand, if not for the very mechanistic task of using keyboard and mouse to input data into a computer (Scheer, 2014).

2. The anatomy of the hand

The human hand comprises of 27 bones, divided into carpal bones (8) metacarpals (5) and phalanges (14). All these bones are connected via joints (metacarpal joints and interphalangeal joints) and tendons which help hold the hand structures in place. With around 30 muscles found in the hand, they help provide the range of movements required for our day-to-day functionality. Anatomically, movements of the hand comprise of flexion, extension, abduction (fingers moving away from the midline) adduction (fingers moving towards each other) and opposition i.e., thumb and little finger touching together. The thumb (*pollex*) also has a range of separate movements (Bazira, 2022).

In the anatomical position (palm facing forward) tendons from our muscles of the forearm (flexor compartment) pass through a structure called the carpal tunnel, alongside 2 important nerves and associated vascular structures. The *flexor retinaculum* (tendinous sheath) attaches to the associated carpal bones either side and creates the tunnel for the muscle tendons to pass under to attach to the phalanges.

The most superficial muscle and tendon is palmaris longus, lying above the retinaculum. For the tunnel, we have 2 muscle groups for the fingers: *flexor digitorum superficialis* (FDS) and *flexor digitorum profundus* (FDP) and one additional, *flexor pollicis longus* (to the thumb). The FDS and FDP originate from the main flexor tendon at the elbow and attach to the middle phalanx, on either side, (FDS) with FDP traversing through the FDS tendon to attach to the distal phalanx. These attach to the 4 distal phalanxes. This helps us create a flexion grip as these muscles help act as a pulley to bring the fingers towards the palm (Bazira, 2022).

The deep intricated muscles of the hand comprise of muscles that lie between the metacarpals (*interossei*) which assist with abduction and adduction of the fingers and worm like muscles (*lumbricales*) which run along the FDP which help aid flexion (at the metacarpal joints) and extension of the fingers (interphalangeal joints). The little finger (*digitus minimus*) also has muscles from the area collectively known as the hypothenar eminence, which are 4 short muscles: digital side of palmaris brevis, *abductor digiti minimi* (ADM), *flexor digiti minimi* (FDM) and *opponens digiti minimi* (ODM).

The thumb side (*pollex*) is called the thenar eminence which contains 3 main muscles: *abductor pollicis brevis* (APB), *flexor pollicis brevis* (FPB) and *opponens pollicis*. There is another large fan like muscle, situated between the pollicis and index finger, *adductor pollicis*, which is a muscle that is innervated by a branch from the ulnar nerve, the recurrent ulnar nerve (Adds & Baker, 2022; Ellis & Mahadevan, 2013). This muscle assists with holding a pencil for drawing. On the dorsal aspect, like the palmar aspect, we have a *retinaculum* called the *extensor retinaculum*, which has individual tunnels for the extensor muscles (most originating from the lateral elbow) to attach to the dorsal aspect of the phalanxes and thumb. The index finger also has its own individual muscle, *extensor indicis*, a powerful muscle also helps with pen holding and it assists in individual precision for drawing and clicking of a mouse. There are dorsal *interossei* (4 muscles) and *extensor digiti minimi*.

Finally, on the extensor and lateral aspects of the thumb, the area known as the anatomical snuff box (called this when “snuff” or Tabacco was inhaled from here) comprises of *extensor pollicis longus* (EPL), *extensor pollicis brevis* (EPB) and *abductor pollicis* (Bazira, 2022; Sapundzhiev &Werner, 2003).

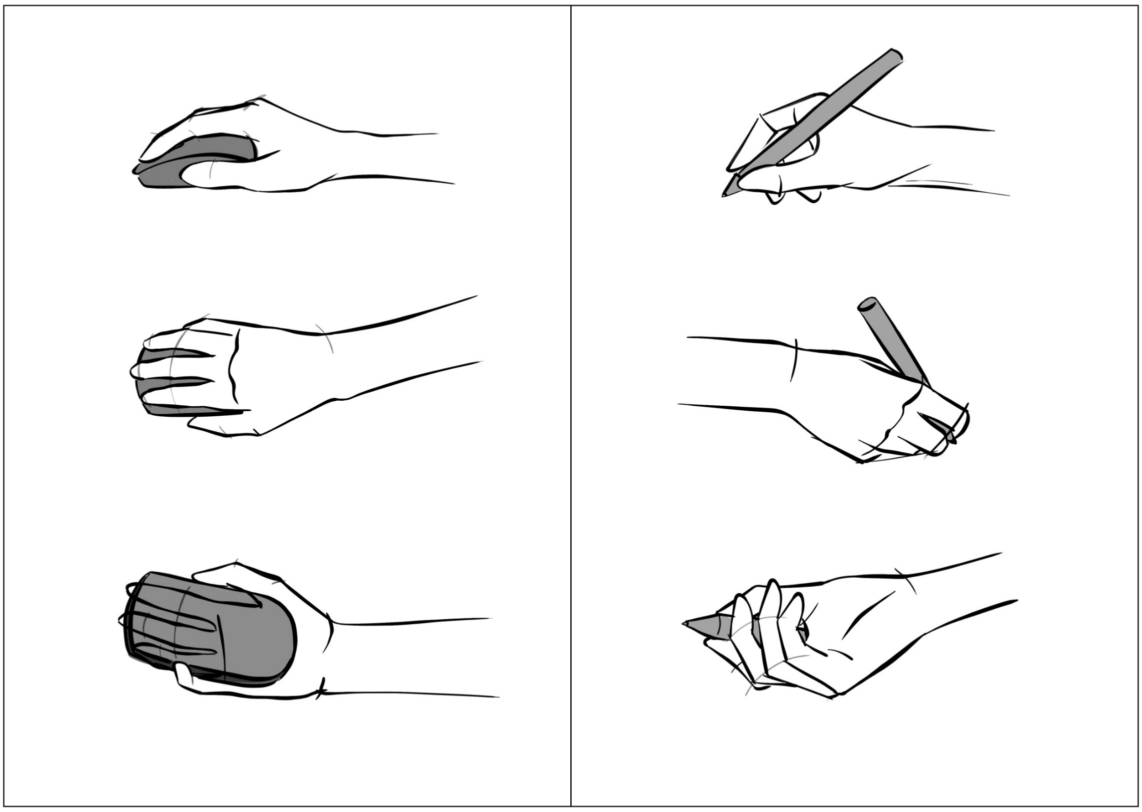

Figure 1 - Different views of the hand on the mouse and holding a pen. Drawings by G. Leandri.

The blood supply to the hand is from the two major arteries, radius and ulnar, that form deep and superficial palmar arteries, which collectively provide our digital arteries to the fingers. The venous return is comprising of superficial and deep veins which in turn help form the cephalic and basilic veins of the forearm (Tan & Lahiri, 2020).

The nerve supply originates from the spinal nerves in the neck (cervical spine). This network of nerves is called the brachial plexus (brachial meaning arm, plexus meaning network). The nerves run their course along the anatomical arm (shoulder to elbow) and forearm (elbow to wrist), to reach and innervate the structures within the hand.

There are 5 terminal branches from the brachial plexus, 3 of which supply the anatomical anterior (palmar) and posterior (dorsal) parts of the hand. They are the median nerve, radial nerve and ulnar (Adds & Baker, 2022).

The ulnar nerve courses down via the ulnar bone, through to the hand over the *flexor retinaculum* and supplies the hypothenar eminence, all the *interossei*, 2 lumbricals (*digiti minimi* and ring finger) and *adductor pollicis* (recurrent branch). It also supplies sensation to the little and ring finger.

The Median nerve is the largest nerve of the hand that passes through the *flexor retinaculum* to supply the thenar eminence and the other 2 lumbricals. Sensation is of the thenar, index and middle fingers.

The Radial nerve course the posterior aspects of the arm and forearm and provides innervation for the extensor compartments of the forearm, hand, and fingers. It also provides sensory innervation to some areas to the back of the hand (Adds & Baker, 2022; Ellis & Mahadevan, 2013).

The function of the hand when holding a pen or mouse comprises of the integrated muscular structures previously discussed. The hand, being one of the most powerful and sensitive areas in the human body, also has precision and power grips. In free drawing, the anatomical and muscular components involved can be considered by the following:

Free hand pen holding

When holding a pen, precision grip or dynamic tripod (Adds and Baker, 2022), the anatomical structures involved are considered as the following for hand stabilisation (see fig) FDM, ADM, digiti minimi and opponens digiti minimi. For pincer grip of the pencil, APB, FPB and opponens pollicis work in combination, with adductor pollicis strengthening the grip of the pencil. FDS and FDP give stability with the lumbricals allowing flexion of the MCPs.

See Figure 1, right set, and Figure 2.

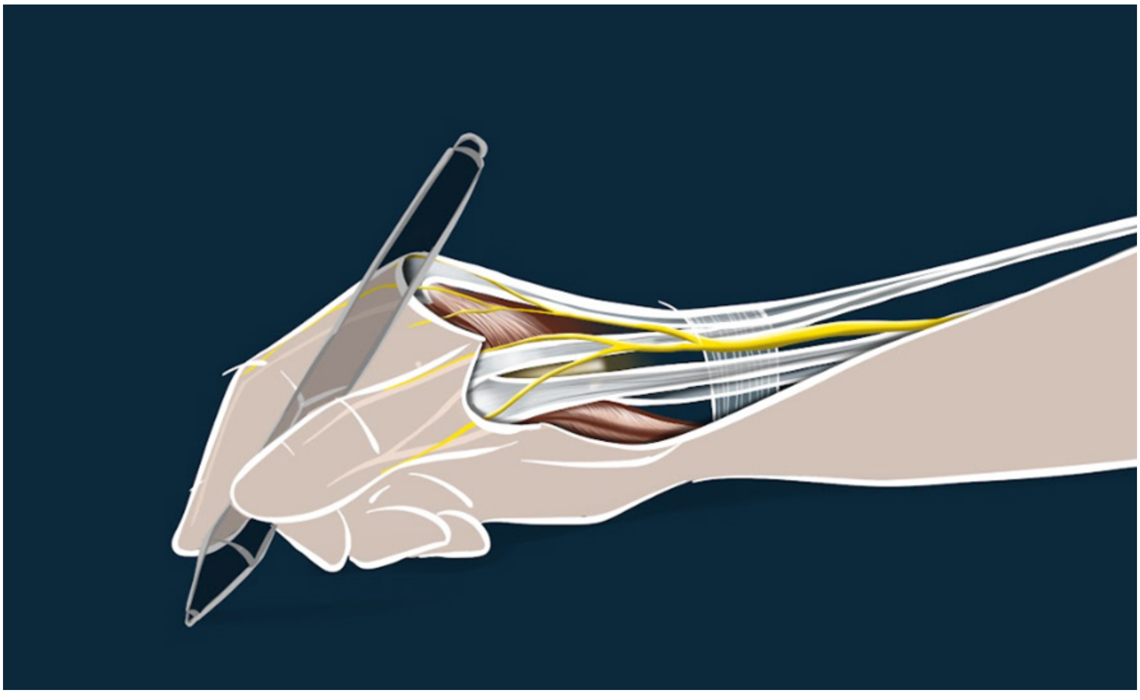

Figure 2 - A view of some of the hand tendons and muscles while holding a pen. Drawing by G. Leandri.

Mouse holding

When holding a 2-button mouse, the anatomical structures involved can be considered the same as the pen holding, however, stability is via the thenar and hypothenar eminences, *adductor pollicis*; the grip the mouse and *extensor indicis* with 1st and 2nd *extensor digitorum* to help provide movements, i.e., clicking.

See Figure 1, left set, and Figure 3.

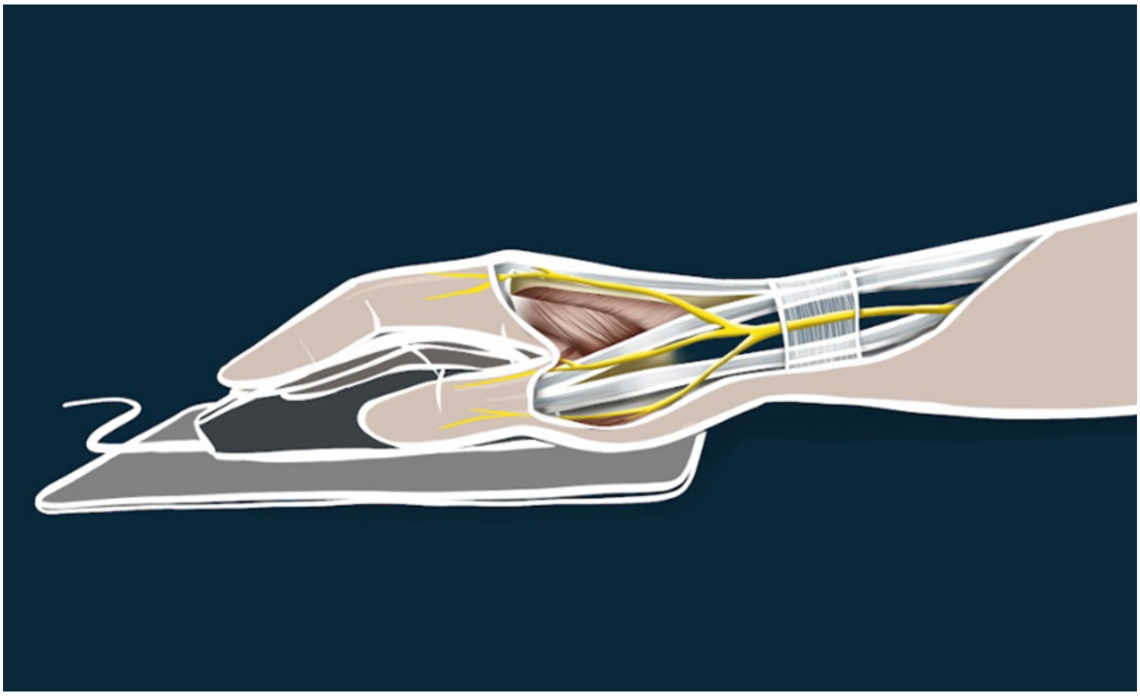

Figure 3 - A through view of some hand muscles and tendons while holding a mouse. Drawing by G. Leandri

2.1 Sensory receptors of proprioception

Proprioception can be defined as the sense of position and movement that arises from the musculoskeletal system (Dietz, 2002). This function is of paramount importance to fine tune all the muscular activity and works combined with other receptors of touch to explore the environment and to manipulate objects. This is the main type of sensation arising from the complex movements of hands performed in drawing or building 3D models and which possibly plays a pivotal role in activating the cortical cognitive functions.

The most important proprioceptors are the muscle spindles, whilst the Golgi tendon organs and joint receptors provide a far lesser contribution to this sense. Both the intrinsic muscles, that originate and insert within the hand itself, and the extrinsic muscles that originate outside the hand (in the forearm) and insert into the hand, are provided with a large number of muscle spindle receptors for better performances (Banks, 2006; Kröger & Watkins, 2021).

2.2 The sense of touch

The sense of touch is especially developed in the hand where it serves as a cognitive tool to explore the outer world and objects. It is an essential guide to skilled motor abilities. Touch not only tells us about the shape of the objects, but also informs us about the surface texture and many mechanical properties.

The sense of touch is transmitted through mechanoceptors, of which several types exist (Gardner, 2010). The palm of the hand and fingers (glabrous skin) are provided with Meissner corpuscle and Meker cells. They are particularly present at the fingertips for discriminative touch (Corniani & Saal, 2020).

Touch on the hairy skin of hand and finger dorsum is provided by the hair follicle sensors and Merkel cells. Both in glabrous and hairy skin we find the Pacinian corpuscles and Ruffini endings, deeper in the subcutaneous. Each hand has around 150000 mechanoceptors innervated by an approximate total of 30000 fast conducting sensory fibres.

2.3 The sense of temperature and pain

The receptors for exteroception of temperature and pain are nerve free endings located in the most superficial layer of the skin. They are innervated by slower nerve fibres than touch and proprioception and are in larger number than the other receptors.

Once again, temperature and pain receptors are more densely located in the fingertips than in the palm. The total number of pain receptors in one hand is estimated to be approximately 17000 (Schlereth *et al.*, 2001).

2.4 Perception of global hand movements

From the distribution of proprioceptors and touch mechanoceptors it may be inferred that the handling of a pen sets in motion much more sensory afferents from the hand than the mouse, whose movements involve more proximal segments. A visual summary of this notion is shown in Figure 4 and Figure 5.

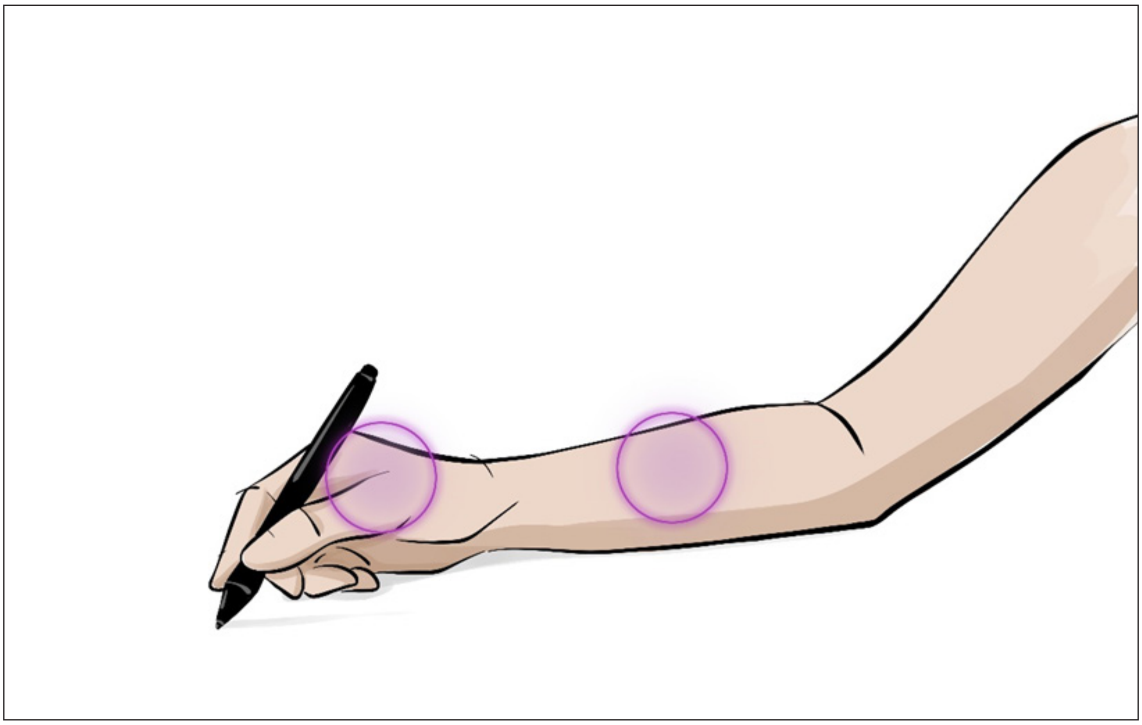

Figure 4 - The pink circles provide an approximate idea of the amount of sensory afferents from the hand set in motion to draw with a pen. Drawing by G. Leandri.

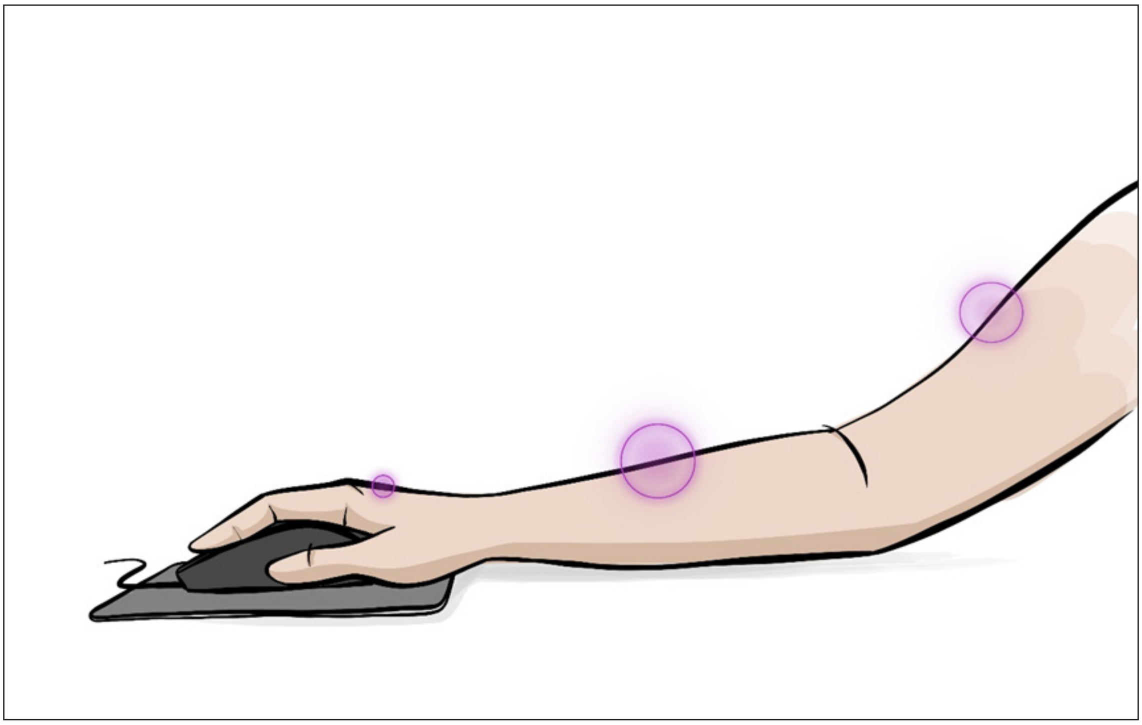

Figure 5 - Movement of the mouse sets in motion more proximal segments and their sensory representation is lesser than in the case of the pen. Drawing by G. Leandri.

3. The hand-brain-hand neural circuitry

Hand and brain constitute a closed regenerating circuit aimed at creation of physical and mental objects. No other part of the human body physically interacting with the outside world is dedicated to creative activity as the hand is. The anatomical and physiological features of the hand make it a unique tool that not only can perform the finest and most delicate movements with accurate control of strength, but also provides the commanding neural centres in the brain with information on the external (exteroception) and internal (proprioception) environment. These sensory informations act as a feedback control on the hand movements, and at the same time stimulate the association areas of the brain cortex linked to cognition and emotion, responsible of decision-making, planning, and regulation of motor activity.

To the end of creativity, the most important hand senses are proprioception and touch. Proprioception and touch are conveyed to the brain cortex through the "lemniscal pathway", the fastest available sensory route (Gardner & Johnson, 2013).

At the cortical level, the sensory afferents from the hand are connected with the parietal lobe, where a disproportionately wide area is devoted to host those neurons that receive and provide a first processing of the afferent signals (the primary sensory area). This area and the number of neurons in it, together with afferents from the face, are much larger than the receptive spots of the sensory cortex connected to other parts of the body. Such features give an idea of the functional importance of the hand from a sensory point of view.

These sensory representations had been investigated during neurosurgical interventions for epilepsy (Penfield & Boldrey, 1937).

The authors stimulated different areas of the cortex and asked participants to report in which part of their body they felt a sensation. By systematically stimulating different parts of the parietal cortex and recording the participants' responses, they were able to create a map of the primary sensory cortex that corresponded to each body part. Several connections arising from this area and directed towards nearby association areas and the motor part of the cortex have been demonstrated, and these play an important role in movement planning (Rizzolati & Kalaska, 2013). Just aside, but rostrally to the parietal primary sensory area, stands the primary motor area of the frontal lobe, responsible for sending commands to the motor neurons of the spinal cord that will output electrical pulses to be converted into mechanical power by the targeted muscles.

This area had also been investigated by systematically stimulating its different parts and recording subjects' movements, and a map, in the shape of a "motor *homunculus*" was created.

The motor and sensory *homunculi* are very similar, and in both the hand, together with the face, is the most represented part of the body, signifying that a very large group of neurons is dedicated to its functions.

In addition to these rather elementary sensory and motor connections of the brain with the hand, there is a satellite constellation of so called association areas, which by the way represent the largest part of the brain cortex, that are devoted not only to decoding sensory information and motor planning, but, most of all to "thinking".

Neurophysiology has not yet progressed as far as being capable of providing evidence on the underlying neural mechanisms of "thinking".

There are, however, some appealing clues that new ideas are born after execution of hand movements. Some experiments have demonstrated that both in parietal and frontal areas, quite far from those labelled as "primary" sensory and motor areas, may arise neuronal activity even 3 seconds before an actual movement suggesting a long forethought of cognitively pregnant actions (Di Russo *et al.*, 2017).

Other parts of the central nervous system besides the brain cortex are supposed to foster creative ideas as a consequence of movement.

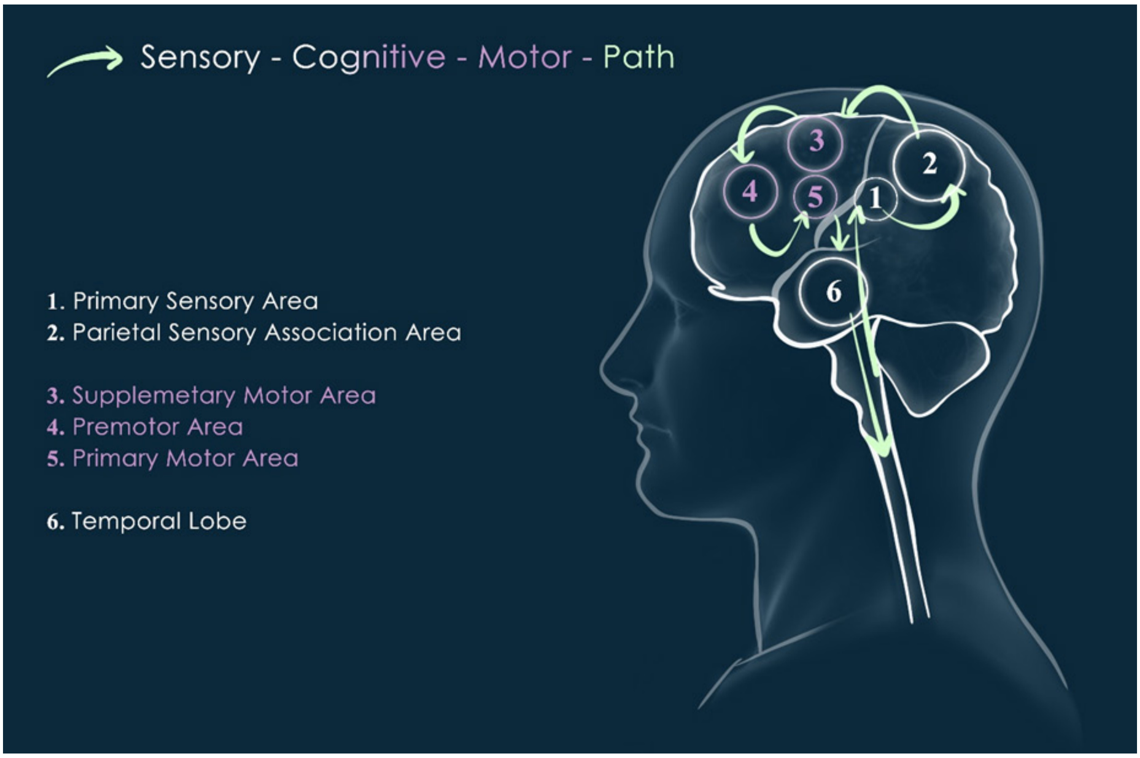

Figure 6 - Sequential activation of brain cortical areas by sensory afferents which recruit parietal neurons first and then, through the appropriate connections the frontal motor areas. Drawing by G. Leandri.

The cerebellum is a structure that traditionally has been considered just as a controller of the movements, but more recently it was claimed to have a role in stimulating cognitively relevant processes (Vandervert *et al.*, 2007). Connections of the cerebellum with the most important cognitively active cortical areas have been demonstrated with several experiments (Buckner, 2013).

In conclusion, there is a growing body of evidence that movement, and especially movement of the hands, should be regarded as a stimulating factor for the birth of new creative ideas. The hands are the main instrument which our self can use to perform a sensory and mechanically active communication with the outside world, and it is plausible that the work of the brain is strongly dependent on them.

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Performance and improvisation in graphic works: new theoretical perspectives

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Abstract

The aim of this paper is to investigate the phenomenology and semiotics of performance and improvisation in graphic works, and, more specifically, to try to identify the role it can have in graphic sciences. Starting with the role of drawing in the communication of design and ideas in architecture, the theoretical basis of performance and improvisation will be analyzed, leading to a description of the different ways of understanding graphic performances based on improvisation in the visual arts.

1. Performance and Improvisation in Graphic Works: New Theoretical Perspectives

Sketching is commonly considered a spontaneous and improvisational expression in the creative design process. This graphic action allows to readily capture and explore ideas, thoughts, and concepts freely and intuitively, without the constraints dictated by more formalized graphical languages — a way to break free from preconceived notions and embrace uncertainty and ambiguity during the design process. Moreover, this tool is not only a device to graphically translate ideas but has also often been used to communicate and argue them.

Before the advent of digital-based modes of public presentation, lectures as well as lessons and seminars on design and architecture could be considered true performances based on graphic improvisation, where the presentation of the images accompanying the narrated information was based on live, almost theatrical graphic production. For example, Le Corbusier emphasized the importance of the sketches to visualize ideas and explore design concepts (Charitonidou, 2022). He often used drawings and diagrams to illustrate his views and to communicate complex ideas clearly and concisely. His lectures, such as the one at the Milan Triennale in 1951, were authentic performative acts in which the sketches were a visual manifestation of the thought process that took place following the patterns of improvisation (Fig.1).

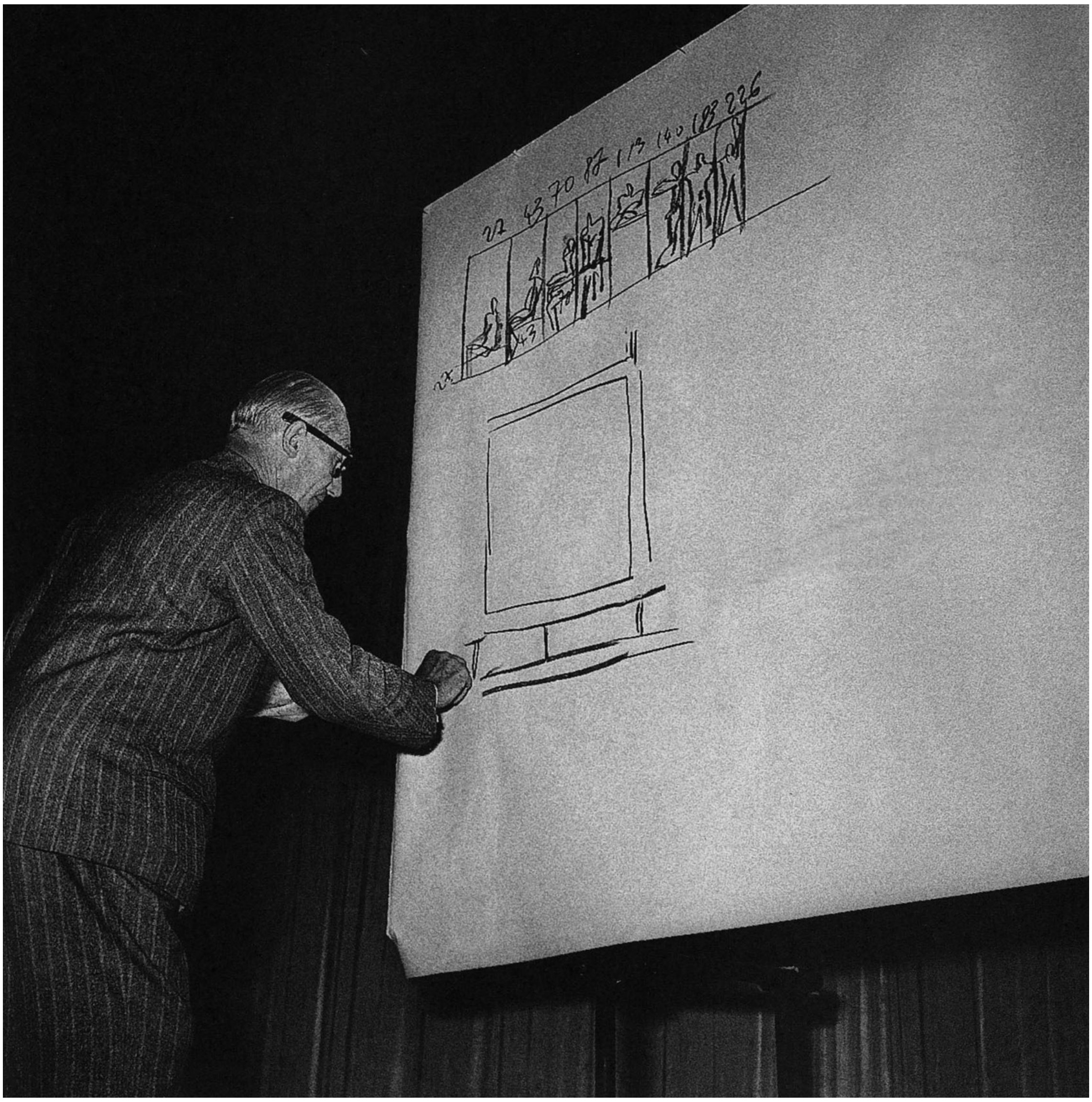

Figure 1 - Le Corbusier performative sketches at the Milan Triennale in 1951. Uzzani, G. (2020). *Progetti di "Ricostruzione": sulle tracce di Gualtiero Nativi*, 170-185.

Similarly, Louis I. Kahn encouraged his students to sketch extensively in his lectures, emphasizing the importance of exploring multiple solutions and iterating this during the project's conception (Kahn & Latour, 1991). More importantly, he emphasized on several occasions the importance of sketching to communicate design ideas in order to make the design process more collaborative and transparent.

Like Le Corbusier, in many of his lectures - including one of the most famous, "Silence and Light", held at ETH Zurich on February 12, 1969 - he used to argue the discourse through sketches on a blackboard, in an improvised performative act between word and gesture that took place in these graphic works (Fig.2).

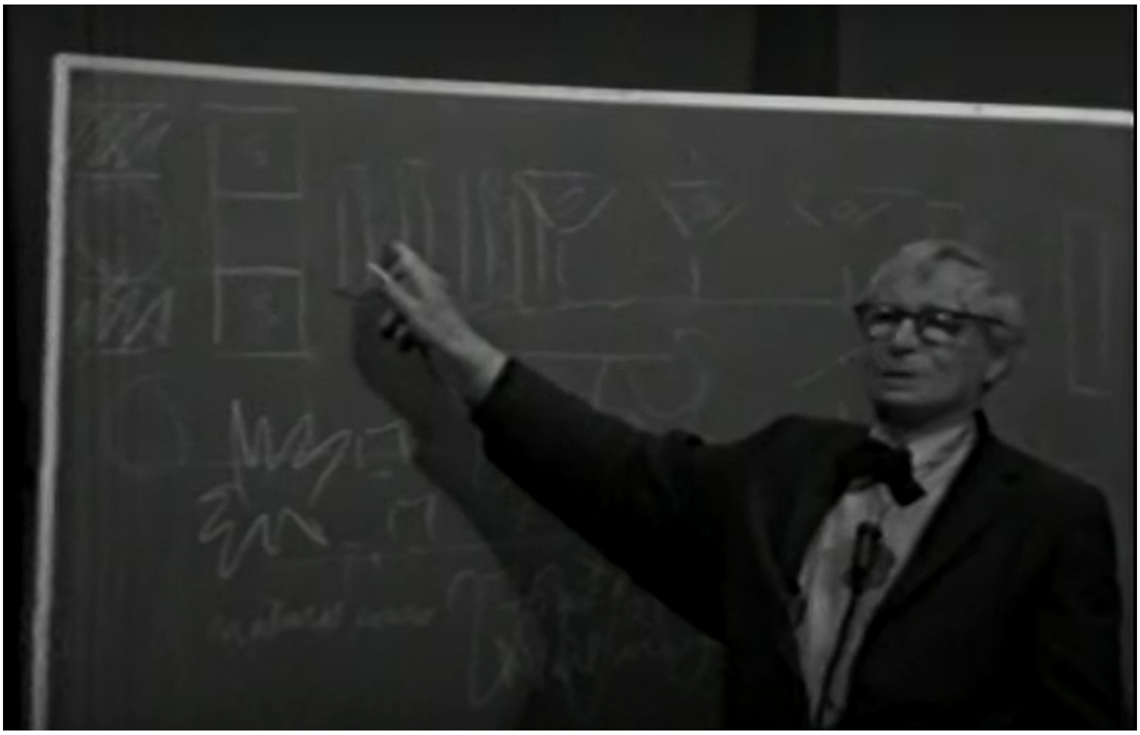

Figure 2 - Louis Khan performative sketches during the lecture "Silence and Light", held at ETH, 1969. Frame from <https://www.youtube.com/watch?v=ZaUtcKqdL5E>

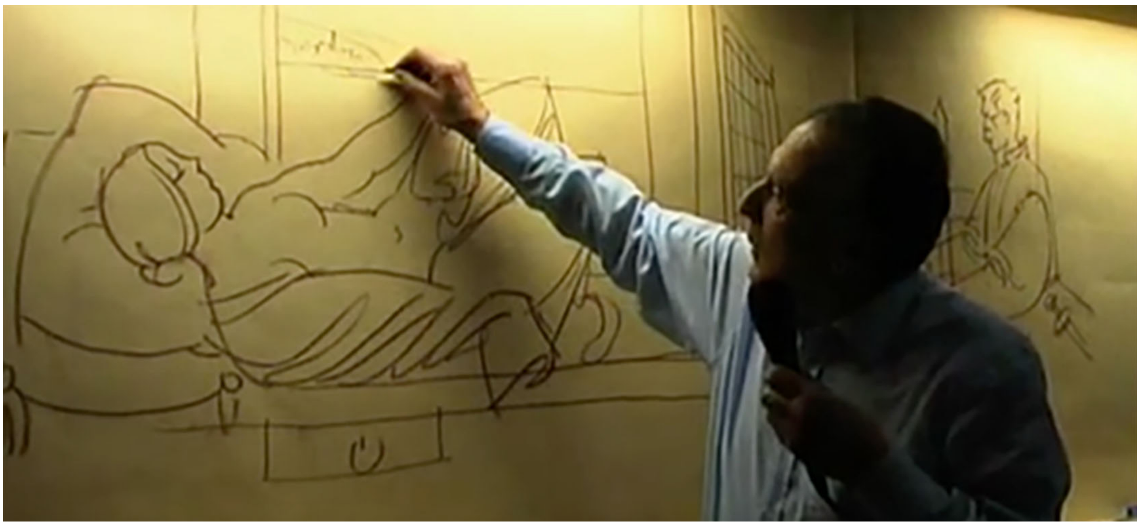

Figure 3 - Gaspare de Fiore lecture at Sapienza University in Rome, 2002. Picture from <https://web.uniroma1.it/dip_diap/archivionotizie/online-su-lamavideo>

Also Gaspare De Fiore has always attributed great importance to the sketch as a tool for the communication ok knowledge as well as for the design and graphic representation of architectural ideas, to the point of using this tool extensively during his lectures and lessons, for expressing concepts quickly and effectively (Fig.3).

2. Theoretical dimension of performance

Performance art has gained increasing importance in the art scenario during the last decades of the 20th and the first decades of the 21st century. Therefore, theoretical views of its nature and characteristics have followed, with a lag of about twenty years. According to many scholars, the properties that are essential to performance are self-regulation and relinquishing control (Mersch, 2022).

One could be tempted to identify performance and improvisation, but these notions should be kept distinguished. According to Mersch (2022, pp. 516-17), «performance is rooted in the creative treatment of practices and their various forms of realization», while «improvisation is rooted in the production, playing out, and variation of rules».

Nonetheless, there is a deep relation between the two concepts of improvisation and performance. As Mersch (2022, 516) puts it, «indeed, there is no improvisation — not in jazz, communication, everyday experimental constellations, or technological applications — without a performative aspect. It is not that the performative is improvisatory. Rather, the improvisatory is performative».

Bertinetto (2021) remarks that the dominant view of improvisation among contemporary scholars in aesthetics is that of an unplanned artistic activity – one whose development, as well as products, cannot be predicted (fore-seen, *pre-visum*). According to Asma (2017), improvisation «is the main activity, method, or operation of the imaginative faculty. Improvisation, more accurately, is not just what the imagination does, but is the adaptive meeting place between the organism and the environment».

However, as Bertinetto remarks, there are two kinds of improvisation – reactive and deliberate – where the latter is the one mostly engaged in artistic production. In any case, there is a strong connection between improvising and imagining: if we look at imagination as a process, it is easier to see it as deeply connected to improvisation.

Against those who reduce the mind to a set of computations, for Asma improvisation is the anti-module.

3. Performance and improvisation in art works

When we come to the relation between graphic works and improvisation, we may have some difficulty. After all, while it is relatively simple to shed light upon the relevance of improvisation in those arts where invention is simultaneous with productive performance, it might be harder to detect improvisation where process and product do not coincide, as in painting, sculpture, and graphic arts (Iacobone, 2021). In these latter fields of art, differently from performance arts, the presence of the artist can be delayed. Thus, the issue becomes what theoretical and aesthetical sense we can give to improvisation as a productive technique adopted by an artist, or author, whose presence is delayed.

Recently, Bertinetto (2021) has argued that improvisation can become relevant in non-performative arts, not just as a productive technique adopted in the creative process, when the artist was present and the interpreter absent, but also at the stage of interpretation, when the artist has disappeared from the scene and the interpreter is alone in front of the artwork. Bertinetto says that improvisation, in these circumstances, can become the aesthetic topic in the interpretation of the work; it can be a door through which we start seeing the work as an actual presentation of its absent producer.

By *perceiving* improvisation in the produced work, we do vividly imagine the artist in the act of producing the work, so we can delayedly perceive the creative process and expand our knowledge of the author as the producer thereafter (Bertinetto, 2021).

But in what sense precisely do we mean that we can perceive improvisation in a finished work, whose production process is completely located in the past? Is this a metaphor — or can we literally *sensorially perceive* improvisation? Does this mean that we indirectly perceive past improvisation via direct perception of present traces of it? Or is it some other way?

If we agree that, in non-performative arts, we can only perceive the traces of improvisation, and we accept to categorise the notion of "trace" under the more general notion of "sign", we have a double implication. First, our perception of improvisation in non-performative arts, as graphic works, is always perception of some signs.

As every sign can stand in the absence of its referent (Eco, 1975), we cannot literally say that we directly perceive improvisation; at best, we can perceive it indirectly — while, at worst, it just *seems* to us that we perceive improvisation, while the work has been actually produced without it. So, we can talk, along with Bertinetto and Ruta (2022), of an “artistic grammar of contingency”, as articulated through different aesthetic properties.

Second, improvisation – as a semiotic device - can become an important part of the *signifier* of the work, thus contributing to crucially determine its meaning, also in case the work has not actually been produced by improvisation. On this regard, apparently perceived improvisation can depict a certain image of the producer as the author of the work, rather as part of the meaning of the work than as a true component of its productive history.

4. Improvisation in graphic works

Bertinetto and Ruta (2022) try to map the aesthetic properties of a painting through which improvisation can be «articulated, displayed, and thematized», or, in other terms, semiotically expressed independently of its actual occurring in the production process.

The first one is the pictorial exhibition of a spontaneous, inspired, and unconscious feeling. The paradigmatic example made by the authors are Kandinsky's *Improvisations*, which Kandinsky himself classified as "improvisations" as opposed to "impressions" — inspired by external sources – and "compositions" — inspired by internal yet conscious feelings or mental states (Kandinsky, 2008, p.116).

Interestingly, however, Kandinsky's Improvisations turn out to be not "improvisations" in Kandinsky's own terms, because they «were planned and prepared by the artist through sketches and preparatory studies». So, improvisation was graphically constructed as a semiotic function which codes for the meaning "this painting is improvised", the aesthetic properties at play being spontaneity and depth (Fig.4).

The second form taken by improvisation in painting is sketch, and notably urban sketch, intended as «the rapid freehand realization of the depiction of an object». A key role, here, is run by quickness — via *realtimeness* — and unfinishedness, which in turn «pictorially express aesthetic qualities such as fugacity, ephemerality, and precariousness». Again, these characteristics have not necessarily been there during the production of the work: the work might merely *mean* them through adequate use of relevant semiotic codes.

An example is the performance of Stephen Wiltshire who draw in 2014 the Singapore skyline on a 4m by 1m canvas at Paragon Shopping Mall in Singapore, in full public view from 10am to 5pm (Fig. 5).

Figure 4 - Coded spontaneous painting: Kandinsky's *Improvvisations*. Image from <https://russkiymir.ru/en/publications/219048/>

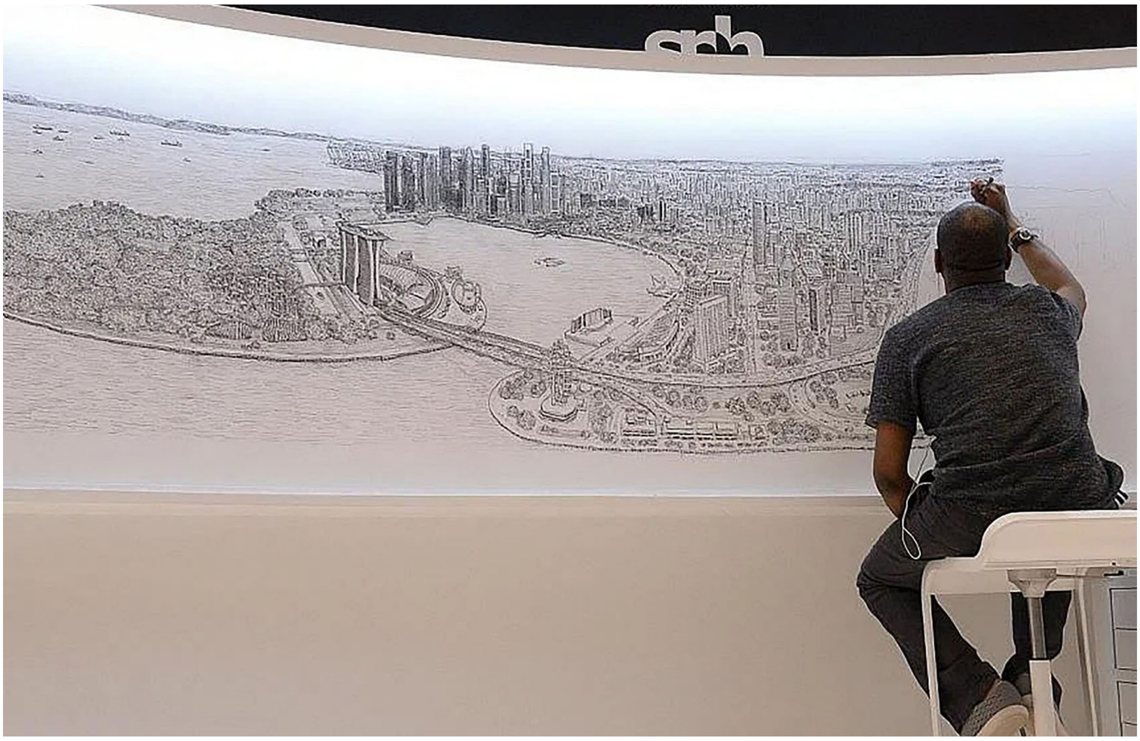

Figure 5 - Depiction painting: Stephen Wiltshire performance at canvas at Paragon Shopping Mall in Singapore, 2014. Image from < https://www.stephenwiltshire.co.uk/singapore-skyline-panorama-drawing>

The third form in which improvisation appears in paintings is autopoietic painting method, where the umpredictibily of the production process is represented as emerging from the author's acceptance of her lack of control and of the work's being determined by the author's interaction with materials and, more generally, the materiality of the world.

One example is Jane Grisewood's 30-minute performance drawing of a 400 x 200 cm work in charcoal and graphite in front of a live audience at the *Draw to Perform - Drawing Per-formance Symposium*, held in London in 2013 and curated by Ram Samocha (Fig. 6). Here the focus in on the surprise effect; while in the fourth form of improvisation the main role is attributed to variation, which is the expressive trait referring to «the evolving and unforeseeably changing life of an artwork».

The exemplification of this fourth form taken by improvisation is the multiplicity of versions of the same paintings, which, again, can be planned just for it to code for "improvisation" as a semantic content.

This is the case with Tony Orrico's "penwald drawings" created at the Shoshana Wayne Gallery in Santa Monica, California in 2011 (Fig.7).

Figure 6 - Autopoietic painting: Jane Grisewood drawing performance at the Draw to Perform - Drawing Per-formance Symposium. Image from <https://janegrisewood.wordpress.com/2013/12/10/draw-to-perform/>

Figure 7 - Multiversion Painting: ‘penwald performance’ by Tony Orrico at the Shoshana Wayne Gallery in Santa Monica, California. Image from <https://tonyorrico.com/penwald-drawings/archive/>

5. Conclusions

Our specific intent in this talk is exploring how a semiotics of improvisation in graphic sciences could be developed, starting from the identification of graphic signifiers coding for “improvisation” until the task of determining the connotative effects over the way the author, as part of the meaning of the work, is meaningfully made relevant and characterised. We move from the hypothesis that sign-functions are multiple and overlapping (Eco,1975), and a set of different aesthetic properties — as those identified by Bertinetto and Ruta (2022) — become relevant from time to time.

We try to make examples of graphic works falling in Bertinetto and Ruta’s four categories of improvisation, and investigate whether, in graphic sciences, we need to offer a partially different classification; and raise the question whether and how we can apply the semiotic concept of "improvisation" to digital graphic works as well, perhaps even in more radical and stronger ways than how we can apply it to traditional graphic works on paper: a possibility, for example, is that we can look at some digital graphic works as *agentive* and *improvisional* entities, in analogy with Iacobone's (2022) proposal to consider some sculptures — as the paradigmatic Theo Jansen’s massive *Strandbeests* (1991–present) that can move thanks to wind propulsion — as literally capable of improvisation as agents, even much later than they have been produced by their author, and independently of this production being improvised in turn. This is exactly the reason why we intend to reread some graphic artefacts that allow us to trace these interpretative possibilities of improvisation.

The choice of commenting on some sketches, as opposed to other graphical artefacts, according to these interpretative keys, lies essentially in the double soul of this object and this practice: on the one hand, it is an action aimed at the author's improvisation, on the other hand, it is an object resulting from the former that can be reread and reinterpreted as its own artefact and authorial expression.

The sketch can be reinterpreted as the expression of a spontaneous and unmediated action between the designer's thought and his figuration, between the mind and the hand, a view that unfolds while acting, an almost intimate performance. At the same time, however, it can be reread as a still unfinished prefiguration of an idea, which sketches and does not define and is open to uncertain and perhaps restless interpretation.

Thirdly, these objects can be reread as an element contributing to design autopoiesis. This sudden apparition does not determine and does not define but contributes to making the image of the idea and the idea of the project appear, thus creating the image of the concept.

Ultimately, however, it allows itself to be reread as a sequential, non-extemporary tool in which different possibilities of representation or interpretation are explored without being limited by a predefined form or expression.

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Technology and neuroarchitecture

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Abstract

This paper is part of an ongoing research project involving the Department of Architecture and Design at the University of Genoa, as well as entities from both the professional training and industrial worlds.

The primary objective of this research is the development of a tool that is useful both for designers and for users.

Based on the concept of smart mock-ups, previously developed by the authors, the focus has been declined on the world of nautical design, with the aim of measuring, through qualitative parameters, the user experience in a built environment, whether it is a relaxing or working environment.

The first and fundamental step involves defining the "state of the user" through a vector of measurable variables using a network of sensors that do not significantly alter the UX with the surrounding space. This article presents the state of the art of techniques and sensors that can be used for research purposes, as well as the proposed experimental setting to verify the initial working hypotheses. Then we will describe how research will move on to obtain an affordable and efficient tool for nautical designers.

Here, we will describe different types of methods that can be used in neuroscience, from standard ones (like emotions recognition software based on FACS, or biometric sensors like heart rate variability, galvanic skin response), to modern ones (like the use of electroencephalography, functional magnetic resonance imaging) and eye tracking.

1. Contribution

The fields of neuroscience and architecture have long been thought of as separate entities, but recent research has shown that the two disciplines can work together to create spaces that promote mental and physical health and the new term “neuroarchitecture” has been recently coined.

Neuroarchitecture is the study of how the built environment affects the brain and behaviour, while neuroscience is the study of the structure and function of the nervous system. By combining these two fields, researchers are trying to use sensors to measure emotional responses to the built environment to understand how different environmental stimuli impact emotional responses (Medhat Assem *et al.*, 2023). Research has shown that exposure to natural environments can have a positive impact on mental health. Natural environments have been associated with decreased levels of stress, anxiety, and depression. By incorporating natural elements into the built environment, such as plants and water features, architects can create spaces that promote relaxation and well-being.

Research has also shown that exposure to certain types of lighting can impact emotional responses: brighter lights have been associated with increased arousal and decreased relaxation, while dimmer lights have been associated with increased relaxation. By designing spaces with adjustable lighting, architects can create environments that promote different emotional states, depending on the needs of the occupants. In addition, research has shown that exposure to music can impact emotional responses. Music with a slow tempo and low pitch has been associated with relaxation, while music with a fast tempo and high pitch has been associated with arousal. By incorporating music into the built environment, architects can create spaces that promote different emotional states, depending on the needs of the occupants.

Technology has the potential to revolutionise the field of neuroarchitecture by providing new tools for measuring and analysing the impact of built environments on human behaviour, cognition, and well-being. We have:

- Sensors and Wearables, which can be used to measure physiological responses such as heart rate, skin conductance, and brain activity in response to different architectural stimuli and whose data can be used to develop evidence-based design principles that promote well-being in buildings and urban environments.

- Eye Tracking, whose technology can be used to measure visual attention and gaze patterns in response to different architectural features. This can help to identify which features are most salient to people and inform designers of wayfinding systems that are more intuitive and effective.

- Virtual Reality (VR) systems, which can be used to create realistic simulations of different built environments, allowing researchers to test the impact of architectural features on human behaviour and cognition in a controlled environment. In further research this could be particularly useful for studying the impact of inaccessible or hazardous environments on different populations, such as people with disabilities.

- Artificial Intelligent Tools, such as machine learning or neural networks algorithms, which can be used to analyse large datasets of human behaviour, providing insights into patterns and trends that are difficult to discern through traditional methods. Besides, AI that can be used to develop predictive models of human behaviour in different built environments, allowing designers to simulate the impact of different design features before construction. This can help minimize the risk of costly design mistakes and ensure that buildings and urban environments are optimized for human well-being.

Figure 1 - Interaction between man and artificial intelligence. Canva Edu Licence.

2. FACS

Facial Action Coding System (Ekman & Friesen, 1978) is a tool that is widely used in neuroscience research to objectively measure and analyse facial expressions.

Unlike subjective ratings of facial expressions, which can be influenced by factors such as observer bias or individual differences in perception, FACS provides a standardized and objective method for measuring facial movements, because it uses a series of codes to describe the movements of different facial muscles, such as raising the eyebrows, wrinkling the nose, or pulling the lips back. By coding facial movements in this way, researchers can objectively quantify and compare facial expressions across individuals and across different experimental conditions with greater accuracy and precision.

FACS has been used in a wide range of neuroscience research, including studies on emotion, social interaction, and decision-making. It has been used to study the neural mechanisms underlying emotion regulation by measuring changes in facial expressions in response to emotional stimuli (Wager *et al.*, 2008) and it is also useful to study the neural basis of social interaction by measuring facial expressions during cooperative and competitive interactions .

By using FACS, neuroarchitects can objectively measure and analyse facial expressions in response to different architectural features, such as lighting, colour, and spatial configuration. This allows researchers to identify which design elements elicit positive or negative emotional responses, and to develop evidence-based design principles for creating buildings and urban environments that promote well-being.

On the other hand, one limitation of using FACS in neuroarchitecture is that it can be difficult to control for individual differences in facial expressions and emotional responses. Participants may vary in their baseline levels of facial expressivity, which can affect the interpretation of facial expressions in response to architectural stimuli.

This problem can be easily overcome by using software trained with machine learning algorithms and multicultural databases. Additionally, FACS only measures facial expressions and does not provide information on other modalities, such as physiological responses or subjective ratings of emotional experience (Clark *et al.,* 2020).

3. Eye tracking

Eye-tracking technology has become increasingly popular in the field of neuroarchitecture as it provides valuable insights into how people perceive and interact with their built environment, because it measures the movements of the eyes and it records how people perceive, react, and navigate through different sites (Duchowski, 2002, pp. 455-470).

There are different types of eye-tracking systems:

- *Remote systems* which use cameras to track the movement of the eyes from a distance, while
- *Head-mounted systems* which use glasses or headsets that are equipped with cameras to track eye movement from a closer distance.

Both systems use infrared or corneal reflection methods to track the movement of the eyes (Rayner & Castelhano, 2007). Another application of eye-tracking technology is to measure cognitive load, or the amount of mental effort required to perform a task. One limitation of eye-tracking technology is that it only measures visual attention and does not provide information on other sensory modalities, such as touch or smell. Additionally, eye-tracking data can be influenced by factors such as fatigue, cognitive load, and individual differences in eye movement patterns.

4. Electroencephalography (EEG)

EEG is a non-invasive technique that measures the electrical activity of the brain using electrodes placed on the scalp. It has been used for many years to diagnose neurological disorders and to study brain function, while more recently, it has been used to study emotional responses to the built environment, since it can measure different types of brain waves, including alpha, beta, delta, and theta waves (Harmony, 2013). These waves are associated with different mental states, such as relaxation, arousal, and attention. By measuring changes in brain waves, researchers can identify emotional responses to different environmental stimuli (Aspinall *et al.*, 2015).

5. Functional Magnetic Resonance Imaging (fMRI)

Functional Magnetic Resonance Imaging (fMRI) is a non-invasive technique that uses magnetic fields to measure changes in blood flow in the brain. Similarly to EEG, fMRI has been used extensively to study brain function and to diagnose neurological disorders, but it can be used to identify areas of the brain that are activated in response to different environmental stimuli, such as colours, sounds, taste, paintings and photographs. fMRI has also been used to study the emotional responses of participants to different types of music that induced strong emotional responses, such as sadness or joy (Logothetis, 2008).

6. Heart Rate Variability (HRV)

Heart Rate Variability (HRV) is a measure of the variation in time between consecutive heartbeats. It is a non-invasive measure that has been used to study the autonomic nervous system, which controls functions such as heart rate, blood pressure, and digestion. More recently, it has been used to study emotional responses to the built environment.

HRV can be used to identify changes in the autonomic nervous system that are associated with different emotional states (Stegagno, 2020).

7. Galvanic Skin Response (GSR)

GSR is a measure of the electrical conductance of the skin, which is influenced by the activity of the sweat glands. GSR has been used for many years to study emotional responses and is commonly used in lie detection tests. More recently, it has been used to study emotional responses to the built environment.

8. Natural Language Processing (NLP)

NLP can be used in neuroarchitecture to analyse written or spoken language related to architectural design, such as user feedback, design briefs, or building codes.

One potential application of NLP in neuroarchitecture is sentiment analysis. This technique involves analysing text to determine the emotional tone behind it. In the context of architecture, sentiment analysis could be used to evaluate how people feel about certain building designs or spaces, and whether those emotions are positive or negative. This information could then be used to inform future designs that better align with people's emotional needs (Warikoo *et al.*, 2022).

9. Experimental setting

In the initial stage of our experiment, we will involve a group of second-year high school students in a physics lab experiment called "Black Box".

The class will be divided into two groups: *experimenters* and *observers*. Paired-up students will play the roles of observed and observer, respectively.

The observed will use their senses and some available magnets to decipher the contents of a black box, without opening or breaking it, while the observer will record the stage of Galileo's experimental method the experimenters is in, every 120 seconds, selecting among: observation/research/hypothesis/experiment/collect data/analysis/conclusion, along with the emotional state they believe the experimenter is experiencing, selecting one of the options of a pre-defined list of emotions (enthusiasm, satisfaction, fun, surprise, curiosity, uncertainty) (Smith & Bellocchio, 2017).

At the end of each two-minute period there will be a break of about 30 sec. so that the observed student can also fill in the same form on his mobile phone, indicating the phase of the method performed and the emotions perceived. An acoustic signal will indicate the end of each period and then the beginning of the following one.

The experiment will last for about 20 minutes, after which the experimenter will have to declare their conclusions. Each pair of students will repeat the same experiment. Data collection will also be carried out in audio-visual format, for a subsequent analysis through an artificial intelligence software that allows estimation of emotions through apposite software for FACS recognition and a NPL analysis.

Students will be recorded by HD quality video cameras and cell phones placed on a tripod about one meter away from the observed. Observers will have to check that their peer do not move too much and do not cover their faces.

The experiment's objective, which has already been widely used in scientific literature, is to compare the observer's data with the data collected by software for automatic emotion recognition and analysis, as well as the data collected by EEG and wearable sensors and software for sentimental analysis based on machine learning algorithms.

Secondly, we would like to test our sensors in a smart mock up (Zignego, & Gemelli, 2020). The eye tracking glasses will be used for analysing the user's fixations, while the EEG helmet and the biometric sensors will allow us to analyse which areas have generated interest in our user and what feelings they have generated.

These data will be compared with those extracted using standard questionnaires for detecting a user's experience. The advantage of using biometric sensors together with eye tracking and EEG helmet is to be able to obtain data that are not influenced by cognitive biases such as response bias, self-evaluation bias and researcher bias.

Finally, the last phase of our research (Zignego *et al.*, 2022) will proceed with the analysis of the data collected in a virtual environment, using a pair of augmented and virtual reality glasses, through which the user will be able to navigate within a reconstructed environment and add objects, modify them in terms of colour, shape, and material. In this case too, biometric and neural data will be collected in order to study which environment has generated greater liking and interest, and a format for sharing with the designer and nautical project manager who will take charge of customizing the vessel for the client will be developed.

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Part II - Techonology and Human Perception

Artificial Intelligence, Virtual Reality, Software

Keywords

Digital transition
Metaverse
Animation
ChatGPT
Cognitive framework development
Performing art

Imagination and digital media in the architecture design process

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Architectural design is a complex process that involves various professional figures, knowledge in multiple fields and competencies, managed by specific cognitive abilities, and that has always found the opportunity to develop, and finally potentially reach a tangible outcome, by integrating tools capable of absorbing some of these abilities.

This research arises from the need to question the role of technology in architectural design, defined as the set of digital tools available to the architect, now that it is equipped with ever greater potential (parametric control of the drawing, management of physical, economic information...) and with interfaces that even exceed the "traditional" screen (es. virtual reality, augmented reality).

Digital media have a direct impact, from the early stages, on the design process and determine the outcomes. This is investigated in various studies in the field of cognitive sciences that have focused on the differences between sketch and digital media in different aspects (Bilda & Demirkan, 2003; Häggman et al., 2015; Ibrahim & Pour Rahimian, 2010; Rahimian & Ibrahim, 2011; Ranscombe et al., 2019; Stones & Cassidy, 2010).

Despite the full diffusion and the well-established integration of digital tools in the practice of architects, it remains surprisingly little investigated their impact in particular in relation to mental imagery, one of the many cognitive skills put in place in the creative process and one of the most "powerful", as it is able to reverse the neuronal patterns activated during the perceptive and multisensory experience of space through the re-elaboration in a new meaningful organization of fragments extracted from long-term memory (Arbib, 2020).

Research in this direction is particularly important because it is increasingly evident, also given the many discoveries made in the field of cognitive sciences in recent years, that the boundary between the designer's mind and the instrumental apparatus at their disposal is increasingly blurred. Studies (Bruner, 2018; Clark & Chalmers, 1998; Malafouris, 2019) consider the interaction between mind and matter with a systemic approach:

body, brain, and "active externality" (Clark & Chalmers, 1998) constitute a network of inseparable interactions, by which the brain undergoes continuous reconfiguration. Going further, Poulsgaard and Malafouris (2020) define digital models of architecture as «technologies of perception, that are inextricably bound up with knowledge and imagination in the wider field of architecture».

We believe that mental images and digital tools are, among the various involved, two of the most interesting components to be compared to analyze mutual interactions, given their similarity and notable differences at the same time. Both are tools for modeling a hypothetical material reality, and yet, if imagination uses sensory content to define a model, digital tools do so by translating matter into binary language, which, as we know it, derives from rational-mathematic reasoning.

This account originates from considering the perception of the environment essentially as atmosphere, that is, an immediate contact from which a synergy of sensory perceptions arises (Canepa, 2022). In this sense, the design must consider that the experience of space is primarily embodied and precognitive (Jelić, 2015) and that the human body is going to interact with space in terms of affordances (Condia *et al.*, 2020)

From a neuroscientific point of view, imagination, according to the IBSEN model (Imagination in Brain Systems for Episodes and Navigation) developed by Arbib (2020, 2021), «can "reverse" the multimodal experience of contemplation and action perception cycle to design spaces that support them»

According to the enactive theory on imagery (recalled or not), imagination is constituted by the (partial) emanation of the perceptive acts that would be performed if one actually perceived what one is imagining (Thomas, 2021). Precisely because of this characteristic, imagination, although used with different degrees of awareness, makes the architect a sentient subject of the space during the design phase. If enhanced and actively used, imagination can be a true instrument of phenomenological control of space. As Peter Zumthor (2019) states,«[Memories of this kind] constitute the basic nucleus of images and architectural atmospheres that I try to fathom in my practice as an architect».

And it is precisely this "fathoming" the other theme that makes imagination a potential tool for design. Kosslyn (1999), the neuroscientist responsible for the recognition of the cognitive effectiveness of mental images, achieved this result by studying the inspection and transformability of mental images in relation to time. Many authors, then, recognized spatial ability and visual cognitive style as some of the main cognitive abilities that favor the professional activity of the architect (Cho, 2017).

With remarkable and undeniable advantages in the speed of modification operations on modeled reality, digital tools have evidently been an integral part of the architect's creative process for decades. The progressive development of software dedicated to design, however, makes the contrast even more evident, especially with the immersive allowed by the imagination. What are the consequences of this constant mandate of capacities that define us as human beings? (Malafouris, 2013)

As mentioned before, experimental studies have been developed to investigate the possible interactions between digital architectural design tools and other spatial modeling and prefiguration systems; sketch and CAD are the two most studied design tools. Although there is already some interesting evidence of the potential of mental images as a design tool in architecture (Athavankar, 1997; Bilda & Gero, 2008), compared to others, the relationship between mental images and digital tools is much less studied, and represents a promising research field.

With the aim of obtaining some initial evidence about the interaction between imagination and digital media, we structured a preliminary cognitive experiment, thanks to the collaboration with Prof. Carlo Chiorri, professor of psychometry (University of Genoa), and Prof. Manila Vannucci, professor of general psychology (University of Florence).

We asked a group of undergraduates of architecture to perform a simplified design activity in two different modalities, namely using "2D-3D CAD software" vs. using "only imagery" (within-subjects design). The task consisted of the design of an outdoor space with a very simple program, using given wood construction elements. Cognitive and emotional dimensions of the experience were evaluated right after the task, by using an ad hoc questionnaire. Expertise with the software and individual differences in psychological dimensions of interest were also assessed.

Under the "only imagery" condition participants reported a more concrete and embodied experience compared to the "software condition", as they simulated concrete interactions with the objects of design, remembered previous similar experiences, and globally felt less constrained in their process of ideation.

These data suggest that the process of architectural design is sensitive to the tools used, at least in terms of the subjective experience reported by participants.

Experimental research on the topic is only at its beginnings and we believe its future developments and results could have an impact on architectural education (Robinson, 2022) as well as on professionals' metacognition of their own creative process.

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Mental imagery and digital media in architectural design process. An experimental study

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Abstract

Over the last decades, digital technology use has transformed our lives, and psychology and neuroscience have begun investigating how technology may impact our brains and behaviors. Digital technology is also transforming architectural practice in all its aspects: ideational, constructive, and managerial. However, this radical transformation is taking place without sufficient critical reflection and systematic investigation.Here, we present the results of a pioneering study aimed at investigating whether and how the use of different tools in the design process may affect its cognitive and emotional aspects.To this end, we asked a group of undergraduate students in architecture to perform a simplified design activity in two different modalities, namely using “2D-3D CAD software” vs. using “only imagery” (within-subjects design). Cognitive and emotional dimensions of the experience were evaluated right after the task by using an ad hoc questionnaire. Expertise with the software and individual differences in psychological dimensions of interest were also assessed. Significant differences were found in various cognitive and emotional dimensions depending on the different conditions.

The results suggest that the process of architectural design is sensitive to the tools used, at least in terms of the subjective experiences reported by participants. The theoretical and practical implications of these findings are discussed.

1. Architectural design process

Architectural design is a multifaceted problem-solving activity in which multiple high-level cognitive processes are involved to face what is considered an “inherently ill-defined” problem (Rittel & Webber, 1973). Many studies over several decades have been conducted exploring the complex dynamics of the design process in various disciplines, but the characteristics of some of the cognitive processes involved in conceptual design remain unclear. As a kind of creative process, the design process involves deliberate actions in parallel with spontaneous mental activities (Vannucci & Agnoli, 2019), which makes it very difficult to shed some light on. A meta-analysis by Hay *et al.* (2017) reported 24 cognitive processes investigated in a subset of 33 studies on architectural design, engineering design, and product design engineering. Some of these cognitive dimensions have been grouped into three categories of reasoning considered fundamental to the design process in architecture: spatial ability, creativity, and visual cognitive style (Cho, 2017) Since it is not possible to determine a unique model of the design process, neither transversal nor specific to a discipline, the problem is necessarily broken down to analyze some specific aspects. One of the approaches to researching the theme of the design process in architecture is to analyze the tools that are an integral part of the process to try to determine its implications at various levels. According to the extended mind theory (Clark & Chalmers, 1998) and its later developments (Malafouris, 2013; Poulsgaard & Malafouris, 2020), it would be very limited to analyze a process or part of it without taking into account the "active externalities" through which this happens: «the human organism is linked with an external entity in a two-way interaction, creating a coupled system that can be seen as a cognitive system in its own right.» (Clark & Chalmers, 1998, p. 9). This approach is in line with the dense strand of situated cognition, which includes the environment in its different forms in the research problem. The sketch is the tool most naturally used by architects to outsource and fix ideas whose control would otherwise be an excessive burden on working memory, and this is what most scientific studies focus on. Two or more of these models often coexist during the process and allow each, with its own input of information, to compose the system of relationships that defines the project. Being a dynamic process, each model allows for the provision of useful information for the development of another; in this account, the project is constituted by the interrelationship between the different models. Digital representation is today's dominant modeling mode in the design process.

In this study, we investigated the association between digital media and mental images as a design tool.

2. Mental imagery as a design tool

Even though imagination has not been studied in a systematic way in architecture or the cognitive sciences as a possible tool for design that can be improved through targeted teaching, it has been investigated in different areas to find out what makes it what it is. However, it has been rarely investigated within the creative process in architecture (Bilda & Gero, 2006). Here we highlight some of the approaches from the various fields of research that contribute to forming a framework for the active use of imagery in architectural design. Based on a long-running philosophical discussion about what mental images mean (Giachetta *et al.*, 2019), the cognitive sciences built their theoretical framework through a number of different, and sometimes even contradictory, contributions. Kosslyn (1983) presented evidence that gave legitimacy to mental images as real psychological entities and as measurable and possible objects of theorization. He also identified the mental operations that we can voluntarily perform on them; these represent the first level of use of mental images for architectural design. The ability to visualize and manipulate spatial information, mental rotation, and spatial perception constitute the so-called spatial ability.

Another level of the potential use of imagery in architectural design resides in its capacity to involve all five senses. There has been a tendency to focus only on visual mental imagery, but recent neuroscientific evidence showed that there is a coincidence of the activated areas in the brain on the occasion of sensory perception and the imagination of perception (Abraham, 2016; Arbib, 2020; Naselaris et al., 2015). This brought to the development of the enactive theory of imagery, which holds that imagery (recalled or otherwise) is constituted by the (partial) enactment of the perceptual acts that would be carried out if one were actually perceiving whatever is being imagined (Thomas, 2021). This is why imagination is also called "quasi-perceptual experience" (Thomas, 2021) and should be considered a proper tool in architectural design. It has the power to make the architect a sentient subject of the environment in the design phase; it allows the architect to «contemplate matters beyond the immediate present» (Abraham, 2016). A direct reference to this capacity is mentioned by architect Peter Zumthor (2019).

Some experimental psychological studies on mental imagery as a design tool have been carried out (Athavankar, 1997; Bilda & Gero, 2008) and demonstrated that architects can produce ideas using only imagery.

3. Experimental study

3.1 Aim

In professional practice, it is impossible to develop a project using imagery as the only modeling system; different models often coexist during one or more design phases. Based on our previous discussion on imagery, we want to highlight the contrast between its quasi-perceptive capacity (multisensorial) and the digital language. This antithesis has led us to the question: What are the implications of using digital tools for design in relation to imagery?

When the faculty of generating mental images is outsourced and visualization is entrusted to software, it is possible that a shift of the focus from material, embodied thought to abstract and conceptual thought, bound to the requests of the specific interface, could interfere with the influx of images recalled. According to a neurophenomenological approach to the study of experience, to think of architecture as an intellectual experience and entrust its design to tools based on a vision of physical-mathematical reality represents a paradox of contemporary architectural culture (Jelić, 2015).

Consequently, the aim of this study was to extend the research on the effects of tools in the design process in architecture by evaluating different aspects of the cognitive and emotional processes involved.

3.2 Method

We asked 90 undergraduate students in architecture to perform a simplified design task in two different conditions, namely using “2D-3D CAD software” (DIG) vs. using “mental imagery” (IMG), following a within-subject design (Fig.1). Participants have been divided arbitrarily into two groups (A and B), in the first session group A was in DIG condition, and group B was in IMG condition. In the second session, two months later, we inverted the condition for each group. The IMG condition consisted of developing the requested project only using mental imagery; the DIG condition allowed them to draw using the digital tools they habitually use: Autocad 2D-3D and SketchUp 3D as their preference. It was not permitted to sketch in either of the two conditions. The task was the same for each group in the same session: in the first session, participants were asked to design a canopy, and in the second session, a meditative space, both with given wood construction elements. Before starting the design activity, they could briefly visit the project area, which was a garden in the Architecture Department where the experiment was conducted.

At the end of the task, in each session, participants were asked to rate, using an ad hoc questionnaire, their mental activity in terms of cognitive (e.g., multi-sensory imagination, empathic imagination, retrieval of past experiences, perception of time, concentration/distractibility) and emotional dimensions (e.g., the experience of frustration, satisfaction) also using the Positive Affect and Negative Affect Scale, and in the end, to evaluate their final output. Expertise with the software and individual differences in cognitive dimensions of interest (e.g., distractibility, attentional control, cognitive style) were also assessed in a third session, using validated psychometric tools: Mind Wandering: Deliberate (MW-D) and Mind Wandering: Spontaneous (MW-S) scales, the Attentional Control: Distraction (AC-D) and Attentional Control: Shifting (AC-S) scales (Carriere et al., 2013), the Object-Spatial Imagery and Verbal Questionnaire (OSIVQ, Blazhenkova & Kozhevnikov, 2009), the Dispositional Flow Scale (Jackson & Eklund, 2002), the Ten Item Personality Inventory (TIPI, Gosling *et al.*, 2003) .

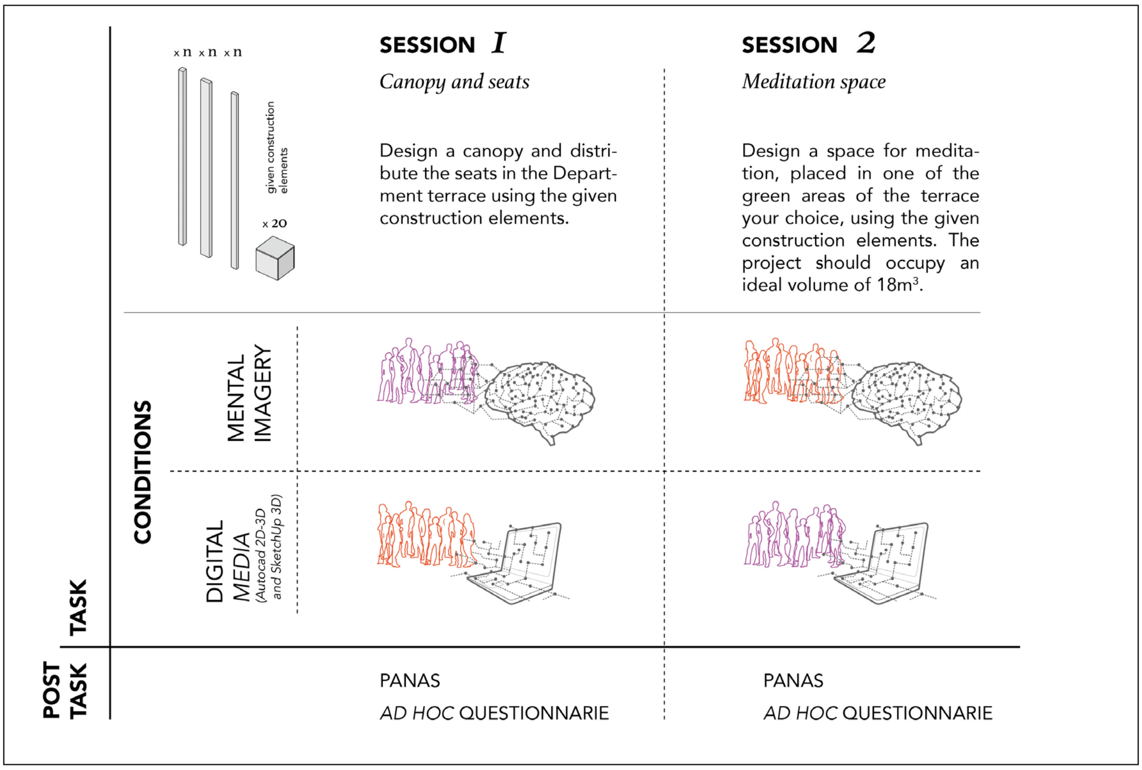

Figure 1 - A schematic representation of the experimental design. Imga eby the author.

3.3 Data analysis

Data from all three sessions were merged. Data from Session 3 allowed us toThe data from Session 3 allowed us to identify 52 possible moderator variables among background information, experience, and proficiency in the use of software, individual differences in mind-wandering, attention control, cognitive styles, personality traits, and flow experiences. For each moderator we specified a Linear Mixed Model that included the main effects of Time (first vs second session), of Condition (Digital Media vs Mental Imagery), of the Moderator, and of the Condition by Moderator interaction.

False discovery rate was controlled using the group method suggested by Hu *et al.* (2010). We also computed effect sizes and we report here only moderate or large effectssizes and we report here moderate or large effects.

4. Results

4.1 Main effects of condition

Here (Fig.2) we report the dimensions for which the difference in average scores was statistically significant.

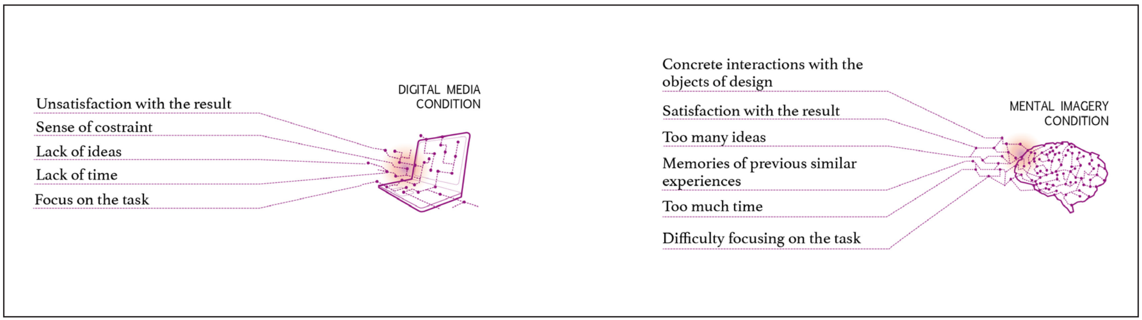

Figure 2 - Dimensions for which the difference in average scores was statistically significant. Image by the author.

4.2 Main effects of moderators

Difficulties in attention switching were found to be positively correlated to feeling confused about the results obtained. Participants with higher levels verbal cognitive style reported thinking more about themselves while narrating the project than about the project itself. Neuroticism was positively correlated with a sense of incompetence and negatively correlated with the referred need to make schematic representations and to refer to models. Those who had a higher score on "being in the flow" reported feeling a weaker sense of incompetence.

4.3 Interaction effects

HHigher perceived competence with Autocad 3D weakened the feeling that time would never pass in the Mental Imagery condition but not in the Digital Media condition, and was associated with higher giving oneself instructions in the Mental Imagery condition.

Higher experience in the use of Autocad 3D was associated with a higher feeling of a lack of ideas and with a higher feeling of difficulty in getting a good understanding of what the assigned elements looked like only in the Digital Media condition.

Students that came from a family of designers reported more mental fatigue and more confusion about the results in the Digital Condition than in the Mental Imagery condition

Higher levels of perceived stress in using a design software were associated a stronger feeling of confusion and a stronger desire to perform the task in another way in the Digital Media condition (FIg.3).

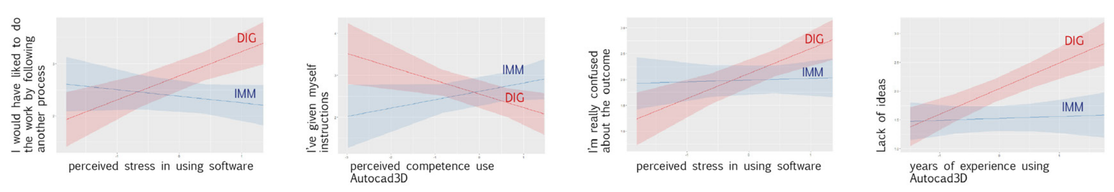

Figure 3 - Interaction effect. Selection of graphs. Image by the author.

5. Conclusions

Which of the many aspects of the design process is most affected by the use of AutoCAD and SketchUp?

In this study, we addressed the issue by analyzing responses to an inventory of cognitive and emotional dimensions administered, post-task, in two sessions to a homogeneous group of participants.

The results showed some significant differences in the effects of the different conditions of carrying out the design task.

It emerged that when the participants were in DIG condition, they felt more constriction about the given construction elements, as if they had considered a reduced range of possibilities for using the elements. This is also confirmed by the increased lack of ideas in DIG mode, which also reflects less satisfaction with the result obtained. From the point of view of spatial cognition, in the DIG mode, it has been reported that there was a greater abstraction of the project area; that is, during the design phase the site was thought more in terms of a plan than in terms of its three-dimensional conformation. The DIG modality has also led participants to a greater concentration on the task, probably mainly focused on the arrangement of the elements in the space abstracted from its real conditions.

If during the activity carried out in DIG condition, the participants were more focused and less open to external content, in IMM mode there was more openness to possible or derived from memories content. In particular, when they could carry out the project using only their imagination, participants expressed that they had many ideas, and mental images of possible sensations in the space they were configuring and of themselves interacting with the project. There has also been a greater re-enactment of lived experiences, evidence that suggests the need to investigate more the correlation between memory and the ability to keep active during the design process fragments of recorded experience . If, therefore, the use of imagination alone has opened the possibility of bringing into the project contents related to multisensorial perception, at the same time it has also recorded a greater difficulty in having the metric aspects under control. Overall, however, at the end of the task carried out in IMM mode, greater satisfaction was reported than the result obtained.

From the study of the two modes of carrying out the project activity emerges, in general, a difference in the modality of cognition of the imagined space: on the one hand, DIG is more unbalanced towards abstraction and limited in the consideration of the possibilities that may arise starting from the design constraints, but more precise in the metric aspects; on the other hand, IMM is more embodied, that is, it includes content arising from the active reenactment of fragments of experience lived in the past -remote or more recent (survey)- or by simulating possible interactions between themselves and the space in the design phase.

Based on these findings, future research could be further focused on the topic of embodiment and how other types of software can interact with this mode of spatial cognition.

Future research developments should also include a different sample of participants, preferably experienced professionals.

From a methodological point of view, design research could move forward by combining some experimental psychology methods with neuroscience methods to find out how brain activity and behavior are related.

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Architecture and Metaverse: Virtual and Augmented Reality technologies for spatial planning

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Abstract

Given the rapid technological advances in recent decades, virtual reality (VR) and augmented reality (AR) technologies have been increasingly adopted to address various challenges in the management and planning of urban environments. Existing VR/AR applications are also described from the perspective of human-computer interaction, however still in the research phase. Virtual reality can be defined as an environment-building technology that allows participants to immerse themselves in their surroundings and interact with their elements.

Augmented reality (AR), on the other hand, focuses on the possibility of visualising the real environment and applying virtual elements superimposed on each other or on real objects. Compared to VR, AR is relatively closer to the real environment because it uses computer-generated information to enhance the physical environment of the real world rather than building a virtual world.

The idea is to exploit the metaverse in a key area that could prove beneficial: urban development. The metaverse in urban development consists of reproducing the city itself, with a minute degree of accuracy, using its digitised version to visualise and facilitate infrastructure and development, test new ideas, technologies and capabilities, and identify improvements for all aspects of urban life.

1. Introduction

Architecture and urban planning play an essential role in social life and a fundamental contribution can be made to this field of specialisation by modern technologies such as augmented reality (AR) and virtual reality (VR).

Augmented reality refers to the combination of virtual objects and the real environment so that users can experience a realistic illusion when using the interactive virtual object to explore the real world.

These technologies can be divided into two basic groups: marker-based systems and markerless systems. Marker-based systems with the use of specific markers for 3D tracking and positioning.

This marker is used to identify the corresponding virtual object to be positioned in the real

environment. Previous research has significantly advanced the application of VR/AR in emergency management in built environments. However, some important limitations have also been highlighted, which should be addressed in future research.

Urban creation can thus be defined as the construction of knowledge and consequent behaviour in the city, derived from the individual-environment relationship. From such synthetic reasoning emerges the importance, for the governance of urban transformations, of being able to construct digital entities to be inserted into the urban environment with which it is possible to interact simultaneously.

The relationship between the construction of human knowledge also through digital entities is one of the most topical themes in the scientific debate. The digital entity, by its construction, satisfies in real time both the endogenous and exogenous characteristics of its urban "graft". In particular referring to: dimension, perspective, three-dimensionality, texture, colour, illumination. The exogenous characteristics concern compatibility with the context of location: shading, noise, dust, atmosphere and movement, human/animal presence, planting. The more these characteristics are convergent and homogeneous the more the hybridisation of space becomes naturally perceived by the observer. It seems useful to propose a classification to allow a better understanding of the hybridisation process.

Thus, the importance of the city information model, also known as the *city digital twin*, as a digital entity usable in the real context through the adoption of augmented and mixed reality, is evident.

City Information Modelling[1] represents the first act in the process of building the hybrid digital space described above. The choice of the information content of the city's digital twin orients and anticipates the enactive process; it is, in fact, the information content that activates, at the moment of interaction between subject and "augmented object", certain sensorimotor schemas rather than others, that triggers one practical action rather than another, that traces a certain perceptive experience rather than another.

Starting from the different information contents and in order to better describe the factualisation of emotional cognition in the new dimension of urban perception, augmented by the digital contribution and hybridised

[1] City Information Modelling: (CIM) takes data collected from a variety of sources and weaves it all together to create a highly interactive 3D model of large-scale urban environments.

by virtual (non-physical) entities, it seems appropriate to propose a taxonomy.

Such a classification stems from the different semantic content of the digital twin and can better describe the different possibilities of the adoption of augmented and mixed reality in urban contexts. In particular, within anthropic systems it is possible to define an augmented reality: participatory prefiguration, virtual recombination, augmented fruition, dynamic figuration.

Virtual recombination involves the use of augmented reality in superimposition on existing objects, urban elements and/or monuments within the built heritage of the urban system. In particular, through this process, a site of high historical-architectural value can be represented in its initial appearance by evoking its initial vestiges.

2. CIM

CIM (City Information Modeling) is an analogue of BIM in urban planning. It is a system of urban elements represented by symbols in 2D space and 3D spaces within. It is also conceived as a 3D expansion of GIS (3DIS or 3D information system) enriched with multilevel and multiscale views, designer toolboxes and inventory of 3D elements with their relationships. The city is an urban system of spaces and channels, activities and communications. Activities are linked by communications and occur and repeat in adapted spaces and channels. Communications are described by origins and destinations, while spaces are defined by location and boundaries.

Other characteristics of space are the type and quality of adaptation and improvement. Adapted spaces and the flow system define the physical form of cities as spaces for people and activities, spaces for vehicles and communication, and shared spaces. CIM emphasises this mosaic definition of urban morphology.

The city is a 3D mosaic of blocks. Blocks are 3D atoms, indivisible spaces in CIM. A block is a 3D object defined by a 2D symbol on different levels (such as ground or 0, underground 1 or -1, elevated 2 or -2), position on the level, boundaries and connections with other blocks. Boundaries are the exits and entrances to other blocks as anchor points of the block as 2D symbol, shape with anchor points as position in 2D space and 3D object with anchor points in 3D space.

Most people have meaningful social contacts only in the city block and with friends around the city. The neighbourhood plays a minor role. Social life is strong within a "social field of view" of up to 100 metres. Urban spaces wider than 200 metres are not considered close, enclosed or even 'urban'. The blocks in CIM are a scale within this "social field of vision".

The city blocks are both 2D symbols and 3D spaces. There are two views of cities, from inside (the perspective) or from above (the plan).

3. Research

In the field of new technologies and urban planning, the metaverse is the potential future of society, particularly in our social interactions and in the areas of gaming, finance and entertainment. Active efforts are also underway to positively exploit the metaverse in a key area that could prove beneficial: urban development. the principle of the metaverse applied to digital urban planning becomes the new tool that offers predictive results; involving the generation of a series of scenarios that correspond to a future event. That is, people - using the internet in its new evolutionary form that is outlined with the 3-D web - form a simulated online immersive social infrastructure (Sim-City[2]), developing a collective intelligence generated in a unique set that can be traced back to a connective intelligence. The metaverse in urban development involves reproducing the city itself, with a meticulous degree of accuracy, using its digitised version to visualise and facilitate infrastructure and development, test new ideas, technologies and capabilities, and identify improvements for all aspects of urban life. By making this technology accessible to citizens and not just the companies and agencies responsible for these changes, each city allows its citizens to see the impact of the changes and feel included in the urban planning process (which usually takes place at municipal and governmental level). Whether it is a metropolis or a city small in terms of population and area, its efforts in using the metaverse and Digital Twin to visualise, plan and facilitate urban planning present an interesting opportunity to exploit emerging digital technologies in a similar way.

Let us look at some examples of countries using the metaverse in various stages to facilitate urban planning processes. Due to the rapid development of virtual and augmented reality technologies, improved performance parameters and increased availability of technologies. Performance parameters and increasing availability of technologies is important to discover new innovative approaches to the use of technologies in different sectors.

Virtual environments, however, have limitations in their effectiveness. The first limitation is that, compared to VR and AR technologies, mixed reality [3] (MR) is less studied in emergency management.

Future researchers can further explore whether MR technology can help emergency management research.

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[2] Sim-City: virtual experimentation on a digital copy of the city and modeling population flows.

[3] Mixed reality : Immersive computer-generated environments in which elements of a physical and virtual environment are combined.

Furthermore, although VR/AR is a promising technique to simulate emergencies in the world real-world emergencies, the behavioural patterns and mental states of the participants cannot yet exactly replicate real-world situations. To solve this problem, researchers can focus on improving the sense of presence in the virtual environment, as a greater sense of presence contributes to a more accurate simulation of people's reactions in real-world scenes. Methods that improve the vividness of the virtual environment, such as a more accurate simulation of earthquake dynamics, better particle effects for real scenes. One possible direction for future research is the application of VR to simulate a community after a disaster such as a flood or fire, where infrastructure recovery and building reconstruction can be studied through the virtual environment. Regarding this research direction, VR is a good deep visualisation to simulate a disaster scene and enable rational reconstruction planning.

Figure 1 - The city by metaverse view.

4. Conclusion

Considering the prospects of population growth for the coming decades and environmental degradation, the problems facing cities are even more complex. The virtual representation of cities is a key step in simulating an environment and thus, in predicting urban management. Given the importance of spatial databases and the need for accurate acidity studies and simulations, the City Information Modeling, should be discussed and explored in order to verify its potential contributions to improving the quality of life in cities. City Information Modeling is the promise of a new paradigm. 3D numerical city models are used to represent different types of urban objects. We have shown that there are several concepts used for CIM, yet there is no conceptual consensus in the literature.

Figure 2 - The city.

Figure 3 - Virtual buildings.

Figure 4 - Urban virtual view.

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Digitazing empathy.
Embodiment techniques for architectural representation in the digital age

Alexandra Mesias

Multistudio

My graduate thesis in 2020 was an investigation into how the body remains present when the strategy of architectural drawings are transferred to the digitized space. Now practicing architecture for two years post graduation, I am confronted with the challenge to execute efficiency - a service our digital tools provide - but where is the empathy in these drawing productions? My questions stands today- can digital drawings be empathetic in the architectural practice?

Now able to learn from what was a thought study into empathy's ability to transcend the two-dimensional stasis of computerized drawings, continues to challenge a traditional architect's routine of production and accuracy. Our learned experience of empathy was a multi modal participation of our own bodies - architecture is a participatory art.

To express the multi-modal nature of architecture, my, then, thesis partner Talisa Hernandez and I created a five-part method to digitally extract atmosphere as an architectural critique of six paintings that demonstrate the behavior of breaking bread - the most basic form of human engagement. By digital, we mean using digital media to a fuller potential by creating videos and animations that add movement and sound to embody the architectural narrative of breaking bread. Artists' observations can teach architects and scientists of the sensitivities to behavioral understanding (Zeki, 1998). Contemporary architectural representation of renderings are often focused on a means of communication.

These representations, then, become like photographs as they function as a means for communicating information through the viewer's central vision. What's missing here is the atmosphere. The flaw in our field is in representation.

The traditional drawings are not wrong, but we seek to critique the medium of how can digits be utilized to its full extent to assert atmosphere. We are not suggesting it will replace drawings but rather point out and add to the conversation of what is missing in architectural representation (Szalapaj, 2005).

Our five-part method to unpack an artist's empathy (embodiment):

PART 1: *Digital Collage* - to read the mood, atmosphere and narrative of the painting.

PART 2: *Architectural Reconstruction* - the architectural reconstruction speculates on the construction of the space within the painting and the space's tectonics.

PART 3: *Animated Short* - an architectural section incorporating movement and sound.

PART 4: *Digitized Hand Model* - the digitized hand models consist of a number of iterations of form configurations that allude to the atmospheric qualities from each painting.

PART 5: *Embodied Drawing* - the Embodied Drawing takes sectional qualities formed in Part 4 and adds our own bodies into the space. The constructed space will be layered with movement and sound.

The discoveries are presented as a model for demonstrating the possibility of architectural techniques applied to computerized drawings. Architects understand the power of imagery, but for architecture to be successful in the modern age, designers must maintain the foundations of the discipline of architecture (empathy and atmosphere) and our addition of a formed narrative when transitioning.

Figure 1 - The six paintings being explored are as follows in order from left to right and top to bottom: Night Revels of Han Xizai, 904 AD, Gu Hongzhong; The Last Supper, 1495-98, Leonardo Da Vinci; Luncheon of the Boating Party, 1880-81, Pierre- Auguste Renoir; The Potato Eaters, 1885, Vincent Van Gogh; Freedom From Want, 1941-43, Norman Rockwell; Nighthawks, 1942, Edward Hopper.

Figures 2,3,4,5 - The figures above demonstrate the animated short of Vincent Van Gogh's *The Potato Eaters*. The process starts with a series of watercolor drawings to capture and construct the atmosphere, narrative, and spatial qualities observed in Part 1 and Part 2. These observations are then translated into a digital image where movement and sound are incorporated to embody the environment in which the activities of the table lie. Movement is used to give the viewer the opportunity to empathize with the activity of the drawing. Sounds are used to express the spatial and material properties of a space. Music is used to set the mood. Use the following link to watch the entire animation: https://vimeo.com/user83927355.

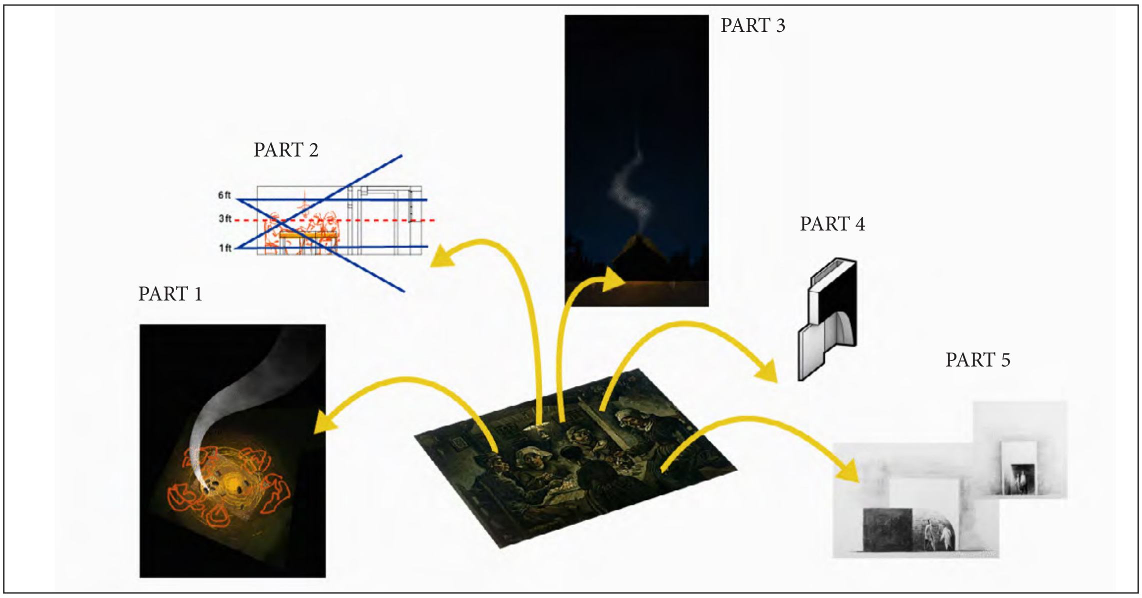

Figure 6 - The figure demonstrates the 5-part technique to digitally extract atmosphere as an architectural critique of six paintings that demonstrate the behavior of a dining table. From a painting's mood, atmosphere, and narrative, artists can teach architects of the sensitivities to behavioral understanding. The five-part technique is to understand how to maintain the transference of corporeal engagement from the forms of visual art to the architectural practice and how to complete this process in the technological environment of the computer (Part 3 is described in Figure 2-5).

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More-Than-Human research using the ChatGPT tool

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1. Introduction

Since the 1980s, design has been based on the approach - or paradigm - Human Centered Design (HCD). This paradigm involves specific methods - focus groups, A/B testing, questionnaires, interviews, and other methods (Tomitsch *et al.*, 2018) - in order to produce products and services designed with an anthropocentric point of view (Norman, 2019a). However, Donald Norman, the father of the discipline himself, questioned whether this approach needs to be broadened with regard to users to be considered during the design phase (Norman, 2022). The goal is to make better products and services, characterized by higher quality in terms of effectiveness, efficiency, and satisfaction, and thus better usability (Gamberini, Chittaro & Paternò, 2012).

Norman is not the only one who has rethought some aspects of HCD; in fact, there are many authors and scholars who, in recent times, are trying to go further, defining a new approach that can move beyond the specifically anthropocentric view, considering species other than our own. The goal of such a new attitude aims to place all species on the planet on an equal level. These theories are based on ideologies for which a balance should exist between humans and the environment, as James Lovelock and Donna Haraway explain (Lovelock, 2020; Haraway, 2020). Such a balance is crucial today to establish and maintain since human beings who live in clean and respectfully treated environments have a better chance of living healthy lives from both mental and physical perspectives (Environment and Health-European Environment Agency, 2023). Moreover, as philosopher Arne Naess' idea, theorized in the concept of Ecosophy, reminds us, it is necessary to understand that the anthropocentric view of nature is wrong. In fact, the human species must pose as part of the whole since human beings are not separate from nature but are connected with it (Naess, 1984).

To understand some aspects of this advancement towards a new approach to design, and thus define a more holistic view in the design field, a study is presented in this contribution that tries to define the methods of such a new approach, with the help of a system equipped with Artificial Intelligence.

2. The More-Than-Human Centered Design Approach

This current of thought has given rise to a new paradigm that to date can be found in the literature under different terminologies such as More-Than-Human Centered Design (MTHCD), More-Than-Human Design, Post-Human Centered Design, Post-Anthropocentric Design, and others. This lack of official definition is due to the fact that a paradigm is based on a specifically defined foundation. In fact, the foundation originates the archetype which, in turn, determines the scientifically recognized executive pattern (Kuhn, 2009). For this reason, it is necessary to consider that even this fledgling discipline of MTHCD needs a phase related to the definition of a theory (Braidotti & Hlavajova, 2018). In addition, it was necessary to understand what topics were, nowadays, most relevant to MTHCD. A literature review study (Vacanti *et al.*, 2022) identified some of the fields that belong to more than human design, that is, considering other elements besides the human subject. There were four fields identified and they were tagged, by the authors of the study, with the following tags:

a) Species and nature: involves design from an ecosystem perspective by considering multiple actors - or agencies - belonging to the same domain and not just creating benefits for humans.
b) City making: involves design for cities with a focus for urban spaces by making sustainable choices.
c) Technology: involves design with the goal of potential human capabilities with the use of smart elements.
d) Social minorities: involves a design that considers more of the diversity of the human species with the goal of having a broader view of humans.

Conducting this study (of which data collection took two weeks) involved analyzing a total of 338 papers, searched over the 2010-2022 time period, within the Scopus, Google Scholar and Academia databases, by entering keywords relevant to More-Than-Human.

This study has certainly helped to define some of the main issues addressed in MTHCD perspective, but what remains to be discovered, since, as already mentioned, research regarding this topic is still at a theoretical state, are the methods by which the paradigm can be applied. In fact, as we have seen, while it is possible for Human Centered Design to conduct interviews and ask people what their needs are, the same cannot be put into practice with species other than our own. Therefore, in order to pursue the goal of maintaining a balance between human beings and all other living things around them, it is necessary to understand the needs of all nonhuman creatures, within a scenario involving human and nonhuman actors.

3. Research of More-Than-Human Centered Design methods using an Artificial Intelligence

In the wake of new digital computing tools, an AI was queried to see what such methods belonging to MTHCD might be, without assuming that the digital AI system could provide an accurate answer. ChatGPT is the tool that was used to carry out the study and try to see if, by treating the chatbot as a research tool, it had been possible to obtain a concrete help output. This Artificial Intelligence responds on the basis of knowledge no later than the year 2021, and works by training algorithms through reinforcement, i.e., machine learning and supervised by humans (Introducing ChatGPT, 2022). Currently, this powerful tool is already widely used in the world of design research, in fact, it is used to conduct user research, give feedback and generate design solutions ('Talent Garden - ChatGPT and UX Design', 2023). But before sending the main question to the system, namely, what are the methods for a MTHCD design, it was necessary to ask some run-in questions to understand how the system worked. In fact, the AI was asked, in English, what its opinion of the Human Centered approach was.

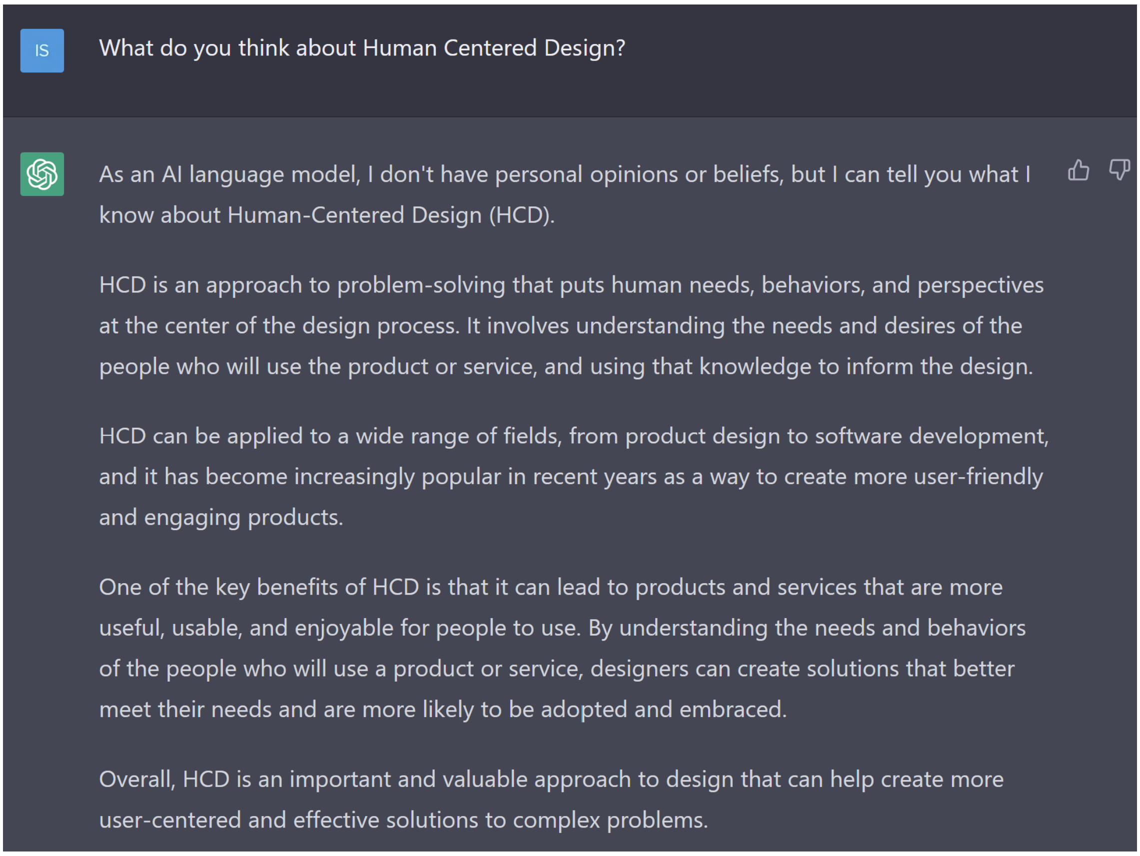


Figure 1

The first observation to be made is that the answer (Fig.1) certainly met the expectations of the Turing test (Turing, 1950), in fact, it seemed for all intents and purposes to be chatting with a human being, except for the first few lines, in which the chatbot explained that it was an artificial writing system. Secondly, it is appreciable that despite the imprecise question, the machine was still able to answer by giving correct information, even explaining HCD principles in a macroscopic way (Norman, 2019b), and defining what such a paradigm is and what it is used for. Then the next question "And what do you know about the new paradigm More Than Human Centered Design" produced another correct and well-articulated answer (Fig.2).

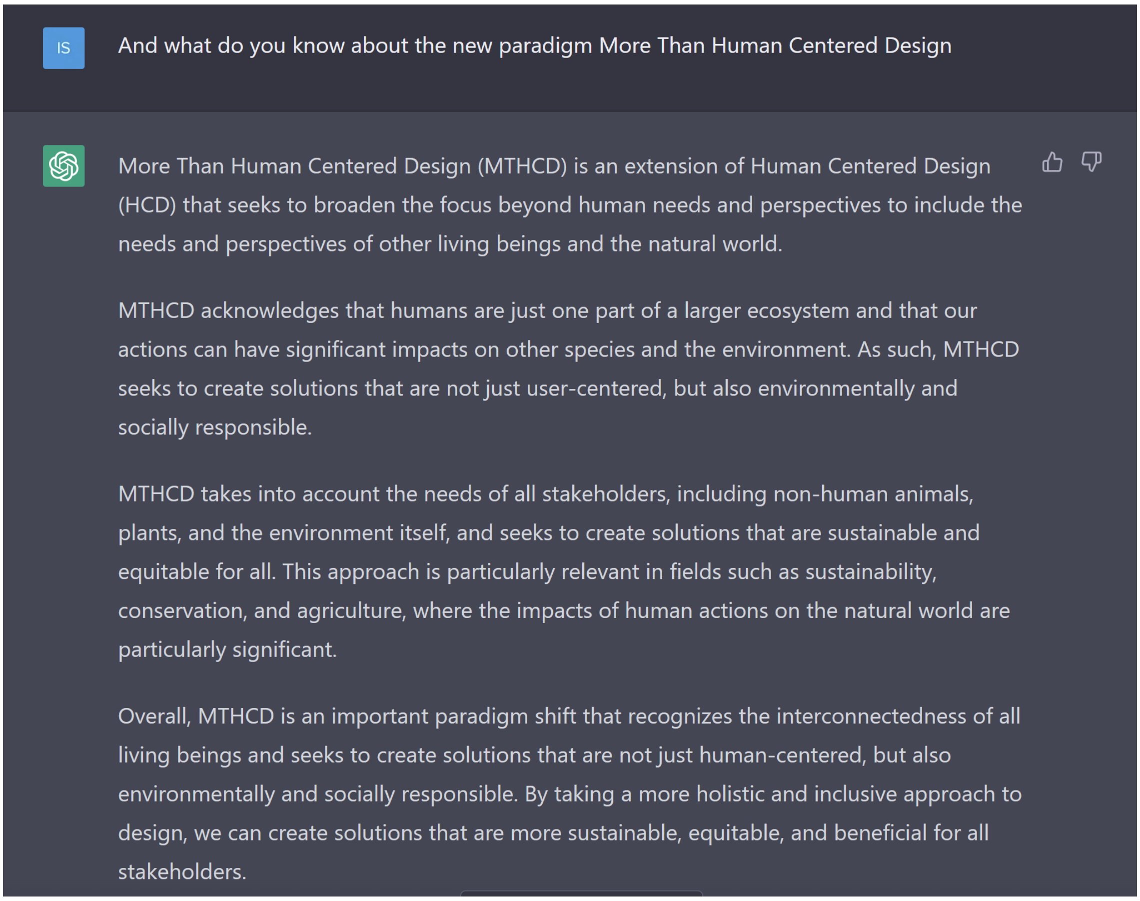
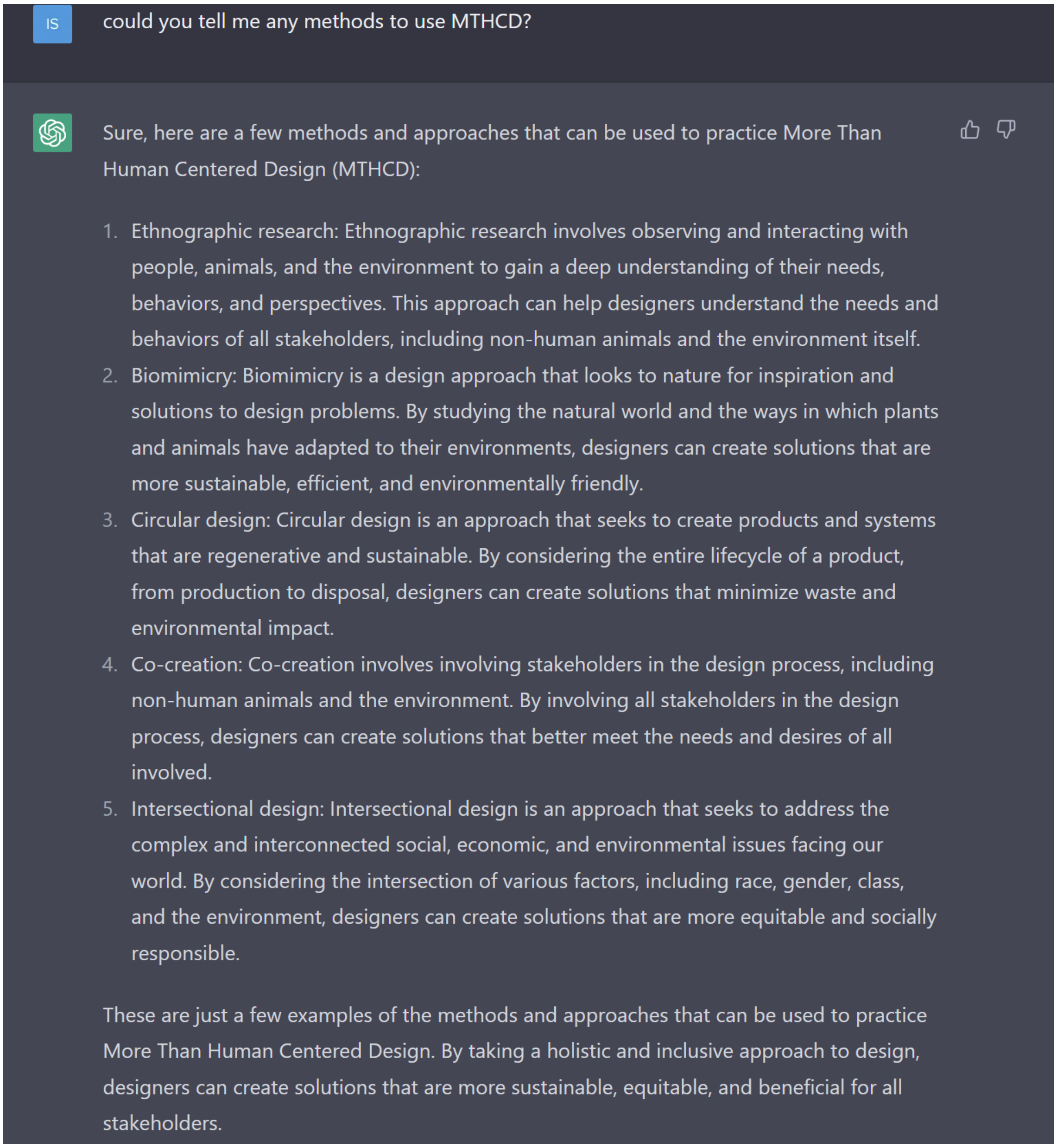


Figure 2

Having carried out these initial tests, in order to become familiar with the tool, it was finally asked, again in English, what are the methods for applying More-Than-Human Centered Design. The answer was very interesting, although not correct (Fig. 3). The output did not describe methods by which data can be collected for understanding the needs of other species, but, in some cases, more or less specifically defined what were identified as themes within the literature review mentioned earlier. Item 5 in Figure 3, for example, fits perfectly with the theme regarding Social Minorities. Moreover, the issued list defines additional items that the chatbot also calls "approaches" and consequently cannot be defined as methods. Although item 1 and item 2, also from Figure 3, could be considered as methodologies that are based on empathy and observation of living elements, complete information on how to carry out such processes on a practical level is still not provided.



IS could you tell me any methods to use MTHCD?

Sure, here are a few methods and approaches that can be used to practice More Than Human Centered Design (MTHCD):

1. Ethnographic research: Ethnographic research involves observing and interacting with people, animals, and the environment to gain a deep understanding of their needs, behaviors, and perspectives. This approach can help designers understand the needs and behaviors of all stakeholders, including non-human animals and the environment itself.
2. Biomimicry: Biomimicry is a design approach that looks to nature for inspiration and solutions to design problems. By studying the natural world and the ways in which plants and animals have adapted to their environments, designers can create solutions that are more sustainable, efficient, and environmentally friendly.
3. Circular design: Circular design is an approach that seeks to create products and systems that are regenerative and sustainable. By considering the entire lifecycle of a product, from production to disposal, designers can create solutions that minimize waste and environmental impact.
4. Co-creation: Co-creation involves involving stakeholders in the design process, including non-human animals and the environment. By involving all stakeholders in the design process, designers can create solutions that better meet the needs and desires of all involved.
5. Intersectional design: Intersectional design is an approach that seeks to address the complex and interconnected social, economic, and environmental issues facing our world. By considering the intersection of various factors, including race, gender, class, and the environment, designers can create solutions that are more equitable and socially responsible.

These are just a few examples of the methods and approaches that can be used to practice More Than Human Centered Design. By taking a holistic and inclusive approach to design, designers can create solutions that are more sustainable, equitable, and beneficial for all stakeholders.

Figure 3

Although output was generated, the latter was not satisfactory because it did not perfectly answer what was asked. Therefore, it was experimented with by requesting the same thing, but in Italian "can you tell me the methods for using MTHCD?" (*puoi dirmi i metodi per usare il MTHCD?*) to the AI. Again the response was vague, in fact, there are no methods, but it is nevertheless interesting that the response, issued in Italian, did not produce a simple translation from English, but rather a series of key points like the first answer, with more or less different content (Fig. 4). In fact, again, we could argue that the points listed are principles, rather than methods, on which the MTHCD is based. Continuing the interaction in Italian, it was asked if the AI had been able to provide other methods, generating a new response with a new list (Fig. 5).

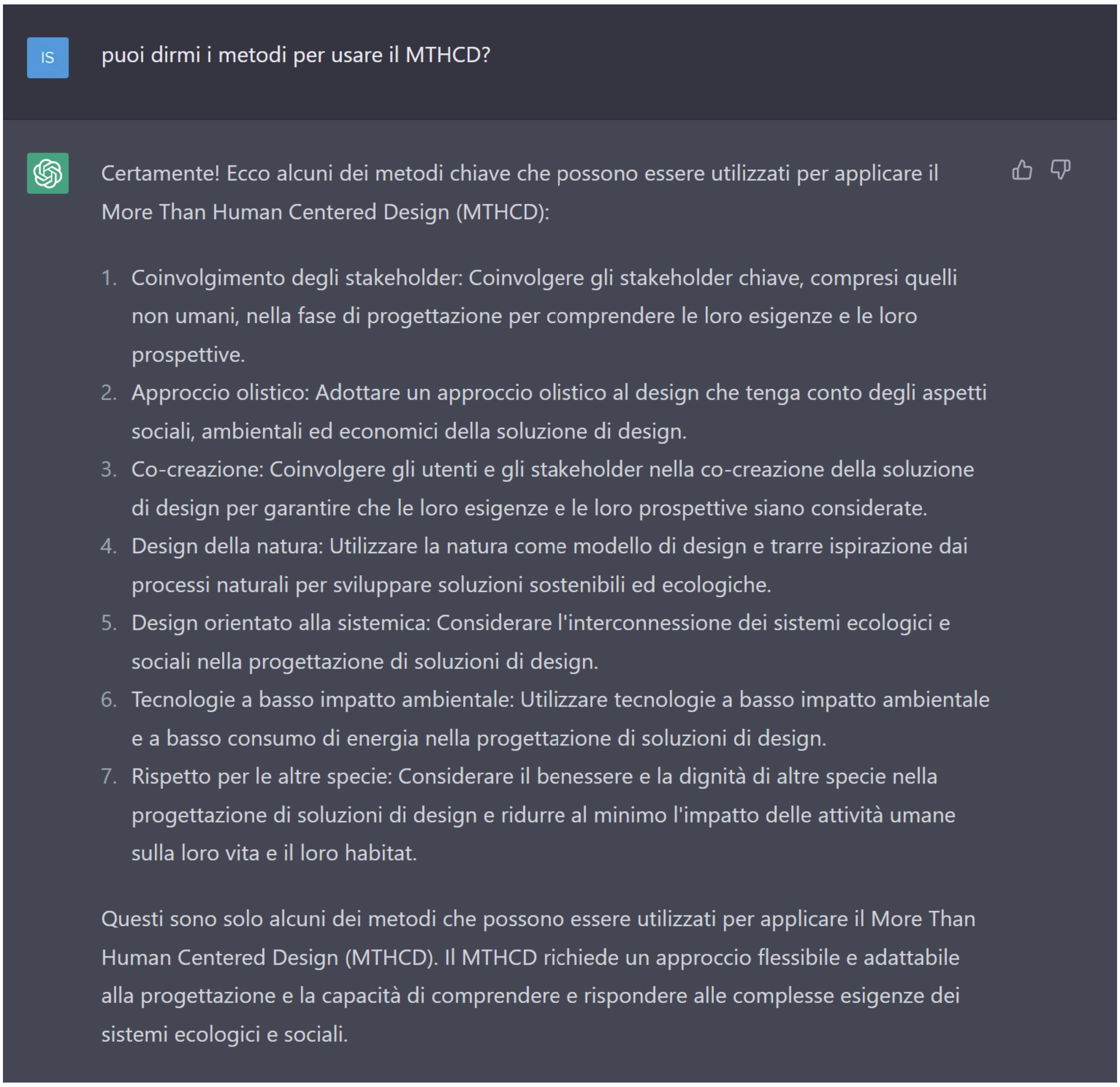


Figure 4

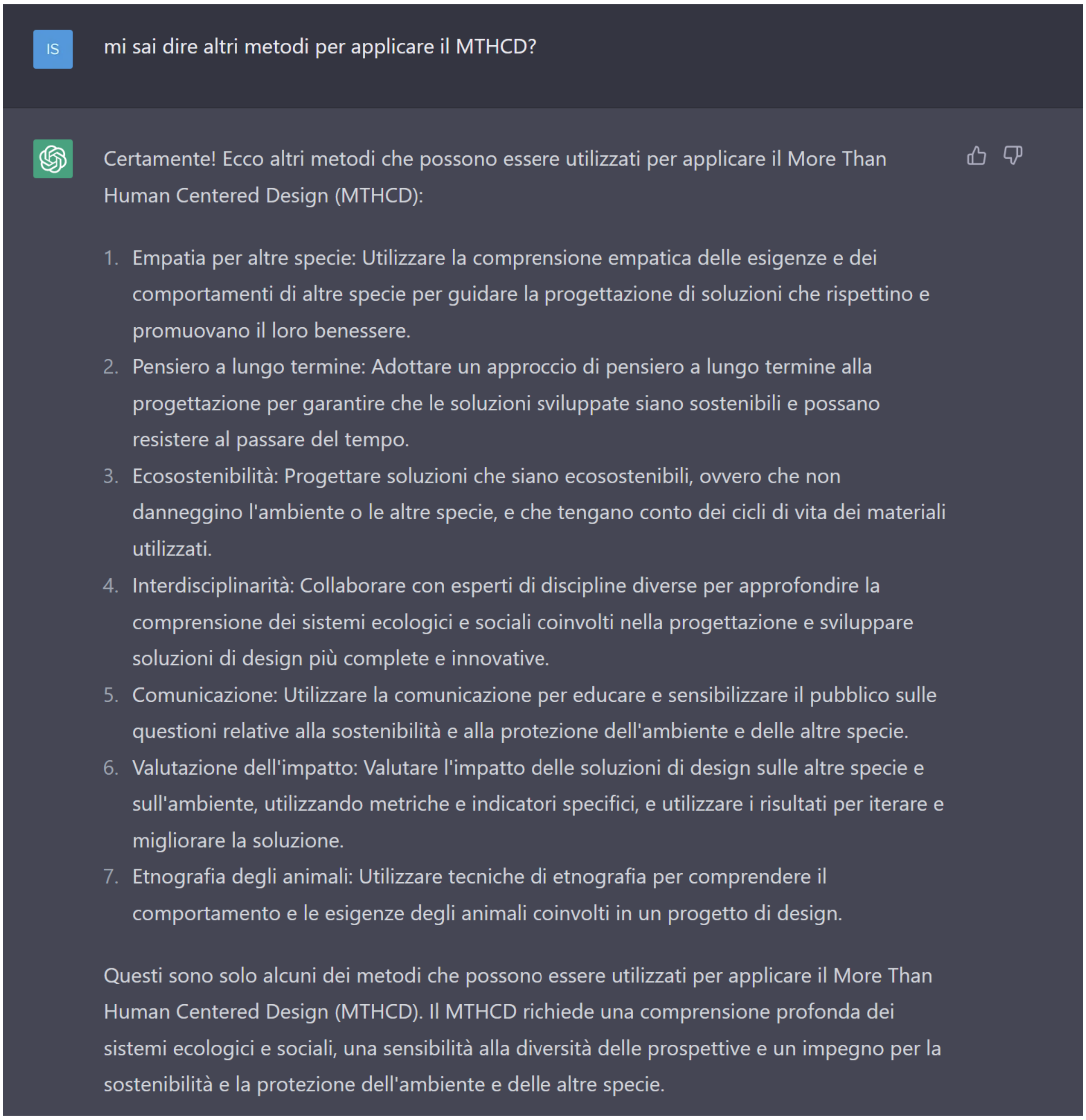


Figure 5

The result, this time, appeared even less specific, as if the system was running out of answers because the requesting user was not satisfied with the previous ones. This case study, supported by ChatGPT, continued with a question that could bring all these "methods" together. So the final and concluding question was, in Italian, "Can you tell me all the MTHCD methods that you know of?" (*Puoi dirmi tutti i metodi MTHCD che conosci?*). The list provided in response (Fig. 6) generated as many as 25 points, this time without explanation of each one as in previous responses, but defining a complete list of what the chatbot knows. To be sure that this answer was complete with all the "methods" known to the chatbot, the same question was asked again in Italian, producing the exact same result as in Figure 6. A further test was made, asking the machine if it knew any other methods besides the 25 on the list, and the answer (Fig. 7) made it clear that knowledge on the subject was exhausted.

The fact remains that the output did not generate methods, but concepts that could define the basis for such methods of application of the paradigm under consideration.

IS

Puoi dirmi tutti i metodi MTHCD che conosci?

Certo, ecco una lista completa dei metodi More Than Human Centered Design (MTHCD) che conosco:

1. Coinvolgimento degli stakeholder
2. Approccio olistico
3. Co-creazione
4. Design della natura
5. Design orientato alla sistemica
6. Tecnologie a basso impatto ambientale
7. Rispetto per le altre specie
8. Empatia per altre specie
9. Pensiero a lungo termine
10. Ecosostenibilità
11. Interdisciplinarità
12. Comunicazione
13. Valutazione dell'impatto
14. Etnografia degli animali
15. Partecipazione delle comunità indigene
16. Partecipazione delle comunità locali
17. Apprendimento automatico basato sulle emozioni degli animali
18. Bio-mimetismo
19. Biomimicry Thinking
20. Analisi del ciclo di vita
21. Sensibilità culturale
22. Intelligenza collettiva
23. Architettura biofilica
24. Design per la resilienza
25. Design per la coesistenza

Ognuno di questi metodi è finalizzato a promuovere il benessere degli esseri umani e delle altre specie, attraverso la progettazione di soluzioni sostenibili e rispettose dell'ambiente. Il More Than Human Centered Design richiede una prospettiva inclusiva, che tenga conto delle diverse prospettive e dei diversi punti di vista delle parti interessate, comprese quelle non umane.

Figure 6

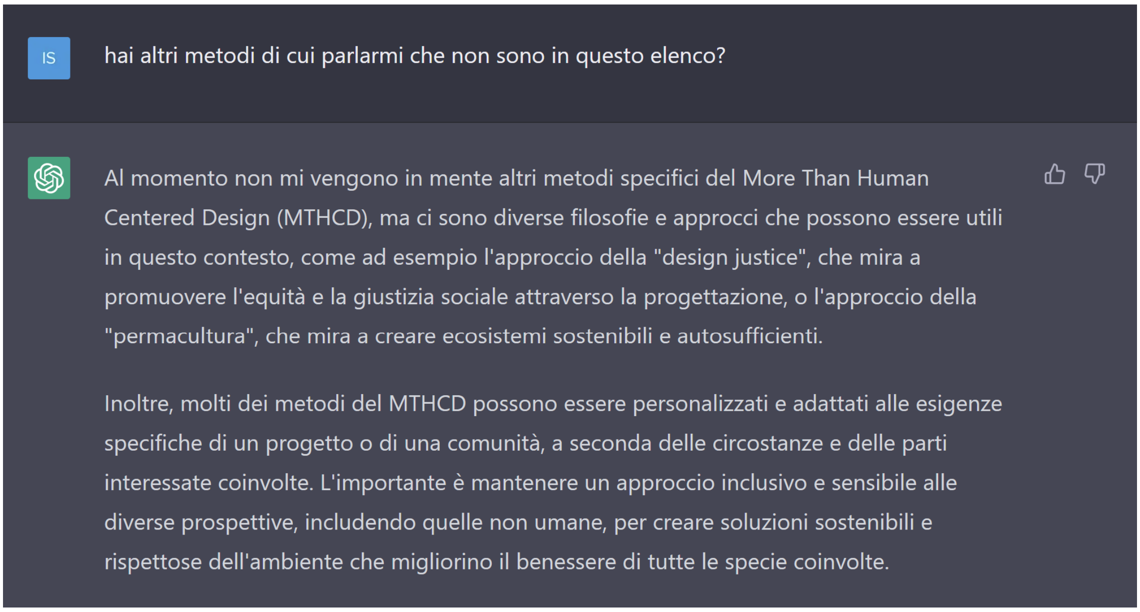


Figure 7

4. Conclusions

Following such a "chat" with the AI, it would be interesting to understand how many times it is necessary to ask the same question to the system, in order to get an identical answer at least once, with the aim of also understanding the limitations of the bot as a search support tool.

Also, following the next ChatGPT update regarding the corpus of data on which it is based, it will prove important to understand whether asking the same questions, will generate the same answers asked during the month of March 2023. This comparison will help in understanding the difference between what the system defines as the MTHCD "method" today and what will be defined as such at the next release. This information will help and support the scientific community that wants to keep abreast of this vast and unexplored topic. In addition, it is remarkable how similar results to those produced by a multi-day literature review were generated in a few hours, seeking, however, different answers. In fact, the purpose of the literature review was to catalog those scientific contributions that were available online, creating numerical values in order to quantify and get an idea of the most widely discussed topics in More-Than-Human Centered Design.

In the case of using the ChatGPT tool, instead, the goal was to identify the methods with which to apply the paradigm. An additional important result is surely the fact that the AI tool used can be supportive in understanding the as-yet-unknown methods, but not in knowing them specifically, as it should be. The dialogue established between a living human being and a non-living machine, but one that is able to respond because of the body of scientific information it relies on, is of considerable interest in stimulating the research of the scholar who decides to use the AI system to pursue research in science. Thus, it emerges that the ChatGPT chatbot cannot replace the research carried out by a human being, but can, however, be considered as a very useful supporting technological tool.

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The role of virtual reality in the predisposition to design foreshadowing: a testing proposal

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Asbtract

Visual design thinking defines a semantic of shapes, thoughts and mental images that helps designers envision complex problems. Innovative learner-centred methods and new technologies could lessen the steep learning curve for novice designers. Virtual Reality (VR) and immersive technologies could aid and motivate the definition of a cognitive framework, supported by interactive learning material. A testing proposal is advanced to investigate the possible usage of VR tools with adequate software to help new designers develop their mental foreshadowing skills. Students from the Bachelor course in Architecture will follow a three-step experiment. In the first phase, students are asked about their knowledge in VR tools and visual design theory. In the second phase, students will be divided in two group and will be asked to address a complex, ambiguous, design prompt with a fixed set of items at disposal. They will be alternating from a traditional approach to an immersive one. Finally, the learning aptitude, cognitive accessibility and validity will be verified with a questionnaire. The results will be based on a blind peer-review, where the students will evaluate each other's designs. The study aims to evaluate the differences between the traditional and immersive approach, looking for corresponding trends from the candidate backgrounds to define how could VR tools be of use in this regard and what type of student could benefit the most from them.

1. Introduction

Visual thinking is ubiquitous in all human activities, carried on by images that simplifies by subsequent representations what is seen and what is imagined (McKim, 1980). The creative process of a technological designer's mind follows a similar ubiquitous imaginative routine, by interposing designing questions to better understand and envision what is being conceived (Ferguson, 1978).

The educational relevance of such approaches is transposed into questioning and understanding how designers act, and secondly how could these skills be taught or improved. Education is, generally, the transmission of knowledge about a phenomenon, but can be recognised as a training in the appropriate methods of inquiry. Cross (1982) expresses the needs to develop students' aptitudes in a "language of modelling", equivalent to the "language" of science (numeracy) and the "language" of humanities (literacy). The systematic exchanges between conceptual and figural arguments represent the rationality of the procedural activity of designing. As a linguistic paradigm, visual design thinking serves as a mean to describe and solve problems. As a tool, it can be learned and optimized (Goldschmidt 1994). Experience in the usage of this paradigm explain the significant differences in mental visualization capacity between novice designers and expert designers. Early-stage experiments proposed non-hierarchical mapping techniques to guide inexperience designers into exploring and adopting advanced frameworks (Kokotovich 2008; Gonçalves *et al.,* 2014).

Traditional teacher-centred methods could profit from a shift of focus on the active role of students in processing new knowledge by being themselves the constructor of knowledge. Learner-centred methods as pedagogical methodologies are successful for addressing problem solving, specifically for architectural design (Yildirim *et al.*, 2012). Recent development in information technology brings opportunities for the development of new methodologies and tools for architectural education. Emerging technologies and immersive tools have deeply influenced the education sector and brough forth innovative educative methods, including in construction education (*Wang et al.*, 2018). In particular, virtual environments open to the opportunity to aid visualization and authoring of design in novice architects (*Sampaio et al.*, 2010).

The role of active learner is further incentivised by virtual worlds, as a derivative of social constructivist learning theory (Vygotsky, 1978). The development of a cognitive framework is reinforced and motivated by the engagement of virtual environments. Moreover, the ability to actively modify the learning material and enhance the content of the immersive scene strengthen the learning process (Jones, 2011). In this learned-centred paradigm, the role of educators should shift to one of instructional designers, actively supporting the learning process of students (Zhao e*t al.*, 2010).

Virtual reality (VR) and interactive simulation tools were first introduced in the 1920s, with the first mechanical flight simulator. Between innovation in computation capacity and immersiveness, in the 1980s the first head-based displays were designed to be available for commercial use. Recently, numerous scholars approached VR tools for its didactic possibilities.

VR models could show the physical development of constructions and its component as an interactive walkthrough (Abdelhameed, 2013; Sampaio

& Martins, 2014; Bashabsheh, 2019). As a creative and interactive process, VR enables object creation (Allison *et al.*, 2012; Dalgarno & Lee, 2010) and manipulation (Bredl *et al.*, 2012; Dalgarno & Lee, 2010).

From this new perspective, an experimentative testing proposal is formed to inquire for possible direct correlations between the development of solid, conscious design foreshadowing skills and VR technologies.

Can virtual environments helps soften the steep learning curve of visual design for novice designers? Mainly, this research aims to evaluate the ability of architecture students to synthetize complex design questions via visual design thinking, by comparing a traditional approach with the use of VR technology.

2. Materials and methods

The experiment will focus on two research methods, for better representing the comparative nature of the experience: observations and surveys (Cohen *et al.*, 2011). Observation of the students' actions and behaviours will be recorded and scrutinized, while surveys will be used to record preferences and results. The use of qualitative and quantitative methods gives a more thorough view of the experience and helps the conclusive discussion.

The concept for the experience is developed for the students of the Bachelor course in Architecture, taken from different classes as to include a more heterogenic pool of candidates. Students will be given a brief a priori questionnaire to investigate the starting familiarity with VR and visual design theory.

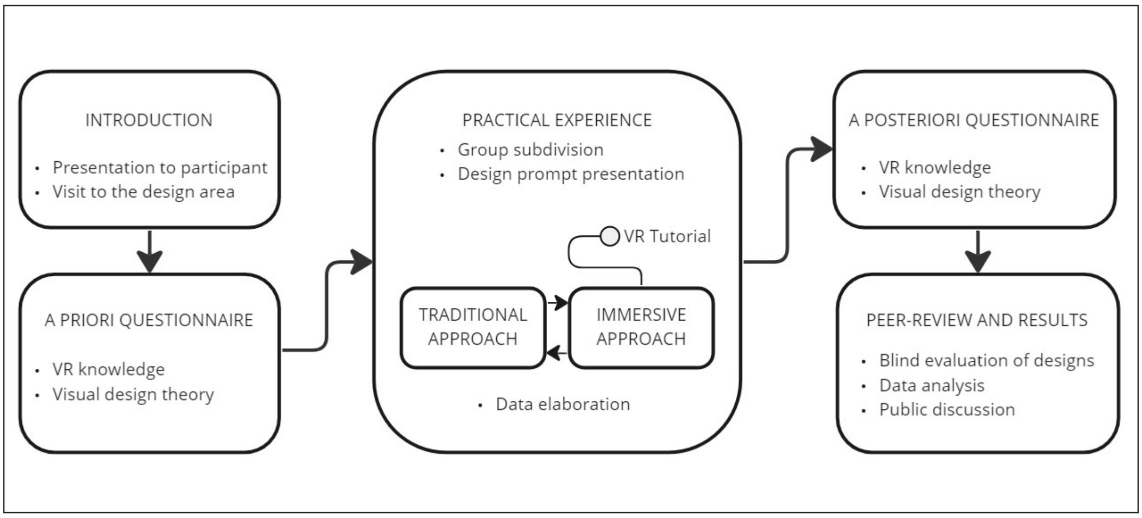

Figure 1 - Experiment flowchart. Diagram by the authors.

The practical experience will then take place, proposing a simple, yet quantitative undefined and imaginative misleading, design prompt. A final a posteriori questionnaire will be used for peer-reviewing the design results (Fig.1).

The experience will start with a visit to Piazza Sarzano, giving the students the possibility to make acquaintance to the area.

3. *A priori* questionnaire

The students will receive a short questionnaire via *Google form*, focused on establishing the background for each participant. The questionnaire will be divided in three sections, each developed for a specific evaluation: stating the designer's generalities, the starting closeness with immersive technologies and acquaintance with mental images and visual design (Table 1). Each question will ask for a qualitative response, following the Likert scale (decisively not – decisively yes), and the results will form the initial dataset profiling each participant. For instance, the question "Do you think it's more tiresome playing a driving simulator with a steering wheel peripheric" underline the possibility of imagining a different peripheric as a liability.

Generalities	• Name, Surname • Age • Gender • Education level
Immersive technologies	• Are you interested when new computers and smartphone are presented? • Do you like videogames? • Do you think it's more tiresome playing a driving simulator with a steering wheel peripheric? • Are you having difficulty replicating something you saw or imagined with the software you know? • Have you ever used immersive reality apps not for gaming purposes? • Do you think immersive systems are overrated? • Do you think immersive reality would have helped envisioning a particular in a part design?
Visual design thinking	• Do you think your design methodology is similar to others'? • Independently to the results, do you like your design approach? • Do you find yourself often scrapping a design because you forgot a crucial detail? • Do you find yourself skipping sketching parts of design because you have them firmly grasped in your mind? • When you explain your design, do you prefer having a visual support? • Do you think realistic renders are one of the most useful representations for correctly understanding a project?

Table 1 - Examples of questions regarding familiarity with immersive technologies and visual design theory.

4. Design prompt

The students will be asked to design a small expositive space with a fixed set of elements in Piazza Sarzano, a public open area near the Department of Architecture. The items serve as a common modelling language, and they are the same for each student. In the narrative of the experience, a local administrator will ask each and every novice designer to creatively organise the open area with a few plants and statues that were gifted to the city. They will be given a short portfolio of each item with measures and photos (Fig. 2, Table 2). In the final notes, the key design prompt will be expressed as a informal requests from the administrator: "*Make sure to make it look Ligurian enough*".

The novice designers will have to satisfy the strictly qualitative and subjective request by envisioning what does it mean to "making it look Ligurian enough".

The items are chosen for their misleading volumetry and spatial encumbrance, while providing lots of possible interactions. The area was selected for its irregular shape and lack of primary points of view, as to better provide different means of interpretation.

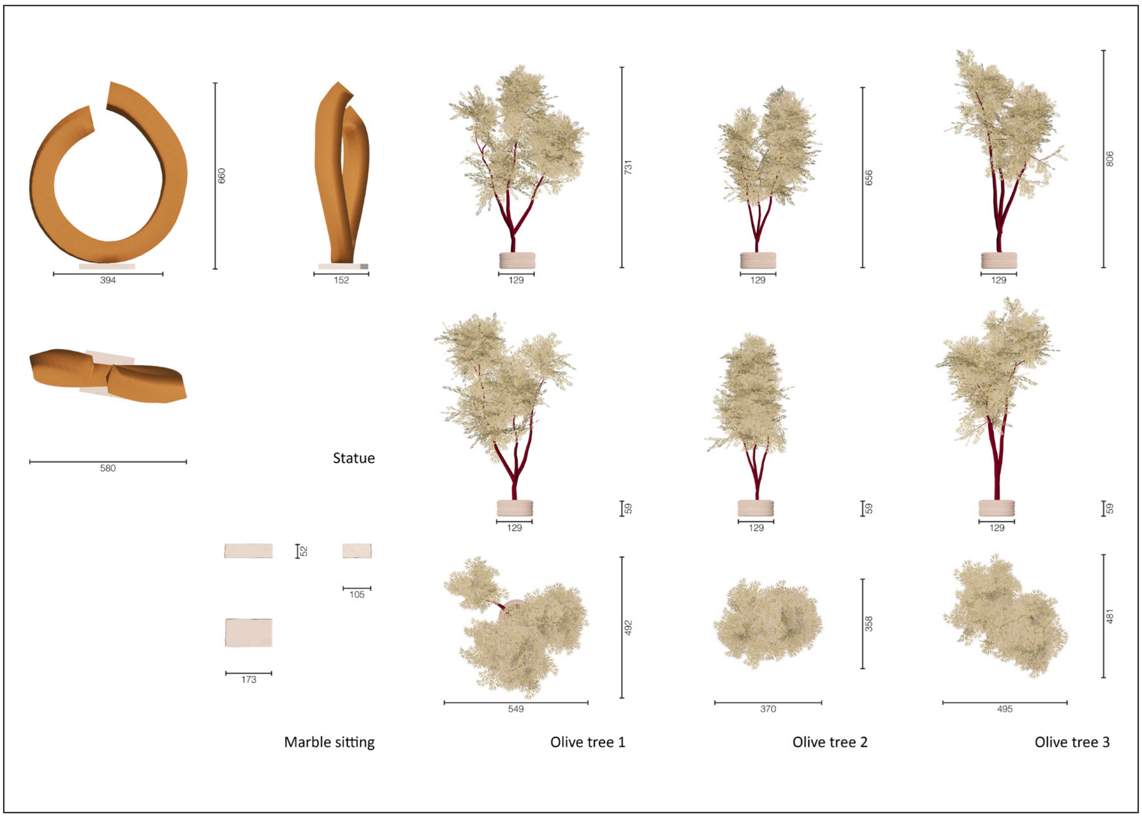

Figure 2 - Representation of the itemset, taken from the design brief for the participants Image by the authors.

Item	Size	Reason for inclusion
Broken Circle, Beverly Pepper, 2012	580x660x152 cm	Open, non-coplanar standing circle reminds of a simple shape.
Celebrative marble sitting	173x52x105 cm	Memorial piece with inscriptions, can be used as a seat.
Olive tree 1, (in concrete vase)	549x731x492 cm	Medium-high, entangled trees with sporadic foliage and complex sun coverage.
Olive tree 2, (in concrete vase)	370x656x358 cm	
Olive tree 3, (in concrete vase)	495x806x481 cm	
Concrete vase	129x129x59 cm	Cylindrical, short vase offers a mental anchor point for each tree.

Table 2 - Item list, with specific dimensions, reason for inclusion, notes.

5. Practical experience

The practical experience consists of two design approaches for each participant. The participants will be divided in two groups and will alternate between the design approaches, as to not create bias by following the same order.

The traditional design approach asks the participant to design from the items set solely from their mind. Each student will be given a short period of time (10 minutes maximum), after which they will be asked to draft their design. As to limit the personality of drawing and simplify the modelling language, a magnetic board representing the top view of the project area will be available for use. Each item will be presented as a magnet. After the experience, the tablet will be photographed and catalogued, then the magnets will be removed.

The VR design approach will begin with a short VR training for all the participants in the group. A short presentation will show the usage of the software.

The model was developed in *Blender* with the *Marui Blender VR Plugin*, making it possible to freely move and create shapes using a VR headset (Fig. 3). The model was obtained via photogrammetry using the *Meshroom* software and a CANON PowerShot SX410 IS, after which the design itemset and several urban assets were modelled in Blender. The Oculus Rift S was used as the virtual asset, supported by a PC Desktop.

Each student will have up to three minutes to familiarize with the VR headset and the commands. Afterward, they will have a short period of time (10 minutes) to move the items and project the scene. At the end, the scene will be saved and recorded, then resetted for the next participant.

Figure 3 - Testing representation of the virtual environment, during a simulation of the interaction with the custom itemset. 3D model and simulation realized by the authors.

6. *A posteriori* questionnaire

Shortly after the experience each participant will receive a second Google form questionnaire, to evaluate the learning aptitude and cognitive validity of the experiment (Table 3). The questions will be answered on a Likert scale, similarly to the first questionnaire, and the answers' validity will be verified with the Cronbach alpha coefficient. The results will be recorded and will serve as a comparison meter with the peer-review.

7. Peer-review

The students will then have to blindly peer-review the designs as to evaluate which better follows the design prompt. The different designs will be reconstructed on the virtual model and a set of drawings from the same perspective will be drafted for each design. A set of eight designs will be blindly assigned to each student for a blind peer-review, where a set of three questions will be asked under a Likert scale:

- How realistically constructable is it?
- How much do you like it?
- How much does it "look Ligurian enough"?

Learning aptitude	• I find gratifying learning new problem-solving approaches. • I think learning to design is gratifying. • I think refining the foreshadowing capacity is significative. • I will document myself on visual design thinking in the future. • When I find difficulties foreshadowing an idea, I actively seek feedback with teachers, colleagues, books, or internet instead of trying deeply to envision it. • I think learning to visualizing ideas is important, even for non-designers.
Cognitive accessibility	• Using a VR software is easy. • I found it easy to follow the tutorial. • The commands and instructions were easy and clear. • I could learned a similar software in a short time.
Cognitive validity	• I think receiving instruction during an immersive experience can make me think more clearly and deeply. • I find an approach similar to videogames useful to control the shape of my design. • This VR software is more effective to any other software I used. • Using this VR software I could study more carefully aspects I didn't considered before. • This VR software enable me to a great space of experimentation, helping me in problem solving.
General satisfaction	• VR education tools are interesting. • This game-like tool can help me discover new problems and queries. • Using VR softwares, architectonical concepts like "encumbrance", "structure", "assembly" are perceived in a different way. • Using VR softwares, qualitative aspects like "quietfulness", "constraintness", "stressfulness" are perceived in a different way. • I would like if other disciplines would adopt VR education tools. • This VR software is pleasent and enjoyable.

Table 3 - Example of closing questions regarding the learning aptitude and cognitive accessibility and validity.

The first question aim to evaluate the student attitude to envision weight and encumbrances, and foreshadow the practical need for realizing a design. The second question gives a strictly qualitative, subjective and sensible grade of enjoyment, that encompass several aspects of designing an open space. The third question gives the opportunity to evaluate how a different consciousness and viewpoint could interpret an ambiguous request, taking into consideration a not so common notion of "looking Ligurian".

The experience will end with the publication of the result and a group discussion, focusing on the trends between the closing data from the different design approaches and the two questionnaires.

8. Conclusion

The experiment aims to evaluate if virtual environments and interactive immersive tools can help with visual design thinking development. Using two design approaches that share the same modelling language of a fixed set of items, a more traditional one and an immersive one, this testing proposal tries to define if and when a VR tool could be utilized during the design process.

With the acquisition of two sets of answers and the blind peer-review, several connections could be formed. While several trends could be hypothesised (familiarity with virtual environments and easiness of learning new tools), some emerging patterns could be of interest.

For example, identifying a particular set of students that find it difficult to mentally envision complex spaces while being enabled by a VR tool, could bring new insights on educational methods. On the other hand, some students could find a new tool a nuisance and a hindrance in envisioning a particular design, being it for the software design or tool’s accessibility. A limitation of this experience is the lack of a common mean of evaluation of design foreshadowing and visual design thinking.

Bresciani (2019) proposed to evaluate the visual thinking skills of an individual basing on the Cognitive Dimensions of Notation framework (Blackwell *et al.*, 2001), adopting seven categories as a practical way to discern the type and method of foreshadowing. A similar approach could be of a didactical relevance, to better understand the needs of a particular student during the design development and revisioning phases.

A second set of limitations could be the difficulty of usage of the particular VR tool, from a software design perspective. A similar software could be developed from a different 3D environment library, such as *Unity* or *Twinmotion*, that hosts native VR integration.

This experiment could be transposed from VR to a mobile augmented reality (AR) app, leveraging on the easy accessibility to smartphones and similar apps. Similarly, an analogue experiment could be formulated on a different scenario with a similar qualitative ambiguous design prompt.

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Purification Rituals and AI Technologies as key in the performative policy around the human body *7 Configurations* by Marco Donnarumma

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As Bruce Sterling writes in the abstract of his opening lecture at IF! Italians Festival 2016[1]in Milan at Franco Parenti Theater[2]:

> You might think that the moment you decide to deal with technological art, anyone in the art world, as well as in technology, will love you. This because since you know these two worlds often in contrast, you automatically turn into a peacemaker. All will be your friends. But anyone who has experience in these areas knows very well that it is not true. The opposite is true. Art and technology are worlds that both look at you with suspicion, convinced that somehow you are there to harm their cultural credibility. As a result, you are not able to receive institutional support either from the world of art or from that of science, and even the public sphere, which is generally attracted to technological art, cannot help you much because there is no commercial sector in which to sell your work to potential collectors (Mancuso 2018:31).

The horizon proposed by Sterling certainly seems synchronic to the wide debate that prevails today around the numerous themes tangent to the link between performing arts, technologies, and AI. It is well known that for about forty years the performative scene has taken on a new dramatic structure, welcoming within the codes of stage writing – already widely debated since the middle of the last century – the expressive

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[1] The IF! Italians Festival program at *IF! Italians Festival*, web page (online) https://2016.italiansfestival.it/programma/index.html (visited on March 12, 2023).

[2] The full intervention by Bruce Sterling, in B. Sterling, *Italy must lead in technology art con Bruce Sterling - IF! Italians Festival 2016* (online) https://www.youtube.com/watch?v=PrY95o5pjTs (visited on March 12, 2023).

potential offered by new technological tools. Many questions proposed by the reflections of artists and scholars on the functionality of the combination of scenic art/ technology that are reflected in a tangible strand of thought that in recent years is providing to characterize the margins of this complex relationship. As Monteverdi claims «the pioneers of this "new theatre" have taught us that the union with technology works as long as it is art to guide and not vice versa, and have shown us, in practice and theories, how the strength of the scene intertwined with the media resides in the project, in writing and ideas, even before in technique» (Monteverdi 2020:9).

The speech is mutually creditable in the more specific field of New Media Art and Performance Art within which converge artists from diverse educational types promoting the development of new languages expressive and representative that provide the hybridization of the code "body" with the new tangible physicality produced by robotics and AI. Within the specific human/machine relationship in the performative context, there is the consistent work of the artist, sound designer and performer Marco Donnarumma. In constant research on the limits of the body bordering on technological hybridization, between 2014 and 2019 Donnarumma started a representative cycle of performances and installations entitled *7 Configuration*s.

It is a performative cycle that focuses essentially on the possibility of the coexistence and its possible implications, the human body with the technological aspect. The "episodes" are consequential insofar as the research expands in the hybridization of the human body with the machine starting from a direct and consequential relationship and ending up in a total absence of the body itself. The research moves on dynamics that investigate movement, sound, and technologies by hybridizing "human bodies, robotic hardware, machine learning software and microorganisms into a particular 'configuration'"[3].

Of particular interest is the close correlation between two specific events of the cycle, the performance *Corpus Nil* in 2016 and the installation *Amygdala* in 2018. In fact, the connotation of the stage writing is totally different but the approach to the use of AI technologies implies for both a link attributable to an express ritual nature that supports the hypothesis of a philosophical approach located upstream of the idea, which develops subsequently tangentially both the performative and algorithmic expression.

[1] Marco Donnarumma *7 Configuration*, website (online) https://marcodonnarumma.com/series/7-configurations/ (visited on March 12, 2023).

1. *Corpus Nil* (2016)

The performance involves the use of artificial intelligence applied to the human body; biophysical sensors are attached to the body of the performer and are able to capture the vibrations produced by the dynamics of movement thanks to the tension and release of muscles, converting them into sound and light thanks to a sophisticated set of algorithms. The peculiarity of this apparatus is that the biological signals of the body influence the choices of the machine without being able to control them. On the other hand, the muscular tensions inherent in the physical narration of the performer are influenced by the sound and visual impact produced by the machine. In this sense, body and machine influence each other, producing a totalizing hybridization to the extent of its own uncontrollability. The question of mutual influence and loss of control gives rise to a singular example of "new birth", a sort of ritual that provides for the relocation of the human instance through the creation of a new body and a new identity. As the artist himself points out in an interview with Vanessa Graf for Ars Electronica:

> The lack of control, the absence of a body which can be defined human, and the loss of conscious awareness are the elements that define the performance. This, of course, can make it difficult for the spectators to rationalize what they hear, see and experience during the performance. And if there’s an aim in this artwork – and more generally in my whole body of works – it is exactly that: to create a performative experience that cannot be immediately rationalized, but instead hits you fast and hard so that it remains vivid in your memories. It is afterwards that a rational interpretation emerges, and with that, thoughts and ideas.
> That’s what I strive to achieve with each performance of *Corpus Nil*; an experience akin to a ritual of birth, an ecstatic celebration of the unknown and the unfamiliar. I want to tear open the stereotypes and prejudices we all have towards different bodies and identities. And I want to show the potential of AI to do that […] In *Corpus Nil*, I wanted to profane the assumption of the body as a pure, whole entity and create a tangible experience of hybridity. A hybrid is an offspring of two different species. In *Corpus Nil* my body and the algorithm create a hybrid human-machine. The algorithmic system can disrupt the functions of my body at different levels - physical, cognitive and experiential. This is not a metaphor. Through repetition and rhythm, the pulsating vibrations, sounds and light patterns created by the AI software affect directly the way I – and the audience – perceive and perform my body on stage. It’s like a trance state, which I can experience only through this particular software (Graf, 2017).

Therefore, the idea intrinsic to the creative process arises as a creator of new "birth" through the instrumental use of artificial intelligence, making the most of its technical potential to promote the development of a new performance, augmented, expanded, which in fact expands the boundaries of the human body (the performer in the strict sense) providing to create a new performing body, perfectly hybridized.

Figure 1 - Marco Donnarumma, *Corpus-Nil*. Picture by Onuk ZKM.

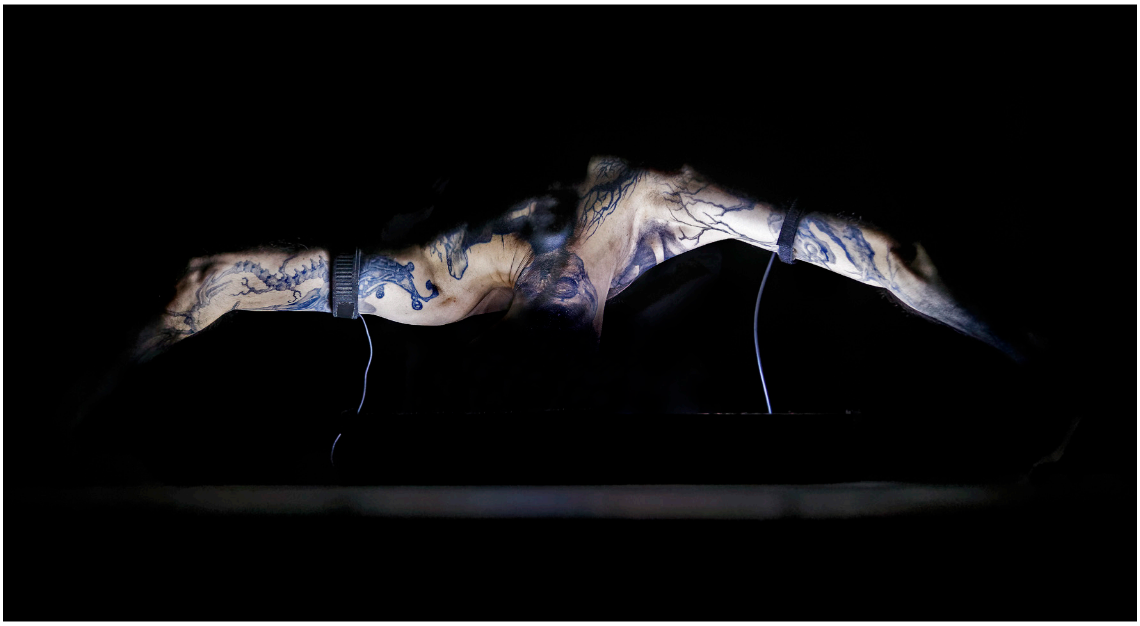

Figure 2 - Marco Donnarumma, *Corpus-Nil*. Picture by Onuk ZKM.

2. *Amygdala* (2018)

It is an AI robot whose main purpose is to "learn" to perform the cutting of the skin. The phenomenological premise lies in the exemplifications offered by a series of rituals found in different indigenous religions of East Asia, Papua New Guinea and the African continent. The incision of the skin in the form of specific patterns produces an alteration of the body and - through the experiential process of pain - produces the coveted phenomenon of "purification" as well as the liminal passage of social categorization (Turner, 2013).

Donnarumma thinks about a comparative process, supporting the key role that both purification rituals and AI technologies share in the political sphere of the "human body". Just as in different societies the liminal passage takes place through the payment of goods for access to the ritual of purification, that is, of "passage", so the current analytical sharing of the AI algorithm regulates the concessions to the management of certain practices that govern society: from medical care to social welfare. Therefore, for Donnarumma, *Amygdala* represents a fundamental symbol of human history, which sheds light on the discussed phenomenological sense of today's technocratic society.

Amygdala is a robot (AI) that has the shape of a human arm attached to a computer server. At the end of the robotic limb is attached a blade that in fact constantly produces cuts on a large flap of skin. The artist Marco Donnarumma describes exactly how it works:

> *Amygdala* is driven by biomimetic neural networks. Essentially, these are iterative mathematical equations, computed by the robot in real time. The specific kinds of neural networks behind Amygdala imitate the sensorimotor system of animals. This means that the robot's movement are not pre-programmed but emerge spontaneously from the activity of the neural networks.
> Because the neural networks receive sensory information from the robot's body in real time, the robot can adapt to any physical change or constraint in its environment. As a result, *Amygdala* is capable of a markedly organic, interactive and changing behavior recalling animal's movements. The prosthesis' ever-changing dynamics of cutting are legible in the remains of the skin garments that it manipulates during each exhibition. All the garments are collected in a series of sculptures entitled Calyx[4].

[1] Marco Donnarumma *Amygdala*, website (online)
https://marcodonnarumma.com/works/amygdala/ (visited on March 12, 2023).

Thus, Donnarumma's work, in the measure of the two examples briefly examined here, can probably be defined as an instance of phenomenological specification of the nexus connecting technologies, AI and the human body.

Through the variations experienced in *7 Configuration*, different possibilities of denoting the impact are expressed that, from an artistic and socio-political point of view, the massive rule of new technologies produces on man.

From the human body, through semantic and phenomenological rituals, to man conceptually understood as acquisition and diffusion of consciousness, in multimodal language for the use of the performing arts.

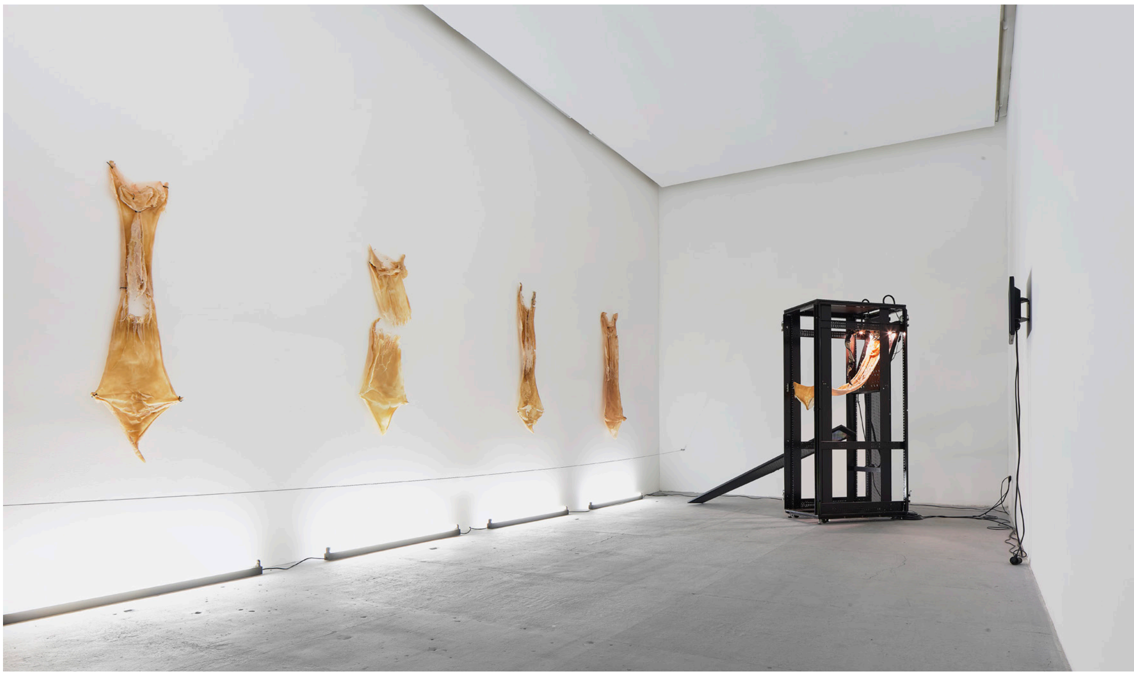

Figure 3 - Marco Donnarumma, *Amygdala Calyx*. Picture by Damjan Švarc KIBLA.

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Part III - Shaping and Experiencing Spaces

Neuroaesthetics, Design for All, Society

Keywords

Inclusive design
Experimental approach
Context
Educational stimuli
Healing environment
On demand

Design for active public spaces: a review

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Abstract

The paper discusses the design of active public spaces and its potential impact on society. Public spaces play an important role in shaping society, and a well-designed public space can have a positive impact on people's well-being and lifestyle. The paper explores the role of technology in creating interactive and responsive public spaces that can adapt in real-time to user needs and environmental conditions. The paper presents 16 case studies that fall within the scope of active public space design and it defines the main categories to which they pertain and the ways through which they dialogue with users. The paper also discusses the physical and social aspects that designers should work on to improve an urban public space, such as physical accessibility, inclusivity, green areas, and interconnection between spaces.

1. Introduction

Public spaces are the places that help shaping society but at the same time are strongly shaped by society itself. People meet, interact and experience urban spaces both individually and collectively. These interactions and experiences contribute to the processes of forming a sense of belonging and identity as well as shaping collective values (Gehl, 1987). The social fabric is strongly conditioned and influenced by the type of public spaces within which it is embedded. For this reason, a virtuous design of places and the elements that characterize them (use of green spaces, layout of buildings, street furniture...) can result in a great deal in terms of spillover effects on the style - and quality - of life of the people who inhabit them. In this sense, technology plays a dual role in such development, both in terms of its ability to digitally transpose public spaces, creating new places for social interaction, and in terms of the possibilities it opens up to make the relationship between cities and users more interactive. More precisely, the field of interactive installations and, more generally, sensor technology seems promising, although such solutions have been, at least initially, the almost exclusive preserve of arts sciences.

The process of transitioning from the mere scope of arts to introducing such practice into smart-city urban design is ongoing, as can be observed by the presence of numerous case studies around the world.

The goal is to make public spaces more responsive, transforming the city into a set of places adaptable in real-time to user needs and environmental conditions, in order to improve people's well-being and lifestyle. In this sense, technology is used as a tool to dialogue with users by obtaining data input from them based on which to react and conveying the reaction by transmitting an output to people.

The paper presents 16 case studies that fall within the scope covered, defining the main categories to which they pertain and the ways through which they dialogue with users.

2. Case studies

CityTree, Green City Solution, 2020

The project consists of a wooden totem that features a bench at the bottom and a moss crop, protected by a grid, at the top. CityTree is able to absorb about 250 grams of particulate matter each day and produce cooling temperatures in the adjacent area. In addition, the project monitors air pollution data and communicates it to the users through a screen placed on one of the sides.

Public Face, Benjamin Maus & Richard Wilhelmer, 2008

Public Face is an eight-meter-high smiley face, made of steel and neon tubes. The emotions conveyed by the sculpture are based on the facial expressions of local passersby, who are filmed by surveillance cameras. Thus, the project aims, in some way, to collect and communicate quality-of-life data and to encourage a happy mood in people.

The Dancing Traffic Light Manikin, Smart Agency, 2015

The project consists of a traffic light for pedestrians that, when the light turns red, plays music inviting people waiting to dance. Users' movements are then played back by the red icon on the traffic light. This reduces the risk of red light crossings and encourages urban sociability.

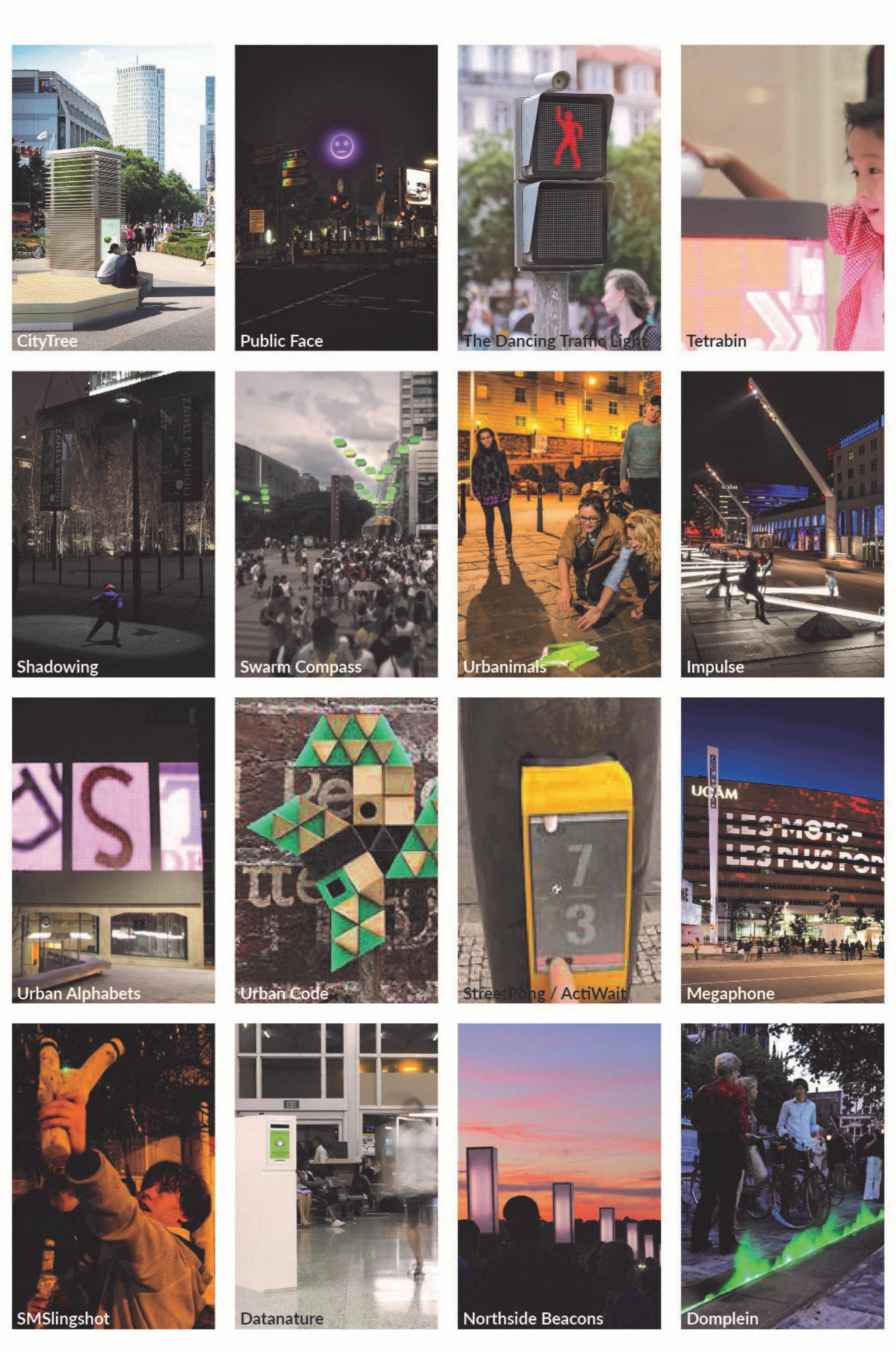

Figure 1 - The figure shows a particularly representative image of each case study taken into analysis. Image by the authors.

Tetrabin, Sencity Corporation, 2018

TetraBIN is an AI and IoT-enabled interactive trash bin that encourages positive behavioral shifts and brings joy to the everyday necessity of waste disposal. Users need to act and put the pieces of rubbish into the bin at the right time to be able to advance in the mixed realities. This had led to the rethinking and awareness of environmental sustainability issues and encourages urban sociability.

Shadowing, Chomko & Rosier, 2014

Shadowing is a smart streetlight that registers the movement of passersby and casts their shadows on the ground as the next person approaches. This creates a mixture of real and virtual, present and past on the sidewalk, and users are encouraged to pay more attention to other people with whom they share public spaces.

Swarm Compass, Ars Electronica futurelab & NTT Service Evolution Laboratories, 2018

The project involves the use of drones to create urban signage. This technology makes it possible to create temporary, modular and adaptive signage as well as generate customized information for users. In this way, it is possible to nimbly direct and modify users' enjoyment of urban spaces.

Urbanimals, LAX Laboratory for Architectural Experiments, 2015

Urbanimals is an interactive visual installation displayed on the empty surfaces in the space of transition across the city. The project aims to make places that generally have little user consideration interesting and interactive. By observing projections of animal figures moving on the sidewalk or on a wall, users are incentivized to interact with them as they move around the city.

Impulse, Lateral Office & CS Design, 2015

The project is carried out in Montreal's art district. It consists of a series of swings that, when not in use, remain in a central position and produce a slight illumination. When used, however, the lighting increases and a harmonious sound is also reproduced. In this way, people are incentivized to exercise and socialize to get the installation activated.

Urban Alphabets, Suse Miessner, 2014

The Urban Alphabets project aims to raise awareness and show the inhabitants and tourists of a city how unique and special it is. Through the Urban Alphabets app and using an integrated system of smartphone, website and multimedia facade, participants create their own version of the alphabet by taking letters from their city, and then leave "Urban Postcards" on the multimedia facades.

Urban Code, street game design system, Troy Innocent, Melbourne, 2016-2017

Urban Code is a way-finding urban game that does not take players from A to B but allows them to discover the location themselves. The installation, made up of objects attached to the walls of the city, is enjoyed by the players through an app which, by taking up the objects, returns sounds, noises, stories and images of a fictitious micronation.

StreetPong / ActiWait, Urban Invention, Hildesheim, 2014

The goal of StreetPong is to get pedestrians to halt and wait while the traffic light is red. Interactive screens have been placed on opposite sides of the pedestrian crossing, so when the traffic light turns red, pedestrians on each side can compete in a game of Pong. The aim is to employ gamification to encourage good behavior.

Megaphone, Moment Factory, Montreal, 2013

A temporary installation called Megaphone turned a public space in Montreal into an arena for debate. The spoken words of passersby are captured by speech recognition software, which then transforms them into projections that show on the facade of an adjacent building.

MSlingshot, VR/Urban - Christian Zöllner, Patrick Tobias Fischer, Sebastian Piatza, Cleveland 2012

SMSlingshot is a temporary project aimed to address the urban public space's rapid digitalization and invasion by advertising messages.
Residents of the city now have the chance to reclaim public space thanks to this project. Passersby may “throw” messages onto a facade using a catapult coupled with a cell phone that allows them to type messages.

Datanature, Ben Hooker, Shona Kitchen, Victoria & Albert Museum, London 2006

Datanature is a multi-site electronic installation in and around the San Jose International Airport in California. It is present both in the city and inside the airport and connected to a series of sensors that collect real-time data from various locations on the daily operations of the airport. It hands out tickets to passersby, fitted with their photograph and real-time random data.

Northside Beacons, Kollision, Martin by HARMAN & Northside, Denmark, 2018

Northside Beacons is a light installation connected to a plastic collection station. It is made up of sixteen large lights that were installed during the 2018 Northside Festival to reward, through light pulses, those who deposited a plastic dish in the recycling station. The goal was to encourage more users to select and recycle materials.

Domplein, OKRA Landschapsarchitecten, Utrecht, 2010

This project brings Utrecht's lost historical past back to life and reinforces the perception of the underground presence of the 160 meters of Roman wall buried below at a depth of four meters.
By inserting corten steel sheets, from which a trail of light and fog emerges at night, the installation delineates the perimeter of the Roman nucleus at the street level.

3. Taxonomy of the physical and social aspects of urban life

The case studies reviewed so far show that even artifacts belonging to the product design scale can to all intents and purposes be a tool for enhancing urban public space as facilitators of processes of urban reactivation, entering this process in the form of generators of opportunities for active improvement. Designing for urban public space means recognizing the potential of empty, unused or underutilized spaces, spaces that are inhospitable or without any function; it means working on interstitial spaces, on everything that advances from the built environment and on seemingly meaningless scraps, recognizing them an active role and transforming them into places with their own identity (Clemente, 2017). Moreover, for a public space to be well designed, it is not enough just to give shape to products, services, and installations, it is necessary to give life to relationships, skills, knowledge, and abilities expressed by a territory and its inhabitants (Bedeschi, Marseglia & Trivellin, 2018).

In fact, in order to improve people's well-being and lifestyle, the designers of public space must act by taking into consideration both the container (the geometry of the space, the built form) and the content (how the space is used, even temporarily), resulting in systems of products, services, and interactive installations that make socializing in a given urban space easier and more likely. Thus, the new role of designers is to make public spaces more responsive, by collaborating in the creation of more favorable socio-material environments (Manzini, 2018).

For this reason, design, and consequently designers, is concerned not only with the physical aspects of a public space but also with the social ones; in fact, the designer has the arduous task of strengthening the existing local identity, or in its absence, building a sense of community by connecting the people who experience the space on a daily basis, starting with the valorization of the area, highlighting the potential of a place and the resources it offers us every day (Pecenka *et al.*, 2021).

According to Fagnoni (2018), local events, spaces of a hybrid nature, and actions by the community are an opportunity to regenerate places; in fact, by applying an enhancement process that aims to make spaces more interactive, responsive, usable, and comfortable for users, even more complex issues are solved.

It should be kept in mind that the designer, during the design process, should confront the physical and social factors that influence human behavior, consequently understanding what offers comfort to users and what causes discomfort in a public space (Deasy, 1985).

4. Case study analysis and conclusions

Following the analysis done on the different case studies, let us extrapolate what are the major physical and social aspects that designers should work on to improve an urban public space. From the physical point of view, an urban public space should always be physically accessible to anyone without any kind of restriction, especially it is crucial that it be inclusive for users of all kinds: children, elderly, people with disabilities, and people of different ethnicities, backgrounds, and interests, not to mention pets.

First and foremost, as a meeting place and landmark, it would be good if it is equipped with both seating, to encourage people to stop, relax and rest by staying in the space longer, and green areas, gazebos or fountains, which improve air quality in public areas and reduce overheating by providing protection from sun, wind and rain.

In addition, given its interstitial nature, it must encourage interconnection between spaces, avoiding barriers and unnecessary bypassing of obstacles, and it must give the passerby a high sense of security, achievable through good lighting and proper street signs. An active public space requires versatility and flexibility so that it can accommodate different types of actions and events during different hours of the day. For this analysis, it is important to highlight how, nowadays, the visually appealing aesthetics of urban spaces and the inclusion of responsive elements that encourage interaction and sociability can make a public space more frequented and appreciated by the community.

From the social point of view, on the other hand, a product, service, furniture or installation designed for an urban public space affects human perception and behavior, and so it must facilitate interaction and socialization among people by generating the opportunity to make friends and thereby create new groups of belonging.

However, in order to facilitate the psycho-physical well-being of the end user, one must allow him or her the natural personal space. Most people feel a strong sense of discomfort and annoyance when their personal space, which has subjective dimensions, is invaded: when we are comfortable we need less space while when we are not feeling well we will need adequate space. By the same principle, we must take into account the innate territoriality in humans: if we place an installation in a territory unconsciously considered by citizens as their own, they will feel a lack of sense of control, bewilderment and anger, and the installation will be seen as an invasion without permission. If, however, the installed product reflects the status of the community, greater community participation will occur, leading to subsequent acceptance. In addition, through good human-centered design approaches designers can give cues to users on how best to navigate the environment safely.

Based on the case study analyzed, some recurring elements emerged that highlight some of the essential characteristics for the design of active, smart and inclusive public spaces. Almost all of the case studies present a technology component, implemented through the use of sensors that collect data and return feedback to users. Such data is used for a variety of reasons, including collecting and communicating information inherent to the quality of life in the cities where the project is placed. Such an element is closely related to an additional one that recurs frequently in the projects analyzed. Many of them, in fact, aim to encourage eco-sustainability behaviors in users. Other aspects inherent to city life that recur in the projects analyzed are the sense of safety, real or perceived, that is aimed to be increased and the sociability among people that is encouraged by many of the installations. In addition, many projects aim to communicate, convey, and highlight in some way the city identity or the identity of the neighborhood in which they are located. Finally, the projects also aim to address and convey the city's enjoyment through wayfinding operations. Lastly, there is a recurring element identified that relates not so much to the aspects that characterize active public spaces, but to the method by which they are interfaced with users. In fact, in several projects user interaction is achieved and enticed through gamification strategies.

As a result, the paper proposes an infographic representation designed to communicate how the individual projects analyzed interface with the recurring elements just described.

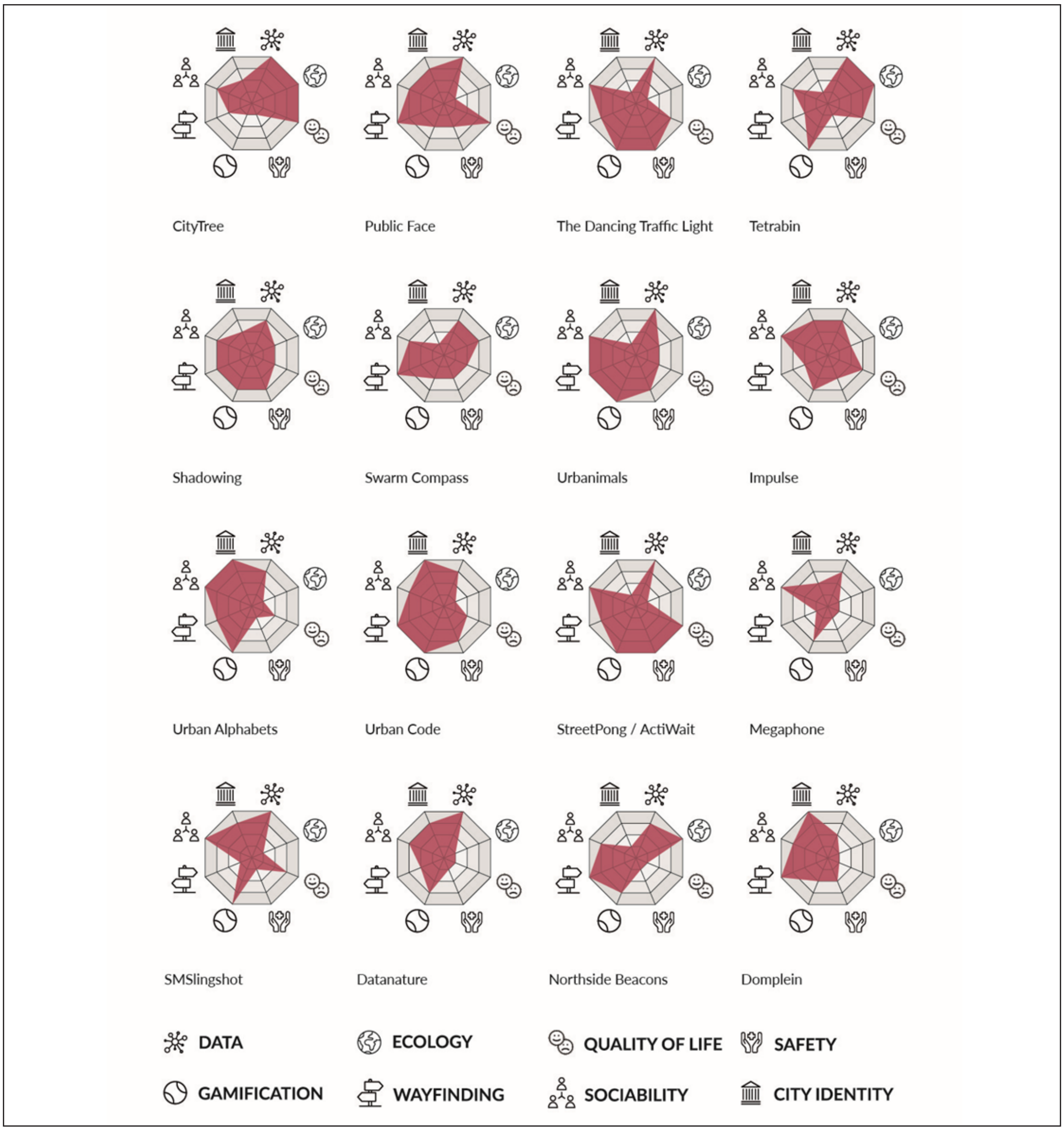

Figure 2 - The figure shows a graphical representation of the data analyzed by the paper: specifically, a Kiviat diagram is made for each case study showing how the latter relates to the recurring elements identified by the authors.

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Architecture as Atmosphere[1]

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Architecture is a complex process of spatial and temporal organization, which is con-ceived, developed, felt, and communicated also (and above all) through its atmospheric manifestations. Atmosphere is the essence of affective qualities we sense in our sur-roundings that confers identity and meaning to a situation or place. In the last three decades, investigations about atmospheres — aimed at comprehending, experimenting, and representing their expressive properties — have been drawing remarkable atten-tion. From the end of the 20th century, some scholars have even observed an 'atmos-pheric turn,' a ramification of the more general 'affective turn' that bloomed in the Humanities in the early to mid-1990s. There is an ever-increasing enthusiasm for the atmospheric approach in architecture: today, atmosphere represents a crucial element for design practice and critical discussion, as well as architectural teaching. It satisfies the pressing need for bodily felt experiences and emotionally arranged ambiances.

Specific education is necessary to craft an architectural paradigm about atmosphere. My Ph.D. project (2019) was one of the first to analyze atmosphere from an architec-tural perspective by studying the topic through the sensory-emotional filter of the per-ceiving subject. Architecture and neuroscience were separate branches of knowledge until we acquired the awareness that the human brain develops in a continuous condi-tion of adaptation to the variations of physical space. Wondering if it is possible to sci-entifically examine atmospheric perception, I completed my Ph.D. dissertation, under-taking a preliminary experiment that was supported by self-report tools. My current postdoc research (2021–2024) combines subjective indicators with measures of both autonomic and central nervous system activity.

The crucial question concerns how we can link a growing understanding and systematization of atmosphere in architecture to the study of the brain, body, and their emotion-related mechanisms, to gain insight into people's emotional complexity.

This IDEA presentation illustrates the jagged background that an architect should de-velop to manage the multidisciplinary essence of an atmospheric education. It is the occasion to show how it is possible to combine architectural theory, (neu-ro)physiological methodology, and experimentation in virtual reality. Specifically, the discussion focuses on the most recent experiment we carried out at the P\Lab2003 di-rected by Professor Bob Condia at Kansas State University (Manhattan, Kansas).

The priming potential of atmospheres is a deep-rooted intuition among architects, but we must consolidate evidence by collecting empirical data. We want to transform a design intuition into an *informed intuition*.

[1] The theoretical premises of this abstract and the physiological-signal-based experiment illustrated during the IDEA 2023 Symposium were developed within the RESONANCES project — Architectural At-mospheres: The Emotional Impact of Ambiances Measured through Conscious, Bodily, and Neural Responses. This project received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement no. 101025132. The content of this text reflects only the author's view. The European Research Executive Agency is not responsible for any use that may be made of the information it contains.

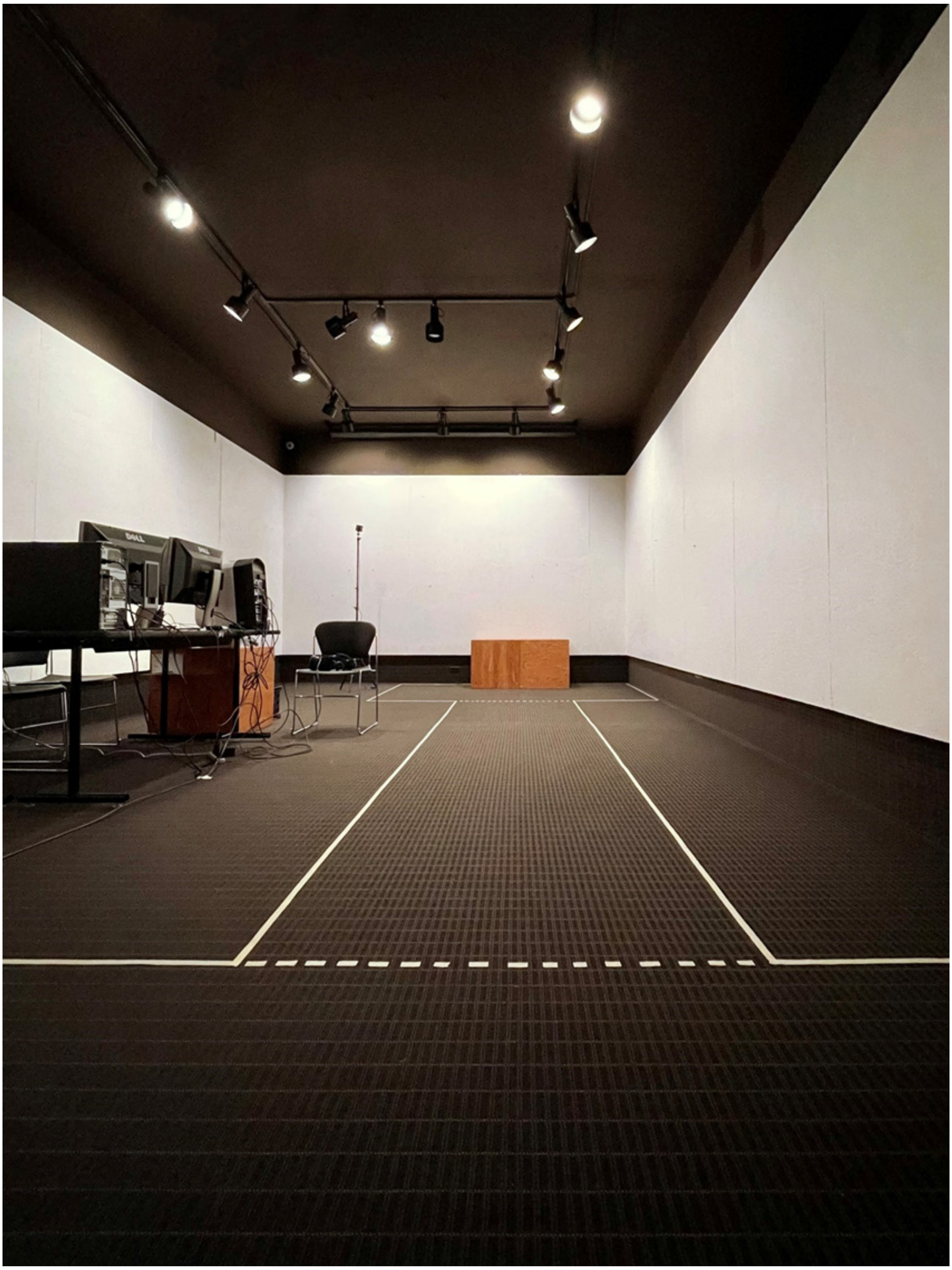

Figure 1 - P\Lab2003 experiments room, Kansas State University © Elisabetta Canepa, 2023.

Figure 2 - Resonances experiment © Alex Mendoza, 2023.

Visual perception and architectural composition: an introduction to the cognitive method

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The issue of visual perception of space is of great interest to the discipline of representation due to the obvious implications for the image. It is equally intuitive to understand how dealing with visual perception can be related to numerous areas of knowledge that are tangential to visual realizations but constitute their presupposition and frame of reference.

The issue of visual perception of space is of great interest to the discipline of representation due to the obvious implications for the image. It is equally intuitive to understand how dealing with visual perception can be related to numerous areas of knowledge that are tangential to visual realizations but constitute their presupposition and frame of reference.

The physical mechanism of seeing, the emotion or sensation that a certain vision determines in the observer, and the connection between sight, object, and its understanding are just some of the fundamental contributions that other disciplines offer to representation.

In fact, in the typological-processual studies referred to in my experience, Gianfranco Caniggia introduces a fundamental differentiation between *perception* and *legibility*, which is a sort of watershed between what is seen and what is made one's own through a subjective approach and what is seen and made one's own through an instinctive reading of what is in front of us. In particular, in this context, we refer to the world of the built environment at the scale of the building and in particular to its maximum expression of image, that is, its external *facies*.

However, it is clear that the same distinction must be made when dealing with anthropic operations at all scales, from the object to the urban layout, to the territory. It is sufficient to think about the perception of an object and the huge difference that can be experienced when such an object hides its function to mimic something else, for example, to appear attractive (such as Alessi's kitchen utensils, like the funnel) (Fig.1) or to hide what is deemed inappropriate (as the *Seggette*, the 18th-century toilets) (Fig.2). This also applies to the urban environment and its form, as well as to the landscape and the many acts of mimicry that are required to conceal invasive anthropic interventions, such as landfills.

Furthermore, it should be emphasized that, regarding the visual perception of the built environment, it is precisely the image perceived that defines the feeling in the observer and consequently a feeling of positivity or negativity, inclusion or exclusion. This feeling depends on many factors, such as the viewpoint, the time of day, the weather: lights and shadows, warmth or coldness, from above or below, all modify the sensations of the observer, so much so that the same image can elicit very different reactions depending on the surrounding conditions.

In addition, the background education of each person, as well as their personal experience and socio-economic condition, also contribute to influencing visual perception. Narrow spaces such as alleys can elicit negative perceptions of discomfort and insecurity or, conversely, a sense of certainty of boundaries and belonging to a well-defined environment.

All of the above makes it clear that, since the visual perception of the built environment is due to both objective and subjective factors, it is possible to intervene in the design to change, modify, and guide the perception and thus the feeling that a particular space elicits in the user. At the same time, however, this possibility makes it very complex to evaluate the components that contribute to its formation. Critically reading what is shown of the built environment provides the opportunity to understand at least in part the variables that impact the appearance of a building, beyond its concreteness. Setting up a deep knowledge process of the components of built environment image is what has been done in typological-processual research, through the duality between perception and legibility, as mentioned at the beginning: if perception is the feeling one has of the vision of the built environment, legibility, on the other hand, is the specific understanding of the relationship that exists between what is seen (the external form) and what is found inside (the materials that compose the structure and the compositional articulation that determines the possibility of using the spaces).

In essence, legibility is what the observer can understand about the built organism through its visual language, which is the ability of any object to communicate itself through its appearance.

This means that while perception is mainly a subjective fact, language is, on the contrary, mainly objective and, therefore, more identifiable in its essential components. In fact, legibility is critically understandable, transmissible in its formative processes, and therefore codifiable and usable as an intentional compositional process.

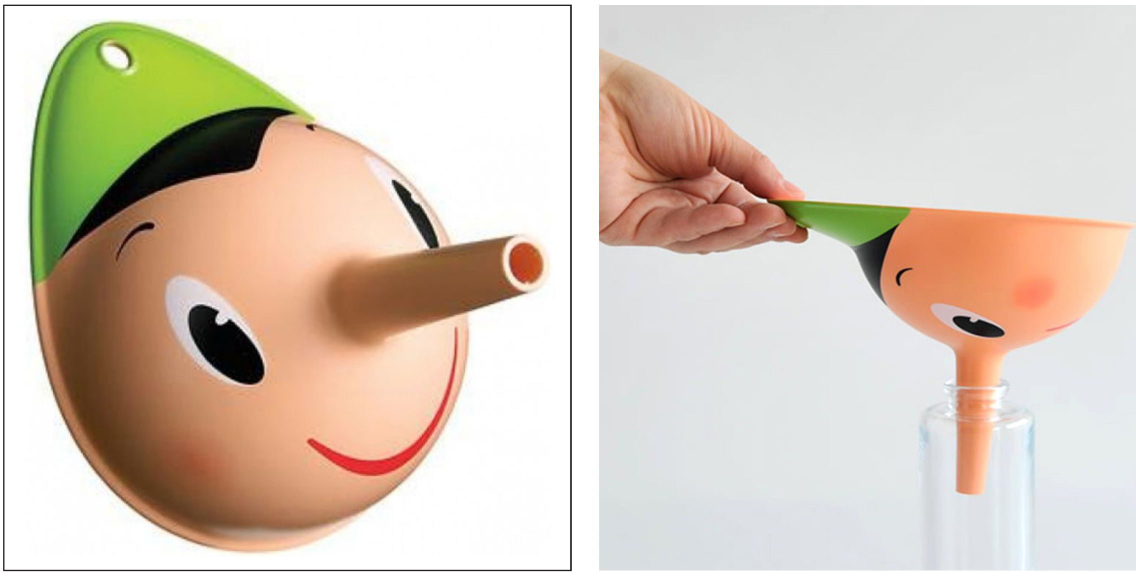

Figure 1 - Alessi's funnel. <https://www.domustore.it/p9842-imbuto-pinocchio-alessi/?gclid=Cj0KCQjw2v-gBhC1ARIsAOQdKY09RLsHuSxIqu-c_oXJswWA9ko-MHQXkFVi1VJfgD-fbKqkMxwhC7kaAs2IEALw_wc>

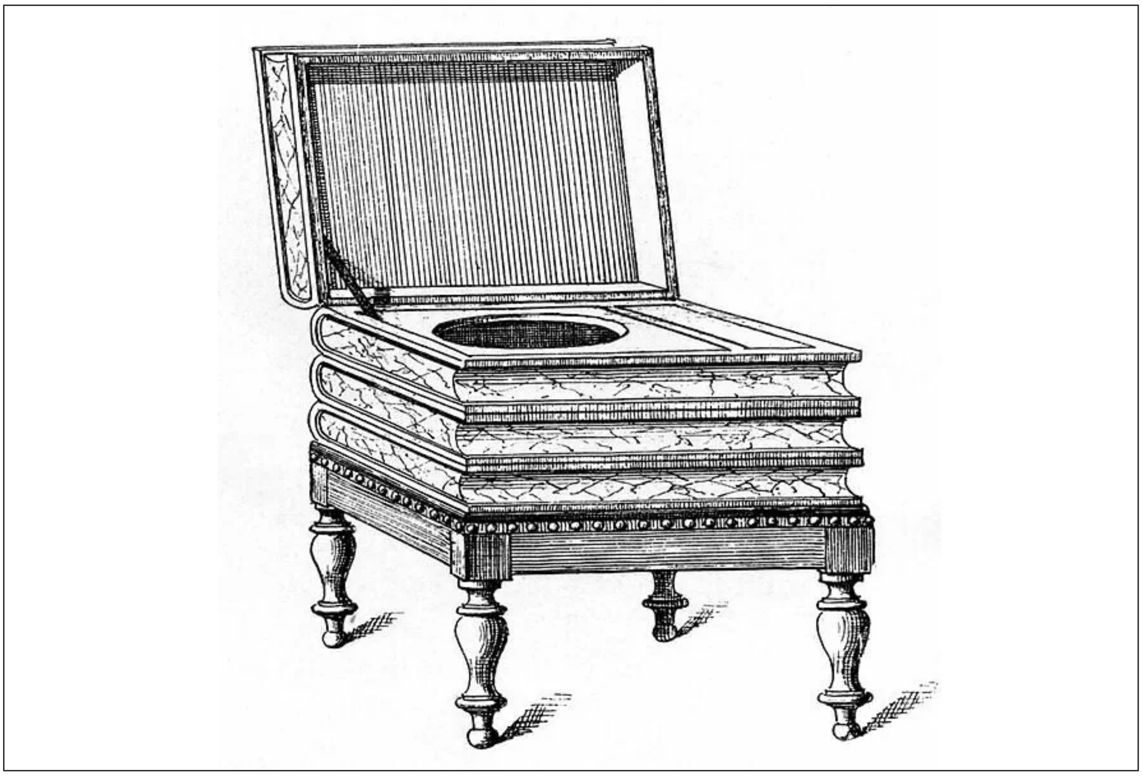

Figure 2 - *Garde Robe, dite Voyage aux Pays-Bas,* 17th Century (engraving). < https://www.mediastorehouse.com/fine-art-finder/artists/wilhelm-auguste-rudolf-lehmann/garde-robe-dite-voyage-aux-pays-bas-23242864.html>

Through doctoral research, a method of critical reading of the visual perception of the external form of a building has been developed, called perceptual impact evaluation, which allows for the shared and transversal evaluation of any façade apparatus. This procedure relates what appears externally to the corresponding internal partitions, in order to highlight the coherence or inconsistency between what is seen and what is actually concretely built: apparently decorative elements such as string courses, lintels, rustication, and so on, can acquire a valence of intentionality and guidance to the perception of a form that actually differs from the real conformation of the structure. Conversely, once the mechanism is understood, it is possible to use corrective elements of detachment between the form and the compositional substance to improve the appearance and guide the observer's feeling towards a purely intentional form. It is easy to understand how the possible contaminations between perception and language are substantially infinite, as they are different modes of balance between what the built environment is and what it shows of itself: the extreme cases are the building body that reflects exactly what it is made of externally, without any interference with representative decorative or embellishment effects - even reduced to the level of plaster that hides the structure and the materials used - and the one in which the form does not respond at all to what it is made of, as happens for many realizations/monuments/installations, in which it is often difficult to even establish what the intended use is.

Intentionality and coherence can be defined as the two nodes of the issue: in the first case, the visual perception of the object is closely connected to the design of special effects and intended to guide a certain feeling in the observer; in the second, instead, the form and therefore the image that results from it depend exclusively on the components (materials and structures) and their setting for the intended use (fruition); in the first case, we can speak of extrinsic legibility, i.e., extraneous (or more or less extraneous) to the answering questions related to realization; in the second, we can speak of intrinsic legibility, i.e., directly and exclusively dependent on realization. It is clear that in the modern history of the built environment up to the present day, it is unthinkable to find realizations with intrinsic legibility, since at least from the separation of the function of the designer-creator from that of the executor, the division of skills inevitably leads to interpretations and variations that also deal with the definition of the form.

All that has been presented so far is nothing more than a kind of introduction to explain and define the principles that have led to the formulation of a process that examines the form of the built environment in order to understand deformations, interventions, and design expedients intentionally introduced to produce a certain visual perception in the observer. It is an analogical methodology that does not require any assumptions, except for the possibility of comparing the external form with the actual structure.

In summary, the process of critical reading involves analyzing the volume of the building under study, divided into undifferentiated, partially differentiated, and fully differentiated volumes, depending on the degree of correspondence to the material and structural components for the specific use of the spaces. This study is then applied to the individual components of the façade, i.e., the resolution of the ground floor, the elevation, and the crown, the openings, and the vertical distribution.

These brief notes only hint at what can be done in the perceptual realm to go deeper and understand the compositional mechanisms that guide and regulate buildings or, conversely, to have mastery and awareness in the optical-perceptual corrections that one wants to introduce.

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Table 1 - Diagram for critical reading of the buildings external *facies*. Diagram by the author.

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Spaces where concepts click. Designing Fab Labs for education

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Abstract

This article focuses on Fab Labs which are spaces equipped with advanced tools and technologies for digital fabrication, such as 3D printers, laser cutters, and computer-controlled machines. The article explains how the environment, atmosphere, and mood of a Fab Lab can play an important role in shaping the perception of the space and influencing the experiences of its users. Various factors such as the layout and design of the space, lighting and colour combinations, noise level, temperature, cleanliness, and the social dimension of the space can affect the perception of the environment. The article argues that the perception of the Fab Lab can significantly impact the experience of its users, and it is essential for managers and designers to consider these factors to create a welcoming, productive, and stimulating space for innovation and collaboration. The article also emphasizes that the design of a Fab Lab involves much more than just selecting equipment and technology, as it is a space where collaboration and the open culture of innovation apply. The article concludes that architects and designers should consider the impact of architectural stimuli on the emotional reactions of users when designing Fab Labs. The article focuses on the framework of digital fabrication university labs.

1. Introduction

A Fab Lab, or Fabrication Laboratory, is a space equipped with advanced digital manufacturing tools and technologies, such as 3D printers, laser cutters, CNC machines, and other computer-controlled tools.

The environment, atmosphere and "mood" of a Fab Lab can play an important role in shaping the perception of space and influencing the experiences of those who use it.

The perception of the Fab Lab environment can be influenced by various factors, including the layout and design of the space, lighting and color schemes (Kwallek, Lewis & Robbins, 1988), noise level and temperature, cleanliness and overall layout of the space. For example, a well-lit and clean laboratory with a clear layout and efficient organization of tools can create a more professional and productive atmosphere, while a cluttered or dimly lit space can create a more chaotic or disorganized feeling (Boubekri, Cheung & Reid, 2014).

The social dimension of the Fab Lab can also play a role in shaping perception. A community, living space, welcoming and inclusive of users and staff can create a more positive and supportive atmosphere, while a competitive or unwelcoming culture can create a negative or intimidating atmosphere (Ross & Ressia, 2015).

The purpose and goals of the Fab Lab can also influence external perceptions: A Lab with a clear and meaningful mission, such as promoting open-source innovation or responding to the needs of the local community, can create a more stimulating and purposeful, while a workshop without a clear goal or purpose may seem aimless or uninviting (Scholz & Schneider, 2017).

Overall, the perception of a Fab Lab environment can have a significant impact on the experience of those who use it, and it is important that Fab Lab managers and designers consider these factors to create a welcoming, productive, and stimulating space for the innovation and collaboration. By definition, it is a space designed for digital fabrication, where users can design and create objects using various tools and equipment, where the fit-out and layout of the space is a major factor on user experience and performance (Orsini & Marchetto, 2005).

Designing a fab lab involves more than just selecting equipment and technology. These laboratories are spaces in which the economy of collaboration is applied, based on the fundamental principle of the "open culture", in which physical spaces, equipment and know-how are made available to individuals, organizations and other entities, constituting a resource community to facilitate the development of projects of different nature, and therefore assuming the role of a laboratory as a facility[1].

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[1]Facilities therefore mean the infrastructures and services supporting the core business processes of an institution: it is therefore clear that the primary objective of laboratory facility management is a sort of "back-end" support.

For these reasons, the architectural space in which the laboratory is located determines the actions performed by the users with a significant impact on their emotional reactions. For example, the intensity of colours, the texture of surfaces and the quality of lighting can influence how people feel when they enter a space. These factors can also affect the productivity, creativity and well-being of those using the space. Therefore, understanding the influence of architectural stimuli on emotional reactions in occupants and producers is essential to creating a successful and effective fab lab. These inputs suggest that architects and designers should consider the impact of stimuli on users' emotional reactions when designing fab labs (Knudsen & Andersen, 2002).

In this case, the contribution focuses on the framework of digital manufacturing university laboratories in Design and Architecture schools, open to students, teachers, researchers and stakeholders housed within universities, in dedicated spaces or within existing laboratories.

In this context, in 2020, U-FAB was born, the Italian network of university Fab Labs and makerspaces, a network inspired by a broader mapping, Makers' Inquiry (2015), to stimulate collaboration between Italian and university Fab Labs and makerspaces, more generally, between academic spaces and laboratories that are characterized by the development of educational and scientific activities based on digital fabrication.

U-FAB is an initiative launched by two university Fab Labs – Polifactory (Politecnico di Milano) and Santa Chiara Lab (University of Siena) to network Italian university makerspaces with the aim of sharing practices and developing operational synergies, co- plan and organize cultural and experimental activities.

U-Labs (University Laboratories) generally have a trichotomic nature, determined by the Missions of the University itself: Teaching, Research and Third Mission. In these places, students can develop ideas, design products, use available technologies to create working prototypes, test them by solving real problems thanks to technologies that are becoming an industry standard. Additionally, these spaces provide a collaborative learning environment, where students can work together to solve problems and share knowledge and skills, practice prototyping skills, and develop problem-solving skills, using STEAM (Science, Technology, Engineering, Arts and Mathematics) on industry standard equipment. They also provide students with opportunities for professional development and reinforce concepts taught in the classroom with practical application.

Fab Labs can be used in many fields of study, including engineering, architecture, design, materials science, synthetic biology, art and computer science, promoting the basic principle of the New European Bauhaus: the interdisciplinarity of art, science and technology, similar to the original vision of the Bauhaus, (concept of "Bauhaus" literally means "built house", reflecting the movement's mission to create a more functional and beautiful built environment) with the aim of developing innovative and sustainable solutions to the problems of the modern world. This interdisciplinary approach is expected to promote a better understanding of Europe's complex environmental, social and economic problems and help to find concrete solutions through effective collaboration between the disciplines involved. 3D printing labs position schools in the arena of cutting-edge technologies, fostering iterative testing and research excellence. Furthermore, they open the door to partnership opportunities with local companies, offering young people the opportunity to put their skills into practice and to acquire new ones, in a real and concrete context.

2. What does a best-in-class academic lab or makerspace look like?

The size, shape and purpose of a lab depends wholly on the goals set prior to its construction and will differ from school to school. Here are three examples of labs — ranked from simple to state-of-the-art.

- *Simple Collaborative Makerspace* (Fig.1)

Simple Collaborative Makerspace Open to all experience levels and specialties, a collaborative makerspace focuses on throughput and creating the final part rather than achieving specific material properties or creating for specific applications. This type of lab is a great place for beginners to learn about 3D printing.

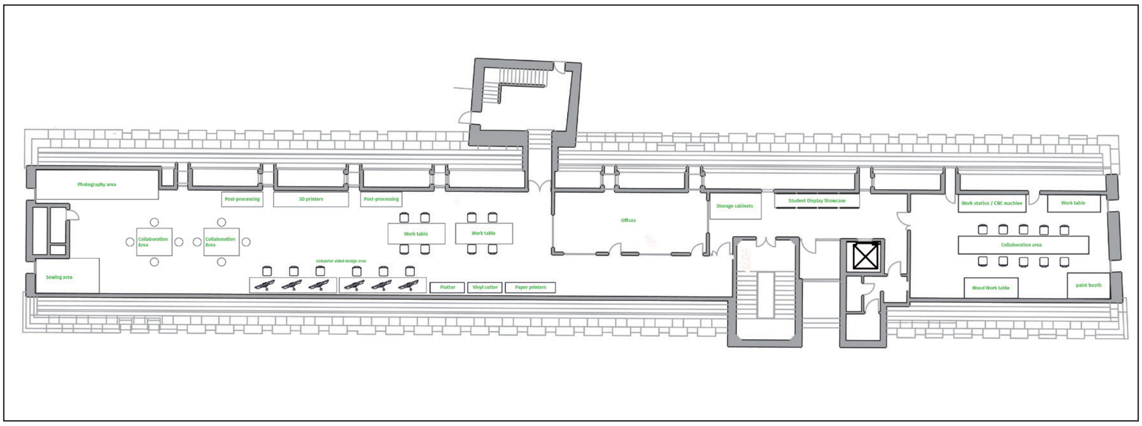

Figure 1 - Example of Simple Collaborative Makerspace. Image by the author.

- *Standard Academic Lab* (Fig.2)

Standard Academic Lab Only available to students in a specific college within a university (e.g., the college of design or engineering), the academic lab typically features a mix of high-end and user-friendly equipment. This type of lab should also be staffed by knowledgeable experts who would ensure the lab runs like a parts provider.

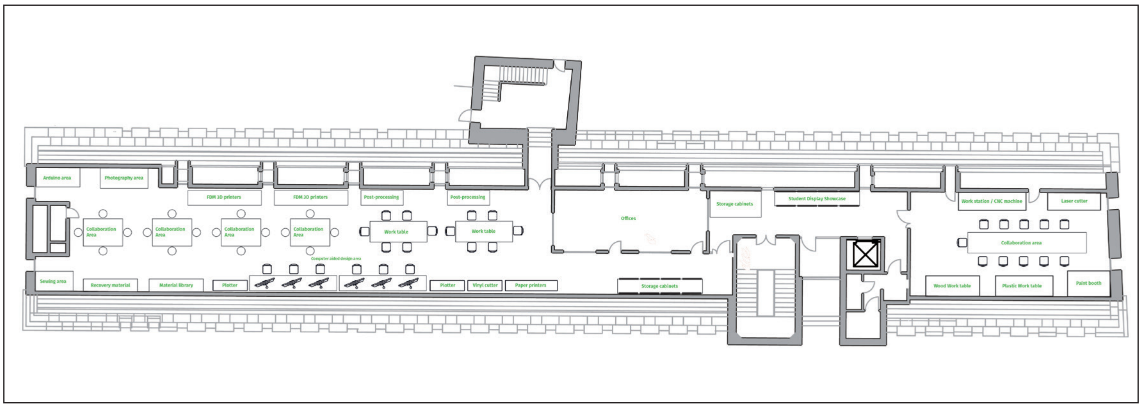

Figure 2 - Example of Standard Academic Lab. Image by the author.

- *State of the Art Center of Excellence* (Fig.3)

State of the Art Center of Excellence Available to students, professors and researchers in a wide range of disciplines, or to all, this type of lab features the latest in high-end 3D printing equipment as well as a streamlined process for part building and delivery. Run and staffed by knowledgeable product experts, this lab also functions as a parts provider and 3D printing resource for the surrounding community.

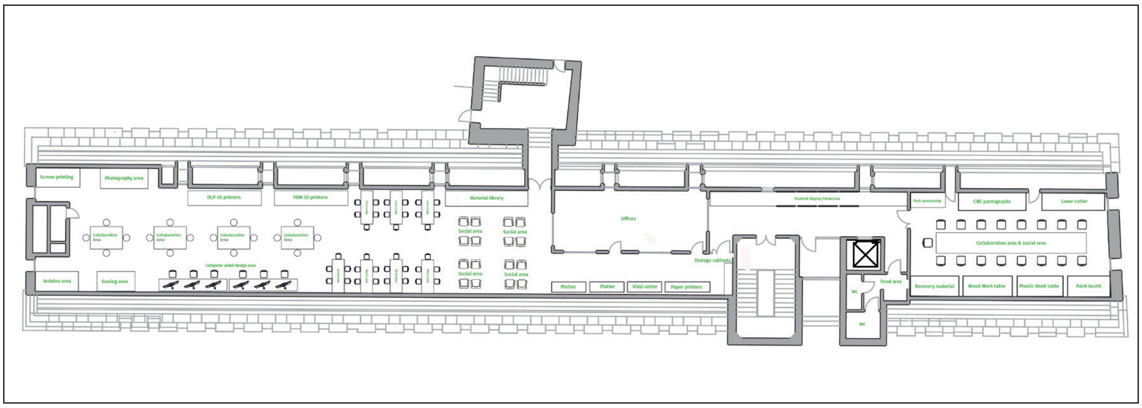

Figure 3 - Example of State of the Art Center of Excellence. Image by the author.

Based on this categorization of laboratories, a handbook has been drawn up for the correct design of the spaces of a Digital Lab, which requires the adoption of some best practices to ensure maximum efficiency and safety of the environment.

Determine the workflow and the influx of equipment requests. Before buying a 3D printer, it's best to evaluate the capabilities of different systems based on the specifics of the space and Start with the right number: use a benchmark formula to determine the number of 3D printers needed to meet demand.

When planning the layout of the laboratory, check with facility management to ensure that there is adequate lighting, ventilation, and power.

Staff Lab with Students:

Create apprenticeship opportunities, internships or 3D printing studios to give students the opportunity to improve their skills and manage the flow of printing jobs, and to make them feel an integral part of the process.

Teach students how to design for 3D:

Offer a course or tutorials to teach students how to create and optimize designs for successful prints.

Try project-based group learning:

Organize teams of students of three to five and assign them a job to replicate the printing process.

The co-planning and active participation of sharing spaces foster interaction between people and organizations, thus creating a stronger and more resilient network (Ratti, 2015). Living in a space and creating it can go hand in hand. «To achieve change», in the words of Dunne and Raby (2013), «it is necessary to unlock people's imagination and apply it to all areas of life at the micro-scale. Critical design, originating from the generation of alternatives, is able to help people build compasses, rather than maps, allowing them to navigate new sets of values».

The synergy can also be applied in the academic field, where design thinking can be used to develop innovative solutions based on understanding the relationships between the various actors.

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Inclusion of "Made in Italy". The role of accessibility for the valorization of cultural heritage[1]

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1. Cultural heritage and the key role of accessibility in its valorization

Cultural heritage has always been understood as a significant element of the economic, environmental and social system, but it is with the Faro Convention (2005) that its importance as a common good - tangible or intangible - is emphasized. This heritage acquires true relevance the moment humanity is empowered to attribute meanings, uses and values to it; in this respect, therefore, it needs to be accessible to the majority of the community.

The extension of the concept of cultural heritage to intangible culture implies that the meaning of inclusion cannot therefore be limited to the accessibility of physical places but must also include access to cultural informations. Majewski and Bunch say full accessibility of a cultural asset goes beyond ramps, bathroom grab bars and access to all floors of the museum, but considers the diversity of people in a wider sense.

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[1] The article is the result of a joint reflection by Isabel Leggiero and Professor Claudia Porfirione. The “Cultural heritage and the key role of accessibility in its valorization” and “Conclusions” paragraphs have to be attributed to Claudia Porfirione, “The value of accessibility and human diversity in creating an inclusive cultural model”, “Design for All and Cultural Heritage” and “Digital humanities and the disintermediation of the designer's role” to Isabel Leggiero.

In this vision, the socio-cultural component becomes central in the design of a space dedicated to human well-being in order to ensure access to knowledge and public participation, despite the fact that this requires long-term visions for institutions. On the other hand, we speak of cultural heritage, instead of patrimony, to indicate a collective identity and diversity. Heritage made up of knowledge, values, symbols, patterns of behavior, "a set of resources inherited from the past that some people identify, regardless of who owns them, as reflecting and expressing their constantly evolving values, beliefs, knowledge, and traditions. It includes all aspects of the environment derived from the interaction over time between people and places (Faro Art. 2) (Lupo,2019). The result of this new reflection on cultural heritage highlights the prominent role assigned to people, who become active in identifying these resources.

Accessibility acquires a key role in the enhancement of heritage, not only in terms of artistic and cultural relevance, but also from the perspective of increasing and differentiating audiences by opening up to new types of users, whose demands and needs we aim to investigate in order to ensure their inclusion.

The totality of the repercussions of rethinking in this direction would make it possible to position cultural heritage as a strategic system for the country's development. In fact, already after the Second World War, the idea of a public, democratic, inclusive, accessible and participatory space arises in the debate about museums, with cultural welfare actions that make local cultural identities stand out (Longo, 2017).

2. The value of accessibility and human diversity in creating an inclusive cultural model

The concept of diversity has been representative of an intrinsic characteristic of a person, but today we look at diversity as a quality that manifests itself in interaction with the environment, objects, or people. According to Sen (1993), a new concept of well-being is understood as what people can be or do in relation to available resources and their potential capabilities.

Generally, the ways in which accessibility is implemented are of two types: physical and cognitive. However, this clear distinction is not sufficient to represent contemporary complexity, in which people's cultural practices are diverse and intersectional, often related to physical and cognitive condition, but even more often related to social factors.

We need to trigger a virtuous circle whereby an inclusive cultural model generates spaces and places that are accessible to all, where people can come together and create opportunities for mutual knowledge and exchange, fostering the growth of an increasingly inclusive culture.

Designing from the perspective of diversity means keeping people's needs in mind, trying to solve complexity and ongoing changes.

One of these is related to the longevity of the population and its aging. As data show (United Nations Department of Economic and Social Affairs), people today are living longer, active and healthier lives with good technology education through the use of devices. This can translate into a very powerful tool for inclusion in many aspects of life - for recreation, leisure, sports and cultural activities.

Just think, for example, of what could be done to facilitate the usability of entertainment venues such as cinemas for all people with hearing impairments.

It becomes immediately apparent that accessibility is a factor for all members of society; this thought that on the one hand might seem obvious and trivial, on the other hand, is certainly innovative in scope.

The idea of creating designs that are usable by the greatest number of people, regardless of their physical, cognitive and social condition, is not new to the field of design, which has always thought holistically about contemporary challenges. In fact, as early as 1993, the European Institute for Design and Disability (EIDD) aims to improve the quality of life by applying Design for All. Similar concepts are being developed in other places, such as Universal Design in the United States (thanks to the Americans with Disabilities Act) and Inclusive Design in the United Kingdom. Even today it is possible to find this line within proactive strategies for sustainable development.

Specifically, the definition of Design for All coined by EIDD in 2004 during the Annual Assembly held in Stockholm on May 9, 2004, defines precisely that "Design for All is design for human diversity, social inclusion and equality." (EIDD Stockholm Declaration, 2004). Over the past two decades, efforts have been made to move beyond the Fordist -standard-based-model of approaching products and services with the goal of enabling all people to have equal opportunity and dignity through participation in every aspect of society, with accessible and affordable objects, services, culture, and information for use by different types of people.

To give an example, in practice, after 20 years we have reached the point where at a concert the person in a wheelchair has a reserved seat but has to separate himself from the community of friends to see the performance, which is still an achievement compared to the past, but in the future it will be necessary to design usable and accessible spaces for all where the meeting and exchange between people is encouraged.

Therefore, applying this approach makes use of the analysis of human needs and aspirations through the involvement of the population in the different stages of design. In this way, it becomes possible to develop solutions that do not discriminate against specific diversities, but represent a wide-ranging solution. This is also because, the focus of development cannot be only on functionality, but must address more important issues, such as understanding the user, how they want to feel, on what occasions they will use the tool, etc. Similarly, thinking of solving a problem without considering likability demonstrates another design error, as a 'ghettoizing' product is not appreciated by anyone.

3. Design for All and Cultural Heritage

> Le città future non sono quelle invisibili di Italo Calvino né quelle visionarie di Fritz Lang. Sono quelle attuali, viste e abitate con una prospettiva più efficiente, al contempo tecnologica e creativa, soprattutto partecipata (Mattei, 2013, p.9).

Considering this new design paradigm when developing new ideas in the cultural sphere would make it possible to achieve some of the goals set by the various global development programs, such as that of social inclusion, an essential imperative for a democratic, advanced and diverse society such as ours. Applying to cultural heritage what Maria Grazia Mattei calls the smart city paradigm, i.e., "where the material hardware of urban territories works in symbiosis with the immaterial software of digital technologies and social networks for the improvement of people's lives," means proposing a different way of reading cultural heritage and designing new systems that are both sensing, i.e., able to collect information, and acting, i.e., able to process this information and produce responses (Ratti, 2014). This approach involves bringing together different disciplines, namely those traditionally related to space (architecture, planning, design) and those related to technology (engineering, computer science, electronics).

Another focus of DfA is to include people in the creative processes in order to understand needs and desires. This is even more relevant when considering the field of Cultural Heritage since, as we have seen, it is closely linked to the past of places, objects and people, who are active participants in identifying value and preserving history. By now it is clear how the figure of the designer cannot be an expert in everything, as was the case in the Fordist model, but today it is essential to respond to the social and cultural diversity in which we live through the involvement of experiencers.

The international trend to democratize museums and other cultural places, with a view to making them more accessible and more open to the needs of the users and potential users, comes from their being connected to the community in which they are embedded and whose values and ideologies they reflect. This proposes the creation of spaces in which all actors in society can interact, opening up to new ways to experience cultural heritages (Delgado, 2009).

In fact, rethinking museums as places of integration and intercultural dialogue increases awareness of multiple identities in the surrounding reality, helping to break down dangerous stereotypes and build a more tolerant and open environment even outside the museum walls. Therefore, museums have an obligation to guarantee democratic participation by ensuring access to all, regardless of age, ability, religion, preferences, etc., also because through knowledge of the past we can interpret the present and act consciously for a better future.

Applying DfA to CH design means committing to recognizing people's diverse identities and reversing inclusion policies based on social models of disability, which often view people with disabilities as a homogeneous community with the same needs and similar perspectives.

4. Digital humanities and the disintermediation of the designer's role

At the end of the 20th century, with the digital revolution, we learned to create greater data structures than any previous era. This computational power and ease of storage began to be used during the century in the field of cultural heritage as well. At first with the purpose of cataloging data, later with the goal of digitizing processes, enabling new ways of working, opportunities for study and forms of enjoyment (Longo, 2017). Indeed, the use of tools such as extended reality, artificial intelligence, and big data change both the approach of cultural heritage users and the work of experts. With innovations in Computer Science, a branch called "Digital Humanities" has developed, representing the intersection of ICT (Information and Communication Technologies) and the humanities (Bellotti et al., 2013). The scientific community has adopted it in the field of cultural heritage, giving rise to new definitions such as "Virtual Heritage" or "Digital Cultural Heritage" (Addison, 2001), which include those solutions addressed to recordation, documentation and visualization (Ruffino, 2018).

The director of Harvard University's metaLAB, Jeffrey Schnapp, speaks of digital humanities as an area of research that studies the impacts of the digital on various aspects of culture. Through the definition of new collective and bottom-up models, it addresses the contemporary scenario of images, information, and sensoriality, activating a process of disintermediation of the role of the designer, understood today as part of a complex process of dialogue between practices and thought (Longo, 2017). The development of digital technologies and the definition of design related to experience design, has contributed to changing the Cultural Heritage scenario through the introduction of material, immaterial and digital practices that allow access to information in a differentiated way that meets different needs. Some well-established technologies are, for example, the cameras of smartphones, which today allow recognizing buildings and works of art and receiving information, videos, interactive materials about it. Similarly, the support of augmented and virtual reality makes it possible to create 3D copies of objects, documents, buildings, to allow reaching those cultural goods inaccessible for different reasons.

The use can be extended to professionals who, thanks to the use of Machine Learning can delegate those complex or repetitive actions, as in the case of research in archaeology that involves many comparisons and consultations of data (Longo,2017).

Figure 1 - Image made through artificial intelligence “Midjourney” with the prompt: “Modern cultural heritage inclusive and accessible for all kind of people”.

5. Conclusions

It is imperative to educate the new generation of designers on the issues of inclusion in relation to the perspectives and problems related to the accessibility scenario of cultural heritage, where technologies play an emerging role.

Accessibility is an indispensable key to the enhancement of cultural places. To implement it, it is necessary to radically change the concepts of museums and cultural heritage: they are no longer just places of "conservation"' but dynamic elements in which a dialogue with the user is triggered. Fundamental places for cultural growth, where usability does not represent the right of the disabled person, but an added value for the community, capable of triggering virtuous pathways that amplify the understanding of the importance of tangible and intangible cultural assets.

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Healing environment: the impact of physical environment on patient outcomes

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Abstract

Contextual factors refer to the physical, psychological, and social elements surrounding the therapeutic encounter. They can influence patient outcomes based on how patients interpret them. Specifically, if they are interpreted positively, a placebo effect will arise. Otherwise, a nocebo effect will occur. Contextual factors encompass patients' and healthcare professionals' characteristics, therapist-patient relationship, treatment characteristics and physical environment. Once the physical environment positively impacts patient outcomes, it is called a 'healing environment'. There is an increase in research investigating the impact of the environment on patient outcomes, bringing to the forefront its psychological and physiological effects not only on patients but also on their relatives and healthcare professionals. Some studies suggested the impact of the environment's lighting, view, colour, artwork, noise and music, sense of control and social support on patient outcomes. For example, the design of the Good Samaritan Hospital (Cincinnati, Ohio) neonatal intensive care unit was able to reduce cost, decrease the rate of some diseases and increase the satisfaction of families by taking into account some healing environment characteristics. These preliminary findings underscore the need for further exploration of the effect of the physical environment on patient outcomes.

1. Introduction

The care process is a complex psychosocial context (Battista *et al.*, 2022) characterised by various contextual factors. Contextual factors are physical, psychological, and social elements that can evoke patients' expectations, memories, and emotions during the therapeutic encounter.

How these factors are interpreted can impact patients' outcomes and the specific effect of the provided treatment (Rossettini *et al.*, 2018). Positive (negative) contextual factors can reduce (increase) patients' symptoms through a placebo (nocebo) effect (Rossettini *et al.*, 2018). Some of the most studied contextual factors include patients' characteristics (e.g., expectations, treatment history, baseline pain severity), healthcare professionals' characteristics (e.g. behaviour, beliefs, reputation), the therapist-patient relationship (e.g. verbal and non-verbal communication), treatment characteristics (e.g. overt therapy, observational learning, patient-centred approach), and physical environment (e.g. architecture and interior design) (Testa & Rossettini, 2016).

When the environment is intentionally designed to promote healing, it is called a 'healing environment' (Hesselink *et al.*, 2020). In the 19th Century, Florence Nightingale posited that environment characterised by natural light, good ventilation, warmth, cleanliness, and basic sanitation would promote faster patient recovery (Nightingale, 1989). In the 1970s, the appearance of hospitals became a crucial marketing strategy as consumers began to consider this factor when selecting a hospital (Altimier, 2004). Then, Burge proposed the "Sick Building Syndrome" (SBS), consisting of symptoms (i.e., mucosal, skin, and general symptoms of headache and lethargy) of unclear aetiology related to working in buildings with poor indoor air quality. This syndrome reduces workers' productivity while increasing absenteeism (Burge, 2004).

Finally, it has been shown that controlling environmental elements, such as views of nature, natural light, soothing colours, and therapeutic sounds, can minimise healthcare professionals' errors and reduce stress (Altimier, 2004). All the findings mentioned above led to the development of the so-called 'evidence-based design', which has its roots in the work of Ulrich (Ulrich, 1984).

Specifically, he noticed that patients recovered faster once exposed to a window with a natural setting view compared to those exposed to a window with a view of a brick wall (Ulrich, 1984). Nowadays, more and more findings posited that specific characteristics of the healing environment might influence patients' outcomes, which are discussed hereafter (Fig. 1).

2. Lighting

Artificial light might cause headaches and visual fatigue. Therefore, softening the lighting could promote a healing environment (Altimier, 2004). Daylight seems to have positive effects on people's physiology and psychology. Physiologically, natural light could increase protein metabolism, decrease fatigue, stimulate white blood cell production, increase endorphin release, and decrease blood pressure (Ott, 1987).

In addition, natural light indicated an improvement in sleep quality and circadian rhythms while attenuating agitation (Joseph, 2006). Psychologically, daylight appeared to be effective in decreasing depression (especially the morning light) and stress and increasing attention and well-being (Iyendo *et al.*, 2016; Joseph, 2006; Walch *et al.*, 2005). Conversely, cognitive disorders can occur in the lack of natural light (Iyendo *et al.*, 2016). Other studies saw that daylight also affects the lengths of recovery and mortality. Patients in brightly lit rooms tended to have shorter hospital stays and lower mortality rates than those in dimly lit rooms (Beauchemin & Hays, 1996, 1998).

Finally, natural light is crucial for healthcare professionals, as natural light seems to boost morale and productivity while reducing medication errors (Buchanan *et al.*, 1991; Iyendo *et al.*, 2016).

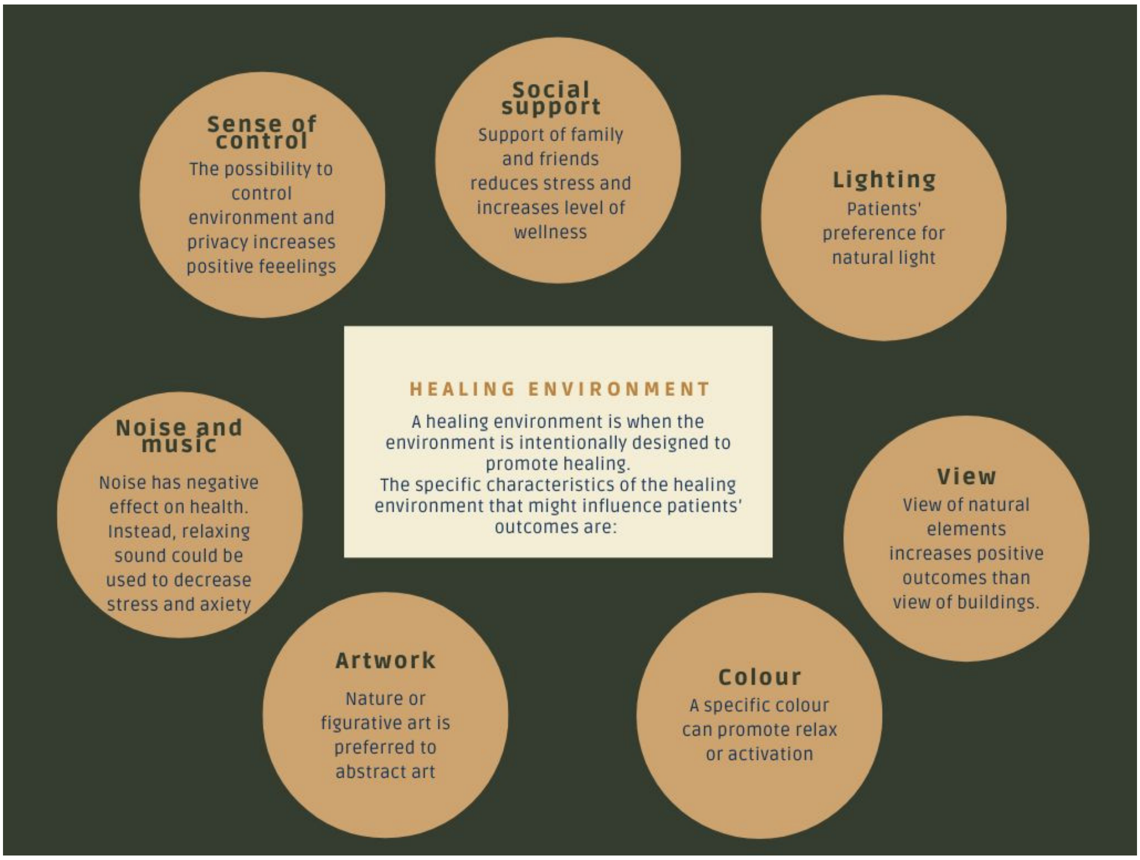

Figure 1 - The healing environment and its specific characteristics that could increase patients' outcome are described. Image by the authors.

3. View

As mentioned above, the first research of Ulrich reported that patients hospitalised in a natural view room view (e.g., trees) had a quicker postoperative recovery and took fewer pain drugs than patients with a brick wall view (Ulrich, 1984). Other authors supported that patients and healthcare professionals preferred a window view characterised by natural or daily outside human activities elements (Verderber, 2016). The connection with the outer world offered by windows is considered an excellent distraction for patients (Hesselink *et al.*, 2020).

Additionally, viewing natural elements tends to increase well-being and positive outcomes and reduce stress and post-surgical complications (Velarde *et al.*, 2007). If a natural view is not possible or windows are not present, patients and healthcare professionals prefer natural images or projections to architectural features or monotonous views (Hesselink et al., 2020; Huisman *et al.*, 2012). A study conducted in an intensive therapy unit highlights the importance of windows. Patients in windowless intensive therapy units were less time oriented and had less accurate memory about their hospitalisation length (Keep *et al.*, 1980). Different findings are reported in a study conducted in warmer climates (e.g., Malaysia), where patients asked to be placed away from windows to avoid the heat. In this case, a tinted glass was suggested to keep out the warmth while maintaining the external view (Arpin, 2007).

4. Colour

In healthcare facilities, colours help with wayfinding and orientation through images and signals (Rousek & Hallbeck, 2011). But colours also have a particular meaning for many individuals and could evocate emotional states and physiological responses. Colours could promote relaxation and sleeping (i.e., ‘cool colours’ such as blue and green) or physical and social activity (i.e., ‘warm colours’ such as red, orange, and yellow) (Gulak, 1991). Waiting rooms for children should be colourful and full of tactile elements to relieve tension and catch the attention, becoming a distractor from the cause of suffering (Dalke *et al.*, 2006).

5. Artwork

Artworks representing nature or figurative art appeared to distract from the pain, reduce stress, anxiety and pain and increase healing outcomes (Ulrich *et al.*, 2008). On the other hand, artwork depicting negative evolutionistic stimuli could produce adverse reactions (Ulrich *et al.*, 2008).

6. Noise and music

According to the World Health Organisation (WHO), noise levels should not exceed 30 dB. Still, usually, the average noise level is much higher and might have a negative impact on health, leading to sleep disturbance, aggressive behaviour, altered memory, increased agitation and less tolerance for pain (Short *et al.*, 2011). In the healthcare setting, the noise source could depend on alarms, monitors, human chatter from workers, patients and visitors, movement of beds and equipment, building design and sound absorption materials (Short *et al.*, 2011).

Long-term noise exposure can impact patients and healthcare professionals, producing negative physical (e.g., hypertension, changes in blood pressure and heart rate) and psychological (e.g., depression, burnout, exhaustion, and irritability) effects (Penney & Earl, 2004).

Noise also affects communication between healthcare professionals and patients, making communication challenging, especially with older people (Joseph & Ulrich, 2007). Instead, relaxing sounds (e.g., birds and water) could act as distractors and be included in a healing environment to facilitate the healing process, improving patient outcomes (Iyendo, 2016). Music has been shown to reduce patient's anxiety and stress before, during and after surgery (Laursen *et al.*, 2014).

Additionally, it has been proved that music can improve mental illness, psychological problems, social cognitive performance, communication skills, and sleep quality (Iyendo, 2016). Besides, it can reduce anger, pain, tension heart rate in different populations (e.g. cancer, cardiac and traumatic brain injury patients) (Iyendo, 2016).

7. Sense of control

Patients who perceive greater control feel secure, informed and valued (Iyendo *et al.*, 2016). However, one of the major problems in the hospital setting is the patient's lack of control (Huisman *et al.*, 2012).

The sense of control can be promoted by controlling privacy and through different environmental factors (e.g., light, sound, temperature) (Hesselink *et al.*, 2020). In addition, giving a choice over nutrition is another possibility to increase sense of controls in patients (Hesselink *et al.*, 2020).

Finally, making control devices easier to access and specifying the urgency level on the nurse call button is the last way to increase patients' sense of control (Hesselink *et al.*, 2020).

8. Social support

Contact with family and friends, who are helpful, caring, and supportive, improves patients' outcomes. Patients with higher levels of social support experience less stress and a higher level of wellness (Ulrich, 1997).

To promote social support, it is essential to ensure privacy for patients. Patients in single-bed rooms felt more secure and able to control social interaction than patients in four-bed rooms (Firestone *et al.*, 1980).

9. An application example

A work conducted at the Good Samaritan Hospital in Cincinnati, Ohio (Altimier, 2004) focused on renovating the neonatal intensive care unit (NICU). The aim was to upgrade service, add space and create a home-like atmosphere.

The ceilings were raised to make the area appear larger, and lavender and teal tones were used to illuminate the space. In addition, an alarm has been inserted when 55dB is reached, not to exceed the maximum noise level. Attention was also given to bed arrangements and traffic patterns. Creating a new design focused on a healing environment helped to improve patients' outcomes. Rates of severe retinopathy decreased by 6% in two years period. Rates of severe intraventricular haemorrhage decreased from 11% to 3%. The saved costs related to the length of stay were estimated at $13,114,000 per year.

Finally, the family satisfaction score increased, including families in the medical round and shift changes. The parents' interaction with their babies improved the caretaking on discharge and decreased the stress during the stay. Though we cannot conclude whether this is a direct effect of the environment per se, this finding justifies further exploration of this phenomenon.

10. Future perspectives

The studies in neuroarchitecture are now divided into two categories: stationary paradigms and mobile paradigms (Wang *et al.*, 2022). The stationary paradigm presents static visual stimuli to immobile participants in a controlled laboratory or a scanner. It uses methods such as magnetoencephalography (MEG), electroencephalography (EEG), functional resonance imaging (fMRI), psychophysiological measures (e.g., Galvanic Skin Response), and eye-tracking (ET). The experimental control is high in these settings, but the ecological validity is low (Wang *et al.*, 2022).

In the mobile paradigms, the participants actively experience the real or virtual environment, which allows for a better understanding of the perception and interaction with the built environment (Wang *et al.*, 2022). However, the negative side of mobile paradigms is the recording noise due to environment and movement-related artefacts (Gramann *et al.*, 2021).

An example of a method adopted in these paradigms is Mobile Brain/ Body Imaging (MoBI) (Wang *et al.*, 2022). Stationary and mobile paradigms are complementary and can contribute to a deeper understanding of how the architectural environment affects the human brain (Wang *et al.*, 2022). It would be interesting to introduce these two paradigms in the study of healing environments to give objective measures in future studies.

11. Conclusions

healing environment is a physical environment considered part of the healthcare process. To build a healing environment, different characteristics of the environment need to be considered.

These characteristics (i.e., lighting, view, artwork, colour, noise, music, sense of control, social support, and privacy) are not just simple elements of architecture or design but seem to impact patient outcomes if controlled positively. Specific architectural features seem to influence psychological (e.g., anxiety and depression) and physiological (e.g., blood pressure) variables. In addition, they also seemed to affect healthcare professionals and patients' relatives positively.

Finally, environments designed for healing might reduce the healthcare process's cost.

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Space, vision and aesthetic. When form follows emotion

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What happens within us when we enter certain architectures, perhaps even iconic buildings? Why are some of them able to move us? Can they really influence our physical and mental wellness, transmitting, as Alan De Bottom would say, a positive state of mind? According to the noted writer and philosopher, architecture, even the noblest and most emblazoned, «can sometimes do less for us than a siesta or an aspirin» (De Bottom, 2006, p.15) and «even if we could spend the rest of our lives in the Villa Rotonda or the Glass House, we would still often be in a bad mood» (De Bottom, 2006, p.16).

Today, De Bottom's cultured disquisition dating back to the early aughts, based on a wealth of case studies, joins an increasingly respected consideration — supported by research in the cognitive sciences, not to mention field evidence — of how the built environment impacts perceptions, emotions and capacities for interactions between human beings, not as a race but as individuals. According to recent neuroscientific studies, which link the everyday experience to multi-sensorial perceptions and the way in which those are transformed into empathy and complex behaviors, all of these processes — whose mechanisms architects have long intuited — find their underlying foundation in our nervous system.

To understand the phenomenon, we have to disrupt neuroaesthetics, a branch within the neurosciences whose interdisciplinary approach connects fields that have long been considered separate, such as science and humanities. This approach looks to the future and stems from the consideration that the human body — when speaking of architecture — is a sensible entity and no longer solely an element for measurements. The invitation, extended to designers and architects, is to explore new interactive technologies as creative tools helpful in determining the aesthetic and function of the inhabited space in response to the emotional component of those who will move, look and touch within it, seen through its subjectivity.

First and foremost, then, are the five senses, which «are not passive recorders, but the result of interaction between mental modules that communicate with one another and in which each sensory impulse itself becomes syncretic with all others: a world of sounds, colors and sensations where synesthesia and integration create the colorful multi-sensorial reality in which we operate» (Buiatti, 2014, p.11).

Before continuing, I must mention, with regard to theories that can be translated into innovative design practices through osmosis and transitive properties, the work of Semir Zeki beginning in the 1990s, a professor of neurobiology at the University College of London considered a pioneer of modern studies on the visual brain, whose research based on the relationship between aesthetic and vision gave life to the aforementioned field of neuroaesthetics. Coined in 1999, the term indicates the field of experimentation that engages the cognitive sciences and aesthetics, applying a neuroscientific approach to the analysis of the experience linked to the production and enjoyment of artworks.

In other words: an inquiry aimed at understanding what is set in motion within the human brain, searching for «an understanding of the biological basis of aesthetic experience» (Zekir, 1999, p.189).

The results have allowed us to enter the cognitive processes and understand the neural mechanisms that connect the senses to emotional, creative, cognitive and operational states of the human brain. As a scientist, Zeki was among the first to have initiated the process of theorization — which is still ongoing — that affects, by extension of the method, the disciplines of architecture and several interesting applications that we will discuss later on. The topic, considering the contemporary experimentations aimed at responding to the needs of an evolving society, is part of a broader picture that places wellbeing at the center of a renewed interest.

We are talking about relationships between interior architecture and the human body, understood in its entirety of both mind and physique.

The genesis of this — in respect to the issues we would like to introduce — can easily be traced back to modern examples cited by Beatriz Colomina in an essay from the volume *Anybody* (Davidson, 1997) before landing on a very recent project (from which this paper was partially born) carried out by a giant of online services working on personalized neuroaesthetics.

That said, to speak of the body, as Fernando Pérez Oyarzun claims, is to speak of something dynamic in both time and space, whose perception is constantly changing along with physical conditions, contexts and gestures. Above all, it means to speak of «a multitude of bodies and the multitude of understandings and representations that surround them» (Pérez Oyarzun, 1997). Among these, without a shadow of a doubt, is the world of science, whose connection with interior architecture and furniture design, especially when speaking of medicine, is nothing new.

Referring once again to the text by Colomina (Colomina, 1997), we need only look at the experiences of two vastly different architects like Le Corbusier and Frederick Kiesler, whose thoughts are intertwined on various occasions with the topic of health — including mental health. It was the early 20th century, coinciding with an obsession for the healthiness of domestic architecture, evoked through constant concern for social hygiene, correct ventilation and sun exposure. Le Corbusier writes at the beginning of *Toward an Architecture*: «men live in old houses and they have not yet thought of building houses adapted to themselves. [...] Engineers fabricate the tools of their time. Everything, that is to say, except houses and moth-eaten boudoirs» (Le Corbusier, 1984).

Not long thereafter — entering the era of sanatoriums, from that of Alvar Aalto in Paimio to José Luis Sert's anti-tubercular dispensary in Barcelona — there is sickness and a debilitation of the body. It's a body that, as Colomina points out, is not just physical, referencing, as proof, writings published by doctors Alendy and Laforgue in the magazine *L'Esprit Nouveau*, evidently referring to the intertwining of psyche and body, which dealt with Freudian psychoanalysis and French psychiatry (Colomina, 1997, p.235).

After all, Le Corbusier himself spoke repeatedly of an intimate relationship between the body and mind, and how new homes should be machines for the recovery of our physical and nervous energy. Kiesler, for his part, described man as a «complex biological, psychological and socio-political being who has to restore the general and complex meaning of living through creativity» (Bottero, 1999, p.10) introducing the concept of psycho-function by linking various colors and materials (glass, leather, wood, metal) to different psychological effects. The emphasis is to meet the needs of inhabitants, whose bodies cannot be separated from the mind. In doing so, the home becomes «a place to regenerate the vital forces and therefore a product of the daily and metabolic activity of those who inhabit it» (Bottero, 1999, p.10).

In respect to the functionalist dogmas of the International Style, it represents an interesting critical position, expressed for the first time by Kiesler in 1949 through the essay *Pseudofunctionalism in Modern Architecture*, aimed at undermining the theory of the standards — the very same promoted by Le Corbusier who maintained that needs were identical for all humans who «from the earliest ages we know, were all made from the same mold» (Le Corbusier, 2015, p.112).

Kiesler, on the other hand, speaks of emotions and dreams belonging to the single individual. This leads us back to two simultaneous instances that we'd like to introduce here as generators of possible ideas for the design of interiors — and not only domestically — imagining a red thread that links the recent past with the present, considered a stage for innovations, especially of the technological variety, which give new meaning to what has already been experienced.

This is because our body has always been intimately connected to the architectural body through a series of relationships that are manifested with greater or lesser evidence depending on the cases and eras — something both ancient and variable. Occasionally, like now, the body reclaims its own importance within the architectural landscape more than in other periods, testifying to the depth and permanence of this connection.

The first instance, which has to do with individuality, concerns the issue of the on demand, specific to digital culture: a service provided on request, tailored to the user, of which platforms like Netflix for TV, Spotify for music, and Flipboard for publishing are the most widespread examples. Since aesthetics is a personal matter — meaning different things for different people — there is, according to neurasthenics, no one-size-fits-all answer to the wellbeing of those who inhabit the spaces.

The second instance refers to the emotional sphere, a field of neuroscience used to prove, through demonstrable data — and this is where another distinctive aspect of the contemporary world comes in with big and small data — that design is not just a matter of aesthetics but something that affects our wellbeing. It makes little difference whether it's home interiors, hotels, offices or nursing homes — where in reality this issue is in full swing — the question is: why does a room, or an environment, inspire us while another induces lethargy or anxiety? And how does our daily aesthetic experience inform our physiology?

This is where, speaking of methods, subjective human perception interpreted to create spacial narratives with colors, materials, patterns, textures and shapes flanking traditional design can intervene as a modern atout. Why, then, not try to harness these results to understand how to improve our way of living within interiors? And once an interior has been set up, how do we gather that information? Some studies rely on in situ assessments of people's reactions, measured by wearable devices that mark physiological reactions. There are also smartphone applications exploring the emotional state, and electroencephalographic headsets that detect brain activity related to mental states and mood, all to assess physiological wellbeing in relation to space and to understand how design can influence our bodies. This is what Google presented in Milan during the Salone del Mobile 2019 at the *A Space for Being* installation hosted in Spazio Maiocchi, spearheaded by Vice-President of Hardware Design Ivy

Ross and developed by applying the principles of neuroaesthetics to the interiors of domestic contexts in order to analyze and study how the mind and body respond to different stimuli of a physical and visual experience[1].

At the center of the experiment sits the interior design of three rooms, characterized by exact proportions, colors, lights, textures, music, artwork and materials, all distributed along a single path. In order to evaluate the personal reaction to individual rooms, each visitor was provided with a wristband designed by Google Hardware and the Advanced Technology & Projects Division, equipped with four sensors programmed to record physiological responses based on heart activity, respiratory rate, skin conductance, temperature and body movements. Each of the rooms was set up with a customized design, featuring subtle but intentional differences implemented to make people feel comfortable.

The spaces were curated by a team formed between Suchi Reddy of the US-based architecture firm Reddymade, and Susan Magsamen, founder and director of the International Arts + Mind Lab at John Hopkins University in Baltimore, a trailblazing research center for neuroaesthetics founded in 2016, whose contribution within the three set ups was fundamental in understanding how to better explore the effects of design on human biology. In order to limit the variables that might affect the results, organizers decided to outline all the spaces like living areas in a house, using the Scandinavian designs of Muuto for furnishings. The first room, *Essential Room*, was defined by soft, almost uterine shapes, warm materials, soft lighting and the smell of burnt wood; the second, *Vital Room*, featuring dynamic lighting, housed brighter, even playful hues, and a vibrant citrus scent; the third, *Transformative Room*, designed with soft lighting and higher walls, explored lighter tones complete with a series of mirrors and a musky aroma. Before starting the tour, and even before passing from one room to the next, is a neutral “preparatory” space to recalibrate the visitors’ senses.

The experiment, in which I participated as a guest, consisted of inviting a few people at a time, gathered in small groups, to explore the rooms by moving around within them, touching materials, sitting on sofas or around tables, and flipping through books, spending five minutes of their time without using cell phones or conversing. Upon exiting, every visitor, after placing their respective wristband on a tray, received a visualization of their data processed by an algorithm capable of reading the biomarkers, which displayed their lived experience in the three rooms, rendering the invisible visible.

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[1] Cfr. Valenti, A. (2019). *Welcoming (Interior) Architecture: l’ospitalità on demand come emozione*, «Area», (165)2019. https://www.area-arch.it/ (visited on November, 5, 2019).

The data was represented through a circle marked with watercolor ink blots, which were nothing more than a clock-like mapping of their five minutes spent in each room. The colors of the circle — each with a customized report — lit up when the person had more active moments based on their biofeedback, or faded away when they registered a calmer phase. Also included in the personal results was a list of the elements present in each environment with which everybody felt better.

The purpose of the entire operation was to show, at the end of the sensorial journey, which of the curated spaces was aligned with the senses, regardless of taste or style. It was then revealed that, according to the data, it wasn't uncommon for someone to feel the most comfortable and relaxed in the room they seemed to like the least.

In examining this discrepancy, an interesting phenomenon emerges, prompting us to reflect on the fact that what our mind believes is not always what our body feels. Of course, when entering into an architecture whose aesthetic satisfies us, perhaps we are more inclined to say that it's our favorite space, or that we feel more relaxed there, only to discover that, in reality, our body is telling a completely different story from the mind. Today, it seems neuroscience is capable of demonstrating that we can positively condition our mind and body through interior design and the objects we choose. It is a matter of awareness that redesigns and updates the map of potential relationships between the body and architecture, charting ulterior trajectories.

For Ivy Ross, this is the future of what can be called mindful, well-thought, or even customized design; for Suchi Reddy, who along with IAM Lab and the Kennedy Krieger Institute of John Hopkins is designing treatment rooms that use neuroaesthetics to help children heal and recover, this is an opportunity to replace the popular modernist mantra form follows function with the more sensorial form follows feeling.

For both, surely, the project presented in Milan is just the beginning of a journey that marks new further practices that could engage interior architecture in unique ways. In addition to designing multi-sensorial rooms, Reddy maintains that «the field of neuroaesthetics has far-reaching effects. It can transform the way in which we even think about how our cities are built» (Dickinson, 2019). Will things really head in this direction? Will we make choices in tune with our physiology? Well aware of the fact that «the present is difficult enough to grasp [and] anticipating the future seems inevitably doomed for failure, […] to those who object that predicting the future is a sterile exercise, we say (quoting Felix Burrichter) yesterday's dreams of tomorrow have long fueled current attempts to construct the present» (Burrichter, 2017, p.22).

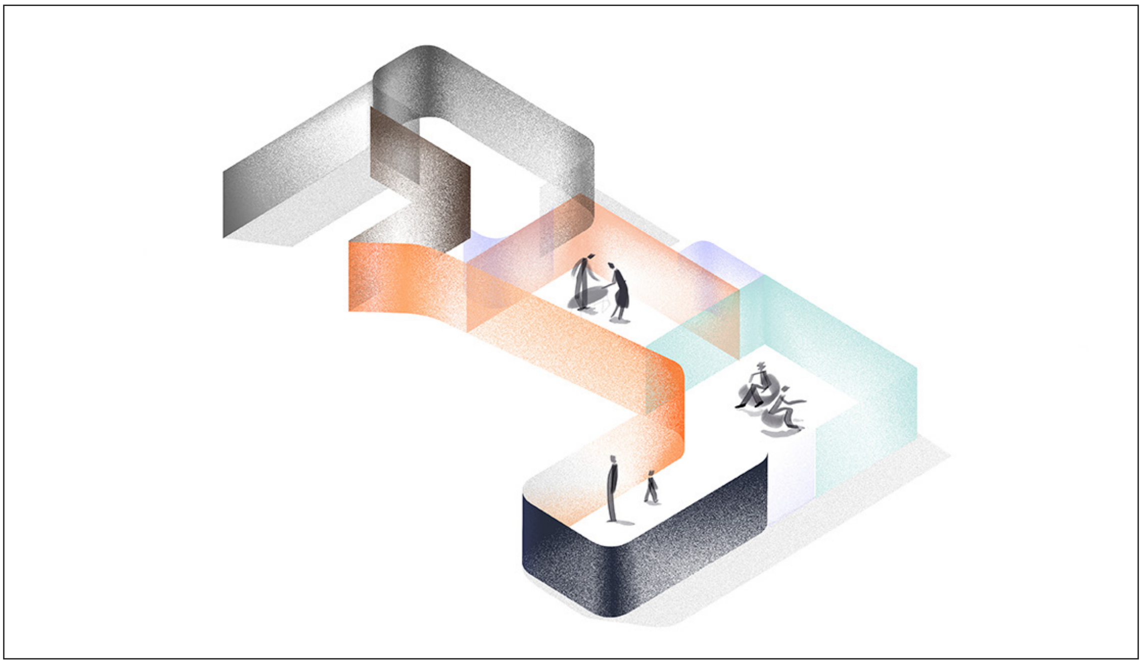

Figure 1 - In a multiroom installation at Spazio Maiocchi, A Space for Being explores the field of neuroaesthetics and how different aesthetic experiences have the potential to impact our biology and well-being. Each room will be unique in design, build, and furnishings, as co-created by Google's Vice President for Hardware Design, UX, and Research, Ivy Ross, in collaboration with Muuto's Design Director, Christian Grosen; Reddymade Architecture and Design Studio Founder and Principal, Suchi Reddy; and Executive Director of the International Arts + Mind Lab at Johns Hopkins University, Susan Magsamen. ©Courtesy Google.

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Afterword

The first IDEA symposium created the opportunity to compare hypotheses, procedures and design proposals in order to evaluate and understand the potentiality in creativity, visuality and perception.

In particular, it was a question of addressing the theme of the mechanisms of the creative process, as an essential starting point for conscious and targeted executive choices; to this end it was necessary to expand the disciplinary field, creating profitable relationships and exchanges with different fields, such as neurophysiology, psychology, critical design and so on.

This experience has already been partially addressed thanks to the participation of ciVIS, the interdepartmental centre of the university, and international collaborations, such as those with France and Spain, addressing the research "Investigating design in architecture" on the themes of the perception of architectural space; on creative imagination and mental models; on spatial relationships in architecture and the urban landscape.

This volume highlights the interest in these aspects and the subdivision into the three macro areas of reasoning on *Body, Mind and Emotions*; on *Technology and the visual perception of human beings*; on *Modelling and Living spaces*, makes us understand how the research path is full of possible insights, enhancements and new interpretations of only apparently consolidated and acquired topics: therefore, we are ready for IDEA 2024!

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The first IDEA symposium created the opportunity to compare hypotheses, procedures and proposals to evaluate and understand the potentiality in creativity, visuality and perception. This volume highlights the interest in these aspects and the subdivision into the three macro areas: *Body, Mind and Emotions; Technology and Human Perception; Modelling and Living Spaces*, shows that the research path is full of possible insights and new interpretations of only apparently consolidated and acquired topics.

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