idea

investigating design in architecture

2023 edition

edited by
Gaia Leandri

foreword by
Angelo Schenone

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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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Tel. 010 20951558 – Fax 010 20951552
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https://gup.unige.it

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

Linda Buondonno, Manila Vannucci, Carlo Chiorri, Andrea Giachetta

Università degli Studi di Genova
Università degli Studi di Firenze

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) .

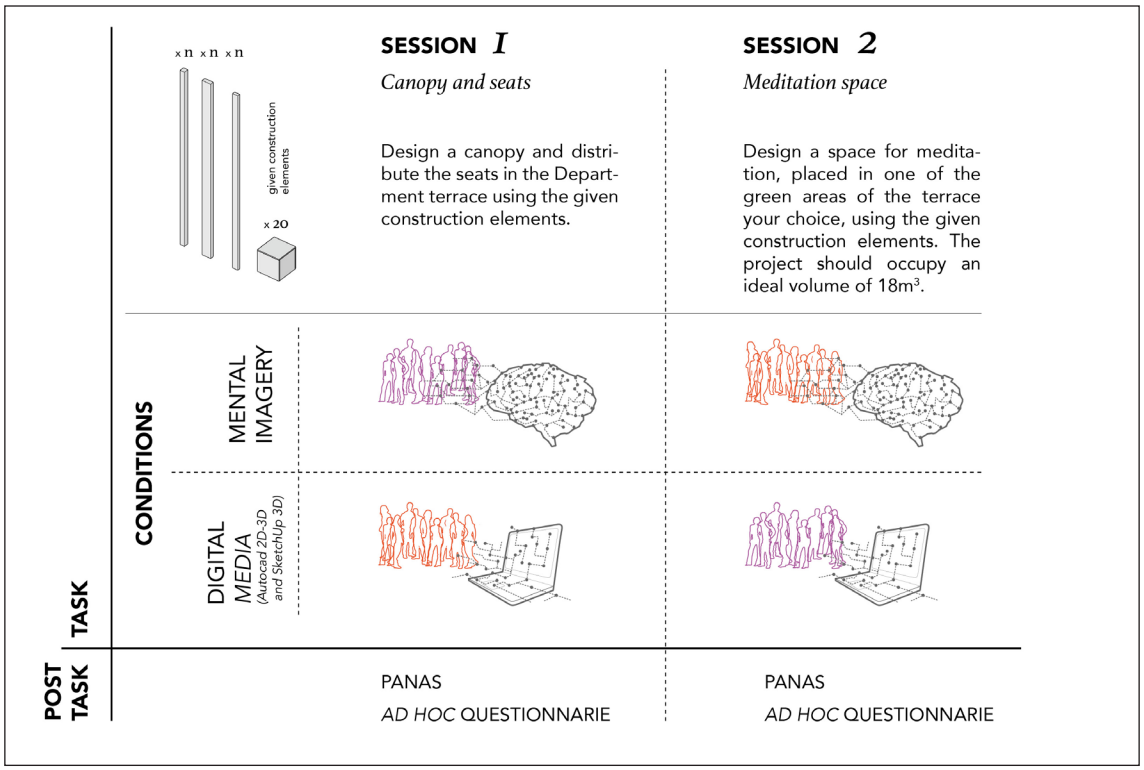

Figure 1 - A schematic representation of the experimental design. Imga eby the author.

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.

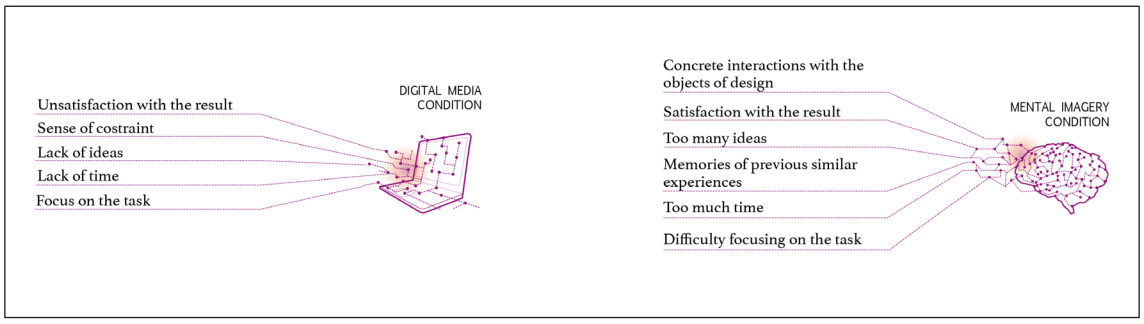

Figure 2 - Dimensions for which the difference in average scores was statistically significant. Image by the author.

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).

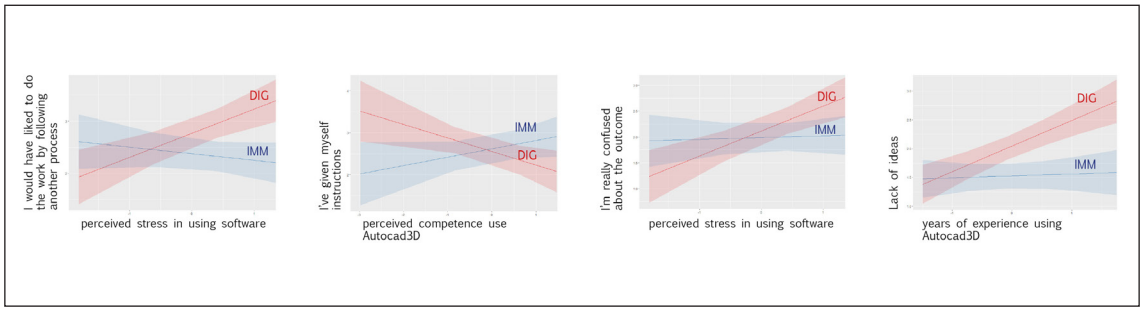

Figure 3 - Interaction effect. Selection of graphs. Image by the author.

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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