The benefits and challenges of AI image generators for architectural ideation: Study of an alternative human-machine co-creation exchange based on sketch recognition

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This paper deals with creative co-design between human and machine. It presents an alternative design method based on an emerging technology of sketch interpretation to support co-creation and collaborative creativity in architecture. This technology embraces spontaneity in design by generating inspirational images linked to the architect's sketches.
Our research aims to determine the benefits and challenges of this alternative instrumentation. We are developing a Wizard of Oz test method by immersing several designers in a studio instrumented by this human-machine co-creation technology. We analyze quantitatively and qualitatively the single-designer ideation activity of these subjects. We then investigate the integration of this co-creation instrumentation within the framework of a team design involving several architects. This confirms known benefits such as speeding-up and freeing-up of ideation and highlights the need for designers to evaluate sketched ideas by means of images simulating their real-life rendering, as well as the need for inspiration to materialize the premises of ideas that are still vague.

Keywords: Architectural creativity, Ideation, Analogical reasoning, AI Image Generator, Co-design

1 Introduction

"Creativity is no longer considerate to be simply an innate ability (…). To that end, there are a range of theoretical models, (…), as well as plethora of support environments, strategies, and tools to support creative activity." (Casakin & Wodehouse, 2021, p. 2). More specifically, Casakin and Wodehouse (2021), in their systematic review of design creativity in architecture, argue that creative thinking is a key resource in architecture, and that it is currently becoming a priority in product design.

AI image generators such as MidJourney or DALL-E have recently been put forward as promising tools to support creative activity. They appear to extend creativity by presenting visual alternatives to building concepts, shape and aesthetics. These forms of intelligent technology establish a real collaboration between human and machine, serving/enhancing co-creation. And collaborative approaches are recognized for their creative potential (Casakin & Wodehouse, 2021).

In this context, we pose the following question: "What are the benefits and challenges of integrating AI image generators into architectural ideation, and how do these vary for different architects and teams?"

More specifically, we address the role of AI image generators in the activity of analogy-based ideation, and question the modalities of dialogue between the designer and these tools.
We begin by describing the general functioning of current AI generative tools and their known advantages and disadvantages (section 2).
We then describe the overall principle behind our proposed alternative (section 3).
We introduce the notions of creativity and analogical reasoning, key concepts in this research (section 5).
We then detail the method developed to identify the benefits and challenges of this human-machine co-creation instrumentation proposal (section 6).
Finally, we present our analysis of the results (section 7) and our interpretive comments (section 8).

2 *Current AI generative tools*

MidJourney (figure 1), such as those similarly developed[1], is a generative software producing collage images of high aesthetic based on text parameters entered by the user in a so-called prompt (Jaruga-Rozdolska, 2022). "The creation process is performed as follows: after entering the imagine command and key words – the so-called prompts – the user receives four draft results of an image generated based on those data. A decision can be made to develop them or create further variants based on them, if judged attractive in the first stage (low resolution and low quality). If none of the proposals meet with the expectations, it is possible to repeat the creation task based on the same key words and obtain different results (Jaruga-Rozdolska, 2022, p. 97). These text-to-image generators present some potential for creative design, but also some limitations.

Figure 1. Digital collage generated with MidJourney and the prompt: "modern concrete house by the lake" (Jaruga-Rozdolska, 2022, p. 97)

[1] As DALL-E, Latent Majesty Diffusion, NightCafe, Stable Diffusion, etc.

One of the challenges of creativity is to overcome the fixation problem (Casakin & Wodehouse, 2021), which is a phenomenon where designers get stuck on an idea or direction and ignore alternative concepts (Kannengiesser & Gero, 2019). In this sense, these AI image generators are a good help to creativity because they free the imagination by overcoming the limits of realism and physical constraints: the proposed image is inspiring without worrying about being realistic. These authors add that unconventional stimuli also enhance analogical reasoning and unconventional thinking. These stimuli therefore encourage creative thinking. For Beyan et al (2023, p. 59), "this technology makes it easy for architects to combine the abstraction of complex thought concepts into visible relationships in tangible design results. This idea inspires and encourages architect designers to explore more design alternatives from new perspectives."
Jaruga-Rozdolska (2022) also adds that these generators speed up the creative phases of the design process. On a practical level, these tools are quicker than a traditional search for inspiration in books or known built projects (Beyan et al., 2023; Radhakrisknan, 2023). And the high aesthetic quality of the visuals provided also contributes to facilitating ideation, the effectiveness of which is directly linked, as observed by Paananen et al. (2023), to the ability to represent ideas.

The first limitation of these generators is that they only produce concept sketches and not complete architectural designs, although their proposals have viable potential (Jaruga-Rozdolska, 2022). As observed by Paananen et al (2023), current AI image generators fail to generate floorplan drawings. However, these plans cover inspirational needs linked to the layout of different building spaces and functions.
Secondly, these generators work on the basis of prompts. The architect must therefore interrupt his design activity to draw up a prompt in order to receive the images. All this disrupts the subject's train of thought. Furthermore, the adequacy of the images received depends largely on the architect's awareness of his/her own needs as well as his/her ability to accurately formulate the prompt (Jaruga-Rozdolska, 2022; Paananen et al., 2023; Beyan et al., 2023).

3 Creative support proposal

Our proposal (figures 2 and 3) retains the forms of design aids exploited by text-to-image tools like MidJourney, but goes beyond their limits. The co-creation exchange is performed as follows: the architect designs his/her project by sketching his/her ideas as he/she goes along on a graphic table. These drawings are captured by the technological partner (i.e. our proposed instrumentation), who interprets them to extract the building's features and their semantic meaning. From this information, it searches for similar images or variants of the element being designed (e.g. zoning of first floor functions, an original staircase shape, a kitchen layout, etc.) on architectural image databases. It sends these images back to the designer, who decides whether or not to integrate them, and modifies his sketches accordingly, continuing to

design. If required, the designer can also directly encode the search keywords, but this is not the primary function. As the exchange between the architect and the technological partner progresses, mutual understanding is refined and the images become increasingly appropriate to his personal style and to the design object.

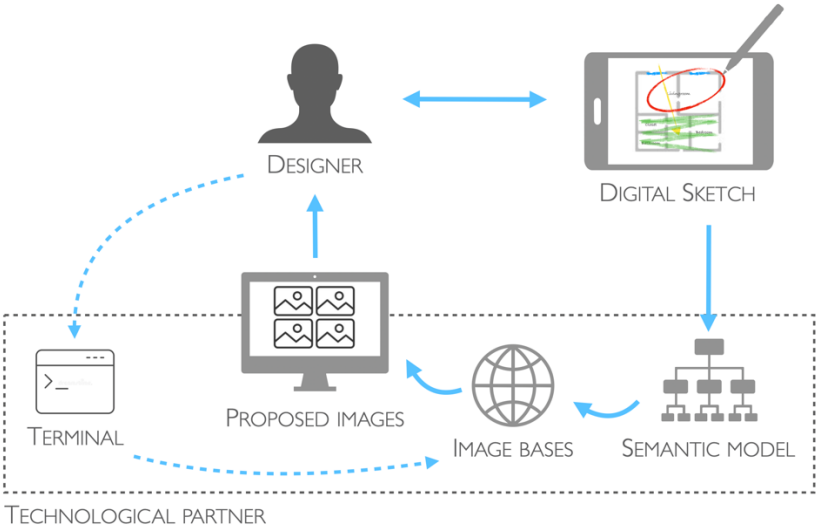

Figure 2. Schematic diagram of our proposal for a human-machine co-design creativity aid.

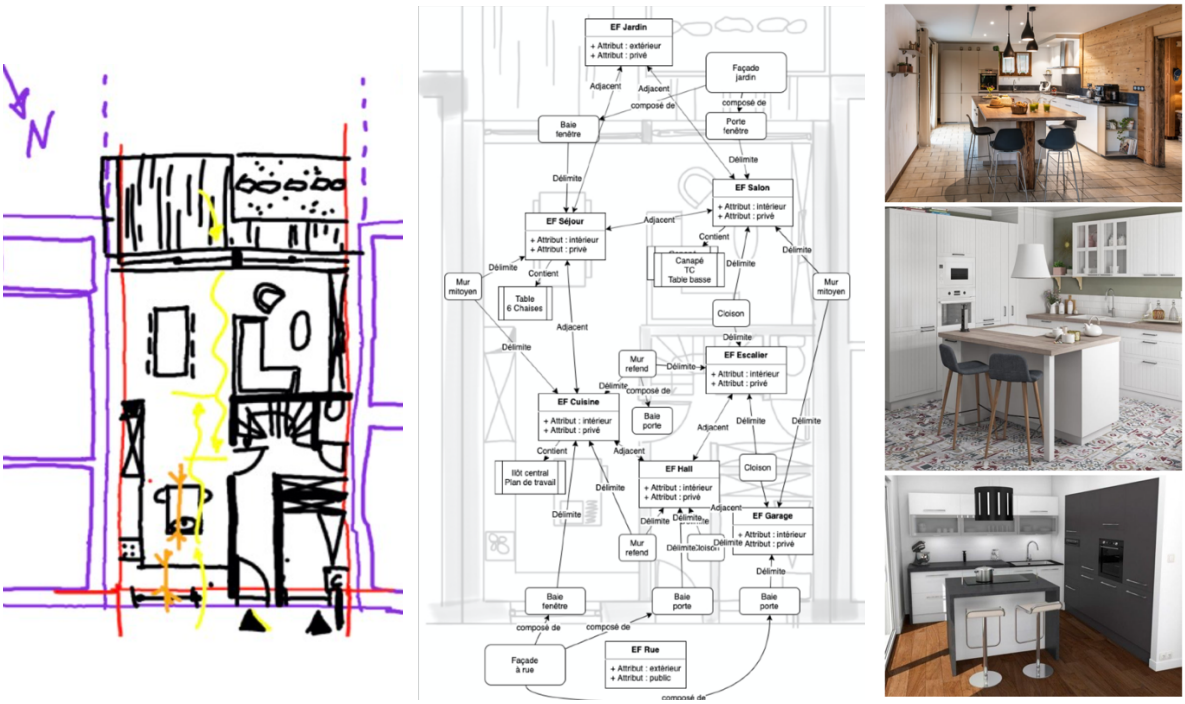

Figure 3. Theoretical illustration of sample project (left), with extractable meaning (center) and machine-provided images of the kitchen layout (right, from Google Image).

Our technological partner proposal remains in the same path as the AI image generator, since it consists of an inspirational image proposal (figures 2 and 3). However, it is based on recognition of the characteristics of the current project, rather than asking the designer to encode a prompt (the main limitation of current tools). In this sense, it feeds creativity without

interrupting the cognitive activity of design. It also offers images that go beyond the sketsh concept proposed by MidJourney, such as plans of similar buildings, photos of real ambiences relating to the project's characteristics, etc.
This technological partner acts as a co-designer, proposing ideas tailored to the current project, which the architect is free to implement or not. In this way, we are also exploiting the potential, recognized in the literature (Casakin & Wodehouse, 2021), of collaborative approaches to help creativity.
Moreover, Goldschmidt and Tatsa (2005) have shown in their study of ideation that the best ideas are those most closely linked to other project features. A tool that spontaneously proposes ideas directly linked to and adapted to the project under conception is therefore more likely to help design creativity.
Finally, these visuals, by being proposed spontaneously by the machine, constitute stimuli, which are thinking expanders (Choi & Kim, 2018).

4 Issue

Before developing this software, our goal is to test it in order to precisely identify its benefits and limitations when faced with the promise of AI co-creation.

5 Conceptual framework for creativity

Several concepts will be mobilized in our analyses and are therefore explained in this section.

First of all, **creativity** is a difficult concept to define with consensus due to its complexity. Moreover, identifying creative solutions is also difficult. It's only with a posteriori that an observer can identify the point in the design process where a creative idea has emerged (Dorst & Cross, 2001). For several authors (Gero, 1996; Dorst & Cross, 2001; Paananen et al., 2023), the literature nonetheless converges on the fact that creativity is the production of new and appropriate ideas, and that it requires skill and talent. Gero (1996) adds that this novelty must lead to an unexpected result. Al-Ababneh (2020) argues that, regardless of the discipline, creativity can come from an individual, but also from a process or a product. Gero (1996) emphasizes that what brings creativity into the design process is to act on the scheme of idea generation. Note that this supports the prospect of creativity-enhancing tools.
Creative activity covers three aspects: (i) creating something new through exploration, (ii) making a new combination from existing elements, or (iii) modifying an existing element by making variations of it (Radhakrisknan, 2023). This generation of ideas from existing elements involves the mechanism of **analogical reasoning**. It is an inductive reasoning that concludes that two objects of thought are similar. Our proposed instrumentation is based on this ideation mechanism.
In their study of analogical reasoning, Leclercq and Heylighen (2002) point out that it represents a potentially powerful design strategy, since it can bring

valuable knowledge from a known situation to the typically ill-defined architectural design situation. Reasoning by analogy takes on two roles in design activities (Ball & Christensen, 2019): on the one hand, identifying a potential new solution, e.g. being inspired by the façade of a building to choose an exterior cladding material, and, on the other hand, validating a proposal, in our example of cladding choice, validating the proposed material because its implementation has been possible and seems to be weather resistant on the neighboring building. The analogy also makes it possible to implement these solution generation and evaluation activities more quickly.

6 Method

To assess the impact of these sources of inspiration on creative design, we are conducting two experiments, with an identical protocol except that one will be carried out with a single-architect design, while the other will allow us to study the new challenges induced when we switch to a design team with several architects.

6.1 Simulation by Wizard of Oz

We instrument architects on the principle of the Wizard of Oz. This technique is regularly used in computer science and robotics to assess the impact of a technology on uses and users, and to study their interactions with the machine (Riek, 2012; Browne, 2019; Rietz et al., 2021). It has the advantage of not requiring prior development of the technology, since it consists of simulating, in real time and by concealed humans, the functionalities of the innovative software. It allows us to study in depth the use and integration of technology in our design activities.
We set up our experiment in two adjacent rooms (figure 4): a first room for the architect(s) and a second where the magician will work to provide the inspirational images. Thanks to a ceiling-mounted camera that frames the work desk, the magician can follow the design in the first room in real time. Every 5 minutes, based on the current project proposal, he/she searches for suitable inspirational images on databases such as Google Image, Pinterest or ArchDaily. He/she then sends them to the designers. It is also possible for architects to order other specific images, in addition to those spontaneously proposed by the technological partner, via an order terminal.

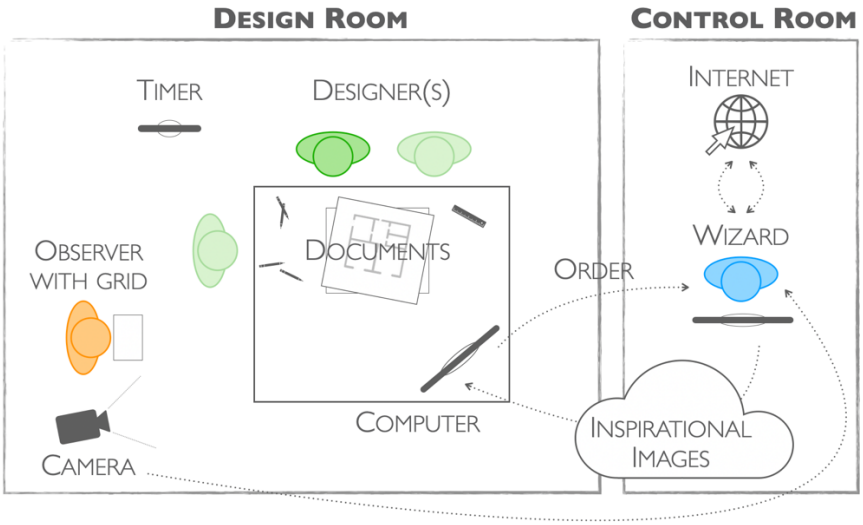

Figure 4. Wizard of Oz simulation protocol set up.

The design session lasts 1h30. During this session, we ask the designer to think aloud, expressing his/her design activities and feelings about the machine throughout the experience. At the end of the session, subjects are invited to present an oral synthesis of their architectural project (10 minutes), and then to give their feedback on the technological partner in a semi-directed interview (30 minutes). Nine professional architects took part in the experiment. The profiles of the subjects were intentionally chosen to be diverse. They include 6 men and 3 women, with 10±8 years of professional experience.

Following this experiment, we carry out a case study on a design team of 3 architects, designing with the help of the device, according to the same protocol. This team is made up of students in their final year of a master's degree in architecture. Note that, faced with the simple exercise chosen for the design capsule, they present the same level of expertise as the previous professionals.

6.2 Data collection

We carry out non-participant observations and collect our data using an observation grid. This observation grid includes a temporal indication of the different inspirational images proposed by the "software", and, as we needed to qualify the explicit analogies made with the proposed images, we build the grid according to these 6 descriptive criteria for analogies (Ben Rajeb & Leclercq, 2016):

- Its *matching*: whether it constitutes a transfer of idea without modification, whether it constitutes inspiration thanks to a common feature between the image received and the artifact produced, or whether it constitutes inspiration because an articulation of objects is taken up.
- Its *source*: does the analogy stem from document content, professional experience/knowledge or personal experience?
- Its *type*: whether spontaneous (in this case, proposed by the machine) or controlled (in this case, the result of an order placed by the subject).

- Its *mode*: evocation of the reference may be implicit or explicit.
- Its *role*: it can be a source of inspiration, or rather a source of evaluation.
- Its *use*: it's a success if it contributes to the project; a failure if it doesn't meet expectations; it can also be unused if it isn't implemented in the project despite its relevance; or it can be chained if it leads to a solution of the following problem.

These researchers scanned several works studying analogy and synthesized analogies' descriptive characteristics into these 6 criteria. These criteria have been tested on several editions of architectural design activity coding and analysis, and have shown their robustness.

In post-processing, based on the audio-visual recordings, we also list the moments when architectural elements from the proposed inspirational images are integrated into the architectural proposal of the design subject.

For the case study of a design team, we also need to code the various collaborative actions that occur. To do so, we again refer to the previous work of Ben Rajeb and Leclercq (2016) and code them according to the criteria listed in the table below. As with the qualification of observed analogies, these criteria have been tested on several editions of architectural design activity coding and analysis, and have shown their robustness and their ability to accurately translate observed collaborative actions.

Table 1. Criteria for analyzing collaborative actions, for team design case study (Ben Rajeb & Leclercq, 2016).

Type of collective action	Exemple
Inform	*Pass on information to others*
Get informed	*Listen to others or ask a question*
Report	*Assert something*
Act on the object	*Draw or graphically modify the project*
Decide by action	*Take action to validate a design choice*
Discuss	*Exchange ideas orally with others*
Validate	*Approve a design choice*
Impose decision	*Impose a design choice orally or graphically*

Thus, we collected 9 times 1h30 of mono-architect design and 2h of team design, i.e. 15h30 of analyzed activity, presenting a total of 186 exchanges of inspirational images with the Wizard of Oz, for 10 architectural projects conceived.

Finally, we use the think-aloud data collected throughout the design exercise and the semi-directed interviews conducted at the end of the experiment to complete our analyses and confirm our interpretations.

7 Results analysis

In this section, we respectively analyze the results of design sessions with a single architect exchanging with the technological partner (subsection 7.1), then those of the design session involving the team (subsection 7.2).

7.1 Detailed single-designer experience

Following is an overview of the images returned, in this case (figure 5) throughout the design capsule of subject 6. We can see that the images proposed become more refined and specific as the technological partner understands the designed project. This observation applies to all the subjects in the experiment. It confirms the adequacy of the proposed images, at the stage of a Wizard of Oz, to the sketches of the architectural project.

Figure 5. Summary, for subject 6, of the images proposed throughout the capsule (from the last, top left, to the first, bottom right).

First of all, we looked at the overall proportion of ideas derived from automatically-proposed images during the summary presentation of the architectural project: this was 23.63% on average. We also looked at the percentage of proposed images that were taken into account in the project design: 23.33% on average. With these rates of integration, we can say that the technological partner is a relevant and potentially rich aid to ideation. The subjects were in an environment that encouraged them to use the proposed tool, but they were also under pressure to design an entire presentable project in a short space of time. As architects are used to mobilizing a wide range of tools on a daily basis in their design activity, with this pressure, an ineffective or uninteresting tool would quickly have been left aside, even if it had been proposed as part of an experiment.

The interviews also show that the exchange with the technological partner and the sudden release of images do not disrupt the design flow. Indeed, on a scale of 1 to 4, the average rating of the level of disruption is 1.28, i.e. not disruptive at all. Subjects report that images either positively influence design by inspiring or helping them; or that they don't disrupt and are simply ignored if they appear at the wrong time. Some subjects also mention that it is the

relevance of the images to the project that makes them so undisturbing and useful.

We have also analyzed in greater detail the analogies made on the basis of the ideas proposed by the technological partner. These are summarized in the two graphs below. We noted a total of 34 analogies and 8 additional image orders. The graph on the left shows the distribution of the different criteria values describing the analogies made. The graph on the right details the roles and uses made of analogies according to whether they appear on images spontaneously sent by the machine or on images ordered by the designer.

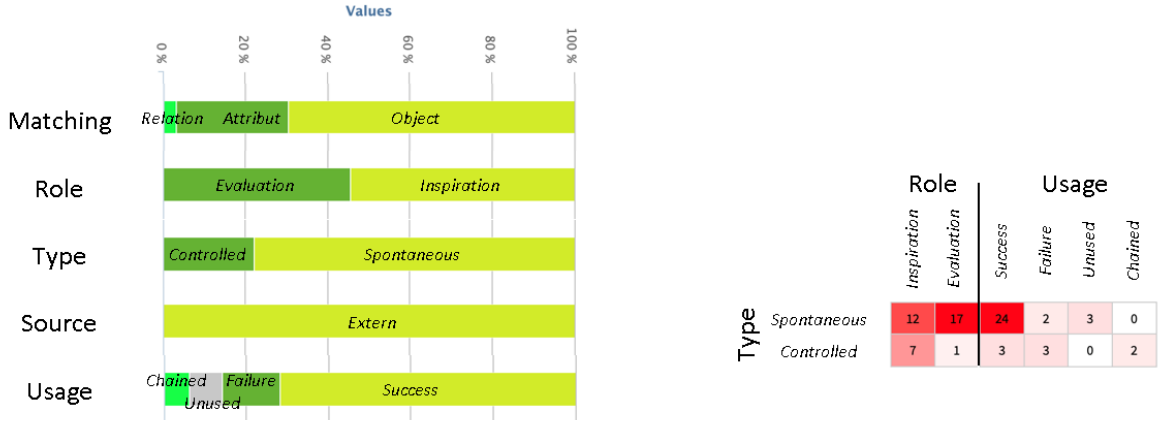

Figure 6. Detailed analysis of analogies made by subjects on the basis of images proposed by the technological partner during the design phase: on the left, proportion of different values of observed criteria characterizing analogies; on the right, details of the roles and uses of analogies depending on whether images are spontaneously proposed by the machine or controlled, i.e. ordered by the subject.

First of all, we can see that image analogies are successful over 70% of the time (figure 6 - Usage), confirming the benefits of offering these images, as advanced above. They also show less than 15% failure rate, confirming that the images proposed by the technological partner are indeed appropriate and of high quality. They may or may not be integrated into the architectural project, depending on the architect's wishes, but they are appropriate.

In addition to the initial role of inspiring ideas, we see another role being given to the images by the participants: evaluating the ideas generated (figure 6 - Role). In addition to inspiring new ideas, our analyses show that the exchange with the technological partner helps to validate or invalidate the ideas proposed by the architect by seeing them illustrated through examples of real buildings or ambiences. This evaluation role is perhaps enhanced by the relevance of the images to the project: since the images are based on recognition of the currently designed project, they are also pictorial concretizations of the ideas sketched out. It may also reflect another need of architects: the need to assess the proposed solutions.

If we now look at the source of the analogies (Figure 6 - Source), it is exclusively external. In other words, the architects only made analogies with the proposed images, never on the basis of personal memories or professional references. This finding is very interesting, and raises two further questions:

(i) either the proposed instrumentation is self-sufficient in terms of inspiration and support for idea generation, an optimistic hypothesis, (ii) or the proposed instrumentation constrains reflection and prevents the mobilization of other inspiration strategies, a pessimistic hypothesis. We will explore these two questions in the case study with the design team of several architects.

Finally, let's remember that analogies could be of two types: spontaneous (i.e., made on the images proposed by the machine) or controlled (i.e., the result of an image order placed by the subject). The possibility of command included in the protocol enabled us to determine whether the architects had the need to complete the images proposed spontaneously by the technological partner. And we found that 20% of analogies were made on ordered images, in addition to the images spontaneously proposed (figure 6 - Type). This finding raises the question of the subjects' motivation behind these commands. There are two possible answers: (i) the images proposed are not suitable; (ii) the subjects want to test their ideas as part of an evaluation process, by requesting images that concretize the ideas they have already developed. We can refute the first hypothesis, since the proposed images are more than 70% successful and less than 15% unsuccessful. To answer the second hypothesis, we take a look at the roles of proposed and ordered images, and how they are used (figure 6, right). Here we see that the commands are in fact given for inspiration, not to evaluate ideas. If we go back to the video recordings and qualitatively observe the episodes in which an order is placed, we see that these ordered images are requested during specific activities: when the architect already has a premise of an idea, but it's still vague, and he/she's looking for inspiration to find out exactly what form this idea will take. These ordered images are as successful as they are unsuccessful.

7.2 Experience of integration in collaboration

Now let's examine the use of technological partners within a team of architects already involved in collaborative design.
This team's design process is organized along four sequences: appropriation of the subject, conceptualization of ideas, production of documents and verification (figure 7).

The first phase begins with the participants familiarizing themselves with the project's constraints, so as to draw up a guideline. The second phase is devoted to establishing the principles structuring the distribution of rooms. This phase is animated by numerous debates within the team as they seek to reach agreement on the proposed ideas. It is also punctuated by asides between two designers to detail certain layouts.
The production sequence is then carried out individually, and the design process ends in the last five minutes with a group check.

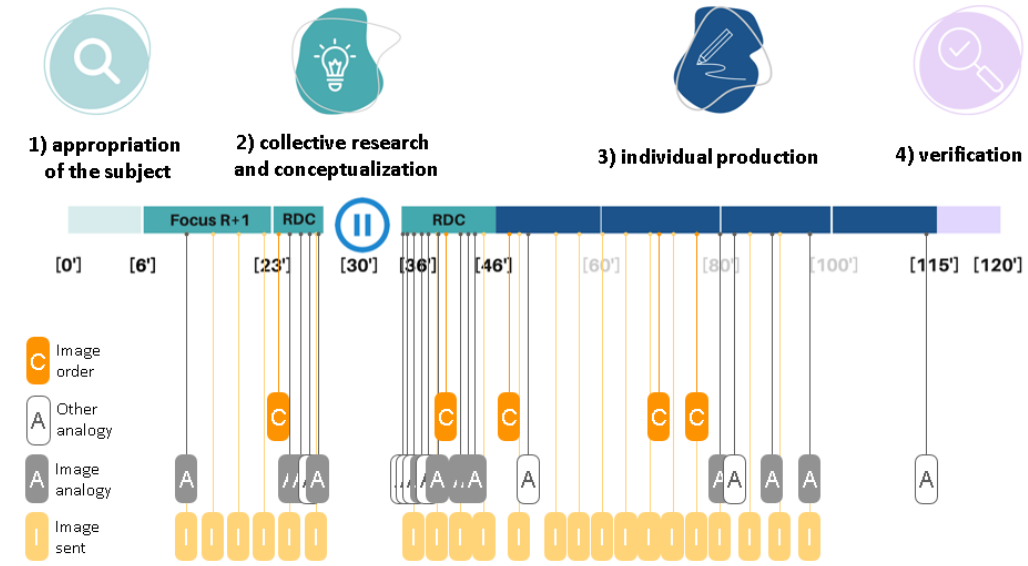

Figure 7. General design process for the design team.

In figure 7, we trace the various stimulus images sent during the process (yellow), the analogies made based on these images (grey), the other analogies from the designers' memory (white) and the specific orders sent (orange). They didn't hesitate to question the technology verbally, seeking specific reference images to express their need for inspiration.
This team established twenty analogies during their design activities, mainly during the conceptualization sequence. 60% of these analogies were derived from stimulus images. The remaining 40% are the result of memory, and thus fall outside the scope of the images sent. If we look at the uses made of the stimulus images, only just over half are actually used in analogies (52%), just under a third are completely ignored (28%) and 20% are consulted but left unused.

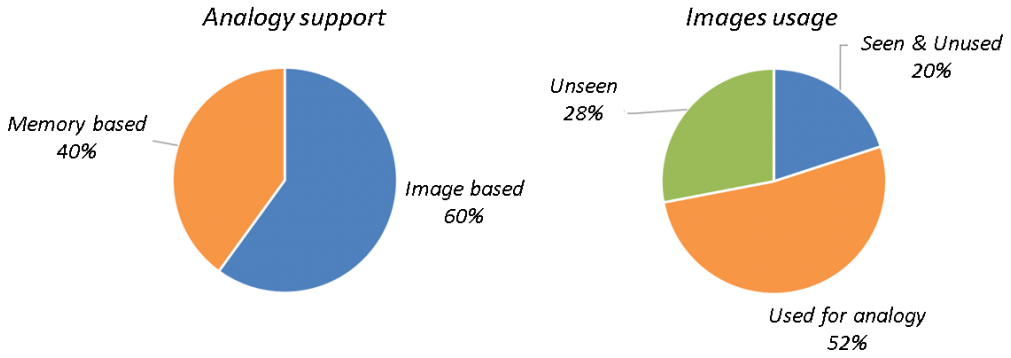

Figure 8. Statistics on design team's analogies.

To answer the questions raised above, we note that in this case study, other sources of analogy were mobilized in addition to the proposed images: personal memories and professional references. We can therefore eliminate hypothesis (II), which suggested that the absence of analogies based on personal or professional memory could be due to the fact that instrumentation would have restricted reflection.

We now turn to the details of the team's collective actions in the moments preceding consultation of the proposed images. Coding de design's actions as in Table 1 and looking at the action timeline for each designer, with the inclusion of moments of analogy, yields figure 9. We can see that these analogies are almost exclusively mobilized during design discussions.

Figure 9. Focus on design activities in the most analogically-charged period ("conceptualization" phase).

Finally, as in the mono-architect experiment, we look at the proportion of different observed criterion values characterizing analogies (figure 10).

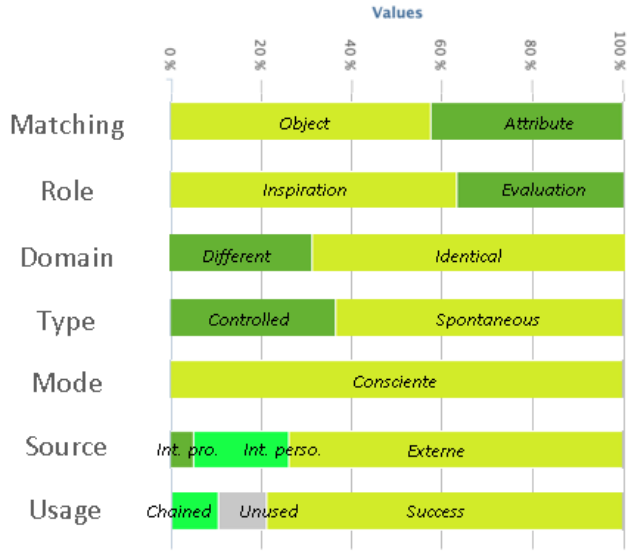

Figure 10. Detailed analysis of analogies made on the basis of images proposed by the technological partner during the design phase: proportion of different values of observed criteria characterizing analogies.

As the images sent are adapted to the object being designed throughout the entire process. Analogies therefore relate mainly to the entire architectural object, and sometimes to attributes of that object. In addition, the analogies established in a stimulated design situation often made a contribution to the project, and can thus be considered a success. Finally, the results obtained in the mono-architect experiment were also verified in this team experiment.

8 General discussion

Firstly, it should be mentioned that Dorst and Cross (2001), in their creative design experiments, found that all designers had come up with the same idea, which they thought was original. Here, in this experiment, the subjects showed singular creativity and came up with unique solutions to the same initial problem. Figure 11 shows how different the projects proposed by the 9 architects were from one another.

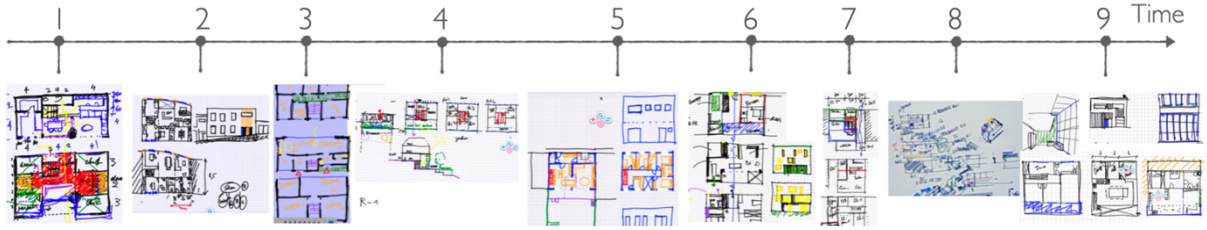

Figure 11. Overview of the 9 designers' final projects.

Overall, the establishment of design exchanges with the technological partner considered here presents three main roles for the creative design activity, identified through our figure 6 related results: (i) to inspire new ideas, related to the project under design but not yet envisioned by the subject, on impulse from the machine; (ii) to inspire, through orders, the concretization of an idea emerging in the architect's mind; and (iii) to evaluate the project under design and validate or invalidate the idea expressed in the sketch and appearing concretized in the proposed images.

Our proposal was to avoid prompts, as this was the main limitation identified in the use of AI image generators such as MidJourney. The use of sketch-recognition-based software during the design process is very valuable and fluid in its use. It doesn't interrupt the design flow as confirmed by the interviewees, since it searches for images based on the sketches drawn by the architect during the design phase, rather than on the prompt to be specified. However, our results show a real need to be able to order specific images, as the designers made a real usage of this provided function (see fig.6). In this case, it is necessary to go back to textual order entry. The advantage of our system over text-to-image AI generators is that the "prompt" can simply be composed of three or four keywords, while the technological partner knows the project being designed and the creative direction in which the architect is heading. So there's no need to specify all the details in a complex prompt. The Wizard was in all cases able to find relevant images based on the three word received. Some interviewees emphasized that the proposed tool is not restrictive in either use or working method.

Another point, raised by Radhakrisknan (2023, p. 6) is that "the AI takes only references from existing sources, which might end up illustrating similar discrimination patterns in visual arts". Indeed, the technological partner selects images from existing image databases such as Google Image, Pinterest or ArchDaily. However, although the images proposed at the start of the

design process are generic, they become more specific as the exchange progresses, and are increasingly suited to the architect's personal style and the object being designed, as stated by the designers all along their think aloud and in the interviews. Moreover, it is completely possible to create new ideas from existing ones. Indeed, two of the three types of creativity outlined in the theoretical section of this paper involve making a new combination from existing elements, or modifying an existing element by making variations of it.
Moreover, we must recall that creativity in design is characterized by novelty and surprise (Dorst & Cross, 2001), as well as by the emergence of a new scheme for generating ideas (Gero, 1996). Given these characteristics, the tool we are proposing here is indeed a support for creative design, since it proposes a different design strategy, including sources of inspiration spontaneously proposed to the designer, constituting an external stimulus to his internal idea-generation process and bringing a surprise factor to the design.

In the end, we can extend that a creative, collaborative exchange takes place between the architect subjects and the technological partner, and this exchange successfully serves both ideation and design. Several subjects stated in interviews that this instrumentation makes their ideation more efficient and saves them time, as well as suggesting relevant new ideas.

9 Conclusion

Faced with the complexity of creativity, we are developing an aid to creative design in architecture. This aid capitalizes on the potential of collaboration as well as AI image generators, such as MidJourney, by aiming to create a technological partner who exchanges with the architect(s) to co-design. This technological partner will recognize architectural sketches and spontaneously suggest suitable inspirational images. The architect(s) will then be able to integrate these ideas into the project, if he/she wants, and order specific visuals.
Before developing this technology, we studied its added value for ideation and its potential impact on design activities via a Wizard of Oz simulation.
Our results show that the benefits identified for AI image generators, i.e. the speeding-up and freeing-up of ideation, are still present in our proposed instrumentation, which on the other hand overcomes their limitations by not requiring complex prompt elaboration. This instrumentation proposal does not disrupt the design flow at all, and offers images appropriate to the ideas being sketched. Not only do they enable architects to draw inspiration, but they also meet a need previously unknown or underestimated in the literature: the need to evaluate sketched ideas by means of images simulating their real-life rendering, as well as the need for inspiration to materialize the premises of ideas that are still vague.
This identified need for inspirational images to evaluate early design ideas by simulating real-life rendering and materialize vague premises is an intriguing

finding, and the key contribution of this paper, warranting further unpacking through the lens of architectural cognition and analogical reasoning.

The first limitation of this study is the low degree of generalizability of the results obtained to each design situation or architect, due to the size of the panel of participants.
The main limitation of this study, however, lies in the choice of the Wizard of Oz protocol which, although common in this type of software prospecting, is not without inconvenience. So far, a human has simulated the sketch recognition and image search functions. So he/she has had a certain influence on the experiment.

A next step in our work is thus to study the Wizard's activity in detail, in order to understand his/her sketch recognition strategies and his/her criteria for choosing images to propose to the subject. To do this, we need to simulate this type of instrumented design session again, but this time varying the Wizard: subjects will take turns in the Wizard's role, and we'll observe their activities.
The main contribution of this paper also leads to further study the cognitive mechanisms involved in the generation of new ideas by analogy. In particular, we are planning to analyze in more depth the nature of the elements extracted from proposed images and used by designers to evaluate their premises or to generate new creative ideas.
Finally, we plan to develop the software that will replace what has so far been a Wizard of Oz.

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