When Architectural Ideation Meets Generative AI: Deciphering cognitive processes in architectural design

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Recent advances in generative artificial intelligence (GAI) are opening new perspectives for architectural design, especially during the ideation phase. However, research on the cognitive processes associated with their use remains limited, raising questions about their potential impacts. This study, grounded in cognitive psychology, analyses experiments conducted between 2022 and 2024. It interrogates the activities of prompt design, image generation, and idea emergence. It identifies key cognitive dynamics: internalisation versus externalisation of ideas, their convergence or divergence, as well as linear versus spatial thinking. These results shed light on the centre role of prompting in ideation through GAI interactions as well as on the cognitive processes involved. It offers an innovative perspective on the impact of generative AI in architecture and its cognitive implications.

Keywords: *GAI, Cognitive processes, Ideation, Prompt engineering, Image generation, Human-machine interaction*

INTRODUCTION

Recent developments in generative artificial intelligence (GAI), capable of generating visuals from textual descriptions or images, offer unprecedented opportunities for ideation in architectural design (Leach, 2023; Marsault and Nguyen, 2022). Recent studies (Paananen, Oppenlaender and Visuri, 2024; Yildirim, 2022) show that GAI enable abstract ideas to be rapidly transformed into visual representations, while encouraging a diversified and intuitive exploration of concepts (Yildirim, 2022). Despite these promises, the cognitive impact of these technologies on the ideation they induce remains little explored.

This article aims to fill this gap by examining the cognitive processes underlying the use of GAI in architectural design. Based on theoretical foundations in cognitive psychology and on experiments conducted between 2022 and 2024 with architecture students, this research analyses the activities of designing prompts, generating images and generating ideas. The aim is to gain a better understanding of the cognitive processes involved, in particular the interactions between internal (mental) and external (materialised) representations, as well as the divergence and convergence strategies that shape the creative process.

Ideation, a key stage in architectural design, is traditionally based on a dialogue between abstract thoughts and concrete representations (Safin, 2025; Baudoux, 2023). The introduction of GAI has upset

these dynamics, offering new ways of materialising ideas.

Context and positioning of the research

The experiments presented here were conducted in 2022, constituting a first empirical account of the use of generative AI by architecture students. The aim of this pioneering work was to document the emerging cognitive activities of designers when faced with this new tool, at a time when models (such as DALL-E 2 or MidJourney v4) were in their early stages of deployment.

Although this article focuses on the first interactions with GAIs, our current research focuses on prompting as a fundamental skill that transforms the ideation process. We are studying how the formulation of queries influences the results, and on how the combination of sketches and texts, including the multidimensionality of prompting, enriches the design possibilities. This approach goes further than passive observation, revealing how generative AI is fundamentally altering design methodologies.

RELATED WORK

GAI and Design

Generative artificial intelligence (GAI) is spreading in an experimental but significant way in the field of architecture (Du et al., 2025; Odiah and Gosling, 2024). These experiments are accompanied by numerous tool developments (Bank et al., 2025; Zhang et al., 2024), including new modes of interaction (Doumpioti and Huang, 2024; Cheung, Wang and Lei, 2025).Text-and-image-to-image GAI, which are available to the general public as turnkey solutions in less experimental tools that are often less suited to architecture, are proving very successful, particularly for ideation.

According to Paananen, Oppenlaender and Visuri, (2024), GAI are able to produce unique and personalised visual representations that are relatively aligned with the designer's initial intentions (Paananen, Oppenlaender and Visuri, 2024), and, according to these studies, more intuitively and quickly than traditional design practices (Yildirim, 2022). These researchers highlight that GAI facilitate the rapid transformation of abstract ideas into visual forms, while also enabling a diverse exploration of creative concepts through the use of textual descriptions to materialise imagined designs (Yildirim, 2022).

Despite these initial enthusiastic observations, we may wonder about the impact of these tools on ideation and the potential biases they may induce. Indeed, GAI are above all tools for reproduction (Masure, 2023) and their ability to support the emergence of new ideas is questionable.

Ideation and Design Cognition

Ideation is a fundamental stage in the architectural design process, characterised by the generation of the first structuring ideas for the project (Safin, 2025; Baudoux, 2023, Yüksek & de Boissieu, 2025). Although this process is mainly associated with the initial phases of design, it also manifests itself in occasional episodes whenever a new problem emerges (Elsen, Darses and Leclercq, 2010).

The ideation process is characterised in particular by a dynamic interaction between the architect's so-called internal (mental) representations and so-called external (materialised) representations, creating a dialogue that is essential to architectural ideation. The introduction of the GAI overturns the traditional dynamics between internal and external representations, transforming the ways in which ideas are represented and formalised.

The architectural design process revolves around an interaction between divergent and convergent thinking.

Divergent thinking is defined by the ability to generate multiple innovative solutions, often in a non-linear way (Aviña et al., 2018; Dorfman and Gassimova, 2017). It enables the exploration of a vast field of possibilities. Convergent thinking then intervenes to select, refine and structure solutions according to specific constraints (Safin, 2025; Kasatkina, Boujut and Garlatti, 2015).

GOAL AND OBJECTIVES

While GAI have been a great success in many fields, particularly creative ones, few studies have examined the cognitive processes underlying their use. This article looks at them, and in particular at :

- The central role of the prompt in the ideation process ;
- The "indirect externalisation" role of images generated by the GAI and the status of these images ;

- The global dynamics at work in the ideation process instrumented by the GAI.

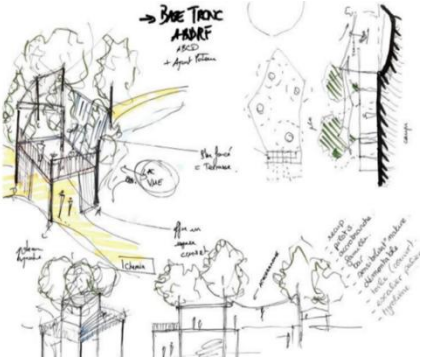


Figure 1b
Extract of collected data: Prompt and generated images

Figure 1a
Extract of data collected: Sketches

METHOD

This research is based on two experiments carried out in 2022 and 2023 with a total of 29 architecture students, aimed at understanding the cognitive processes of the designer in the ideation phase supported by generative AI (Yüksek, 2023; Yüksek and de Boissieu, 2025).

Experimental protocol

Both experiments involved an ideation exercise in architecture conducted over a limited period of time (1 hour), entirely recorded, and followed by questionnaires. Both experiments involved a population of Master of Architecture students at the University of Liège: 15 for experiment 1 and 14 for experiment 2. During both experiments, the students were designing in groups of 2 or 3. The design tasks were as follow:

- For experiment 1, in 2022: to design a demountable guinguette for the botanical garden of Liège using Midjourney V4 ;
- For experiment 2 in 2023: to design a concrete 3D printed street furniture Stable Diffusion 2.1 (hugging face).

The GAI tools used were distinct due to the rapid evolution of the technology. During the experiments the data collected was particularly numerous and diverse: verbatims, sketches, screen recordings of the use of the AI tool, and finally the images generated by the AI (fig 1a and b).

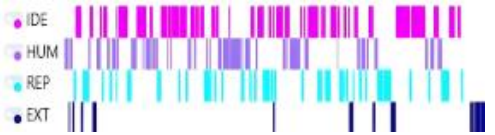
Data processing protocol

To analyse the interactions during the experiment, we carried out an in-depth examination of the recorded dialogues led by the participants during their design process.

The aim was to identify and classify the activities relevant to this study. The method used is based on an inductive approach founded on grounded theory (Lejeune, 2019), which allows categories of analysis to be constructed progressively from the data itself, and then, through an iterative approach, to be related to various existing concepts stemming from Cognitive Design.

Data processing began with the full and careful transcription of the collected data (verbatim and representations produced), followed by coding (Figure 2). First categories of recurring activities emerged from the analysis of the transcripts. They were then grouped and refined in an iterative process, where the examination of an initial dataset is progressively extended to build a more complete analysis.

This detailed analysis has enabled us to identify results relating to 1-: a dynamic alternating between divergence and convergence; and 2-: a cycle of internalisation and externalisation.



IDE: ideation-related activities **HUM**: collaborative work **REP**: design of external representations **EXT**: operation of the GenAI tool

BETWEEN EXPLORING OF NEW IDEAS AND CONSOLIDATING EXISTING ONES: DIVERGENCE AND CONVERGENCE

In-depth analysis of the design sessions reveals a characteristic alternation between phases in which new ideas emerge, known as divergence, and phases in which existing ideas mature, known as convergence. These processes and their alternation are well known in traditional ideation processes (see RELATED WORK), yet we have observed specificities in ideation instrumented by the GAI.

Generative AI is revolutionising architectural exploration by broadening the possibilities for the emergence of ideas. These tools enable rapid experimentation with styles, materials, morphologies and ambiences, enriching the conceptual process. The results depend on a precise dialogue with the AI through the prompt, bringing out new design skills. More than just a visualisation tool, this technology becomes a genuine creative partner in the ideation phase, opening up new avenues.

Key role of divergent thinking

It should be noted here that while divergence and convergence are inseparable in the traditional ideation process, we have observed that divergent thinking has a key role in ideation instrumented by the GAI. Divergent thinking is a process of exploring a wide range of solutions and ideas in a random and unorganised way (Aviña et al., 2018; Dorfman and Gassimova, 2017).

We have observed how designers can initiate their design process by starting with a general idea which they then refine and enrich through a series of prompts adjusted throughout this iterative process. During this process, designers carry out a great deal of work on the formulation of prompts, in particular to refine the effectiveness of their communication with the AI tool.

In this way, the designers test different formulations, adjust the chosen terms and keywords, and carefully observe how each modification influences the results generated before iterating again.

Among other things, it is through these successive adjustments that the designers can establish a divergent dynamic by introducing new elements and exploring various conceptual avenues.

A particularly revealing case (fig. 3) illustrates this process and shows how the gradual introduction of key terms in the prompts generated unexpected proposals which were then judiciously reinvested in the final project. In this example, an initial prompt, although basic, serves as a starting point for structuring an initial idea.

Figure 2
Extract from the coding of Experiment 2

Based on the results obtained, a new prompt is drawn up, aimed at enriching the initial idea by introducing a reference to parametric design, thus opening the way to more complex morphologies. By incorporating additional specifications at each iteration, the designer expands the field of possibilities and explores combinations of ideas.

Figure 3 shows the succession of nine iterations of image generation, with or without the emergence of an idea (marked in purple).

Figure 3
Design example #01: Case of divergence

Significant indeterminacy

It is interesting to note that the discrepancies between the expectations of the designers and the actual production of the GAI can be beneficial and contribute to the dynamic of divergence, making it possible to enrich an initial idea (fig 3).

This phenomenon is similar to what Marin (2024) identifies as significant indeterminacy. This notion, which stems from the researcher's observations on the use of genetic algorithms in architectural design, points out that the unexpected or the random in a creative process is not a simple error or failure, but an opportunity for designers to find new meaning in an unexpected element.

In the case of designer #01 (fig. 3), although the prompts have been carefully designed to generate specific shapes, it is often an unexpected texture, detail or visual feature that catches his attention and stimulates his imagination. To a certain extent, this is also similar to the phenomenon of reading stimuli as inspiration (Dissaux, 2024) or unexpected discoveries (Goldschmidt, 1991).

a b

It is worth noticing that the analysis of the results shows that in group #01 the final design incorporated several concepts found during their experiment of generative AI. Two elements in particular marked this transposition of IAG ideas to physical implementation: texture and the spiral shape (figure 4 ,left: explored texture, middle and right, the spiral design from).

Alternating between divergence and convergence

We also observe sequences of convergence, where designers, starting from an initial idea, have refined and evolved their ideas through interaction with the GAI. By integrating the new ideas that emerge, they gradually evolve their general idea into a more precise and complete solution. This convergence phase illustrates how AI can act as a catalyst to deepen and enrich an initial idea, while maintaining consistency with the project's objectives.

The alternation between divergence and convergence is well documented in sketching practices (Goldschmidt, 1991), where it is manifested by : 1- creative expansion marking the process of divergence through idea generation via graphic exploration; and 2- critical consolidation, marking the process of convergence through technical evaluation and constraint verification. Here we can see that creative expansion involves much more than a simple sketch, and that the prompt in particular plays a crucial role (see following sections). And that the critical consolidation that marks convergent thinking remains limited.

Indeed, during the short period of experimentation, the designers were unable to return to the architect's traditional tools for technical evaluation and verification of constraints.

Cognitive flexibility issues

The cognitive dynamic of alternating between divergence and convergence was not observed in all the design cases analysed. These cases highlight the cognitive difficulties experienced by the designers in their use of the GAI for ideation.

Some designers remained trapped in a cognitive fixation. This phenomenon manifests itself in the designer's tendency not to explore, or even to be incapable of considering different approaches to defining and responding to a design need (Condoor and LaVoie, 2007).

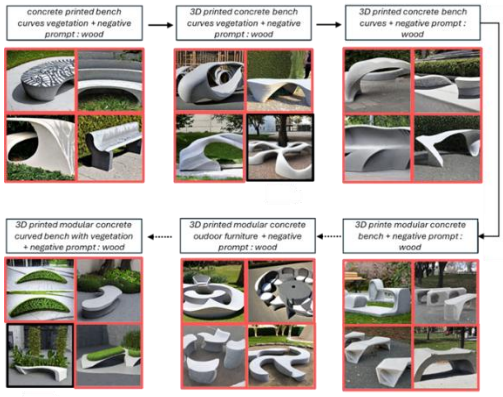
This is the case in example #02 (fig. 5), which shows a design where the process got bogged down in repetitive iterations with no new input. The

Figure 4
Integration of AI-generated concepts into architectural design: 4a- 3D printing in concrete for texture testing, 4b-modelling the first prototype

designers were unable to go beyond their initial intention despite the AI's alternative proposals.

These observations confirm that the effectiveness of generative tools depends above all on the ability of users to maintain sufficient *cognitive flexibility* and an attitude open to *significant indeterminacy*.

Figure 5
Example #02:
Cognitive fixation



THE CYCLE OF INTERNALISATION AND EXTERNALISATION

The second major dynamic analysed concerns the constant dialogue between the designer's internal representations and his external representations.

Safin (2025) argues that "cognitive activity can be seen as divided between internal resources (cognitive, affective and perceptual processes), external resources present in the environment (external representations, tools, spatial arrangements, etc.) and social and cultural resources (socio-affective and collaborative processes)". The external representations manipulated during the experiments were in particular sketches and prompts, and in an indirect way, which we will discuss later, the images generated by the GAI themselves.

In these external representations, the prompt plays a particularly central role.

The central role of the prompt

The prompt can be either text or image. The main purpose of the prompt is to be transformed into images by the GAI. From text to image, it is a real transmutation: a transformation of textual material into visual material, operated by the GAI algorithm. We have observed that these are part of a dynamic and a constant dialogue between internalisation and externalisation for the maturation of the idea (fig. 3) (Yüksek and de Boissieu, 2025).

While the prompt is primarily a tool for communicating with the GAI, it also acts as a tool for structuring the designers' ideas. In fact, one of the main characteristics of the prompt is that it is a text developed iteratively. The image generation process itself requires a great deal of trial and error, from which the designer learns and through which his ideas evolve.

Iterative alternations between internalisation and externalisation

When the prompt is transmuted into an image by the GAI algorithms, this image is in turn internalized and integrated into the cognitive work. This process illustrates a constant to-and-fro between internal and external resources, where the externalisation of a starting idea (via the prompt) and the internalisation of new ideas (via the generated image) feed each other.

This cyclical dynamic encourages iterative exploration, with each stage enriching the previous one (fig. 6).

The designers' general internal representation (IR1 + IR2 + IR3 in Fig. 6) enables the process of maturation and the emergence of clear, structured ideas. These ideas are then externalised in the form of external representations, which can be linear as in the case of the textual prompt, or spatial as in the case of the sketch or visual prompt. This stage marks the transition from abstract thought to tangible reality. These external representations can then be transmuted into new spatial external representations, which are the images generated by the AI.

These visualizations offer new perspectives on the initial idea, enriching its interpretation (fig. 3). The images generated can then be interpreted by the designer as "Significant indeterminacy" (see Significant indeterminacy section). They then act as incoming information in the internalisation process. They become a source of inspiration, analysis and reflection. Mental processes process this information to develop, refine or bring out new ideas. This stage closes the cycle while re-launching the creative process, enabling continuous, iterative exploration.

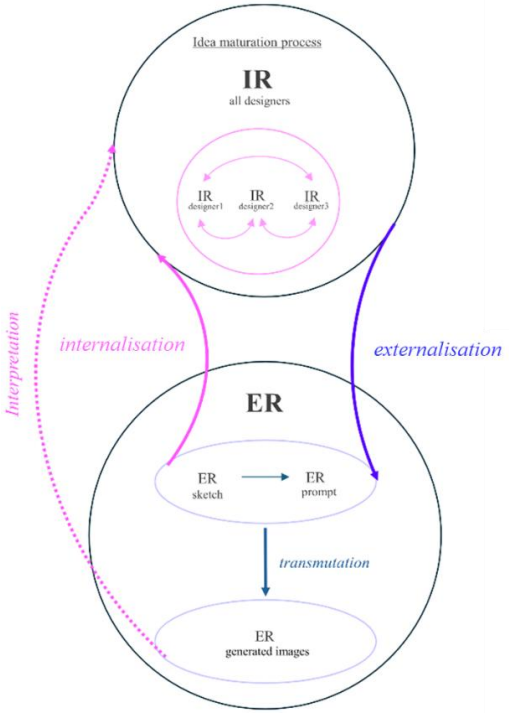


Figure 6
Internalisation and Externalisation cycle

DISCUSSION

Research limits

As GAI tools are evolving rapidly, this research focuses on prompt-centric usage, rather than on algorithm settings, now integrated into tools such as Midjourney V6 and StableDiffusion.

Further experimentation is also needed to investigate the uses of a population more familiar with GAI.

Additionally, future research should investigate not only the use of algorithmic settings, as previously discussed, but also the practices related to dataset creation and the training of generative AI models.

Research Contributions

This research highlights how architectural ideation processes can integrate generative AI through three key dynamics: (1) the alternation between divergent and convergent thinking, (2) the cognitive cycle of internalisation and externalisation, and (3) the emergence of new modalities of human-machine collaboration via the prompt. Our experiments reveal that while AI tools enrich ideation, their effectiveness depends above all on designers' ability to maintain cognitive flexibility and interpret the proposals generated.

This work stands out for its innovative approach, which combines the principles of cognitive psychology with architectural design practices in the era of generative AI. These results show that generative AI reconfigures traditional architectural design processes, introducing both opportunities such as increased serendipity and rapid iteration, and challenges such as cognitive fixation.

Given the rapid evolution of GAI technologies and practices, it should be noted that this research is mainly intended to be an opening. Further developments are necessary in order to build an in-depth understanding of the cognitive processes involved as well as their evolution.

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