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Original Research Article

Reducing Design Fixation in Ideation by AI, with the Intervention of the Morphological Analysis Method

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Abstract

Introduction: Artificial Intelligence (AI) is emerging as a novel tool in the domain of «human-computer collective intelligence», with the potential to enhance creativity during the design process significantly. Recent studies indicate that leveraging AI enables rapid generation of valuable concepts and improves overall ideation, divergent thinking, and creative output. However, despite AI's access to vast datasets, the persistent challenge of design fixation, characterized by a limited variety in the resulting ideas and final outputs, remains a fundamental obstacle. This constraint severely complicates the realization of divergence in ideation. The primary goal of the present research is to investigate the effect of the morphological analysis method in reducing design fixation within AI-based ideation processes.

Research Method: This study adopts a mixed-methods (combined) approach and is fundamental in terms of its objective. Essential information for the theoretical framework and literature review was gathered through library resources. For the empirical aspect, an experimental test was conducted in three distinct stages. Data was collected through the execution of the experiment and subsequent evaluation of the results by a panel of experts. The outcomes from direct AI ideation were then compared and analyzed with those obtained when the morphological analysis method was applied in an analogous process.

Findings: A comparison of the results, based on metrics such as the number of ideas, degree of novelty, and percentage of fixation, revealed that while signs of design fixation were observed in both scenarios, the use of the morphological analysis method demonstrably reduced the level of design fixation in the generated ideas. This method was found to increase the number of unique ideas, thereby improving the novelty score. Furthermore, by explicitly breaking down the expected functions, AI used the components in the user's request as a foundation, leading to the presentation of more complete, holistic ideas.

Conclusion: Integrating morphological chart analysis into AI-based ideation processes is an effective strategy for reducing design fixation and enhancing the novelty and innovation of ideas. Beyond this, its application reinforces divergent thinking and overall creativity.

Keywords

Design Process, Idea Generation, Design Fixation, Generative Artificial Intelligence, Morphological Analysis Method

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Introduction and Problem Definition

Undeniably, creativity stands as one of the fundamental competencies required of designers in the development of new products. By leveraging creativity, designers can substantially refine their initial ideas and pinpoint truly innovative solutions to complex challenges. From the perspective of cognitive psychology, creativity is generally conceptualized as an inherent, internal cognitive process encompassing a spectrum of mental, cognitive, affective, and behavioral activities. These processes predominantly originate in the unconscious mind and operate primarily outside conscious control. Consequently, the mind's underlying cognitive processes exert a significant influence on a designer's creative output. Researchers have consistently endeavored to identify the cognitive factors that modulate creativity. One particularly relevant factor is design fixation. When individuals encounter existing examples and established solutions, they unconsciously tend to generate new designs that closely resemble the prototypes they encounter. In recent years, dramatic advances in generative artificial intelligence have positioned this technology as a novel tool for enhancing human creativity. Emerging studies suggest that integrating human-computer collective intelligence within design teams can facilitate the rapid generation of conceptual ideas, thereby significantly streamlining the ideation process and fostering creative thinking. As a result, the investigation into the effect of generative AI systems on mitigating design fixation and stimulating ideation in the design process has recently garnered increasing attention. However, existing evidence indicates that the direct, independent use of AI to generate novel ideas, especially when the inputs are selected based on keywords derived from the design brief or the designer's preliminary concepts, can paradoxically lead to the reproduction of analogous patterns, thereby intensifying design fixation. Therefore, a critical and unresolved challenge in AI-assisted design remains: how to effectively reduce fixation while simultaneously augmenting the novelty of ideas during interaction with these systems. AI operates on the foundation of predefined patterns and machine learning algorithms. While this system can rapidly integrate vast amounts of information from diverse sources into its learning patterns and generate new outcomes by establishing data connections according to specific algorithms, its structure and mode of operation fundamentally differ from those of the human mind. Consequently, its application in the design process is distinct. This context raises a crucial question: Is it possible to reduce the level of design fixation during the AI-assisted ideation process by employing the morphological analysis method? The present study is thus designed to investigate the impact of the morphological method on reducing design fixation during the ideation process using generative AI. With the exponential growth in AI applications in product design, generative tools like Midjourney have emerged as innovative resources for idea generation. Nevertheless, prior research highlights design fixation as a key challenge associated with these tools; a phenomenon that often leads to the repetition of similar ideas and a resultant decrease in design divergence. Furthermore, most prior studies have focused primarily on the independent use of AI to reduce design fixation, paying less attention to the efficacy of systematic methodologies when interacting with AI. A notable gap in the literature is the lack of research specifically investigating the effect of the morphological chart on diminishing design fixation within an AI-driven environment. In other words, the core innovation of the current study lies in adopting a hybrid AI-assisted design approach. This approach involves systematically decomposing the design problem, generating separate concepts, and ultimately synthesizing them. The primary objective is to actively reduce design fixation and enhance the novelty and creativity of the generated ideas. This study represents a focused attempt to bridge the existing research gap and to offer a sophisticated

model for leveraging artificial intelligence capabilities more deliberately and effectively in product design.

Research Method

The methodological approach adopted for this investigation is a mixed-methods (quantitative-qualitative) design, and, in terms of its objective, it is classified as fundamental research. Essential background and theoretical foundations were compiled through a comprehensive review of library resources and the relevant literature on design fixation and artificial intelligence. The present study specifically examines the effect of the morphological box method on design fixation during the ideation process, using generative artificial intelligence (AI). From an implementation perspective, this research is experimental and was executed in three distinct stages with the assistance of a focus group. The focus group comprised five industrial design experts who were meticulously selected based on criteria, including a firm grasp of the study's theoretical underpinnings, proficiency in design methodology, skill in applying the morphological box tool, and familiarity with AI tools. The evaluation metrics used to assess the degree of design fixation in this research include the total number of ideas generated, the novelty of concepts, and the percentage of design fixation. The quantitative values corresponding to these indices are subsequently examined, analyzed, and presented in the relevant tables.

Research Background

Few studies have specifically examined the impact of morphological analysis methods on design fixation. Crucially, most of these studies were conducted independently of AI technologies and their associated tools, meaning their findings are not directly generalizable to this domain. Below, we review several key studies related to AI and design fixation. Many researchers have explored various interventions to overcome design fixation (Alipour et al., 2018). These interventions include: utilizing prototyping during the ideation phase (Kershaw et al., 2011; Viswanathan et al., 2014; Youmans, 2011); decomposing products into sub-components (McCaffrey, 2012, 15-16; Toh et al., 2014, 95-113); employing design-by-analogy (Linsey et al., 2010; Moreno et al., 2016); examining the influence of group work on fixation (Youmans, 2011a; 2011b); and applying design heuristics such as TRIZ and SCAMPER (Yilmaz et al., 2010). A smaller body of research has explored the effect of using the morphological chart analysis on reducing design fixation. These studies strongly suggest that this tool can significantly prevent fixation by systematically decomposing products into their constituent parts and subsequently rigorously analyzing alternatives for each structural element, allowing designers to uncover a multitude of potential solutions (Toh et al., 2014, 16). The influence of generative AI systems on mitigating fixation and stimulating ideation in the design process has recently received increasing attention (Cascini et al., 2022). «Hoggenmueller et al.» (2023) in their study on «Creative AI for HRI Design Explorations» investigated the use of generative AI to reduce design fixation in the ideation of robotic artifacts. Their findings demonstrated that images generated by generative AI not only enhanced designers' creativity in developing conceptual and visual ideas but also increased co-creativity and reduced design fixation. «Lee and Chiu» (2023) conducted research entitled «The Impact of AI Text-to-Image Generator on Product Styling Design», comparing the impact of AI-generated visual stimuli with that of visual stimuli sourced from Pinterest during the product design process. The

results indicated that although designers experienced fixation under the influence of both types of visual stimuli, the degree of fixation was lower when encountering AI-generated images. In a similar vein, «Cai et al.» (2023) compared the effects of AI-generated images with Pinterest-sourced images on design fixation in a study entitled «Using Generative AI and Semantic Diversity for Design Inspiration». This research found that while generative AI was inspiring and provided diverse conceptual and visual ideas, the direct, standalone use of these images and ideas was insufficient to overcome design fixation. The researchers therefore suggested that using keywords different from those in the original design brief might yield more unique outcomes when leveraging AI. In one of the most recent studies, «Wadinambiarachchi et al.» (2024), in their research entitled «Investigating the Effect of Generative AI on Design Fixation and Divergent Thinking», examined the impact of generative AI on fostering creativity and reducing fixation. They observed that the direct use of keywords from the design brief and inspiration drawn from AI-generated images not only failed to reduce design fixation but could potentially increase it. They subsequently proposed that employing specific design methods and strategies alongside AI might help alleviate fixation. In summary, the review of the research literature reveals mixed results regarding AI's effectiveness in reducing design fixation. Given that research on human-AI co-creativity is still in its nascent stages, a clear consensus on how to best utilize generative AI to reduce fixation has yet to emerge. This study will address this gap by investigating the application of the morphological analysis method in the AI-based ideation process and its effect on design fixation. This will contribute new empirical evidence to the literature on human-computer creativity, providing valuable results for both researchers and designers.

Theoretical Structure

1. Design Fixation: Design fixation occurs when a designer is unduly influenced by an existing design exemplar or the content of a design brief, leading them to produce a new idea or design that retains features highly similar to the preceding example. Essentially, fixation is viewed as an unconscious phenomenon of adherence to existing information and solutions, which consequently restricts ideation and creativity (Jansson & Smith, 1991; Youmans & Arciszewski, 2014) and significantly impacts an individual's ability to innovate and solve problems (Crilly & Cardoso, 2017; Wang et al., 2023). For instance, in a study entitled «The Puzzle Box Design Competition», students were tasked with designing a tool to extract remaining puzzle pieces from a box while adhering to specific rules (Youmans, 2011a). The results revealed that when students were exposed to a sample design that did not follow the competition rules, they nevertheless attempted to reproduce the ideas of that sample, disregarding the non-compliance. The existing research literature clearly demonstrates that fixation frequently arises during the creative process, hindering the generation of both novel and useful ideas (Chrysikou & Weisberg, 2005). Design fixation can be observed across numerous design disciplines that necessitate creativity, including industrial design, engineering design, architecture, software design, interaction design, and service design (Crilly, 2015).

2. Artificial Intelligence and Design Fixation: The recent development of generative AI as a viable tool in the ideation process has sparked extensive discussion among researchers concerning the potential for human-AI co-creativity. New studies suggest that AI can function as a collaborative creative assistant, helping to reduce mental barriers and enhance overall creativity (Hoggenmueller et al., 2023; Hughes et al., 2021). By strengthening

designers' capacity for creative and divergent thinking, this technology encourages the generation of diverse ideas and distinctive solutions, thereby potentially mitigating mental blocks to creativity, including design fixation (Shi et al., 2023). Although recent research has not reached a consensus on the exact impact of AI utilization on design fixation, given the accelerating capabilities of AI and the critical importance of creative thinking, we anticipate a significant increase in studies investigating the effect of generative AI on fixation reduction in the coming years.

3. The Morphological Analysis Method: The morphological analysis method is a systematic approach to analyzing a problem or product based on its expected functions, operations, or affordances. It proposes various ideas for each of the product's structural components. This method facilitates the discovery of alternative solutions for sub-structures by decomposing the product's main elements into their sub-components. It assists designers in systematically considering a wealth of potential solutions that might otherwise be overlooked under normal circumstances (Belaziz et al., 2000). Diverse stages of implementing the morphological method are presented across sources on creativity and ideation techniques. However, the method is generally executed in three core phases: 1. Decomposing functions or operations, 2. Ideation, and 3. Synthesis or combination of ideas (Cross, 2021, 126). Ideation within the corresponding morphological charts can be executed in various ways. Nevertheless, since the ideas must be synthesized in the final stage of this method, it is more effective to present them as much as possible in the form of sketches or visual schemes to enhance their evaluation and combination. The term "morphological" itself is derived from this emphasis on form (Fig. 1).

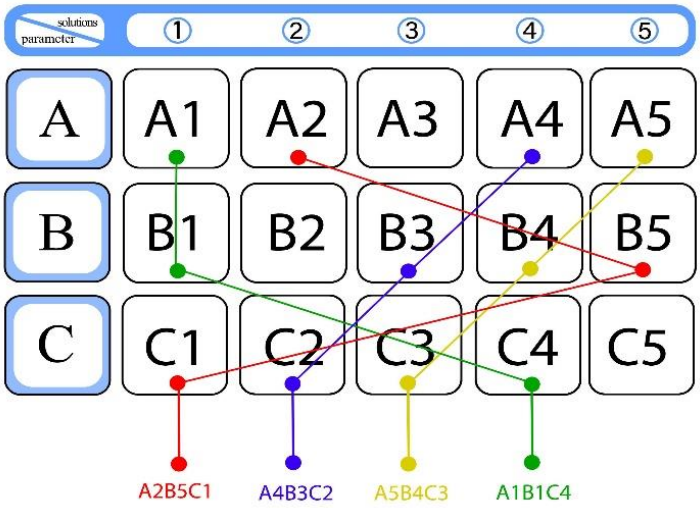


Fig. 1. Presentation of solutions corresponding to functional parameters in the morphological chart and the method for final synthesis. Source: Authors.

Validity and Reliability Midjourney as an Ideation Tool and Measures of Design Fixation

Prior research has demonstrated that the Midjourney tool, as a rapidly advancing technology, can play a pivotal role in conceptual design and early-stage design exploration by synergizing human creativity and artificial intelligence. By facilitating rapid visualization, this tool speeds up the design process and enhances creativity (Yin et al., 2023). In the design ideation phase, Midjourney enhances conceptual and visual creativity by providing precise, rich, and highly comparable visual stimuli. Furthermore, analyses indicate that the images generated by this system exhibit greater efficacy than those from other AI systems, due to their strong alignment with the study's conceptual frameworks and research variables, specifically the criteria for evaluating design fixation (Lee & Chiu, 2023). It is important to note that, given the inherently creative and non-deterministic nature of Midjourney in idea generation, if the tool were prompted to produce designs for a walker multiple times under identical conditions, the outputs would not be completely uniform; exact replication of results would not occur. In other words, the reliability of Midjourney's outcomes cannot be assessed in the conventional sense of verbatim output repetition across different iterations. Moreover, the principal objective of using this tool in conjunction with the morphological box method is to generate diverse, innovative ideas with the explicit aim of reducing design fixation. Therefore, within the context of this study's goals, the expectation of perfectly consistent and exact repeatability is not relevant. Conversely, the validity of the assessment measures was ensured by referencing standardized indices established in the research literature. Metrics such as the number of ideas, novelty, and fixation percentage, which have been validated in prior reputable studies, served as the basis for our measurement framework. These indicators have previously established their content and construct validity and, within the scope of this research, enabled a valid and precise evaluation of Midjourney's impact on design fixation. Reliability in the evaluation segment of this study was defined based on the consistency of human judgments regarding the design outputs. The inter-rater reliability method was employed to measure it. Five independent evaluators assessed the quality and creativity of the outputs across multiple stages to examine the degree of consensus among their judgments.

Research Procedure

In the initial step, the focus group was tasked with selecting a product for design that met several criteria: it should not be overly complex, yet the issue of design fixation needed to be prominently present; and the product had to comprise multiple components and functionalities. Furthermore, the design topic had to be chosen so that its expected functions were entirely unambiguous, minimizing interpretive variance and ambiguity, and accounting for intervening factors to ensure the highest possible validity of the test results. Initially, 20 product design themes were proposed and recorded by the group members. Ultimately, by consensus of the focus group, the topic selected was the design of a walker for the elderly, based on the following detailed design brief: «Design a specialized walker for the elderly, ensuring its main frame provides sufficient stability and ease of use for the user. The walker's height must be adjustable to accommodate users of varying dimensions, while remaining lightweight, robust, and durable. It must be collapsible to reduce volume when not in use. It requires ergonomic handles, a suitable seating surface for short rests, a storage basket, reliable wheels and safety brakes, and stable, non-slip connecting components for contact with various surfaces. Crucially, the walker must facilitate walking

and support the user's weight while simultaneously reinforcing the elderly user's sense of independence, confidence, and safety in ambulation». Additionally, considering the characteristics and operational method of the Midjourney tool, a simple, schematic image of an existing standard walker was prepared, along with a summary of the design brief, to initiate the ideation process. The walker image is shown in Fig. 2.

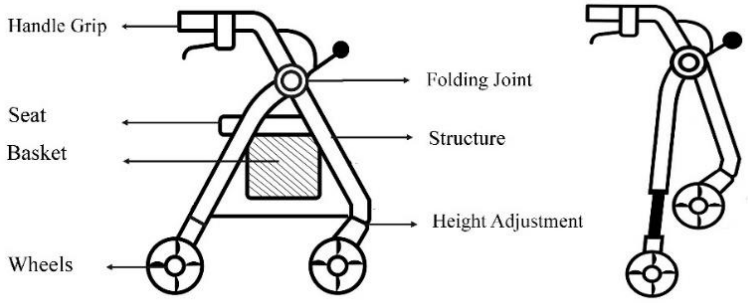


Fig. 2. Schematic diagram of the intended walker sample, with seven parameters and key functional features. Source: The Authors.

The target walker comprised seven distinct functional components, presented to the focus group as metrics for measuring design fixation and evaluating test results. Once the input information for the Midjourney tool (including the textual components usable in the design prompts) and the design fixation criteria were finalized, the experiment was conducted in three sequential phases. In the first phase, key phrases extracted directly from the design summary were structured into design prompts and provided to the Midjourney tool for direct ideation. These prompts were first refined and optimized using the conversational AI tool ChatGPT (15) to ensure their maximum effectiveness when used in Midjourney. This approach served as the baseline, representing standard, non-structured AI prompting. In the second phase, instead of directly using the components extracted from the design brief, the researchers initially employed the morphological analysis method and its corresponding chart. This step systematically identified the product's components and their expected characteristic functional features. Each of these disaggregated components was then presented to the Midjourney tool, which was prompted to generate different ideas for each element of the morphological chart. It is essential to note that while the AI's data sources remained consistent during this phase, the basis for ideation was fundamentally different, relying on the structured output of the morphological chart. Subsequently, the ideas from this disaggregated step were reintroduced to Midjourney to facilitate synthesis and achieve complete, final designs. At the conclusion of this phase, a total of 32 complete and final walker product ideas were saved. In the third and final phase, the visual images of the final ideas generated in the previous two phases were presented to the focus group separately and systematically. The group's task was to evaluate the degree of design fixation using predetermined criteria by comparing the results of two distinct AI-based ideation methods.

AI-generated brainstorming results

Ideas Generated from First Phase: In the first phase of this study, a total of 32 ideas were generated directly, without using morphological analysis. Samples of these generated ideas are presented in Fig. 3.

Ideas Generated from the Second Phase: In the second phase, 35 initial ideas were generated using artificial intelligence, specifically by leveraging components derived from the morphological chart. This process involved employing the structural decomposition

inherent in the morphological method to facilitate the formation of more precise, detailed ideas. Subsequently, the final images were produced by synthesizing these initial concepts using Midjourney's image-blending tool. These final outputs accurately reflected the underlying structural analyses and morphological features identified during the decomposition process. The morphological chart, along with the resulting AI-generated ideas, is presented in Fig. 4.



Fig. 3. Sample of ideas generated by the AI in the first phase; direct use of keywords in the summary of the design brief. Source: Authors.

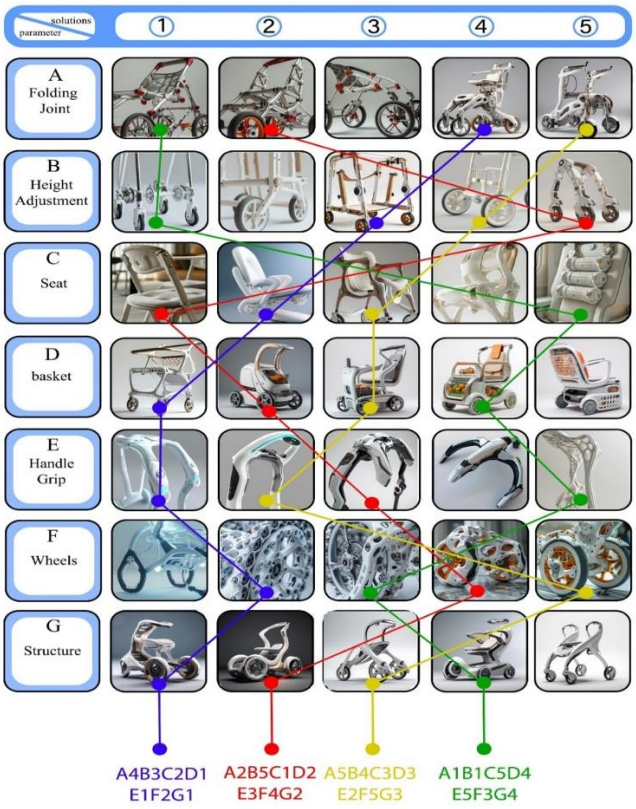


Fig. 4. A total of 35 ideas obtained based on the morphological chart using generative artificial intelligence. Source: Authors.

Following the second phase, the solutions derived from the morphological chart were combined and integrated, and the image-blending capability of Midjourney AI was subsequently employed. The ideas generated through this synthesis method yielded notable results concerning visual composition and the integration of forms and colors. However, a key observation was made: certain critical design elements initially outlined in the primary components of the morphological chart were inadvertently omitted or overlooked in the final outputs. Concurrently, it was evident that the AI technology placed greater emphasis on visual and aesthetic aspects, such as form and color. While functional and technical aspects were considered, they did not receive sufficient attention and were consequently not fully reflected in the final generated ideas (Fig. 5).

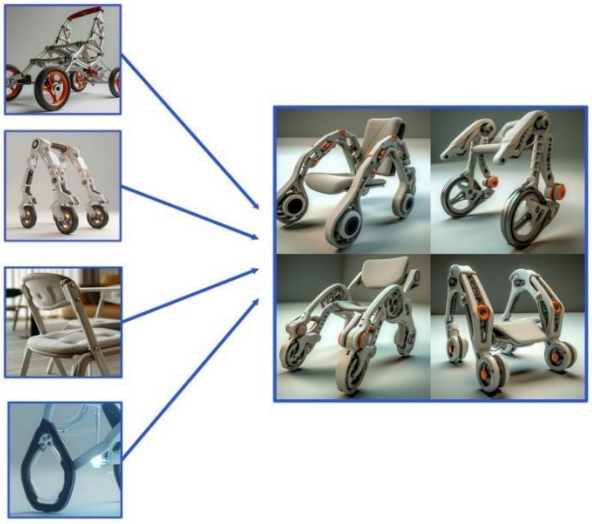


Fig. 5. A sample composite of morphological chart solutions generated using the Midjourney AI's image-blending feature. Source: Authors.

After combining the solutions presented in the morphological chart using the AI image-blending tool, 32 final ideas were generated. A selection of the final ideas resulting from the third phase is shown in Fig. 6.



Fig. 6. A sample of the ideas generated by artificial intelligence at the conclusion of the second phase, resulting from the synthesis of concepts extracted from the morphological chart. Source: Authors.

Evaluation Metrics: This section examines the established criteria for measuring design fixation. Within the literature on this domain, two primary categories of metrics for evaluating design fixation in ideas are proposed: Direct and Indirect criteria. Direct criteria explicitly and precisely measure the degree of fixation present in the generated ideas, making the designer immediately aware of its existence. In contrast, Indirect criteria assess fixation implicitly and non-explicitly but do not furnish the designer with accurate information to confirm the results (Moreno et al., 2016). In this study, to define the independent variables for assessing idea fixation, we utilized the direct criteria introduced by Linsey et al. in 2010 and further developed by Moreno et al. in 2016. These criteria comprise three main indicators: Total Number of Ideas Generated, Novelty, and Percentage of Fixation.

1. Total Number of Ideas: For the quantitative assessment of ideas, the number of ideas resulting from each morphological chart component is calculated. The Total Number of Ideas Generated (Q_{Total}) is defined as the sum of Repetitive Ideas (Q_R) plus the Non-Repetitive Ideas (Q_{NR}). Repetitive ideas are those where the AI generated minor variations of preceding ideas, whereas non-repetitive ideas are unique, lacking a similar component in prior outputs (Moreno et al., 2016).

$$Q_{Total} = Q_R + Q_{NR}$$

2. Novelty: signifies the non-repetitive and unique nature of an idea or solution. Conversely, an increase in similar solutions indicates a reduction in novelty and innovativeness. In alignment with the approach of Moreno et al., the novelty criterion is calculated by subtracting the ratio of the total number of repetitive ideas to the total number of ideas generated from the number one (Moreno et al., 2016).

$$Novelty = 1 - frequency = 1 - \frac{\mathrm{QR}}{\mathrm{QTotal}}$$

3. Fixation: Based on the definition by Moreno et al., the Percentage of Fixation can be defined and calculated as the ratio of the number of repetitive ideas to the total number of ideas generated (Moreno et al., 2016).

$$\mathrm{Fixation} = \frac{\mathrm{QR}}{\mathrm{QTotal}}$$

Evaluation of Findings: In this phase, the images corresponding to the ideas extracted from the two previous phases were presented separately to the focus group, which consisted of five industrial design specialists. The purpose was to compare the results of the two AI-based ideation methods and to determine the level of design fixation using the metrics mentioned above.

1. Analysis of Idea Count: To calculate the fixation percentage, repetitive ideas, non-repetitive ideas, and also images lacking a suitable idea were first identified. Table 1 shows these values across the different phases. In Phase 1, where AI was used for direct ideation, 18 non-repetitive and 160 repetitive ideas were generated from the design components. Furthermore, 46 of the presented images were identified as lacking a suitable idea. In Phase 2, where analytical morphological charts were employed in the generative AI ideation process, a total of 137 ideas were obtained, of which 78 were non-repetitive and 59 were repetitive. Additionally, 87 of the generated images were deemed to lack a suitable idea (Table 1).

Table 1. Values obtained from a quantitative review of ideas for each component, separated by the two research phases. Source: Authors.

PHASE 1					PHASE 2				
Parameters	**No Idea**	**Has Idea**	**Repeated Idea**	**UnRepeated Idea**	**Parameters**	**No Idea**	**Has Idea**	**Repeated Idea**	**UnRepeated Idea**
Folding Joint	17	15	11	4	Folding Joint	19	13	4	9
Height	9	23	18	5	Height	20	12	2	10
Seat	3	29	28	1	Seat	13	19	10	9
Basket	12	20	17	3	Basket	16	16	6	10
Handle Grip	5	27	25	2	Handle Grip	19	13	3	10
Wheels	0	32	32	0	Wheels	0	32	28	4
Structure	0	32	29	3	Structure	0	32	6	26
TOTAL	46	178	160	18	TOTAL	87	137	59	78

2. Analysis of Fixation Percentage: Based on the definition provided in the preceding section, the average percentage of fixation was calculated to be in Phase 1 and in Phase 2. Although the results demonstrate that design fixation is present in both phases, the fixation percentage decreases significantly in Phase 2 due to the intervention and application of the morphological analysis method (Table 2).

Table 2. Fixation percentage for each design component and their averages, separated by the two research phases. Source: Authors.

PHASE 1		PHASE 2	
Parameters	**Fixation**	**Parameters**	**Fixation**
Folding Joint	73%	Folding Joint	30%
Height	78%	Height	16%
Seat	96%	Seat	52%
Basket	85%	Basket	37%
Handle Grip	92%	Handle Grip	23%
Wheels	100%	Wheels	87%
Structure	90%	Structure	18%
average	87.7%	average	37.5%

3. Analysis of Novelty: Considering the seven components outlined in the morphological chart, 18 non-repetitive ideas were generated in Phase 1, whereas 78 non-repetitive and unique ideas were produced in Phase 2. Corresponding to the definition of novelty provided in the preceding section, the average novelty score for the ideas was calculated to be in Phase 1 and in Phase 2. This substantial difference indicates a remarkable and significant increase in idea novelty when the morphological method was employed in Phase 2 (Table 3).

Table 3. Novelty scores for each design component and their averages, separated by the two research phases. Source: Authors.

PHASE 1		PHASE 2	
Parameters	**Novelty**	**Parameters**	**Novelty**
Folding Joint	0.27	Folding Joint	0.70
Height	0.22	Height	0.84
Seat	0.04	Seat	0.48
Basket	0.15	Basket	0.63
Handle Grip	0.08	Handle Grip	0.77
Wheels	0	Wheels	0.13
Structure	0.10	Structure	0.82
average	0.12	average	0.62

Discussion

This research investigated the effect of the morphological analysis method on design fixation during the ideation process using Artificial Intelligence (AI). In the first stage, which involved design prompts based on keywords extracted directly from the design brief summary, 178 ideas were generated, of which 160 were duplicates, resulting in a design fixation rate of approximately 88%. This figure indicates a significant negative impact of design fixation in the AI ideation process. In the second stage, by applying the morphological analysis method, 137 ideas were generated, including 78 non-repetitive ideas, and the design fixation rate was reduced to 37.5%. Furthermore, the novelty rate increased from 0.12 in the first phase to 0.62 in the second phase, demonstrating the generation of unique and innovative ideas. These results clearly show that, although evidence of design fixation persists in ideation across both methods, applying the morphological chart analysis method can be an effective strategy for reducing design fixation and generating more creative, divergent concepts. But how does the morphological method contribute to increasing the diversity and novelty of ideas while reducing repetition in AI-generated outputs? As noted, this method provides a systematic framework for analyzing a design problem or product based on its expected functions, operations, or affordances. In other words, this method decomposes the target design problem or product into its anticipated functional components, enabling focused attention and subsequent individual ideation for each component. When the design brief summary is given directly to the AI as a single prompt, certain details or components of the request may be overlooked or become repetitive in the resulting ideas. However, by applying the morphological method, the AI request is segmented into specified components, each treated separately as a new prompt and an independent basis for ideation. Consequently, the distinct components presented in each request are emphasized and incorporated into their respective ideas. Therefore, during the final synthesis, more differentiated components will be available for combination and innovation, thereby increasing idea novelty and reducing the rate of design fixation. In light of these findings, the following suggestions are offered for applying the morphological analysis method within the AI-assisted ideation process: As mentioned previously, the morphological chart method can be executed in three main stages:

decomposition of functions or operations, ideation, and synthesis or combination of ideas. However, it is paramount to recognize that the most critical stage in this process is the decomposition of the problem into components, or the breakdown of the product into its expected functions and operations. Should this stage be executed improperly, the method will not yield the desired outcomes. Consequently, this step should not be entirely delegated to the AI; it must be repeatedly reviewed, corrected, revised, and completed by the designer or design team until the design objectives are fulfilled. In addition to aesthetic and functional characteristics, AI can generate ideas for technical and mechanical features by using precise prompts that emphasize the intended mechanism's function, potentially suggesting combinations of mechanisms. It should be recalled, however, that this observation does not constitute an endorsement of the computational or technical aspects of the mechanisms, their standardization, or the feasibility of accurately measuring their performance. Fig. 7 illustrates examples of mechanisms suggested by the AI in response to the walker's requirement for collapsibility and height adjustability.

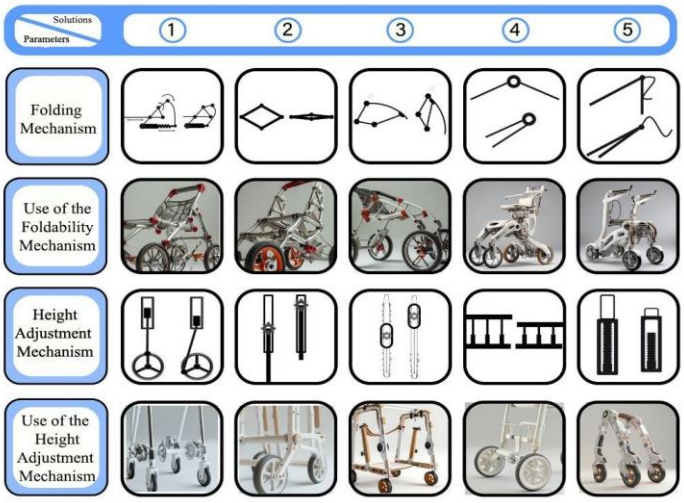


Fig.7. Application of some technical mechanisms generated by AI in the morphology chart. Source: Authors.

The utilization of artificial intelligence as an assistant or support tool in the design process necessitates familiarity with the method of prompt writing (prompting). By refining and upgrading the formulated prompts at each stage, one can clearly observe an improvement in the results, including the number, diversity, accuracy, and quality of the generated ideas. To this end, the designer must be familiar with the key vocabulary, synonyms, and specialized terminology applicable to artificial intelligence. In this context, the conversational AI tool ChatGPT can play an effective role in generating and refining prompts for use with Midjourney or other AI interface tools. This tool was also employed in the present study. Before the synthesis or combination phase of the ideas, it is essential to identify the distinct, valuable, and practical ideas generated by the AI for each component of the morphological chart, thereby preventing ambiguous ideas from entering the synthesis phase. This approach does not imply bias in idea selection or steering the final design toward a specific outcome; rather, it is performed with the aim of facilitating the combination of

distinct and valuable design components while simultaneously preventing repetition and design fixation, ultimately leading to the highest possible degree of creativity and innovation in the final ideas.

Conclusion

The results of this research demonstrate that proficiency in the morphological analysis method and its correct application in the AI-assisted ideation process can not only foster divergent thinking and increase creativity but also significantly reduce the rate of design fixation and enhance the novelty and innovation of ideas. As noted in the body of the article, some researchers believe that generative AI can function as a co-creative assistant, helping to eliminate mental barriers, boost creativity, and reduce design fixation. However, there is no consensus among researchers on whether AI alone can reduce design fixation. The findings of this research clearly indicate that, in the absence of specific tools or methods to mitigate design fixation, the AI ideation process remains characterized by design fixation. This issue, stemming from the repetition and stability of design foundations during the ideation process, impedes creativity and divergence when using this tool. Therefore, future research should not only examine the pathology of this phenomenon in the process of creativity and design but also investigate the causes of design fixation in ideation with generative AI and propose novel, distinct strategies for its control or reduction.

Author Contributions

This article is the result of collaborative efforts by all authors. All authors participated in the drafting of various sections, the review of findings, the analysis of results, and the final approval of the manuscript.

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Conflict of Interest

The author (s) declare that there are no potential conflicts of interest related to this research, in writing, and publication of this article

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