MASTER

Exploring ambiguity in generative AI images and its impact on collaborative design ideation

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Award date:
2024

Link to publication
Exploring ambiguity in generative AI images and its impact on collaborative design ideation

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1654284
in partial fulfillment of the requirements for the degree of

Master of Science
in Human-Technology Interaction

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Acknowledgments

As a committed planner and a perfectionist, I often find myself unsettled in uncertain situations, wishing to know and have control over how things would or should go. And yet, I also see the potential and beauty in things that are undefined and ambiguous. The topic of this study is very close to my heart, as it encompasses all of my academic interests in design, cognitive science, and human-computer interaction. It is also my attempt to embrace the ambiguity and find creativity in it.

Firstly, I would like to thank Alvin, Victor, Qianhui, Yuwan, Xinhui, and Ted. When I was feeling lost, these people took their time to listen to me sharing my research ideas and study setup, and helped me clarify my thoughts. I am also very thankful to Jakob for proofreading my report and providing me with insightful suggestions on my writing.

I would like to express my deepest gratitude to my supervisors, Wijnand, Pei, and Kristina. Despite their insanely busy schedules and other responsibilities, they took the time to regularly meet with me and patiently guided me through this whole journey. I am immensely grateful for this opportunity to work with them and learn from them, and I have grown so much as a researcher from their valuable and in-depth feedback. Particularly, I would like to thank Pei for helping me with my research across time zones, even during holidays, and for even introducing me to other researchers who are also passionate about human-AI collaboration. Also, a special thanks to Sanne who was my supervisor for my HTI research project a year ago. Even though she was not involved in this current research, I am deeply grateful for her patience and professional guidance in my scientific writing, which built the foundation of my writing today.

Finally, I would also like to thank my boyfriend, Chris, my counselor, Marja, my parents, and many friends for their love and emotional support. These are the people who kept checking on me and encouraging me to believe in myself. Their support kept me grounded and motivated to keep chasing my academic ambitions.
Abstract

With the advancement of machine learning (ML) models generating high-fidelity images from natural-language-based text, generative Artificial Intelligence (AI) tools have sparked considerable discussions in the design field. The current study explores how using these text-to-image generative AI tools may influence designers’ collaborative ideation process. In particular, the research examines the impact of ambiguity in generative AI images on designers’ creative thinking and collaborative design ideation. During five workshops, 15 experienced designers were invited to ideate on an open-ended design brief in two sessions: one through the use of manual sketching tools, and the other through co-creating with Midjourney. Participants were instructed to evaluate the visual representations most relevant to their best ideas generated, and then reflect on their ideation experience collectively and individually. The results show that the ambiguity in highly detailed AI-generated images facilitated designers’ ideation by encouraging wide exploration, creative interpretations, and open discussion. However, ambiguity was not deemed helpful when it hindered designers’ creative train of thought or distracted them with polished visual details that contained arbitrary design choices. The AI-generated images were perceived as more concrete but still open to more interpretations, and less valuable than one’s manual sketches. For ambiguity to enhance the design processes, it must be understandable and contribute to clarity. Finally, the study discusses how the mechanisms of ambiguity and the use of generative AI impact designers’ creative thinking and collaborative ideation process, compared to traditional manual sketching. Implications and suggestions are further discussed for designers engaging in creative ideation and for the development of future AI-powered design tools.

Keywords: ambiguity, design ideation, human-AI co-creation, co-creativity, embodied cognition, text-to-image generative AI, sketching, creativity support tools, Midjourney
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I. Introduction

The increasing prevalence of Artificial Intelligence (AI), such as generative machine learning models and large language models, has sparked a keen interest in exploring novel opportunities and challenges AI systems bring to the design field. These technologies offer huge potential in facilitating and transforming designers’ creative workflows, especially with image-generating tools that can rapidly produce variations of visual outputs based on any given text prompts from users with minimal effort.

However, these powerful tools are not yet to be incorporated into most designers’ creative workflows. An online questionnaire by Sanchez (2023), who examined the text-to-image community of practice, revealed that text-to-image generative AI tools are still primarily used for recreation activities. The current user base is found to have relatively narrow demographics, and many users identified challenges in formulating effective prompts and the technical limitations in the AI models (Sanchez, 2023). For example, current AI models often fail to produce visual outputs that accurately match human users’ expectations and preferences, known as the human-AI alignment issue (Wu et al., 2023; Lee et al., 2023). Therefore, users often have to engage in iterations of trials and errors with text prompts until they can retrieve desirable results from the language models (Liu & Chilton, 2022). By re-structuring the input prompts in ways that tailor the results to desired tasks or goals, a process known as prompt engineering, users can clarify their prompts to help the AI models understand better and achieve the desired outcomes (Mehrabi et al., 2023).

In Why Greatness Cannot Be Planned: The Myth of the Objective, Stanley & Lehman (2015) argued that attempting to reach set objectives may be counterproductive to creativity and novel innovations. They argued that much of human progress is an open-ended process of walking on stepping stones, rather than a clear path that can be planned in advance. Therefore, they invited AI researchers to consider challenging the status quo and allowing room for inspiration and novelty search while continuously improving AI algorithms.

Therefore, the current study takes a novel approach, diverging from the human-alignment focus in image-generative AI research. Building on Green & Lindley's (2021) perspective of ambiguity as a crucial and emergent aspect in design research, this study investigates the potential of ambiguity in AI-generated images for facilitating designers' creative ideation process. An explorative study was conducted to investigate the complete process of designers collaborating and freely interacting with Midjourney, a state-of-the-art text-to-image generative AI in their exploratory ideation. This includes how they write and iterate their
Ambiguity is defined as “a situation in which something has more than one possible meaning and may therefore cause confusion” (Cambridge University Press, n.d.). Although ambiguity can be considered an issue in design, it can be a valuable resource, as the process of making sense of presented ambiguity fosters curiosity and encourages thought-provoking designs (Gaver et al., 2003). While the impact of visual ambiguity on design ideation has been studied with controlled levels of ambiguity (Tseng, 2018), little research has been directed toward how ambiguity in uncontrolled settings (i.e., in freely generated AI images) may facilitate designers’ creative thinking.

In collaborative design settings, manual sketching is used as a well-established and efficient ideation method that preserves high levels of ambiguity. With the current advancement of image-generative Al's, these Al systems provide an alternative way that also allows designers to iteratively and rapidly create ambiguous visual examples, regardless of sketching skills. However, there is a trade-off of the ambiguity in these Al-generated images, as they also contain more detailed visual outputs than traditional sketches, leaving less room for ambiguity. Therefore, this current research aims to examine the ambiguity in Al-generated images used in a collaborative ideation setting. This led to the main research question: How does the ambiguity in the images generated by text-to-image generative Al influence designers’ creative ideation process? In particular, the current research aims to answer the following sub-questions:

- What are the mechanisms of ambiguity engaged in idea revisions and iterations?
- What features of ambiguity provided by the Al may benefit or limit the ideation process?
- How does the Al challenge the traditional co-ideation process with manual sketching?
- What roles or functions does the generative Al have in a collaborative ideation process?
II. Theoretical Background

1. Visual Inspiration in Design Ideation

Within the design process, ideation is the early-stage phase that involves divergent concept generation and plays a pivotal role in influencing the ultimate creative output of a design (Wang & Han, 2023). Ideation has several implications to be considered at the beginning of the design process: the need for research or exploration, interpretation of problems, and identification of solutions; various concepts are explored until main ideas emerge and serve as the guiding principles for further development and refinement (Goldschmidt, 2017). Goldschmidt (2017) also argued that the result of the design process is a set of primarily visual representations of the designed entity, focused on the speed of making. Many ideation methods have been developed and commonly practiced to help overcome designers’ mental blocks, such as brainstorming, metaphors, mind mapping, and scenario creation (Bettaieb, 2022).

While generating ideas, inspiration is key to the designers’ ideation process, but different sources of inspiration influence the generation of ideas differently (Howard et al., 2010; Battaieb, 2022). Designers often utilize both internal and external stimuli, which are one’s working and long-term memory, such as mental imagery and verbal information, and entities in one’s surroundings, which can be pictorial, verbal, audible, or tangible (Gonçalves et al., 2014). Compared to textual stimuli as external stimuli, pictorial stimuli have been found to inspire more complex and original thinking and encourage the use of drawing for idea generation (Bettaieb, 2022). This was supported by Malaga (2000), arguing that picture stimuli are more effective in stimulating more creative ideas. This is because pictures require less cognitive effort to interpret and provide richer and more immediate visual information, which can trigger broader associative thinking and lead to more diverse and creative ideas (Mednick, 1962; Malaga, 2000). However, Gonçalves et al. (2014) argued that exposing people to visual examples can have both positive and negative effects on design performance. Inspirational sources are beneficial if they expand the potential space for creative solutions, but they can also be harmful if they limit ideas to merely replicating existing examples.

In particular, Wang & Han (2023) highlighted the significant efficacy of generative visual stimuli in influencing designers’ creativity during ideation tasks for conceptual integration. In their study, the stimuli were generated by a computational generation method and combined certain features of two unrelated products (e.g., bikes and headphones) in one image. Because these generative stimuli decrease the designers’ workload in the initial integration of
two concepts, designers are found to be able to refine their designs and form new ideas more quickly (Wang & Han, 2023).

2. Sketching and Cognition

Traditionally, designers use sketching in the initial stages of creative design, primarily as a tool for exploration and visualization (Goldschmidt, 2017; Kavakli & Gero, 2001). However, sketching is an essential design activity from the start for initial idea generation, and throughout the design process to refine and evolve the concept (Prats & Garner, 2006; Buxton, 2007; Dalsgaard, 2017). Sketching allows designers to rapidly externalize and develop their thoughts, helping them conceptualize and refine their initial ideas (Prats & Garner, 2006; Goldschmidt, 2017). By definition, sketches are characterized by quick thinking, undefined thought, and being task-specific (Bettaieb, 2022). Sketching is a cognitive process of mental imagery (Kavakli & Gero, 2001; Prats & Garner, 2006), as it bridges the gap between abstract ideas and concrete representations, allowing designers to consider a wider range of design alternatives and solutions.

Design sketches of shape and form, in particular, combine perception and interpretation with creation and evaluation (Prats & Garner, 2006). Designers engage in a visual reasoning process, as they interact with the self-produced visual depictions through sketching (Kavakli et al., 1999; Tholander et al., 2008). When designers draw with sketching tools, they construct new meanings to what they see in their sketches and discover unexpected and fuller understandings of their work, which further their conceptual design (Schon & Wiggins, 1992). This process of reinterpretation is referred to as a “seeing-as” activity (Goldschmidt, 1991). Unexpected discoveries in sketches are the driving force for the situated invention of important design issues and requirements (Suwa et al., 1999).

In general, the use of tools does not only involve internal or mental representations but also external representations that define the human-environment-tool-object system (Baber et al., 2014). This argument builds upon the theory of distributed cognition, which states that the cognitive processing of information does not merely occur inside the individual brain, but is distributed in sociocultural systems that encompass external artifacts for us to think and perceive the world (Hutchins, 2000). Baber et al. (2014) argued that distributed cognition includes not only the physical affordances of a tool, but also the anticipated actions by the user toward manipulating the tool, and the relationship between the tool and the object that is being used on. Based on the theory of embodied cognition, Kirsh (2013) argued that tools modify and shape our perception, conception, and our body schema. That is, with physical
tools in our hands, we think along with the tools that are separate from our bodies, selectively seeing tool-dependent affordances and extending our exploratory and probative capacities.

With the capability of iteratively customizing visualizations based on human commands, text-to-image generative AI presents huge potential in stimulating creative thinking in design. Little research has been done on how such AI systems may be used as a valuable alternative to traditional manual sketching tools in rapidly iterating on raw design ideas. Therefore, this research aims to investigate how designers incorporate sketching and interacting with a text-to-image generative AI in their ideation to see if the latter brings new opportunities and potential values to the creative ideation process.

3. Ambiguity

Ambiguity refers to the quality of affording multiple interpretations (Boon et al., 2018). It is often associated with creativity, which is crucial for idea generation in the design field. Tan & Kvan (2019) discussed three types of ambiguity, which exist when a word has multiple meanings, (i.e., lexical ambiguity), when a sentence holds multiple interpretations (i.e., syntactic ambiguity), and when a situation eludes different meanings (i.e., semantic ambiguity). According to Tan & Kvan (2019), ambiguity commonly arises at the stage of divergent thinking that focuses on the quantity over quality of ideas, before ideas are evaluated via convergent thinking. The capacity of sketches to display ambiguity is key to their role in assisting designers in their creative process and the development of visual qualities (Prats & Garner, 2006). Individuals who are more tolerant of ambiguous situations and stimuli are significantly more creative, as they keep an open mind and continuously optimize solutions to complex problems (Zenasni et al., 2008). Tseng (2023) also found that more ambiguity gives designers greater freedom to search for ways to resolve the presented ambiguities and produce more creative ideas. Sanders (2005) argued that the design development process is fostered through research emphasizing experimentation, ambiguity, and surprise.

Moreover, ambiguity is a property of the interpretative relationship between people and artifacts, and it sets the scene for creative meaning-making (Gaver et al., 2003). In other words, ambiguity can be a beneficial resource for design because of its interpretive space for designers. According to Gaver et al. (2003), ambiguity may arise out of the way information is presented by the artifact, the context that is used to interpret an artifact, and the interpreters’ relationship with the artifact. In particular, the reinterpretation of design sketches and the utilization of ambiguity, defined by the low complexity in the types of information provided by the sketches, are crucial in design generation (Prats & Garner, 2006). As shown in the
observation study by Prats & Garner (2006), designers produce sketches with low and high complexity levels in an iterative manner to attend to both local details and general structures of a design. Similarly, Tan & Kvan (2019) argued that ambiguity prompts designers to question and re-evaluate their assumptions, discovering overlooked or innovative opportunities in design problems.

Nonetheless, ambiguity is not always beneficial for design, such as a lack of clarity in design communication (Stacey & Eckert, 2003). Stacey & Eckert (2003) argued that design representations that fail to clearly convey uncertainties can lead to misunderstanding and confusion in the design process, which hinders effective communication and collaboration.

4. Human-AI Collaboration in Design

Introduced in the 1960s, Computer-Aided Design (CAD) and its software tools were developed to optimize the design process (Tholander & Jonsson, 2023). Nowadays, these design software tools, such as Adobe Photoshop, have been significantly advanced through AI. For example, Photoshop AI allows sky replacement, which simplifies complex tasks like selecting subjects and replacing skies in images. The goal of the AI in these tools is to offload repetitive tasks to computers, enabling designers to concentrate more on the creative facets of design (Albaugh et al., 2020).

Gradually, advances in design computing gave rise to generative design systems, which use algorithms to rapidly produce design variations and facilitate the exploration of bigger design spaces (Mountstevens & Teo, 2020). In recent years, generative AI combined with large language models have introduced new opportunities in CAD. These generative AI-enhanced design tools have notably decreased the barriers to engaging in design iteration by enabling designers to rapidly create detailed imagery from preliminary concepts, thereby facilitating faster and more iterative feedback on their design ideas. For example, an interview study conducted by Ko et al. (2023) revealed that visual artists from 35 distinct visual art domains confirmed the versatile usability of large-scale text-to-image generative models (e.g. DALL-E, Midjourney) in automating the creation process, expanding their ideas, and facilitating their communication.

Traditionally, designers are seen as the sole active agents in design activities. However, Tholander et al. (2012) investigated how design materials actively engage in a dynamic interaction with designers. They argued that design processes include not only the designers constructing meaning but also the design materials continuously contributing to the meaning-making process and influencing how the design activity unfolds.
Although generative AI tools do simplify and speed up the generation of design alternatives, the generated results are too generic and lack an understanding about the context of the design problem (Tholander & Jonsson, 2023). Despite successfully imitating the artistic presentation of formal features, AI technology fall short of conveying the underlying emotional context of the images generated (Lyu et al., 2022). Shneiderman (2020) proposed the framework of Human-Centered Artificial Intelligence (HCAI), in which he argued that technologies that maximize performance require high levels of both human control and automation. Because computers are intrinsically different from humans, both have their unique advantages, such as computers’ sophisticated algorithms and voluminous databases, and humans’ innovative thinking and responsibility for mistakes. In other words, design products with artificial intelligence should be made that amplify and enhance users, and thus increase their performance. Fundamentally, Tseng (2023) argued that AI-rendered images still require much human reflection, interpretation, and design experience for them to be considered truly useful in design ideations.

Furthermore, the various roles of AI systems influence users’ perceptions and expectations of the AI system. McComb et al. (2023) introduced a 2x2 AI-human teaming matrix that categorizes AI roles based on their focus (problem-solving or process improvement) and modality (reactive or proactive). These correspond to AI being used as a tool, a partner, analytics, or a guide. Rezwana & Maher (2023) found that when AI is perceived as an assistive tool, users feel a stronger sense of ownership of the final product. In contrast, viewing the AI as a collaborator or an independent entity introduces more ethical concerns over where accountability and leadership each lie. Kim et al. (2023) also identified four AI role clusters, depending on how much human involvement and AI autonomy are involved. In particular, AI “assistants” (high in AI autonomy, low in human involvement) and “mediators” (high in human and AI agency) are preferred over AI “tools” (low in human and AI agency), which suggests a preference for AI with high autonomy. AI “servants” (high in human involvement, low in AI autonomy) and “mediators” are preferred over “tools”, which suggests a preference for AI enabling human control. Tholander & Jonsson (2023) found that users often expect that interactions with a conversation-based system are similar to human social interaction, which is beyond the system’s actual capability. When the AI system does not seem to perform as expected, users may experience frustration and disappointment. Therefore, AI systems should be designed to clearly indicate to users when they are interacting with an AI system and what content is AI-generated (Weisz et al., 2024).
5. Current study

Exploratory ideation is often associated with the early, creative stages of conceptual design, where the problem tends to be fuzzy and abstract (Hay et al., 2019). Such ideation involves open-ended design tasks, which are more frequently used to encourage original idea generation, exploratory problem interpretation, and divergent thinking (Sosa, 2018). For the current study, design briefs were also formulated in open-ended and fictional problems, which would allow participants to solve them easily and generate as many solutions as possible (Shah et al., 2000; Boon et al., 2018). Keeping the brief ambiguous would also encourage designers to explore ideas from various perspectives, expanding the scope for opportunities, rather than focusing on finding solutions and practicalities (Tan & Kvan, 2019).

The study’s participant criteria required a minimum of three years of professional or academic experience in design. According to Kavakli et al. (1999) and Tseng (2023), experienced designers were found to be better at working with higher degrees of ambiguity. That is, they are more skilled in interpreting visual features within the presented figures (sketches or AI-generated images) and taking inspiration from them.

This study’s ideation sessions were structured around small group collaborations among three designers for two primary reasons: firstly, to mirror real-life design team dynamics and maintain ecological validity, and secondly, to stimulate associative mechanism that leads to a greater quantity and quality of ideas, due to the unique stimuli provided by group members in small groups (Bouchard, 1969).

With the theoretical background mentioned above, the current study aimed to examine the mechanisms and impacts of ambiguity in AI-generated images in collaborative ideation settings, as well as the new opportunities provided by interacting with text-to-image generative AI in the creative process. The study provides a detailed examination of these dynamics, offering insights into the complexities of how designers collectively navigate and make sense of the ambiguities provided by a text-to-image generative AI in a co-creative environment. This understanding is crucial for fostering effective human-AI collaboration in creative design and potentially using text-to-image generative AI as a new ideation method.
III. Method

1. Research Design
Due to the exploratory nature of the study, a qualitative approach was chosen to capture the contextualized dynamics of how designers work with their own perceived ambiguity that naturally arises in their ideation process. The current research took place in the form of five collaborative ideation workshops. Experienced designers from different design backgrounds were invited to ideate on an open-ended design brief and to share their collective and individual reflections on ideating with manual sketching and with the addition of Midjourney, a state-of-the-art generative AI tool. More specifically, the workshops aimed to explore how designers perceive and interpret the inherent ambiguities within their sketches and AI-generated images, exploring the impact of such ambiguities on their ideation process.

Each workshop consisted of two ideation sessions, one with manual sketching only, and the other with the addition of a text-to-image generative AI tool, Midjourney. Since manual sketching is a commonly practiced ideation method, the manual sketching sessions were designed to be the control condition, compared to the AI sessions, which is the main focus of the current study.

Participants were randomly assigned into groups of three, with Group A engaging in manual sketching in their 1st session, and then adding the use of the AI tool in their 2nd session, while Group B followed the opposite order. More specifically, Workshop 1, 3, and 5 followed the order of Group A, and Workshop 2 and 4 followed the order of Group B. The switching order aimed to account for the potential differences in the influence of AI-generated images and manual sketches on designers’ creativity.

2. Participants
The study included a total of fifteen participants, comprising ten females and five males. Participants’ ages range from 20 to 34, with a median age of 25. Eight participants were pursuing or had completed a bachelor’s degree, seven held a master’s degree in design, and three were pursuing a Ph.D. degree in design. Their years of experience in design ranged from 3.5 to 10 years, with a median of 6 years. The selection criteria were to have at least three years of professional or academic experience in design and to feel comfortable with manual sketching.

Among the 15 participants, ten were recruited from the Industrial Design (ID) department of the Eindhoven University of Technology (TU/e). The other five were currently pursuing or had
completed a master’s degree in the Critical Inquiry Lab, Geo-Design, Contextual Design, and Social Design programs at the Design Academy Eindhoven. Participants were recruited through personal connections and academic affiliations within the ID department of TU/e.

All 15 participants had prior experience with AI, but only seven participants had used Midjourney before the study. In every workshop, there was at least one participant who had previously used Midjourney before. Four participants indicated a daily usage of generative AI tools, five indicated a weekly usage, five indicated a monthly usage, and one indicated that they had only used such tools once or twice.

Participants rated an average of 5.6 in their subjective creativeness on a 7-point semantic differential scale (1 being uncreative and 7 being creative), an average of 4.6 in their confidence in manual sketching (1 being not confident and 7 being very confident), and an average of 4.9 in their attitude of using AI in their design process (1 being skeptical and 7 being positive).

Participants’ primary sources of design inspiration were identified, with the majority citing others’ visual work on the Internet, including social media platforms like Pinterest, Behance, Instagram, and Tumblr. Conversations and interactions ranked second, followed by nature and places visited, research materials, and media (e.g., films and animations), with AI and poetry being mentioned by one participant each.

All participants were compensated at an hourly rate of 12 euros for a total of 3-3.5 hours, following the compensation guidelines established by the Human-Technology Interaction (HTI) department for research participation. The institutional Ethical Review Board reviewed and approved the research proposal and protocol, prior to executing the study.

3. Materials
During ten informal interviews prior to the study and a 30-minute pilot study conducted with masters’ students in the industrial design program at TU/e, Midjourney was found to be the most popular and helpful text-to-image generative AI tool, compared to other existing alternatives, such as DALL-E and Stable Diffusion. The consensus was that Midjourney could produce the most visually appealing images with customizable styles. To alleviate participants’ necessary learning curve on using an unfamiliar AI system, Midjourney was chosen for the current study. Notably, Midjourney is accessible to the public through the Discord interface, and it generates four high-fidelity images for every textual prompt entered in the chat box during each iteration (shown in Figure 1).
During every workshop, sketch paper, markers, and highlighters were provided throughout, and one laptop was provided with Discord installed to access Midjourney in the AI sessions. Participants were invited to sit freely around a table in a private meeting room on the TU/e campus. During the sketching sessions, participants had free access to all tools provided. During AI sessions, participants took turns prompting the AI on the given laptop (see Figure 2 and Figure 4).

Figure 2: Participants engaging in ideation with manual sketching tools only

For each session, participants were instructed to work on the same design brief, “As a group, please watch the video clip from the movie, ‘Downsizing’. Your design task is to ideate on
designing a physical product that would help the downsized people interact with the normal-sized world, including normal-sized humans and everyday items”.

A two-minute movie clip titled “A Little Advice Scene (1/10)” (Movieslips, 2020) was played to contextualize the design brief from a sci-fi movie, “Downsizing” by Alexander Payne. Such a fictional design brief was chosen so that participants did not have to engage in research or further investigations to generate concept designs. In the design brief, participants were also suggested to discuss what they had seen and design problems they would like to address, then ideate and visualize product ideas that would address the issues, with suggested timeframes and prompting examples.

4. Workshop Procedure

Upon their arrival to the study at the TU/e campus, participants were given informed consent forms (See Appendix A). These informed them about the aim and benefit of the study, study procedure, risks, duration, reasons for selection, voluntary participation, compensation, confidentiality and use of their data, and contact information of the research group. New participants without a registered account in the HTI participant database were also provided with a registration form to consent to the creation of new accounts for them. After signing the consent forms, every participant was asked to fill out an anonymized pre-workshop questionnaire (See Appendix B), which included basic demographics, educational backgrounds, sketching skills in design, and their prior experience and attitudes toward using generative AI tools in design. Then, they were each given a copy of the design brief and watched a two-minute movie clip from “Downsizing” as a group on one given laptop. Participants were then informed about the start of recordings of their anonymized interactions, conversations, and the laptop screen. No facial expression was included in the recordings.

![Figure 3: an overview of the workshop procedure](image)

During Workshop 1, 3, and 5, participants were advised to ideate with only manual sketching tools for about 45 minutes in the 1st session, followed by a 10-minute group interview and a
10-minute break. In their second session, a brief tutorial on Midjourney was given by the researcher, going over the official website pages of “Midjourney Quick Start” and “Writing Prompts”. Due to limited time, basic prompts were suggested over advanced prompts. Then, participants were prompted to generate new ideas on the same design brief for about 45 minutes in the 2nd session, followed by another 10-minute group interview and 10-minute individual writing reflections at the end of the workshops. The time duration was chosen because 75% of ideas appropriate to a design ideation task were found to be generated within the first 30 minutes of brainstorming sessions (Howard et al., 2010).

At the end of each design ideation session, participants were asked to discuss and write down three best ideas and select three “Key Moments” that were most relevant to their best ideas. A 7-point semantic differential scale (see Appendix D) was given to rate the chosen “Key Moments” from their own sketches or AI-rendered images, depending on the sessions.

Figure 4: Participants evaluating a “Key Moment” they chose in the AI session

Likewise, participants in Workshop 2 and 4 were given the same Midjourney tutorial. They were instructed to ideate with Midjourney in their 1st session, followed by a group interview (see Appendix E). Then, only manual sketching tools were provided in their 2nd session, followed by another group interview (see Appendix E). Lastly, individual writing reflections with four open-ended questions on paper were issued (see Appendix F).

5. Data Analysis
The data collected for the current study fall under three categories: 1) anonymized video, audio, and screen recordings that capture participants’ interactions, conversations, and verbal responses during their ideation, 2) generated AI outputs (i.e., AI-generated images
and manual sketches), and 3) written responses from questionnaires and individual reflections. Data saturation was reached after five workshops.

Audio recordings were transcribed using Whisper API on an encrypted computer. Video recordings were coded with timestamps, and key interactions and “Key Moments” were identified. Answers from interviews and writing were also included as part of thematic analysis.

Thematic analysis was mainly chosen for the qualitative approach of the current study. It involves organizing and describing the dataset in detail by identifying themes and patterns concerning the research (Braun & Clarke, 2006). Such a flexible and commonly practiced framework provides a rich, detailed, yet complex analysis of exploratory studies. For the current study, patterns were identified and categorized by thematically analyzing participants’ interactions, transcripts of their discussions, and written reflections. Themes and insights were discussed and validated through intersubjective convergence with the supervisors of the study. Given the interconnected nature of these themes, subthemes are included to offer more detailed perspectives and a nuanced understanding of specific focuses within each theme.

Additionally, a 7-point semantic differential scale (see Appendix D) was designed and used to investigate where participants’ views lie on a continuum between two contrasting adjectives closely related to ambiguity in the visual images they found most relevant to their best ideas generated (i.e., “Key Moments”). Python was then used to generate a stacked bar chart to visualize the results from the semantic differential scale.
IV. Results

Ambiguity in the AI-generated Images in Ideation

1. Perception of the Impact of Ambiguity on Ideation
Participants argued that ambiguity could generally open up room for divergent exploration, interpretation, and discussion, which were all valuable for an early phase of the design process like ideation. The random and unpredictable details produced by the AI could trigger more creative ideas and allow designers to expand their imagination in the given context. For example, P2 explained, "The ambiguity plays with the tendency of our brains to define everything. It makes it so that two people can look at the same image and completely reinterpret the subtle details, making it powerful for the theater of the mind. I like it a lot—it adds to the ethereal vibe AI art often has". P15 also said, “The ambiguity of a sketch is nice because this opens the space for interpretation. You look at things and you think if there are any other ways to use it, that's how designers become creative, like design relabeling.”

However, if the ambiguity introduced by the random and surprising details could not be understood, then it would appear aimless and unreasonable, thus restricting one’s creativity and slowing down the ideation process. For instance, P3 said, “Ambiguity has steered us in so many directions that the process has lost efficiency. In a pressure cooker context or generally a period without a lot of time, I would not go for this method, as it is more time-consuming and less specific.” P6 also said, “Ambiguity is great, as long as it's 'on topic'. It leaves space for ideas to grow, but Midjourney was not really 'on topic'."

One way to resolve the ambiguities and navigate towards more desired outputs was through iteration. As P1 said, “The ambiguity comes from the limited understanding of word choices and combinations. I think iteration is the key for ambiguity. This would be done by either iterating/changing the words used or developing an image that AI has offered repeatedly.”

2. Evolved Mental Models of the AI-generated Images
Regardless of participants' prior experience with Midjourney, participants had multiple assumptions and expectations of how AI-generated images could be used in their design process. Their mental models of these AI-generated images evolved throughout their workshop experience. These three mental models have been identified and summarized.

2.1 High-fidelity AI images are for visualizations in the final stage of design
Before their ideation workshop sessions, participants expected Midjourney to be a visualization tool merely used for visualizing the finished looks and details of specific ideas at a later stage of design. For example, P6 said, “It doesn't try to make something that inspires
you but a final artwork.”. P9 added, “I don’t really use it for the ideation phase. I only use it for really looking at the high-fidelity final imagery.”

However, the ideation sessions of the study helped them realize that the same tool could also be used in an early stage of design like ideation. For example, participants found that they could exchange ideas and keep interacting with Midjourney for idea generation with less required cognitive effort. After the 1st sketching session and the 2nd AI session, P2 said, “At the beginning, it gave me something I didn’t want, but then I realized it gives me something to bounce off of.” They later added, “I think the AI session is way more interactive for me in the sense that not all of the energy is coming from us. It’s not our raw brain power. I can do this when I’m super tired, but I can’t do the first one when I’m super tired. Nothing will come out of my hands. It feels less intellectual.”

2.2 Mixed opinions on visual inspiration provided by AI images
Some participants also expected the AI to be able to come up with creative ideas or design opportunities independently and autonomously. However, through their workshop experience, participants recognized that Midjourney was not creative on its own. Rather, it required human input for crafting prompts and creatively interpreting the AI-generated images. For example, P5 said, “In my mind, it was more magical than it actually is”. P7 added, “We hoped that the AI would come up with ideas for you, but it’s actually more of a collaboration.” And P9 said, “I like that it gives me only 4 options to choose, but it would be nice to have a bit more flexibility of the AI, not just the exact visualization of what we wrote... I wish the AI could listen to everything we say and suggest ideas around what you’ve said.”

Mixed opinions were found on whether AI-generated images offered enough visual variety to inspire designers in ideation. For example, P11 said, “Regarding ideation, it’s more useful if you want to ideate on something visually, like graphic design, because then you get a lot of visual options.” However, P10 disagreed and argued, “Midjourney has a very specific, quasi-realistic style. I don’t think you can get much visual variety if you’re looking for visual inspiration or ideation.”

2.3 AI images need to be prompted with detailed wordings and tool-specific experience
Participants anticipated the necessity of refining their prompt engineering skills to enhance the effectiveness of AI-generated images for optimal results. They also believed that prompting experience may not be transferable across similar AI tools, due to inherent differences in how these tools process and interpret prompts. As P6 said, “You have to know how to talk to it to get what you want. If you just type in the design brief, it’s gonna do
nothing." While being new to Midjourney but familiar with DALL-E, another popular text-to-image generative AI, P13 said, "I use DALL-E to generate inspirational cards for my workshops. I can describe my ideas as much as I can, and I can keep rephrasing until I get the pictures I want. But now, I have no clue, I'm just trying out to see how it can help me".

After the ideation sessions, participants mentioned that they had gained new insights into how to use Midjourney more effectively in their design process. They were surprised by the helpfulness of non-descriptive prompts for ideation in some workshops. For example, participants in Workshop 4 decided to experiment with a slightly modified version of the design brief without providing any context (shown in Figure 7), and later they found this iteration of images to be one of the most helpful “Key Moments” to their best ideas generated. Reflecting on the results, P12 said, “When we gave a vague prompt and it ended up being thought-provoking. Kinda showed me a trick of using Midjourney for ideating.”

Figure 7: an image generated from Workshop 4, with the prompt written as “physical product helping downsized people interact with normal sized world”

3. Influence of Goal and Context on AI-generated Images

Participants who lacked a clear direction in mind and expected to be inspired were dissatisfied with the images generated by the AI tool. However, once they had a more specific context or goal in mind, they had an easier time putting their ideas into written prompts. This led to more discovery of useful inspirations, as they could interpret the details of the images within their desired context. As P6 put it, “The place where it’s the best is between sort-of ideas to sort-of concepts…If I were to have a more definite concept, I would
value it more than sketching on paper”. P12 elaborated on this idea and said, “The AI-generated images are unpredictable but fun. It depends on your intention when you're generating. If you have a concrete idea that you just want a visual to explain it, then it's going to take some time to get the right image. But if you're just looking for images to provoke some thoughts, then it might be more useful.”

Through the iterative process of adjusting their prompts, participants also learned to refine their approach to optimize the outputs with AI-generated images. As P7 said, “We quickly understood that maybe we should not say tiny person, but just a little person and a giant, which kind of helped. But it was much easier after we had a concept and we narrowed it down a bit, then give that as input for that.” P14 summarized her creative workflow and said, “AI can expand my creativity in a different stage of ideation: coming up with an idea, drawing, using AI, drawing myself again, then changing prompts.”

**Integrating Generative AI into Design Ideation**

1. **Generative AI for Visualization, Communication, and Inspiration**

During interviews and post-workshop reflections, participants discussed their use of AI-generated images for ideation. Three main functions of the AI tool have been identified from their discussion around how the AI was used for generating the “Key Moments”. Although these functions often overlap during collaborative ideation, they have been categorized based on participants’ intended use of the AI at various stages of the creative process, demonstrating the tool's multifaceted purposes.

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<thead>
<tr>
<th>AI for Visualization</th>
<th>AI for Communication</th>
<th>AI for Inspiration</th>
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<td>Workshop 1: P1</td>
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<td>Workshop 2: P4, P5, P6</td>
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<td>Workshop 5: P13, P15</td>
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Figure 8: an overview of participants who explicitly indicated their use of the generative AI tool in their ideation process

1.1 **AI for Visualization**

The primary function mentioned was visualization. Participants sought a quick and straightforward way to depict their ideas with illustrative examples. In the context of ideation,
the focus of visualization was not to illustrate the finished looks as in the final stage of design but to explore potential and alternative conceptualizations in a more concrete way. In particular, the use of generative AI for visualization meant that participants had a certain idea or direction in mind, which was different from participants seeking inspiration from the AI. Both P4 and P5 explained that the AI sped up the ideation process because “it replaces a bit of sketching with detailed visualization, mood boards, or inspiration boards, and showed more unexpected things than Pinterest, for example”.

Participants also used the generative AI as a visualization tool to get a “reality check” and see how the AI would understand the ideas they had in mind. This process helped them gain a deeper understanding of their ideas and allowed them to see alternatives to their ideas with more details. P1 said, “I wasn't able to visualize it in my head, so it helped me clarify how it would look like in real life. But other than that, regarding my ideas in the ideation phase, it helped by opening up/encouraging more ideas.” P9 said, “We could have used the AI to generate images of everyday objects and attach whole new functions to them”.

1.2 AI for Communication

Within a collaborative environment, participants needed effective ways to express and present their ideas, ensuring mutual understanding and alignment. In this context, the visual images created by the generative AI served as a communication medium, facilitating the establishment of a consensus regarding both intended and undesirable concepts. P8 said, “I like using AI to present and communicate my ideas with others, but I come up with ideas in my head before using the AI.” P9 also said, “I would never be able to quickly sketch such high fidelity, so AI visualizing the ideas in my head helped me communicate to my peers.” They later added, “It was valuable when we did look at the images together and agreed ‘this is not what we want’.” P10 said AI saved them time to explain their ideas to each other, and P11 added, “Usually, I would sketch for this purpose, to get everyone on the same page”.

Additionally, participants mentioned how the generative AI was used to stimulate new group discussions and perspectives. They stated that the random and surprising details of the AI-generated images served as a discussion catalyst, especially at times when they felt stuck in their ideation. When participants had difficulties coming up with new ideas to discuss, they turned to AI to overcome the obstacle. The AI-generated images introduced new information and served as a new stimulus in the group dynamics. P12 explained, “AI helps in the sense that we commonly have a big idea and then we visualize it. Then we do discuss the more details in there and also figure out what we were thinking. It did help, even if it's just the wrong details, but it got us to talk.”
1.3 AI for Inspiration

Besides clarifying existing ideas and initiating discussions, participants also used it for inspiration, particularly observed when participants did not know how to approach the open-ended and fictional design brief. Inspiration happened irrespective of the participants actively seeking it. On one hand, participants sought inspiration by exploring the generative AI’s unexpected interpretation of the design brief, generating images of potential design scenarios and use cases. For instance, P5 said, “It’s a narrower inspiration tool because it opened up more ideas. For example, I can think of the mechanism of the capsule, even if there are only stripes on the images.”

On the other hand, inspiration spontaneously happened during discussions where novel ideas emerged through the diverse interpretations of the details within the randomly generated images. P1 said, “Seeing blue and red tubes (shown in Figure 9) triggered me to think of different ways of commuting; and made me think what these colors should be used for, such as one for walking and one for going to the metro stop.”

Figure 9: A “Key Moment” selected from Workshop 1, with the prompt written as “transparent pipes in the style of Mario kart through a lively city”

From another workshop, P13 explained, “I find that last image to be helpful because it is the most random one. It gave me ideas of what can be used from that”. P15 also added, “I thought it’s like an image generation software, just a tool to help me visualize my idea. But actually, the last image showed a good example of how I might work with it in the future. It gave me a very abstract picture, something that I would never have in my mind. It is very open to multiple interpretations, and then I get inspired for more ideas.”
Moreover, the generative AI also encouraged participants to consider alternative viewpoints. In this context, the AI served as an additional collaborator for participants to exchange ideas with. P3 said, “It might be even better to use AI than I thought. It might not do what you want, but it generates ideas just like talking to people who are not in the design field.” P2 agreed and continued using a metaphor, arguing that the AI could be just like a family member who would challenge the designers to look at their design in a non-designer way and think outside of the box. P2 said, “Midjourney completely hindered us when we were just talking, exploring the space. But when we had an idea that was semi-valuable, and we could feed that into Midjourney, it made us think about the implications of the moments if we try to explain to someone who doesn’t know what’s going on”. P3 said that in their usual practices, they saw the AI as a collaboration partner whom they would give credit to cite in their reference list.

2. Creative Process Change

Integrating a text-to-image generative AI tool into collaborative design ideation introduced changes to the creative process. This shift brought both advantages and challenges regarding inspiration sources, cognitive reasoning, and group interaction dynamics. It presented a contrast to conventional ideation methods, such as manual sketching and drawing on environmental or social inspirations. For example, P13 said, “My way of being creative is to draw in my mind. I'm more inclined to talk to people and think in my head, and then we can build upon each other’s ideas, which doesn't happen here with AI. I tried to avoid looking at the screen for a bit. I was thinking, for example, my bottle is the size of the people I can interact with”. These changes in design ideation included creative divergence and disruption, challenges in integrating the AI, and design biases and unexplained design rationale.

2.1 Creative Divergence and Disruption in Design Ideation

Because every image generation of the AI requires the user to give a text prompt, the AI was found to break the designers’ creative train of thought. As P7 put it, “There is this extra step to translating your thought into a prompt”, which requires additional cognitive effort and “time to come up with a prompt and wait for the results” (P8).

These interruptions posed new creative opportunities that guided the creative process in a divergent way. P1 said, “AI helps you diverge ideas and prevent you from scooping down too early….Getting pushed forward by AI when the ideation phase stagnated. It was really encouraging to keep going after receiving creative and aesthetically presented visuals.”. P2 also said, “It breaks my cycle of thought, which makes me think about more aspects of the problem and of the solution that I'm making. I think it makes it more ambiguous because I'm
not deepening one specific aspect of the design, but the concept grows so much because it's taken on the context. So I think it makes it clearer in the end.”

However, as the AI did not provide any explanation of their design choices, participants felt distracted and limited by the high-fidelity details generated at the stage of idea generation. P15 explained, “At the beginning of the creative or ideation stage, we don't really care about the exact look of the ideas. We give up on ideas very easily, so it doesn't make sense to look at the details…I got distracted in thinking why it generates like that, and why there is no big person, instead of how I can build upon it.” From the same workshop, P14 said, “Abstract pictures can leave more space for your mind to create ideas yourself, but here, lots of details can make you get hung up on them.”

Because the AI took about one minute to generate every iteration of images, disruptions were also seen in group dynamics. Many participants expressed frustration about the AI's processing time “taking too long”. Some participants continued their discussion among themselves as they waited for the image generations, while others typed in multiple prompts one after another, hoping for more efficient iterations of ideas. In Workshop 3, after one participant tried experimenting with multiple prompts on their own, they felt isolated and excluded from the group discussion with the rest. P7 said, “AI has a big influence on how you work together as a group. One person gives input to it and is excluded from the conversation of the others. It is also hard to include again in the conversation with the AI findings because they might have moved on since the ideation can be so fast. Quick sketching is very valuable in the ideation process.”

2.2 Challenges in Integrating AI into Design Ideation
Participants in Workshop 5 experienced a difficult time integrating AI into their ideation process. They spent the whole duration of their 2nd ideation session exploring the AI tool, without being able to generate new ideas in addition to their ideas from the 1st session with traditional sketching tools. Comparatively, this workshop had two of the three participants with the lowest rating scores in their attitude towards AI, meaning that they leaned towards skepticism about using AI in their design process. As P14 said, “We had a bit of trouble integrating the AI into the process. Our conversation got a bit stuck and maybe a bit distracted by the laptop, and it was difficult to steer away from the ideas we had earlier.” P13 said, “Midjourney didn't understand us well. We are not familiar with the tool and had to spend a lot of time exploring how it could help us. Also, I'm not an English native speaker, so probably the prompts I used are not that accurate enough to be understandable to Midjourney.”
During two other workshops, participants also mentioned that they felt forced to use Midjourney in their ideation. The other participant with the lowest rating score on their attitude towards AI said, “If we didn't have to use Midjourney, I'm not sure if we would have.”

2.3 Design Biases and Intransparent Design Rationale
Given the obscure nature of its algorithms, the generative AI produced images without any context or explanation, leaving users to freely interpret these outputs and the underlying rationale on their own. This introduced biases and confusion in the ideation. For example, P2 said, “Midjourney often results in creating context, filling in the blanks of our quite limited prompts. It essentially makes ideation choices for us. Evaluating and discussing why one would make those generated choices, and how that would change or mold the concept is incredibly valuable.”

3. Sketching versus AI
Participants compared their experience ideating with manual sketching tools versus with the addition of a text-to-image generative AI. The unique affordances (i.e., action possibilities) of these two ideation methods resulted in participants interacting with each other and ideating differently.

3.1 Different Purposes and Intentions for Sketching
Participants explained that the addition of the AI tool shifted their purposes and intentions of sketching. More specifically, AI could produce more concrete details than manual sketching, but manual sketching was more intuitive and faster. As P9 explained, “I sketch differently. (When AI is involved), AI does the concrete design (i.e., visualization) for you, so you only need to come up with scenarios and rough ideas on sketches…Sketching is useful because (in the stage of ideation), it doesn't matter what shape this product gets. It's more about the concepts.” P11 also said, “Our ideation flowed more with lots of sketches…The conversation was way more generative than Midjourney.”

While examining participants’ sketches in both sessions, all of the sketches demonstrated a series of ideas with annotations close to each other. They also wrote down ideas in lists to organize and keep track of their ideas. However, the sketches produced in sketching-only sessions (shown in Figure 10) appeared to be less complete and less concrete than the ones produced in the AI sessions (shown in Figure 11).
Figure 10: sketches produced during sketching-only sessions

Figure 11: sketches produced during AI sessions
3.2 Differences in Group Collaboration
Participants had either neutral or negative opinions on how the addition of AI in ideation changed their group dynamics and collaboration. On one hand, P2 said, “Frustration was allowed towards AI as a third party, and the frustration does not hinder the team dynamics and collaboration.” On the other hand, P4 said, “The 2nd sketching session was more interesting, since it focused more on brainstorming, without having to spend energy on elaborating a prompt”. P7 also reported, “AI made us work less as a group. We talked less and didn't share our thoughts as much.”

3.3 Differences in Design Ideas Generated
Groups of participants who began with sketching sessions were found to continue ideating around the same topics of design opportunities in their 2nd AI sessions. For example, they took inspiration from issues they identified from the movie clip, specifically how downsized people could communicate with normal-sized people, and how they could be transported and navigate in the normal-sized world. No new idea was generated from the 2nd AI session in Workshop 5, as participants were unfamiliar with Midjourney and struggled with generating new ideas distinct from those from their 1st sketching session.

In contrast, participants found it easier to begin ideating on new design topics in their 2nd sketching sessions, focusing on even more granular interactions and specific design opportunities. During Workshop 2, participants initially explored transportation issues in their 1st AI session, but then narrowed their focus on the challenges of down-sized people in preparing food for gatherings at normal-sized homes, such as processing ingredients of lasagna and cracking normal-sized eggs. During Workshop 4, participants also started with design opportunities around transportation in their 1st AI session, but then concentrated on ideating ways to help downsized people make eye contact and play board games with normal-sized people in their 2nd sketching session.

Ambiguity Perceptions of the “Key Moments”
During every workshop, participants were asked to collectively evaluate and rate the self-chosen six “Key Moments”, three from their sketching sessions, and three from their AI sessions. These moments were selected as the visual images that were most relevant and contributed to generating their best ideas.

As shown in Figure 5, all ratings were given based on five criteria with a 7-point semantic differential scale, namely, (1) predictable/surprising (7), (1) understandable/confusing (7), (1) concrete/abstract (7), (1) valuable/very valuable (7), and (1) single interpretation/multiple
interpretations (7) of the visual images themselves, not the ideas behind them. These five criteria were decided based on their close relation to ambiguity.

Figure 5: stacked bar visualization of participants’ perceived ambiguity of the “Key Moments” during both sessions, centered on neutral (rated 4), represented by the vertical line. The size of the colored bars represents the amount of “Key Moments” rated from 1 to 7.

The most contributing and relevant images (i.e., “Key Moments”) remained inconclusive in terms of their predictability, but they generally leaned towards being understandable in both graphs. Comparatively, the “Key Moments” from AI-generated images were perceived to be more concrete, less valuable, and open to more interpretations than participants’ sketches.
Figure 6: “Key Moments” selected during the AI sessions in each workshop
V. Discussion

Principle Findings

In recent years, text-to-image generative AI models have introduced a novel way to produce images based on natural-language textual commands alone, which enables anyone to produce stunning imagery without much artistic or technical background. Despite their significant promise for on-demand visual creation, these models are mainly used for recreational purposes or artistic exploration (Sanchez, 2023), rather than effectively implemented in creative exploration for design purposes.

The current study aimed to understand the potential of text-to-image generative AI models in facilitating the exploratory phase of design, compared to traditional ideation methods, such as manual sketching. In particular, this research explored the paradoxical nature of the ambiguity in AI-generated images. While these AI systems create stunning and ambiguous visual outputs, they also automatically fill in the solution space with concrete and arbitrary design choices, leaving less room for ambiguity than manual sketching. Despite this, their creation requires relatively low effort, which allows designers to use it collaboratively and iteratively, much like traditional sketching.

Through collaborative ideation workshops with sketching tools and Midjourney, the dynamics of ambiguity were closely examined in influencing designers' idea generations, revisions, and iterations. The following principle findings are organized to systematically address the four sub-research questions of the study.

1. Ambiguity and Creative Thinking

This first section addresses the mechanisms of ambiguity that are essential to idea revisions and iterations. This study reveals that ambiguity in AI-generated images disrupts designers' usual creative ideation process by challenging them to think further and resolve the ambiguities that arise in the process. When the ambiguity is seen as random and chaotic, it can interrupt designers' creative train of thought and hinder their creativity with unproductive distractions. This suggests that for ambiguity to be beneficial, it needs to ultimately contribute to clarity within the process.

The ambiguous information seen in AI-generated images may first appear random to users, but they also present themselves as combinations of associative elements from distant domains, which form the foundation for creativity (Mednick, 1962). The current study shows that designers came up with more novel and specific design opportunities in their ideations.
when they interacted with the AI systems first, compared to sketching first. This may suggest
that the ambiguity in the visual stimuli introduced by the AI contributes to associative thinking
and allows for more divergent thinking. According to the associative theory, one mental state
tends to evoke other mental states, creating a series of associative elements for the basis of
creativity (Malaga, 2000). After images are created based on the user’s input, visual
eamples are generated that may appear distant from the start, but when placed in
juxtaposition to the context within designers’ initial ideas, the ambiguous visual details could
evoke a series of new ideas.

The current study also aligns with the findings of Tholander & Jonsson (2023) that human
reflection and interpretation are critical in design ideation with AI. For the ambiguity to be
properly resolved and utilized effectively for creativity, designers cannot rely on the
text-to-image generative AI to be creative autonomously. Designers have to take the initiative
to come up with creative opportunities and directions first so that the ambiguous visual
information can be interpreted in the right contexts for desired outcomes.

For stimulating creativity in the ideation phase, the findings also reveal that inspiration can be
drawn from the ambiguous details of the AI-generated images, even if users do not have an
explicit idea or way to clearly describe their idea yet. This is different from designers' con
tventional use of text-to-image generative AI for visualization purposes in the later phases
of design, where the goal is to reach a close alignment between the generated images and
users’ expectations. Nonetheless, participants have shown clear individual differences in their
ability to effectively resolve ambiguity. Designers would first need to align their intentions and
goals to properly resolve ambiguity in the generative AI during their design ideation.

2. Features of Ambiguity in Ideation
The second section discusses what features of ambiguity provided by the AI benefit and limit
the ideation process. For the ambiguity to be beneficial for the ideation process, designers
need to be able to translate their visual ideas into descriptive words that are also
understandable to the AI. Many participants perceived this translation process to be
challenging and even disruptive to their creative thinking process, thus swaying the direction
of ambiguity in the AI’s output.

At the start of design ideation, the problem might not be fully understood or defined. The
flexibility of interpreting ambiguous details allows designers to accommodate various
perspectives while framing the design problem. During ideation, ambiguity also allows
designers to explore a wide range of possibilities without converging prematurely or being
confined to preconceived notions (Tan & Kvan, 2019). Counterintuitively, findings show that although AI-generated images are considered more concrete and high-fidelity than people’s sketches, they are also open to more interpretations. This may suggest that the additional information provided by the details of the AI inspires designers to think beyond conventional boundaries and discover novel opportunities.

The external visual information provided by the generative AI in the form of ambiguity introduces new perspectives to the designers and challenges them to approach the problem differently from how they initially discussed among themselves. Participants expressed that AI provided a non-designer way of thinking that they found inspiring. The current study shows that this ambiguity has to be well understood for it to be relevant and contribute to successful idea generation. Essentially, ambiguity prompts designers to engage in perspective switching, creative interpretations, and open communication, all of which enhance the overall collaborative ideation process.

Lastly, ambiguity provides mediation for collaborative efforts for multiple designers. It prompts them to discuss and align their shared goals, define their ideas through prompting, and evaluate the relevancy of new, unpredictable pieces of information. Meanwhile, ambiguity encourages open communication among team members. Designers can share incomplete or unclear ideas without fear of judgment, fostering collaboration and the exchange of diverse viewpoints.

3. AI versus Sketching as Visual Thinking
This section outlines how AI impacts the traditional co-ideation process with manual sketching. Findings reveal that manual sketches are still considered more valuable than AI-generated images in ideation, although participants agreed that it could be complemented by a text-to-image generative AI. This is because sketching is a manifestation of one’s visual reasoning and serves as an extended mind (Tholander et al., 2008). It is intuitive to designers and part of their internal visual reasoning (Kavakli et al., 1999). In other words, sketching is an embodied design practice that also involves talking, bodily movements, gestures, and interactions with the design materials (Tholander et al., 2008).

Pen and paper are familiar cognitive tools that allow designers to externalize their thoughts in a controlled manner. For example, artists were found to prefer curating art with traditional sketching tools over the random generation of AI because they preferred having more control over their creative process, which was also perceived as more efficient (Lyu et al., 2022). The findings suggest that this intuitive cognitive flow is not yet achievable with an external source.
of information, such as from a generative AI, and thus may influence how the design activity unfolds. The AI could even disrupt the natural process of “thinking while drawing” by introducing unexpected and unexplained stimuli, which may or may not be productive or helpful. This may also be due to most participants’ relative inexperience in using Midjourney in ideation, compared to traditional sketching tools. For fluent integration of cognitive tools as an extension of cognition, an intuitive and embodied sense of their affordances and expressive power is needed, which comes with practice (Baber et al., 2014).

Although ambiguity lies in both manual sketches and AI-generated images, they are embedded in different parts of the visual representations. The ambiguity in roughly made sketches lies in the abstract structures of illustrating one’s ideas, which is the externalization of the designer’s thinking process (Goldschmidt, 2017). That is, they have free control over the sketches and could add written annotations or additional drawings to iterate and clarify their ideas to themselves and others. However, findings reveal that the ambiguity in the AI-generated images lies in the multiple interpretations of the images randomly introduced, which may contain design biases and restrict design solutions. Since generative AI does not understand the context of design problems or present any clear design rationale, it is critical for designers to carefully evaluate AI design decisions with human values.

4. Roles and Functions of Text-to-Image Generative AI in Collaborative Ideation
The last section discusses the implications of how the generative AI has been used for visualization, communication, and inspiration throughout the collaborative ideation process. The visualization of generative AI facilitates a broader exploration of ideas for designers by allowing them to focus on concept development without being preoccupied with aesthetics or details. The workshops reveal that participants appreciated the aesthetically pleasing and high-fidelity visualization produced by Midjourney. It also generates visual imagery that achieves a finished look faster than traditional human sketching capabilities. However, participants expressed mixed opinions on whether the visualization of generative AI truly helped with their creativity in the process of idea generation. This perception likely stems from the belief that creativity lies in the originality of ideas, but generative AI is incapable of having its own design rationale or creativity, which makes it resemble a search engine that generates random example imagery. Individuals may also become overly occupied with evaluating the polished look of their rough ideas, which can divert attention and time away from the productive and generative aspects of the ideation phase.

Meanwhile, the impact of generative AI on designers’ communication depends on how the designers choose to interact with the AI among themselves during their ideation. If the group
agrees on one prompt and also evaluates the image outputs together, the AI can facilitate critical dialogue among the designers, assisting them in aligning their objectives and collective thinking. However, if one person decides to experiment with the prompts on the side, the generative AI then serves as an additional agent that may isolate the individual from the rest of the group discussion, which negatively impacts the group dynamics and communication. The AI’s processing time, approximately one minute per iteration to generate images, also introduces delays in the designers’ discussions. To compensate for these interruptions, designers were found to engage in further dialogue to utilize the waiting period effectively.

Lastly, generative AI is an inspirational source because it provides designers with more contextual information and perspectives to consider and reflect upon. Findings show that the AI was able to quickly produce arbitrary contexts that could accommodate the raw ideas of the designers. This process may have expanded their imaginations and deepened their understanding of their initial ideas, allowing them to consider more nuanced design scenarios. This could be explained by participants making a series of mental associations that spark new creative directions and ideas based on the new information provided by the AI. Because the generative AI does not follow along with the entire design ideation or keep track of the ongoing discussion like a human designer, it introduces new stimuli that challenge the designers to reflect on their ideas from an outsider’s perspective.

Limitations & Future Research

The first limitation lies in the language used with prompting AI-generated images in English. The study was conducted in English, which was the common language that all participants were fluent in. However, participants came from various language backgrounds, and none was a native English speaker. This might imply that they could not express themselves as well as they could have in their native languages, using a richer vocabulary. Many of the text prompts they wrote also contained spelling errors and inaccurate use of word choices and grammar, which may have impacted the objective quality of prompts and generated images.

Although the participants in this study managed to integrate text-to-image generative AI in their design ideation, the process was not smooth or intuitive to them. This might imply that integrating such AI in design ideation requires more experience and the ability to work with the ambiguity and randomness in its image generation to harness the most benefits from it. Additionally, interacting with generative AI in the design process requires designers to take an extra step to translate their ideas into specific and accurate words and phrases, which can
be challenging at the early stages of the design, where design opportunities and goals are not clearly defined. For text-to-image generative AI to be successfully used as a new medium for design ideation, designers may need to develop new skills and strategies to work through the various layers of ambiguity.

Participants were recruited based on their design experience, and their experience and prompt engineering skills were not strictly controlled. Although designers cannot always be expected to excel at prompt engineering in real life, the AI-generated images may not be optimized by the novel users' limited knowledge and prior experience. Due to the limitations in participant recruitment, the study also involved an imbalance of workshop conditions, with three workshops beginning with sketching followed by AI, and only two workshops starting with AI and then moving to sketching. This limitation could be mitigated with more participants in the future research.

Due to the limited time, participants were suggested to only use basic text prompts, even though many text-to-image generative tools, such as Midjourney, are already capable of taking multi-modal input, such as images and website URLs. Future research could include additional advanced prompts to see how that may impact designers' ideation process.

Furthermore, participants were only provided with one laptop to work on, despite working in groups of three. This setup of the study may have restricted designers' interactions with one another, as well as their interaction with the AI tool as a design method. In future research, it would be interesting to look at how AI could play a role in designers’ collaborative design process if every designer had access to the AI system.

Another limitation of the study design lies in the semantic differential scale designed. One of the criteria was phrased as “valuable/very valuable”, which may have caused some slight confusion among the participants. For future research, a complete set of bipolar adjectives should be used in semantic differential scales.

Lastly, while the current study mainly takes a qualitative approach to investigate the impact of ambiguity on designers’ ideation, more quantitative methods could be used to analyze the ambiguity in designers’ manual sketches and AI-generated images in the future. For example, the ambiguity of AI images and sketches could be further analyzed by computational models for more objective comparisons.
VI. Conclusion

The current research aims to explore the ambiguity in generative AI images and how it impacts the collaborative design ideation process. Towards this goal, the study mainly takes a qualitative research approach and examines how designers collaboratively ideate on an open-ended design brief, using sketching tools and a text-to-image generative AI. More specifically, this study explores the mechanisms of the ambiguity introduced by the AI in design idea development, examining its benefits and limitations to the collaborative creative thinking process, and how that contrasts with using traditional sketching tools for ideation.

Results show that ambiguity disrupts designers’ creative thinking process by introducing random visual information to the designers. Unlike the traditional manual sketching method, generative AI is still an external resource that does not actively facilitate one’s visual reasoning or intuitively help externalize one’s visual ideas.

The flexibility, mediation, and external visual stimuli provided by the AI in the form of ambiguity challenge designers to consider a wider range of perspectives, reflect on their existing ideas, and align goals among themselves. However, the highly detailed contextual information can also distract designers from efficiently brainstorming ideas by introducing “finished looks” with arbitrary design choices and biases. Ultimately, ambiguity has to be understandable and contribute to a certain level of clarity for it to be beneficial to the process.

Finally, the study helps establish a new understanding of ambiguity in the context of human-AI co-creative ideation. From this, designers are encouraged to embrace the randomness of generative AI images, rather than viewing it as an obstacle. In their future design workflows, designers could consider using a text-to-image generative AI as a complementary tool to stimulate divergent thinking in the phase of exploratory ideation, in addition to visualization in later stages of design. Uncovering the intricacies behind ambiguity also helps improve the advancements of more AI-powered design tools in ways that fit designers’ collaborations and creative thinking more intuitively. For example, a collaborative interface that allows designers to co-edit text prompts and virtually collaborate on image generations from multiple laptops could be useful. AI-powered design tools could also implement interfaces that allow designers to sketch and annotate, as well as AI algorithms that take designers’ sketches as inputs and generate more iterations and variations as outputs.
References


Midjourney. (n.d.) Discord Interface. Retrieved February 8, 20204, from https://docs.midjourney.com/docs/midjourney-discord


Appendices
Appendix A. Informed Consent Form

Information form for participants
This document gives you information about the study “Co-creative Ideation between Designers and Generative AI Tools”. Before the study begins, it is important that you learn about the procedure followed in this study and that you give your informed consent for voluntary participation. Please read this document carefully.

Aim and benefit of the study
The aim of this study is to observe and investigate the human-AI collaboration in a design ideation process. This information is used to facilitate improving generative AI tools that can better enhance designers’ creativity and design abilities.

This study is performed by Sherry Ma, a student under the supervision of Wijnand Ijsselsteijn, Kristina Andersen, and Pei-Ying Lin of the Human-Technology Interaction group.

Procedure
You will be asked to ideate on a creative design task with 2 other designers in a collaborative workshop setting. The workshop consists of 2 sessions: one with manual sketching, and the other with a text-to-image generative AI tool. After the 2 ideation sessions, you will be interviewed as a group and asked to write down your thoughts individually on your experience.

Risks
The study does not involve any risks, detrimental side effects, or cause discomfort. You have the right to abort the experiment immediately if any unforeseen risk occurs.

Duration
The instructions, measurements, and debriefing will take approximately 3 hours. Both design ideation sessions will take about 45 minutes each, and there will be a 10-minute break in between. After each session, you will be asked to reflect and discuss your experience for about 20 minutes each.

Participants
You were selected because: 1) You were registered as a participant in the participant database of the Human-Technology Interaction group of the Eindhoven University of Technology, or 2) You are in connection with the Industrial Design Department at the Eindhoven University of Technology.

Voluntary
Your participation is completely voluntary. You can refuse to participate without giving any reasons and you can stop your participation at any time during the study. You can also withdraw your permission to use your data up to 24 hours after they were recorded. You can
also withdraw your permission to use your data immediately after completing the study. None of this will have any negative consequences for you whatsoever.

**Compensation**

You will be paid a total of 42 euros (plus an additional €3.00 if you do not study or work at the TU/e or Fontys Eindhoven), after you have completed both of the sessions. If you are only able to complete one of the sessions, you will be paid 21 euros.

**Confidentiality and use, storage, and sharing of data.**

All research conducted at the Human-Technology Interaction Group adheres to the Code of Ethics of the NIP (Nederlands Instituut voor Psychologen – Dutch Institute for Psychologists), and this study has been approved by the Ethical Review Board of the department.

In this study, demographic data (age, level of education and professional experiences), personal data (name, signature, email address for participant database) and experimental data (conversation recordings, rendered images and text prompts, oral and written responses, sketches) will be recorded, analyzed, and stored. The goal of collecting, analyzing, and storing this data is to answer the research question and publish the results in the scientific literature. To protect your privacy, all data that can be used to personally identify you will be stored on an encrypted server of the Human-Technology Interaction group for at least 10 years that is only accessible by selected HTI staff members. No information that can be used to personally identify you will be shared with others.

Your personal data will be stored on a TU/e encrypted laptop before uploading to the SurfDrive and in a password-protected file.

The data collected in this study might also be of relevance for future research projects within the Human-Technology Interaction group in an online data repository. The coded data collected in this study and that will be released to the public will (to the best of our knowledge and ability) not contain information that can identify you. It will include all answers you provide during the study, including demographic data (e.g., age, level of education and professional experiences) and experimental data (conversation recordings, rendered images and text prompts, oral and written responses, sketches), if you choose to provide these during the study.

At the bottom of this consent form, you can indicate whether or not you agree with participation in this study. You can also indicate whether you agree with the distribution of your anonymized data by means of a secured online data repository with open access for the general public. You are not obliged to let us use and share your data. If you are not willing to share your data in this way, you can still participate in this study. Your data will be used in the scientific article but not shared with other researchers.

If audio or video recordings are made, they will not be distributed and will not be played back in the presence of persons other than the researchers. The material will be used only for scientific analysis. The data will be transcribed, using Whisper API in Python on the local computer. No data will be uploaded to any third-party server.
Further information

If you want more information about this study, the study design, or the results, you can contact Sherry Ma (contact email: y.ma@student.tue.nl).

If you have any complaints about this study, please contact the supervisors, Wijnand IJsselsteijn (contact email: w.a.ijsselsteijn@tue.nl), Kristina Andersen (contact email: h.k.g.andersen@tue.nl), and Pei-Ying Lin (contact email: p.y.lin@tue.nl). You can report irregularities related to scientific integrity to confidential advisors of the TU/e.

Co-creative Ideation between Designers and Generative AI Tools

- I have read and understood the information of the corresponding information form for participants.

- I have been given the opportunity to ask questions. My questions are sufficiently answered, and I had sufficient time to decide whether I participate.

- I know that my participation is completely voluntary. I know that I can refuse to participate and that I can stop my participation at any time during the study, without giving any reasons. I know that I can withdraw permission to use my data up to 24 hours after the data have been recorded.

- I agree to voluntarily participate in this study carried out by the research group Human Technology Interaction of the Eindhoven University of Technology.

- I know that no information that can be used to personally identify me or my responses in this study will be shared with anyone outside of the research team.

- I □ do □ do not give permission to make my anonymized recorded data available to others in a public online data repository, and allow others to use this data for future research projects unrelated to this study.

Certificate of consent

I, (NAME) .................................................................

...............................

want and provide consent to participate in this study.

Participant’s Signature       Date
Appendix B. Pre-workshop Questionnaire

Pre-workshop Questionnaire

Before the study begins, please take some minutes to fill out this questionnaire. The purpose is to understand your basic demographics, academic background, and prior experience with design and generative AIs.

About you
1. How old are you?
2. How creative do you consider yourself to be?
   *(Uncreative) 1 2 3 4 5 6 7 (Creative)*
3. Do you have any creative hobbies? If so, what?

Academic background
1. What is your academic background (i.e., what you have obtained and/or currently pursuing)?
   a. Your bachelor’s field of study:
   b. Your master’s field of study:
   c. Your PhD field of study:
2. How many years of experience do you have in design?

Design experience
1. Which design fields do you have experience in? Please circle all that apply, and mark the ones that you feel confident in.
   a. Graphic design
   b. Product design
   c. Interaction design
   d. Industrial design
   e. UX/UI design
   f. Interior design
   g. Communication design
   h. Automotive design
   i. Fashion design
   j. Brand design
   k. Furniture design
   l. Design research
   m. Others:
   (Not confident) 1 2 3 4 5 6 7 (Very confident)
2. How confident are you in manual sketching?
3. Where do you usually get inspiration from?

4. What do you think is the most challenging part of ideation?
Artificial Intelligence

1. How do you feel about the use of Artificial Intelligence in your design process?  
   (Skeptical)  1  2  3  4  5  6  7  (Positive)

2. Do you have prior experience with any generative AI tools?  
   a. Yes (please continue to Question 3)  
   b. No (please skip to Question 6)

3. If yes, which tools (plug-ins included) have you used? (Circle all that apply)  
   a. ChatGPT  
   b. Bing  
   c. Bard  
   d. Midjourney  
   e. Stable Diffusion  
   f. Adobe Firefly  
   g. Dall-E  
   h. Github copilot chat  
   i. Others:  

4. How often do you use them, on average?  
   a. Daily  
   b. 1-3 times a week  
   c. 1-3 times a month  
   d. I have only tried them once or twice

5. What purpose(s) do you usually use these AI tools for?

6. If no, what are your biggest concerns/reasons against using them?
Appendix C. Design Brief

Design Brief

As a group, please watch the video clip from the movie, “Downsizing”. Your design task is to **ideate on designing a physical product that would help the downsized people interact with the normal-sized world, including normal-sized humans and everyday items.**

1. Discuss what you have seen, what specific problems you would like to solve, and what product you would like to design. [about 15 minutes]
2. Generate creative ideas and visualize your ideas with sketches and/or Midjourney. [about 15 minutes]
   a. For Midjourney: use `/imagine` to write your text prompt. You can either re-write, modify your prompt, or create new variations (U for upscales, V for variations) of the current image generation.
      i. Basic prompt: a single word, an emoji, a phrase
         1. The Midjourney Bot works best with simple, short sentences that describe what you want to see. Avoid long lists of requests.
            - Instead of: Show me a picture of lots of blooming California poppies, make them bright, vibrant orange, and draw them in an illustrated style with colored pencils
            - Try: Bright orange California poppies drawn with colored pencils
   3. As a group, select the best 3 ideas with the most potential to be pushed forward. Please explain why in words. [about 10 minutes]
4. Select 3 key moments (i.e., someone’s sketches or an AI-image) that you find the most relevant to choosing the best 3 ideas. [about 5 minutes]
Appendix D. Ambiguity Semantic Differential Scale

Ratings

Next, for each of the 3 key moments that you have just selected as a group, please rate these key moments on the following scales.

**Key moment 1:**

This iteration of AI-generated images/sketch is or has….

(Predictable) 1 2 3 4 5 6 7  (Surprising)
(Understandable) 1 2 3 4 5 6 7  (Confusing)
(Concrete) 1 2 3 4 5 6 7  (Abstract)
(Not valuable) 1 2 3 4 5 6 7  (Very valuable)
(Single interpretation) 1 2 3 4 5 6 7  (Open to multiple interpretations)

**Key moment 2:**

This iteration of AI-generated images/sketch is or has….

(Predictable) 1 2 3 4 5 6 7  (Surprising)
(Understandable) 1 2 3 4 5 6 7  (Confusing)
(Concrete) 1 2 3 4 5 6 7  (Abstract)
(Not valuable) 1 2 3 4 5 6 7  (Very valuable)
(Single interpretation) 1 2 3 4 5 6 7  (Open to multiple interpretations)

**Key moment 3:**

This iteration of AI-generated images/sketch is or has….

(Predictable) 1 2 3 4 5 6 7  (Surprising)
(Understandable) 1 2 3 4 5 6 7  (Confusing)
(Concrete) 1 2 3 4 5 6 7  (Abstract)
(Not valuable) 1 2 3 4 5 6 7  (Very valuable)
(Single interpretation) 1 2 3 4 5 6 7  (Open to multiple interpretations)
Appendix E. Interview Questions

Post-workshop Interview Guide

Group A (sketching -> AI)

**Sketching ONLY interview questions**
1. Why did you choose these 3 key moments just now? Can you describe what happened?
2. How was your experience, ideating with manual sketching, as a group? How did you use sketches in your ideation?
3. What is your approach to iterating your ideas with sketches?
4. How is your experience of sketching as a group different from sketching by yourself?

**Sketching + AI interview questions**
1. How was your experience, ideating with Midjourney, as a group? How did you make use of the AI-generated images in your design?
2. What do you think of the AI-generated images you have produced?
3. Has the AI made your ideation process more ambiguous or clearer?
4. How is it different from the last session?

Group B (AI -> sketching)

**Sketching + AI interview questions**
1. Why did you choose these 3 key moments just now? Can you describe what happened?
2. How was your experience, ideating with Midjourney, as a group? How did you make use of the AI-generated images in your design?
3. What do you think of the AI-generated images you have produced?
4. Has the AI made your ideation process more ambiguous or clearer?

**Sketching ONLY interview questions**
1. Why did you choose these 3 key moments just now? Can you describe what happened?
2. How was your experience, ideating with manual sketching, as a group? How did you use sketches in your ideation?
3. What is your approach to iterating your ideas with sketches?
4. How is your experience of sketching as a group different from sketching by yourself?
5. How is it different from the last session?
Appendix F. Individual Reflection Questions

Post-workshop Reflection

1. What moment(s) did you find the most interesting or insightful today? Please elaborate on your answer.

2. How did you make use of the AI-generated images in your design ideation? Please elaborate on your answer.

3. Has the AI expanded OR limited your creativity? Please elaborate on your answer.

4. What are your thoughts on the ambiguity of the AI-generated images?