International Association of Societies
of Design Research Congress 2023
LIFE-CHANGING DESIGN

Politecnico di Milano
9-13 October 2023

Compass for the voyage of ideation: unlocking the stimulation potential of service design heuristics

Zhou, Zihan[a]; He, Renke[a]; Hu, Ying*[a]; Du, Xing[a]; Bai, Yiming[a]

[a] School of Design, Hunan University, Changsha, China
* dkm88@163.com

doi.org/10.21606/iasdr.2023.364

Design heuristics facilitate the generation of innovative solutions by pooling expert knowledge and experience through external stimuli. While heuristic tools have been widely studied in various design domains, most research has focused on evaluating their efficacy in enhancing creativity and usability rather than examining how they stimulate the process of design. In this study, based on Service Design Heuristic Cards (SDHC), we explored the stimulating effects of design heuristics on the ideation process, filling a relevant research gap. We confirmed the existence of four types of stimulation of heuristic tools, compared the effects of stimuli on different levels of design capability, categorized the stimulus preferences and the types of ideas generated by each stimulus, and attempted to summarize the thinking shuttle routes induced by heuristic. These findings provide insights for modifying heuristic-based design pedagogy methods to improve the comprehensive thinking abilities of novices on the path to becoming experts, as well as lay the groundwork for stimulating and regulating concept generation and enabling appropriate problem-solution jumping.

Keywords: inspirational stimuli; design heuristics; mind shifting; ideation

1 Introduction

In order to develop innovative solutions, designers will actively search for inspiration, even unconsciously or by chance (Goldschmidt & Sever, 2011; Herring et al., 2009). In the process of generating ideas, designers not only utilize their background experience and skills (internal stimuli) but also seek external stimuli (Eastman & Computing, 2001) to solve the problems they encounter (Goldschmidt, 1997; Gonçalves et al., 2013). Diverse and rich stimuli can help designers break free from fixations (McCaffrey & Krishnamurty, 2015; Hao et al., 2017), and extensive research has investigated the impact of external stimuli on idea generation (Yang et al., 2005; Howard et al., 2010; Fu et al., 2013).

Design heuristics are defined as contextual directives based on instincts, tacitly recognized knowledge, or experimental understanding, which point out the direction of the designing process (Fu et al., 2016). The design strategies contained therein are extracted from observations and studies of experts and can guide the formation of design solutions from different perspectives through external stimuli. Heuristic tools have been widely developed and applied in various design fields, such as 77 Design Heuristics (Yilmaz et al., 2016a), the Portability Design Heuristics (Hwang & Park, 2015), Design Heuristics for Additive Manufacturing (Blösch-Paidosh & Shea, 2017), Heuristic Design of a Hybrid Presentation Medium (Edge et al., 2016), among others.

Although heuristic tools have been developed for multiple fields and have been shown to have a positive effect on creative idea generation, most studies focus on evaluating their efficacy in enhancing creativity and the usability of the tools themselves (Wang et al., 2021) rather than on how design heuristics stimulate concept generation. Some researchers also express concerns that Design Heuristics developed to stimulate conceptual derivation may become "traps" for design fixation, leading to over-reliance on an imitation of expert experience (Leahy et al., 2020), particularly for novice designers. Therefore, exploring the specific stimuli of heuristic tools in depth is necessary.

We use the Service Design Heuristic Cards (SDHC), a design heuristic tool developed by our team for the service design field, as the basis for this research. By analyzing the use of SDHC in design practice, we attempt to clarify the following questions:

1. How do design heuristics stimulate designers to engage in design activities?
2. What types of stimuli are present in this process?
3. What impact do these stimuli have on the generation of conceptual inspiration?

2 Background

2.1 Ideation and design fixation

Design concept generation, also known as design ideation, is arguably the most crucial phase for infusing creative inspiration and shaping the creativity of subsequent design phases. (Cross, 2001; Yang, 2008; Hay et al., 2019). This process provides potential ideas, basic building blocks, and source materials for the final design, making an effective ideation process essential for achieving high-quality design outcomes. However, ideation in service design is complex (Ali et al., 2017). Service designers need to conduct information searches specific to the design scenario and target audience, drawing inspiration from diverse sources, including design precedents (Patil & Athavankar, 2022), pictures, written documents, and even diverse forms of life and nature phenomena (Gonçalves et al., 2014). This process requires mobilizing individuals' experience and knowledge reserves to identify specific design problems and conceive a wide range of service concepts, including service processes, functions, touchpoints, etc. These challenges often hinder novice service designers from generating a large number of creative ideas and lead to design fixation (Jansson & Smith, 1991).

The interdisciplinary nature of service design (Ali et al., 2017) requires designers to possess both service design experience and domain-specific knowledge in specific projects during the concept generation phase. Most experienced service designers can extract field-specific implicit knowledge from their extensive past experiences and freely apply it to new projects (Yilmaz et al., 2016a; Christensen & Ball, 2016). However, it is clear that novice service designers lack such reliable experience (Jain & Sobek, 2006), which leads to the dilemma of "creative drought."

2.2 Design stimuli methods and tools

Stimuli serve as an essential source of creative inspiration in the design process (Tang et al., 2019). Aggregated external resources (stimuli) can effectively compensate for designers' cognitive limitations because designers can easily use clues to spark inspiration and break down design fixation, thereby fostering creative thinking (Vasconcelos & Crilly, 2016; McCaffrey & Krishnamurty, 2015; Hao et al., 2017). Textual descriptions (Vandevenne et al., 2014), images (Goldschmidt & Smolkov, 2006), ontology (Han et al., 2018), color (Damle & Smith, 2009), and stories (Alon-Mozes, 2006), among others, have been shown to be beneficial for concept generation.

In particular, design heuristics, as an extracted "intermediate knowledge" (Yilmaz et al., 2016a), provide methods, strategies, or generative prompts that represent a class of design actions, linking conceptual creation to past experiential knowledge (Gray et al., 2016) and providing "cognitive shortcuts" for generating satisfactory solutions (Fu et al., 2016). Numerous studies have demonstrated that design heuristics can serve as design stimuli for the early stages of concept design, supporting practitioners in exploring larger design spaces (Jin et al., 2021). However, based on a literature review, most research on design heuristics focuses on the development of tools specific to certain fields and the validation of their utility but has yet to deeply analyze and discuss the specific details and effects of stimuli from an external perspective.

2.3 Stimulus properties of Design Heuristics

Design tools, according to Howard, can be categorised into three domains: creative-analysis tools, thinking tools, and stimuli tools, with Design Heuristics being classified as a stimuli tool (2008). Design heuristics provide a series of expert strategies and experiences as stimulus materials, enabling designers to pull out information that can help initiate research from an informed starting point to a more open and creative conception of design outcomes (Yilmaz et al., 2015). Gigerenzer and his research team (2002) conducted in-depth research on the ecological rationality of heuristic applications. They proposed the Adaptive toolbox theory, which compares the human brain to a toolbox and various heuristics as tools in the toolbox. When confronted with unique problems, designers will independently select tools or tool combinations hidden in their minds to process them. This metaphor implies that the thinking process uses many individual adaptive strategy collections and emphasizes the possibility of heuristics being recombined and nested.

We have reason to believe that the diversity of design heuristics brings more flexible and moldable changes to their stimulating effects. Therefore, based on the SDHC tool developed by the team, this article aims to understand further the stimulating effects of design heuristics during the concept generation phase and lay the groundwork for better understanding the traits of heuristic stimuli and additional generative pedagogical methods (Ali et al., 2017).

3 Service Design Heuristic Cards (SDHC)

SDHC is a set of design exploration tools applicable to service design that can stimulate novice designers' concept generation. The tool's development was inspired by previous research (Hwang & Park, 2018) and adopted an expert-case-based extraction method. After a wide range of collection, internal screening, expert evaluation, and integration modification, 100 heuristic cards containing service design expert strategies were ultimately determined. Each card mainly consists of textual information, including "Title," "Paraphrase," "Example Case," and "Maker's Information," as shown in

Figure 1. After the tool's development, we tested the helpfulness of SDHC for novice designers through practice. We set up three criteria - novelty, usefulness (or value), and integrity to evaluate how concepts originating from each SDHC affect solutions, thereby determining the tool's effectiveness in enhancing creativity and testing its usability.

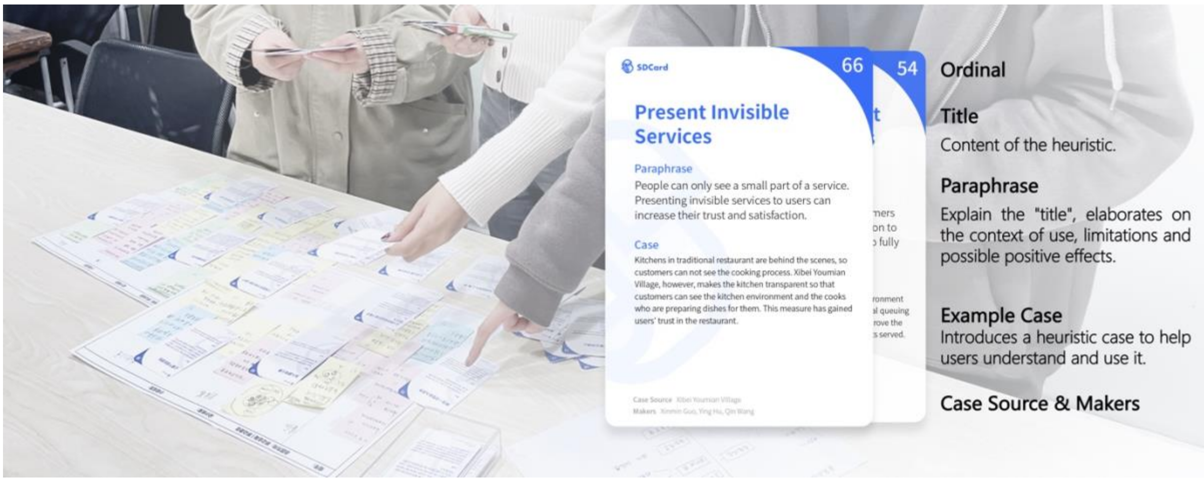


Figure 1. SDHC usage process and content examples.

SDHC was developed in a bottom-up manner and is currently unstructured. Each heuristic is determined by a specific case and conveys corresponding value propositions, solution methods, design processes, constraint conditions, and sometimes comments from professional designers. The diversity of these contents results in different specificities and purposes in the textual descriptions of SDHC (Yilmaz et al., 2016b). In our hypothesis, this "unstructuredness" may precisely achieve high flexibility in application, allowing SDHC to serve as a springboard for thinking and potentially stimulating a space that increases the possibility of design evolution.

4 Experiments: measuring the stimulus effect of SDHC-based inspiration

4.1 Coding system

In the realm of design and creativity, the Ideatin process often occurs vaguely and chaotically (Kimbell & Street, 2009; Sanders & Stappers, 2008). The related theories of design thinking (Rowe, 1991; Owen, 2007) posit that design is a perpetual cycle of analysis, synthesis, evaluation, and communication to realize the iteration of abstract ideas and thoughts into concrete models, products, and services. The design funnel theory describes the design process as the continual convergence and generation to select concepts (Hollins & Pugh, 1990; Stefano & Rocchesso, 2019; Greenberg et al., 2011). The Double Diamond model proposed by the UK Design Council consists of two iterations of divergence and convergence in the form of discover, define, develop, and deliver. In addition, Dorst & Cross confirmed through a series of protocol studies that creative design involves an exploratory phase, during which the problem and solution space evolve continuously until a temporary pairing of problem-solution is fixed by an urgent bridge (2001). Based on the research content of process models in design and development, as well as the characteristics of SDHC in practical application, we conclude that SDHC will have an impact on both the solution space and problem space and that there are two aspects of stimulation, namely, divergence and convergence. Therefore, we have summarized the types of stimulation that SDHC triggers (Figure 2). The coding table (Table 1) provides detailed definitions and explanations of the four stimulus types, as well as relevant examples from the actual use of SDHC.

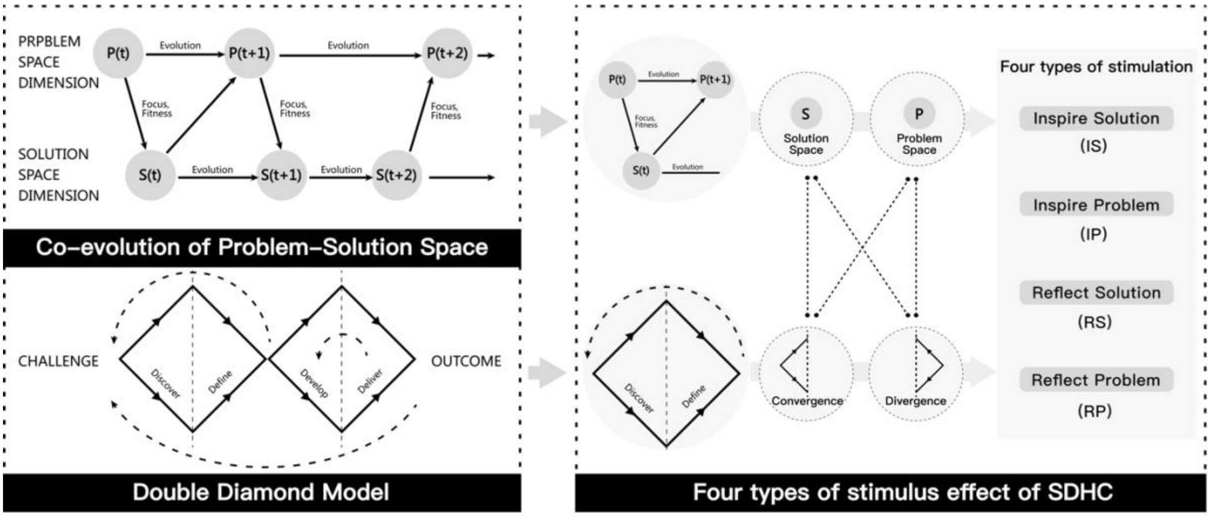


Figure 2. The process of stimulus type analysis of SDHC.

Table 1. Stimulus type code table

Stimulus	Abbr.	Definition	Example
Inspire Solution domain	IS	SDHC provides feasible and borrowable solution strategies, which allow users to generate concepts directly based on these strategies.	The heuristic "Provide Feedback Channel" inspired two ideas: 1. "Add AI messages to the invitation text before the service to reflect the friendliness of AI," and 2. "Display pain reactions when AI is subjected to human violence during the service" (G11).
Inspire Problem domain	IP	SDHC indicates the specific aspects that need attention, enabling users to explore new design problems by searching for relevant information.	The heuristic "Eliminate Unnecessary Parts" made the user aware of the negative issues that customers may have in the current context, and through information search, ultimately unearthed the design problem of "customer anxiety during book serialization service waiting process" (G24).
Reflect Solution domain	RS	SDHC highlights certain design standards, principles, or limitations, prompting users to review their designs or services to ensure compliance with these standards.	The heuristic "Control the Volume and Scale of Information" prompted the user to consider whether the current solution displays too much information and to reflect on which information the customer sees that easily triggers anxiety (G07).
Reflect Problem domain	RP	SDHC suggest something that was not previously considered, leading users to reflect on the comprehensiveness and accuracy of their current design problem.	The heuristic "Establish Supervision-Punishment Mechanism" prompted the user to consider whether such a mechanism is needed in the plan and realized the possibility of criminal behavior in "gene editing," further clarifying the problem that "the government has not established a supervision-punishment mechanism to prevent crime and maintain fairness" effectively (G19).

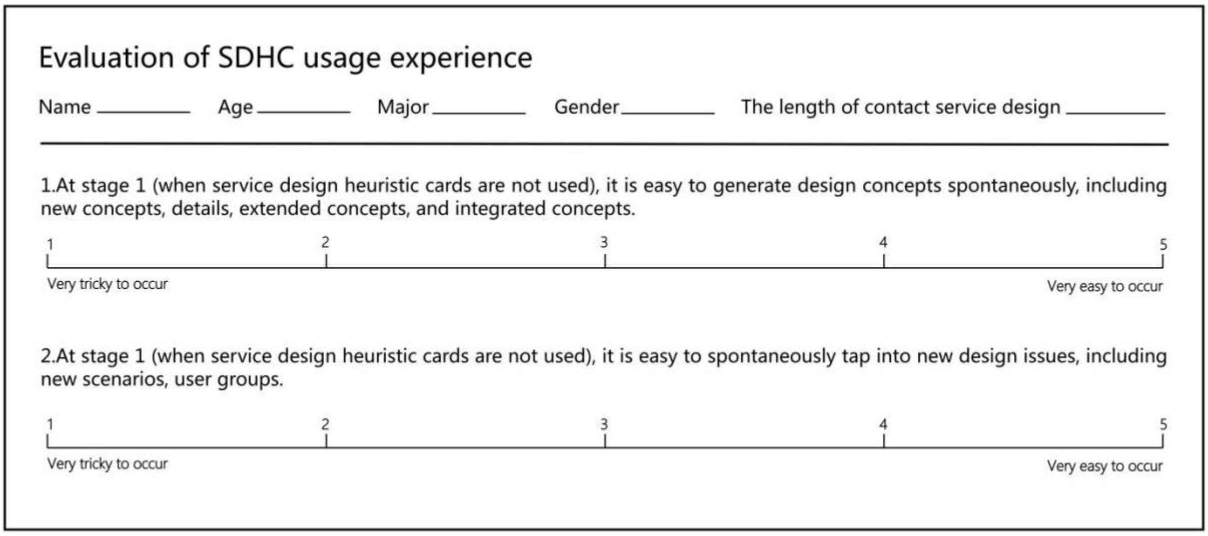
4.2 Study I

We conducted two experiments. The first experiment was carried out in a small service design workshop to explore whether SDHC has a stimulating effect and whether there are differences in the stimulating effects on designers with different capability levels.

4.2.1 Procedure

We designed two stages for self-comparison, where participants were asked to design a service solution around environmental ecology. In the control stage, participants were required to identify a design problem related to the theme within a specified time and conceive a service solution using conventional design methods. In the experiment stage, we added the SDHC tool and asked participants to identify a new design problem and refine their solution.

At the end of the design process, each participant reviewed both phases of the workshop and completed an evaluation questionnaire assessing the difficulty of IS, IP, RS, and RP occurrence with/without SDHC on a 5-point Likert scale (1=very tricky to occur, 5=very easy to occur). An example of the content of the evaluation questionnaire is shown in Figure 3.


Evaluation of SDHC usage experience

Name ________ Age ________ Major ________ Gender ________ The length of contact service design ________

1.At stage 1 (when service design heuristic cards are not used), it is easy to generate design concepts spontaneously, including new concepts, details, extended concepts, and integrated concepts.

1 2 3 4 5

Very tricky to occur ... Very easy to occur

2.At stage 1 (when service design heuristic cards are not used), it is easy to spontaneously tap into new design issues, including new scenarios, user groups.

1 2 3 4 5

Very tricky to occur ... Very easy to occur

Figure 3. Examples of parts of the evaluation questionnaire.

4.2.2 Participants

The workshop participants comprised 35 design students, including 23 undergraduates and 12 graduate students. Based on the general professional model proposed by Dreyfus (2003), which distinguishes six design capability levels, we defined the undergraduate students as Novice level and the graduate students with a richer mastery of foundational design knowledge and experience as Competent level. Among them, 13 students had a background in product design, six students in visual communication design, eight students in industrial design, and the remaining eight students were from the digital media art program.

4.2.3 Data analysis and results

We conducted a paired-sample t-test to compare the data between the control and experimental stages. Before the t-test, we confirmed that both data sets were normally distributed. Table 2 shows four pairs of data, all of which showed significant differences ($p<0.05$). The average score in the control stage was significantly lower than in the SDHC stage. SDHC had a significant impact on IS, IP, RS, and RP in terms of stimulation.

Table 2. Paired T-Test analysis of the control and experimental phase

Control - Experimental phase	Mean	SD	t	p-value	Analysis
IS (Tool-less phase)	3.20	0.80	-3.256	0.003	significant
IS (Using SDHC phase)	3.80	0.80			
IP (Tool-less phase)	3.06	0.91	-4.547	0.000	significant
IP (Using SDHC phase)	3.91	0.66			
RS (Tool-less phase)	3.17	1.04	-2.186	0.036	significant
RS (Using SDHC phase)	3.66	0.87			
RP (Tool-less phase)	3.06	1.06	-4.440	0.000	significant
RP (Using SDHC phase)	4.03	0.66			

Figure 4 presents the descriptive statistics of the rating distribution for the two levels of participants (Novice and Competent) in the Control phase (Tool-less) and the Experimental phase (Using SDHC). Comparing the Control and Experimental phases, the overall trend in the line chart has shifted to the right, demonstrating that heuristic tools facilitate more accessible exploration of design-solution space and corresponding divergent thinking and reflection for both levels of designers. Although Novices initially have less design experience, their improvement is significant after using the tool, narrowing the gap in creative solutions compared to Competent designers.

Overall, undergraduates were most affected in the IP domain (Cohen's d=1.000). In contrast, the impact on different domains for graduate students was relatively similar, with RP (Cohen's d=0.920) and RS (Cohen's d=0.505) domains being relatively more significant.

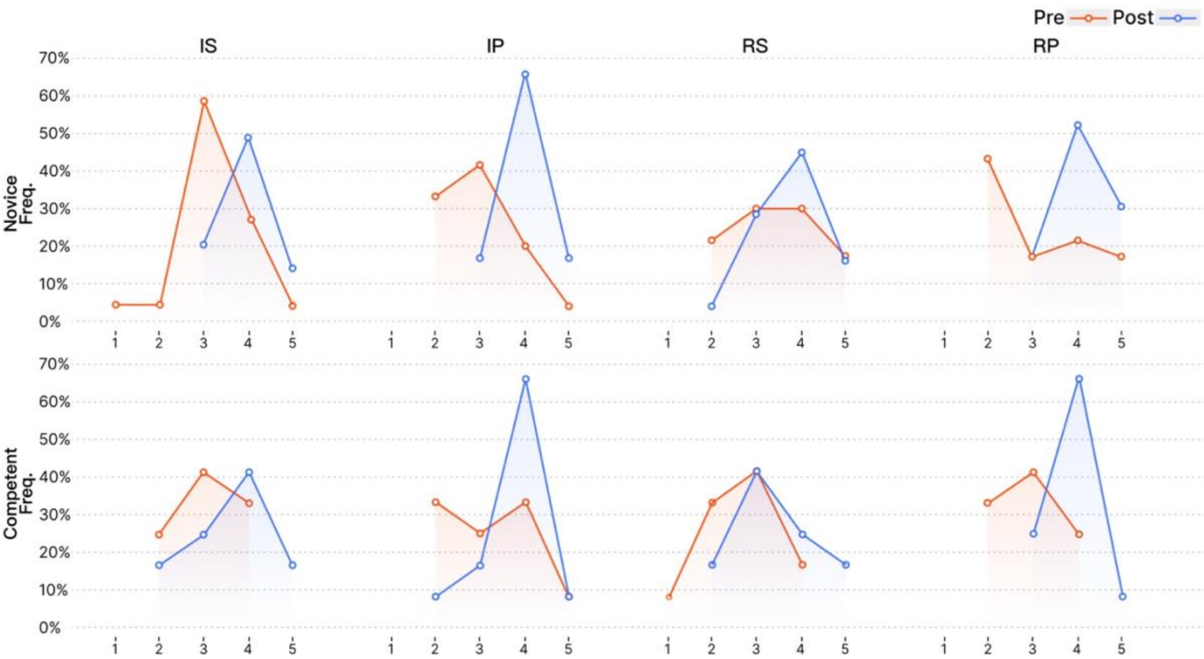


Figure 4. Distribution of rating score of two design capability levels.

We conducted a one-way ANOVA analysis (Field, 2017) to examine the influence of gender and major on the impact of the card stimuli. The results showed no significant difference ($p>0.05$) in the performance of participants of different genders or majors in both the control and experimental phases, suggesting that the impact of the card stimuli was consistent across all genders and majors.

4.3 Study II

Further, we introduced the SDHC tool in a course on "Service Design and Business Models." During the course, we were able to more thoroughly document the steps, processes, and methods used by design teams when using SDHC, particularly the conversations that occurred throughout the entire discussion process. By analyzing the natural usage and results of the cards, we delved deeper into the stimulation modes of SDHC and the potential for driving the shift between design space and solution space.

4.3.1 Procedure

The course "Service Design and Business Models" focused on two topics: mobile communication services and mobile financial services. Before using the service design heuristic cards, each group had already completed a preliminary definition and exploration of the design problem. Each group was asked to use SDHC to derive concepts around the design problem within 2 hours and to record and paste their ideas on the discussion paper. Figure 5 shows the scene of a team discussion in the classroom. Students should "think aloud" while undertaking the design task. Through the form of interactive group dialogue, to some extent, can reduce the situation of capture failure due to implicit thinking. Each group recorded their discussion process. A representative from each group participated in a semi-structured retrospective interview with the research team after the tool was used, answering open-ended questions about the usage, feelings, and effectiveness.

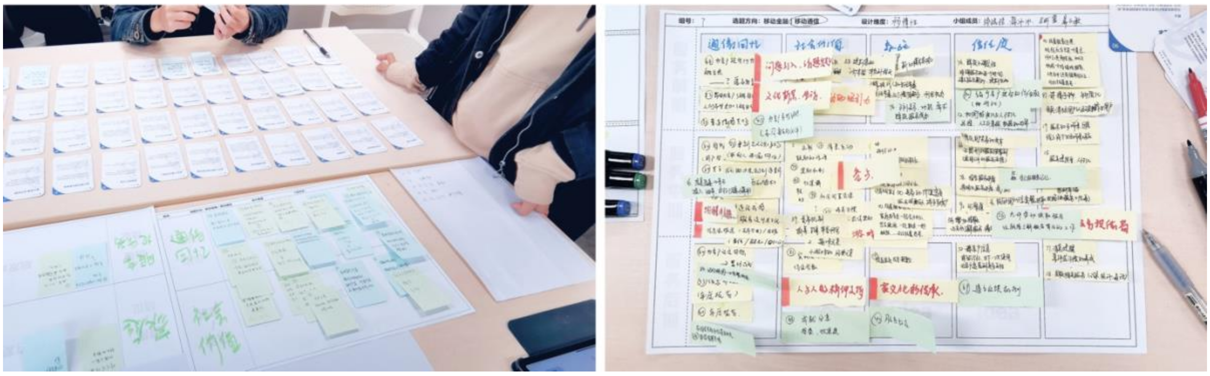


Figure 5. Team discussions and drafts in the classroom.

4.3.2 Participants

The participants in the course were all third-year undergraduate students majoring in industrial design (n=102), all of whom were novices in service design. The course was organized in teams of 3 or 4 students, a standard design education grouping format. Ultimately, the participants were divided into 26 groups (two groups of three and twenty-four groups of four). To ensure the consistency of the experimental data, we excluded the discussion data from the two groups of three from the final analysis.

4.3.3 Data analysis and results

The collected data included all the paper documents used during the process (such as drafts, solution records, and post-it notes) and the audio recordings of the groups' discussions. Following the participants' willingness (if any group members objected, we would not use this data set) and the potential impact of the noisy classroom environment on audio quality, 15 sets of audio data were ultimately selected for further detailed analysis. These recordings totaled 34.3 hours, and 714 instances of the stimulus were collected.

4.3.3.1 Stimulation propensity

Three coders with more than five years of coding experience used ATLAS software to conduct protocol analysis (Gero & Neill, 1998) on the collected discussion recordings. The four-stimuli coding system was used to code the noise-reduced data, and these features were assigned to each discussion related to the design solution. The ICC correlation coefficient was 0.728, which was considered to be in a fair range (Hallgren, 2012).

The discussions of the four group members were carefully segmented (5-minute segmentation) in chronological order, and we classified the discussions of each segment that were triggered by which heuristic card. Discussions after 5 minutes of card use were defined as group discussions and were not categorized as discussions triggered by SDHC stimuli. Figure 6 shows some of the coding results for G-02.

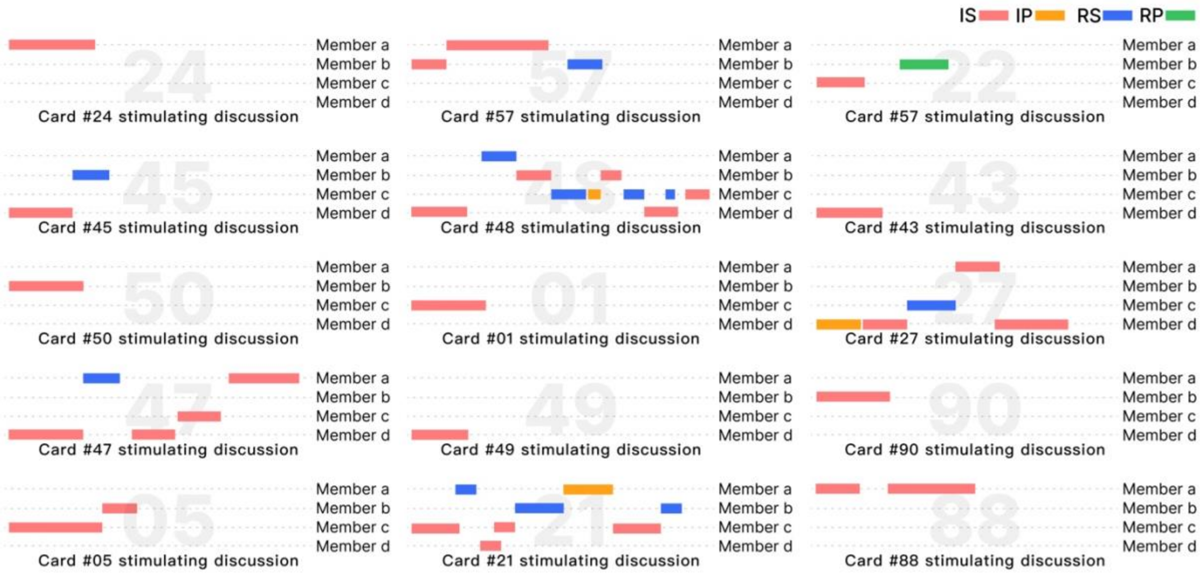


Figure 6. Partial coding results of G-02.

By comparing the plotted coding results, we were able to identify the stimulus situations triggered by the specific numbered cards. Although the effects of the stimuli were influenced by various factors and showed some variation in the results. Some heuristic cards still showed significant design stimulus preferences due to their inherent tendency to carry textual information.

Some heuristics only show one type of stimulation during use, which we categorize as a single-stimulation type. Such cards are more intense in triggering a certain type of stimulus. In contrast, other heuristics exhibit multiple-stimulation properties. The stimulation possibilities of these cards are not unique and are influenced by design scenarios, discussion patterns, participant experience, and thinking styles, resulting in more diverse changes.

For example, heuristics 14, "Balance the Interests of Stakeholders," and 29, "Define Service Boundary," exhibit a strong RS stimulation tendency during use. Heuristic 76, "Reduce Service Uncertainty," prompts users to pay attention to the current uncertain elements in the design scenario, search for relevant information, and then inspire design problems. Some heuristics also have an additional role in transforming users' discussion perspectives, such as heuristic 10, "Attention to Non-targeted Customers." We have sorted the specific card stimulation preferences, as shown in Table 3.

Table 3. Stimulation propensity of SDHC

Type	Propensity	SDHC
Single-stimulation	IS	01.Add Familiar Elements 02.Add Interesting Elements 04.Add Natural Elements 27.Data-Driven Services
Single-stimulation	IP	09.Attention to Needs beyond Services 31.Distract Negative Attention 66.Preparatory Design 76.Reduce Service Uncertainty
Single-stimulation	RS	14.Balance the Interests of Stakeholders 29.Define Service Boundary 68.Provide Action Trigger Points for Customers 83.Self-fulfillment
Single-stimulation	RP	10.Attention to Non-targeted Customers 60.Make Service Providers Happy First
multiple-stimulation	RP、IS	07.Attention to Dynamic Needs of Customers 13.Balance Standardization with Customer Friendliness 33.Divert Customers 92.Sunk Cost
multiple-stimulation	IP、RS	17.Change Transformation into Participation 20.Control the Volume and Scale of Information 68.Present Potential Information
multiple-stimulation	IP、IS	11.Automatic Service Process 32.Diversified Service Points 61.Migrate Non-targeted Scenes to Current Scenes 67.Present Invisible Services

To gain a deeper understanding of the reasons behind the diverse effects of multiple stimuli, we conducted interviews with some students who showed significant differences in their performance when using the same heuristic card. The results showed that students with higher scores were better at discovering the potential of heuristic cards from diverse perspectives. They pushed their design process based on actual needs and the prompts from the cards, deliberately avoiding similarities with the case contents indicated on the card, especially when designing for similar scenarios. On the other hand, students with poorer design abilities often tended to imitate and copy the cases blindly, resulting in issues such as "it seems that I have been diverging a lot when using heuristic cards, with many small points, but there is no logical relationship between them, and the process is quite jumpy."

4.3.3.2 Types of concepts generated

We utilized Grounded Theory (Long, 1993) and conceptualized the experimental data based on open coding principles to summarize further the types of ideas facilitated by different stimuli of heuristics (Table 4).

Table 4. Idea types facilitated by each stimulation

Stimulation	Idea Types	Explanation
IS	New ideas	Conceptual breakthrough inspired by card examples or similar strategies that were not previously considered
	Details	More detailed description of existing concepts, including form, content, and behavior details
	Extension	Supplementing existing ideas in the order of events/activities
IP	Requirement mining	New user pain points and needs
	Perspective shift	Switching to a new user group as a design perspective
	Object refinement	Focusing on a more specific user group and redefining the core user for design
RS	Concept integration	Highly summarizing/integrating a higher-level concept of one or more existing concepts
	Design guidelines	Limiting factors and default principles that need to be followed in the design process
	Evaluation comparison	Judging the logic, functionality, feasibility, acceptability, and value of each alternative solution
RP	Problem definition	Reconsidering and supplementing the definition, scope, urgency, and importance of the design problem (accuracy and completeness)
	Requirement clarification	More specific and precise user requirements, including design scenarios, objects, urgency, and necessity

The overall data shows that IS is the most common (frequency=48.9%) during the use of heuristics, followed by RS (24.4%) and IP (21.4%), while RP (5.3%) appears with the most minor frequency. Therefore, most groups are more focused on using heuristics to generate new concepts and details. Some students showed an advantage in using heuristics to explore user needs and design objects. After interviews, we found that these students were already better at conducting user research in their usual design activities and had strong empathy and insight abilities. We invited experts to score the design results of each group (Novelty, Usefulness, and Integrity), and the data shows that groups that produce a more diverse range of stimulus and idea types using SDHC can generate more beneficial design solutions and effectively avoid the disconnect between problem space and solution space.

4.3.3.3 Shuttle routes

Using inductive method (Znaniecki, 1968), we attempted to summarize the shuttle routes of each group's discussions under the SDHC stimuli. For example, in the case of G-21 discussing communication services for migrant workers' parents, left-behind children, and elderly in rural areas, they were stimulated by Card 69, "Provide Action Trigger Points for Customers." and consider a solution that "helps participants take the first step in communication, making them more proactive in sharing stories and perspectives." However, they later discovered flaws and reflected on the previous solution, and then discussed and came up with a better solution of "providing users with fixed mode choices, such as basic or advanced modes" by realizing that "users cannot choose when they are unclear about the impact of privacy rights." This discussion process was defined as a shuttle process from IS to RS and back to IS. We used solid lines with arrows to indicate clear shuttle directions and dotted lines with arrows to represent probabilistic shuttle situations. Figure 7 shows the shuttle patterns starting from IS, IP, RS, and RP and the typical shuttle routes we have summarized.

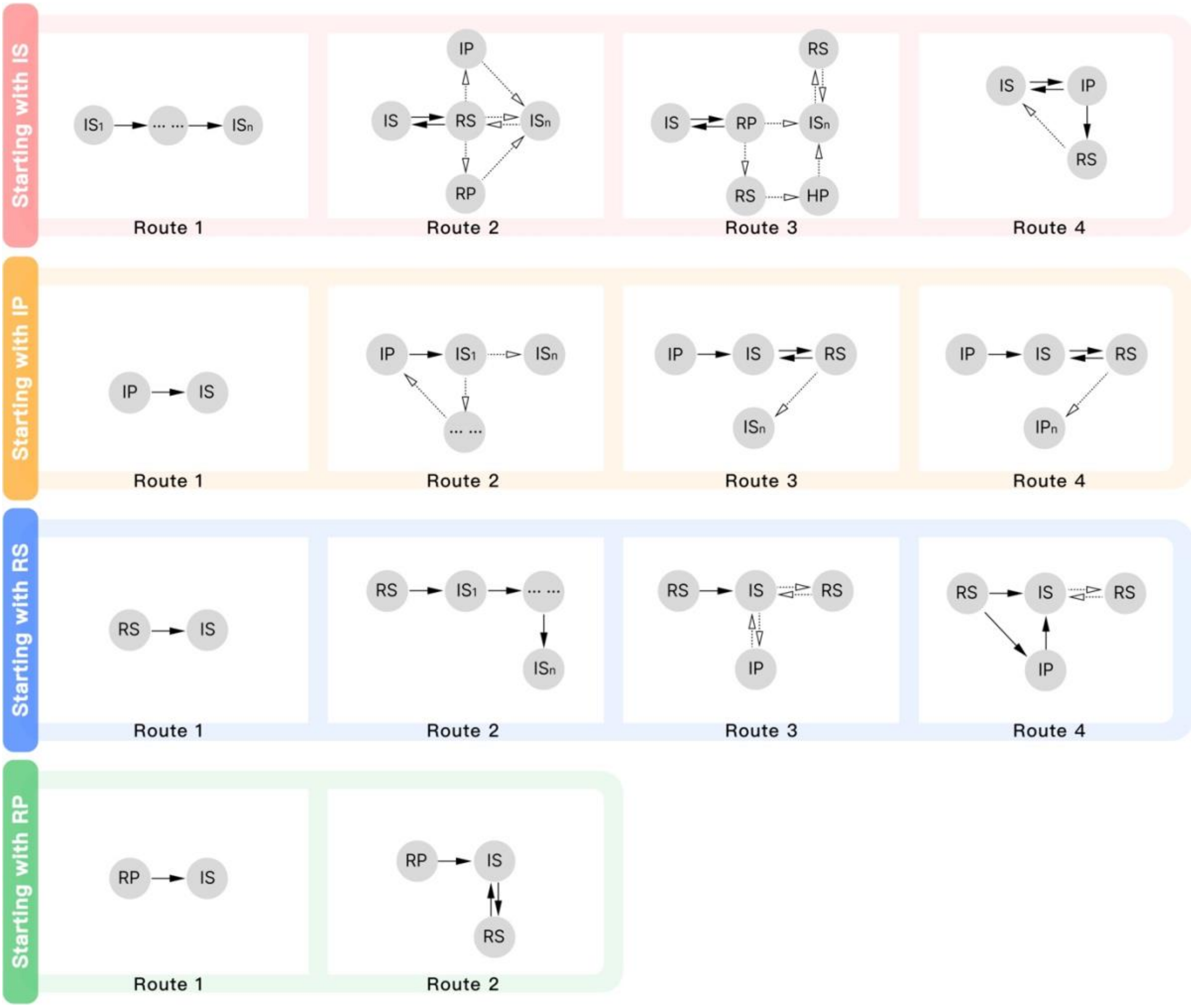


Figure 7. Typical shuttle routes.

5 Discussion

5.1 Traits and generated concepts of each stimulation

Design heuristics provide a plethora of "idea seeds" for novice conceptualization by supporting analogical reasoning with existing knowledge (Hwanga & Park, 2018). We categorized the four types of SDHC stimuli into four directions: Inspire Solution (IS), Inspire Problem (IP), Reflect Solution (RS), and reflect Problem (RP), and our workshop study confirmed the existence and significance of these four stimuli. When stimulating the IS domain, users can directly generate concepts based on feasible and adaptable solution strategies. When stimulating the IP domain, SDHC indicates what needs to be focused on, and users discover new design directions by searching for information. When SDHC suggests certain design standards or principles, it often stimulates the RS domain, where users examine whether the current solution or service meets these standards. Some SDHCs also implicitly indicate previously unconsidered customer needs, stimulating users to reflect on the comprehensiveness or accuracy of the design problem and redefine or optimize it accordingly.

In the second study, we explored the impact of each stimulus and the particular types of concepts (details, integration, design guidelines, for instance) that they generate. These findings reveal more sufficient results of each stimulus and provide adequate support for a better understanding of the creative generation process stimulated by design heuristics.

5.2 Stimulus effect for different design capability levels

In addition to confirming the stimulating effect of SDHC, we compared the evaluation data of Novice and Competent designers in the workshop. The analysis showed that the SDHC stimulation positively affects spatial exploration and divergent-convergent thinking for both design capability levels. During the use of heuristics, Novice designers' abilities improved significantly, and the gap between the two levels of designers narrowed as a result. Novice designers were most affected in the domain of IP, while Competent designers were equally affected in all aspects, with RP and RS being relatively more significant. This may be because experienced designers tend to focus more on proposition and reflection in the concept generation stage, while novices often focus on action (Ahmed et al., 2003; Hu et al., 2014).

These conclusions reveal the potential of SDHC as a teaching tool and bring new thinking to the design pedagogy based on heuristics. Students at different ability levels should develop matching heuristic training methods according to the characteristics of their design activities to teach the skills most needed at their level of ability and cultivate novice designers to advance to experienced experts.

5.3 Motivating problem-solution space shifting

Despite the fact that the efficacy of heuristics is influenced by a variety of factors, including design scenarios, the designer's background, thinking style, and learning style, certain heuristic cards continue to exhibit significant stimulus tendencies. We summarized cards with single and multiple stimulus tendencies in the second study. We discovered that students adept at using heuristics to generate various stimulus types perform better on average. To produce high-quality solutions, designers must master the ability to switch activity modes rapidly (Cross, 2023). Experts and novices differ considerably in their ability to shift their focus between different tasks frequently (Atman et al., 2005; Park et al., 2008).

Spontaneously and appropriately, sifting and coevolving between problem-solution spaces is challenging for novices (Du et al., 2022). Each heuristic provides a starting point for transforming existing concepts. It is possible to specify the nature of each heuristic and the specific transformation it provides within a design, actively and dynamically constructing new solutions (Yilmaz et al., 2010). Especially, cards presenting different stimulus tendencies can play a bridging role in linking different spatial design activities, achieving high-quality and purposeful thinking shifting, and providing accurate navigation. Recurring cards with the same stimulus tendency are advantageous for increasing the exploration depth in this dimension. In contrast, cards with different stimulus tendencies indicate the introduction of new elements, thereby switching tasks and design spaces to stimulate discussion, which is also helpful for regulating the design team's discussion process.

In addition, we attempted to reconstruct the user's design process by tracking the temporal order of the four stimulation and by summarizing the shuttle routes that appeared frequently. Understanding and describing the design process has been the focus of design research since its inception (Cross, 2007). We believe that modeling these shuttle routes offers meaningful explanations for the varying performance of concept generation participants. From a lateral perspective, shuttle routes reflect the design activity mode of designers in Ideation.

6 Conclusion

Based on the SDHC, this study discusses the role of design heuristics as external stimuli. First, the article summarizes the four types of stimulation (IS, IP, RS, RP) that SDHC possesses by analyzing and summarizing the Double Diamond Model and co-evolution theory and combining them with the actual use of the tool. A design workshop confirmed the existence and significance of the four stimuli types. By comparing the rating data from two capability levels (Novice and Competent), we explored the differences in the stimulative effects of SDHC, which is vital for designing targeted instructional methods and developing new approaches for novice designers to advance to design experts.

In the "Service Design and Business Models" course, we carefully encoded the stimulation during group discussions and classified the resulting types of ideas under each type of stimulus. Furthermore, we attempted to summarize the thinking shuttle routes triggered by design heuristics. These results close a gap in design stimulus research in the field of heuristic tools and demonstrate the potential of design heuristics as a purposeful navigational concept for Ideation processes. Studies on the relationship between design heuristics stimulation and the switch of different thinking types and design activities can be adopted to establish operative interventions and strategies to stimulate the shifting process of design teams, which can then be implemented in future design education classrooms.

7 Limitation and future work

This article has some limitations. While it explores the specific effects of design heuristic tools as external stimuli, the research in each aspect is not sufficiently in-depth. For example, the study identifies differences in the effects of heuristic stimuli on novice and competent designers. However, due to the limited sample size, some individual differences may still affect the experimental results. Future research should examine and analyze these potential differences in a more detailed and nuanced manner.

Moreover, there are still many questions to be addressed. The practical significance of different shuttle routes and their specific impact on solution development still need to be determined. Can we explore more effective shuttle routes to identify the timing and methods of shifting and even adopt the shuttle patterns of professional designers to stimulate and regulate the shuttle process for novices? How can we regulate the appearance of SDHC with different stimulus preferences and maximize the stimulus effect based on the context? These questions are meaningful and challenging and require more digging.

References

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. Research in Engineering Design, 14(1), 1–11. https://doi.org/10.1007/s00163-002-0023-z

Ali, H., Grimaldi, S., & Biagioli, M. (2017). Service design pedagogy and effective student engagement: Generative tools and methods. The Design Journal, 20(sup1). https://doi.org/10.1080/14606925.2017.1352659

Alon-Mozes, T. (2006). From 'reading' the landscape to 'writing' a garden. Journal of Landscape Architecture, 1(1), 30–37. https://doi.org/10.1080/18626033.2006.9723362

Atman, C. J., Cardella, M. E., Turns, J., & Adams, R. (2005). Comparing freshman and Senior Engineering Design Processes: An in-depth follow-up study. Design Studies, 26(4), 325–357. https://doi.org/10.1016/j.destud.2004.09.005

Blösch-Paidosh, A., & Shea, K. (2017). Design heuristics for additive manufacturing. In DS 87-5 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 5: Design for X, Design to X, Vancouver, Canada, 21-25.08. 2017 (pp. 091-100).

Christensen, B. T., & Ball, L. J. (2016). Creative analogy use in a heterogeneous design team: The pervasive role of Background Domain Knowledge. Design Studies, 46, 38–58. https://doi.org/10.1016/j.destud.2016.07.004

Cross, N. (2001). Design cognition: results from protocol and other empirical studies of design activity. In R Newstetter, W. C., McCracken, W. M., Eastman, C. M., & Eastman, C. M. (Eds.), Design Knowing and Learning: Cognition in Design Education (pp. 79–103). Elsevier Science. https://doi.org/10.1016/B978-008043868-9/50005-X

Cross, N. (2007). Forty Years of Design Research. Design Studies, 28(1), 1–4. https://doi.org/10.1016/j.destud.2006.11.004

Cross, N. (2023). Design thinking: Understanding how designers think and work. Bloomsbury Publishing.

Damle, A., & Smith, P. J. (2009). Biasing cognitive processes during design: The effects of color. Design Studies, 30(5), 521–540. https://doi.org/10.1016/j.destud.2009.01.001

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem–solution. Design Studies, 22(5), 425–437. https://doi.org/10.1016/s0142-694x(01)00009-6

Dreyfus,H.L. (2003) The Spinoza Lectures. University of Amsterdam, Amsterdam

Du, X., Ji, T., Hu, Y., Wang, H., & Wang, Q. (2022). How thinking patterns and strategies drive idea generation: From novices to experts in service design. [ ] With Design: Reinventing Design Modes, 3203–3220. https://doi.org/10.1007/978-981-19-4472-7_207

Eastman, C., & Computing, D. (2001). New directions in design cognition: studies of representation and recall. In Design knowing and learning: Cognition in design education (pp. 147-198). Elsevier Science. https://doi.org/10.1016/B978-008043868-9/50008-5

Edge, D., Yang, X., Kotturi, Y., Wang, S., Feng, D., Lee, B., & Drucker, S. (2016). Slidespace. ACM Transactions on Computer-Human Interaction, 23(3), 1–30. https://doi.org/10.1145/2898970

Field, Andy (2017) Discovering statistics using IBM SPSS statistics, 5th edition. SAGE Publications, London. http://sro.sussex.ac.uk/id/eprint/77862

Fu, K., Chan, J., Cagan, J., Kotovsky, K., Schunn, C., & Wood, K. (2013). The meaning of "near" and "far": The impact of structuring design databases and the effect of distance of analogy on design output. Journal of Mechanical Design, 135(2). https://doi.org/10.1115/1.4023158

Fu, K. K., Yang, M. C., & Wood, K. L. (2016). Design principles: Literature review, analysis, and Future Directions. Journal of Mechanical Design, 138(10). https://doi.org/10.1115/1.4034105

Gero, J. S., & Mc Neill, T. (1998). An approach to the analysis of Design Protocols. Design Studies, 19(1), 21–61. https://doi.org/10.1016/s0142-694x(97)00015-x

Gigerenzer, G., & Selten, R. (2002). Bounded rationality: The adaptive toolbox. MIT Press. Elsevier. https://doi.org/10.1016/j.jebo.2003.09.001

Goldschmidt, G. (1997). Capturing indeterminism: Representation in the design problem space. Design Studies, 18(4), 441–455. https://doi.org/10.1016/s0142-694x(97)00011-2

Goldschmidt, G., & Smolkov, M. (2006). Variances in the impact of visual stimuli on design problem solving performance. Design Studies, 27(5), 549–569. https://doi.org/10.1016/j.destud.2006.01.002

Goldschmidt, G., & Sever, A. L. (2011). Inspiring design ideas with texts. Design Studies, 32(2), 139–155. https://doi.org/10.1016/j.destud.2010.09.006

Gonçalves, M., Cardoso, C., & Badke-Schaub, P. (2013). Through the looking glass of inspiration: Case studies on inspirational search processes of novice designers. In s.n. (Ed.), Proceedings of 5th IASDR conference: Consilience and innovation in design (pp. 1-12). s.n..

Gonçalves, M., Cardoso, C., & Badke-Schaub, P. (2014). What inspires designers? preferences on inspirational approaches during idea generation. Design Studies, 35(1), 29–53. https://doi.org/10.1016/j.destud.2013.09.001

Gray, C., Seifert, C., McKilligan, S., Yilmaz, S., Daly, S., & Gonzalez, R. (2016). What is the content of “design thinking”? Design heuristics as conceptual repertoire. International Journal of Engineering Education 32(3), 1349-1355. http://www.ijee.ie/latestissues/Vol32-3B/05_ijee3220ns.pdf

Greenberg, S., Carpendale, S., Marquardt, N., & Buxton, B. (2011). Sketching user experiences: The workbook. Elsevier.

Hallgren, K. A. (2012). Computing inter-rater reliability for Observational Data: An overview and tutorial. Tutorials in Quantitative Methods for Psychology, 8(1), 23–34. https://doi.org/10.20982/tqmp.08.1.p023

Han, J., Shi, F., Chen, L., & Childs, P. R. N. (2018). A computational tool for creative idea generation based on analogical reasoning and ontology. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 32(4), 462–477. https://doi.org/10.1017/s0890060418000082

Hao, J., Zhou, Y., Zhao, Q., & Xue, Q. (2017). An evolutionary computation based method for Creative Design Inspiration Generation. Journal of Intelligent Manufacturing, 30(4), 1673–1691. https://doi.org/10.1007/s10845-017-1347-x

Hay, L., Duffy, A. H., Gilbert, S. J., Lyall, L., Campbell, G., Coyle, D., & Grealy, M. A. (2019). The neural correlates of ideation in product design engineering practitioners. Design Science, 5. https://doi.org/10.1017/dsj.2019.27

Herring, S. R., Chang, C. C., Krantzler, J., & Bailey, B. P. (2009). Getting inspired! Understanding how and why examples are used in creative design practice. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 87-96). ACM. https://doi.org/10.1145/1518701.1518717

Hollins, B., & Pugh, S. (1990). Successful product design: what to do and when. Oxford, UK: Butterworth Heinemann.

Howard TJ. (2008). Information management for creative stimuli in engineering design. University of Bath.

Howard, T. J., Dekoninck, E. A., & Culley, S. J. (2010). The use of creative stimuli at early stages of Industrial Product Innovation. Research in Engineering Design, 21(4), 263–274. https://doi.org/10.1007/s00163-010-0091-4

Hu Ying, He Renke, Ji Tie, Guo Yinman and Francesco GALLI, "Design Pattern and Strategy in Ideation", 19th DMI: Academic Design Management Conference Design Management in an Era of Disruption, London, 2–4 September 2014. ISBN 978-0-615-99152-8. pp2991-3009.

Hwang, D., & Park, W. (2015). Development of portability design heuristics. In DS 80-4 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 4: Design for X, Design to X, Milan, Italy, 27-30.07. 15 (pp. 081-090).

Hwang, D., & Park, W. (2018). Design heuristics set for X: A design aid for assistive product concept generation. Design Studies, 58, 89–126. https://doi.org/10.1016/j.destud.2018.04.003

Jain, V. K., & Sobek, D. K. (2006). Linking design process to customer satisfaction through virtual design of experiments. Research in Engineering Design, 17(2), 59–71. https://doi.org/10.1007/s00163-006-0018-2

Jansson, D. G., & Smith, S. M. (1991). Design fixation. Design studies, 12(1), 3-11. https://doi.org/10.1016/0142-694X(91)90003-F.
Jin, X., Evans, M., Dong, H., & Yao, A. (2021). Design heuristics for Artificial Intelligence: Inspirational design stimuli for supporting UX designers in generating AI-powered ideas. Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/3411763.3451727
Kimbell, L., & Street, P. E. (2009). Beyond design thinking: Design-as-practice and designs-in-practice. In CRESC Conference, Manchester (pp. 1-15). https://scholar.google.com/citations?user=3XUt30kAAAAJ&hl=fr
Leahy, K., Daly, S. R., McKilligan, S., & Seifert, C. M. (2020). Design fixation from initial examples: Provided versus self-generated ideas. Journal of Mechanical Design, 142(10). https://doi.org/10.1115/1.4046446
Long, D. R. (1993). Review of Basics of Qualitative Research: Grounded Theory Procedures and Techniques, by A. Strauss & J. Corbin. The Modern Language Journal, 77(2), 235–236. https://doi.org/10.2307/328955
McCaffrey, T., & Krishnamurty, S. (2015). The obscure features hypothesis in design innovation. International Journal of Design Creativity and Innovation, 3(1), 1-28.https://doi.org/10.1080/21650349.2014.893840
Owen, C. (2007). Design Thinking: Notes on Its Nature and Use. Design Research Quarterly, 1(2), 16–27. http://www.designresearchsociety.org
Park, J. A., Yilmaz, S., & Kim, Y. S. (2008). Using visual reasoning model in the analysis of sketching process. In Workshop Proc. 3rd Int. Conf. Design Computing and Cognition (DCC'08) (pp. 15-22).
Patil, K., & Athavankar, U. (2022). Design precedents to design innovation: Category-based reasoning in problem-solving. The Design Journal, 25(1), 62–85. https://doi.org/10.1080/14606925.2021.2006923
Rowe, P. G. (1994). Design thinking. MIT Press.
Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. Co-design, 4(1), 5-18. https://doi.org/10.1080/15710880701875068
Stefano, D. M., & Rocchesso, D. (2019). Sketching sonic interactions. Foundations in Sound Design for Embedded Media, 79–101. https://doi.org/10.4324/9781315106359-4
Tang, Y.-chuan, Huang, J.-jie, Yao, M.-ting, Wei, J., Li, W., He, Y.-xing, & Li, Z.-jian. (2019). A review of Design Intelligence: Progress, problems, and challenges. Frontiers of Information Technology & Electronic Engineering, 20(12), 1595–1617. https://doi.org/10.1631/fitee.1900398
Vandevenne, D., Verhaegen, P.-A., Dewulf, S., & Duflou, J. R. (2014). A scalable approach for ideation in biologically inspired design. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 29(1), 19–31. https://doi.org/10.1017/s0890060414000122
Vasconcelos, L. A., & Crilly, N. (2016). Inspiration and fixation: Questions, methods, findings, and challenges. Design Studies, 42, 1–32. https://doi.org/10.1016/j.destud.2015.11.001
Wang, T., Xiao, D., Dong, Y., & Goossens, R. H. (2021). Development of a design strategy for playful products of older adults. The Design Journal, 24(4), 525–545. https://doi.org/10.1080/14606925.2021.1912903
Yang, M. C., Wood, W. H., & Cutkosky, M. R. (2005). Design information retrieval: A Thesauri-based approach for reuse of informal design information. Engineering with Computers, 21(2), 177–192. https://doi.org/10.1007/s00366-005-0003-9
Yang, M. C. (2008). Observations on concept generation and sketching in Engineering Design. Research in Engineering Design, 20(1), 1–11. https://doi.org/10.1007/s00163-008-0055-0
Yilmaz, S., Seifert, C. M., & Gonzalez, R. (2010). Cognitive heuristics in design: Instructional strategies to increase creativity in idea generation. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24(3), 335–355. https://doi.org/10.1017/s0890060410000235
Yilmaz, S., Daly, S. R., Seifert, C. M., & Gonzalez, R. (2015). How do designers generate new ideas? design heuristics across two disciplines. Design Science, 1. https://doi.org/10.1017/dsj.2015.4
Yilmaz, S., Seifert, C., Daly, S. R., & Gonzalez, R. (2016a). Design heuristics in innovative products. Journal of Mechanical Design, 138(7). https://doi.org/10.1115/1.4032219
Yilmaz, S., Daly, S. R., Seifert, C. M., & Gonzalez, R. (2016b). Evidence-based design heuristics for idea generation. Design Studies, 46, 95–124. https://doi.org/10.1016/j.destud.2016.05.001
Znaniecki F. (1968). The method of sociology ([Nachdr. d. Ausg.] 1934). Octagon Books.

SAbout the Authors:

Zihan Zhou: Zihan Zhou is a doctoral candidate in the School of Design at Hunan University. Her research interests focus on design thinking, idea inspiration, and innovation.

Ying Hu: Ying Hu is a professor in the School of Design at Hunan University. She holds a Ph.D. in Design and Arts, and her research focuses on design thinking and service design, especially design ideation activities.

Renke He: Renke He is a Professor in the School of Design at Hunan University.

Xing Du: Xing Du is a doctoral candidate in the School of Design at Hunan University. Her research interests focus on design education, service design, and design ideation activities.

Yiming Bai: Yiming Bai is a doctoral candidate in the School of Design at Hunan University. Her research interests focus on collaborative design, team creativity, and personality traits.

Acknowledgement: This work was supported by the Art Program of National Social Science Foundation of China (Grant No. 22BG126).