Exploring Designers' Encounters with Unexpected Inspirational Stimuli

Elisa Kwon, Vivek Rao, and Kosa Goucher-Lambert

Abstract In prior work on designers' search for inspirational stimuli, random discovery of stimuli through passive search processes has been underexplored. This paper primarily investigates how unintentionally discovered stimuli influence design outcomes, and why designers select these stimuli despite not meeting their initial expectations. In the present work, designers' search for inspirational stimuli is explored through their use of a multi-modal search tool developed by our team. Fifteen designers used the search tool to find inspirational stimuli to solve an open-ended design challenge. During this study, many search results were found not to meet designers' expectations. Nonetheless, designers incorporated a portion of these unexpected stimuli into their design ideas, resulting in the design outcomes: introduction of novel features, fulfillment of needs in an unanticipated way, and acceptance of readily available stimuli. This work suggests that encounters with unexpected stimuli can be beneficial, suggesting implications for future design tool development.

Introduction

For designers to become inspired, encounters with external stimuli are often needed. These encounters may occur when designers search for inspiration through processes that are both active and deliberate, or passive and random [1]. While active search implies an intention to find a stimulus to fulfill a specific goal, passive search is related to the random discovery of results [2], which can be beneficial for designers [3, 4]. The aim of this paper is to further understand how designers engage with

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passive search processes and the impact of inspirational stimuli discovered through these processes on design outcomes.

Prior work on search for inspiration has focused on what designers tend to look for through the specific search queries they initiate [1, 2]. However, as designers search for inspiration, they may not always have a fully defined search query or be able to retrieve exactly what they are intending to find through searching. While past work (e.g., by Goncalves et al.) has shown how unexpected stimuli can be fortuitous for designers [2], the results of passive search procedures have rarely been studied systematically. Insights about these processes are especially valuable for informing the development of design tools. While the discovery of unexpected stimuli through passive search is a phenomenon known to assist designers with idea generation, design tools are not typically made to support this process and focus rather on improving the retrieval of desired stimuli [5].

In this work, we present examples of how the unintentional discovery of unexpected results can affect design outcomes. These examples are drawn from a cognitive study we conducted in which designers used an AI-enabled tool we developed to support search for inspirational stimuli using multiple modalities of input. The results outlined in this paper present opportunities for future work to better understand and support designers' use of inspirational stimuli they do not explicitly intend to discover.

Related Works

In this section, we provide an overview of prior work on designers' search for inspiration. First, we introduce designers' inspirational and informational search processes and, second, the features of inspirational stimuli designers tend to prefer.

Processes Designers Use to Search for Inspiration

There are many aspects of the search process that are important to consider to understand how designers search for inspiration. Highly important are the intention and goal of the designer engaged in the search process [2], which have been suggested to include both specific detail and resolution of stimuli [6] and contextual, perhaps less-defined information contained in stimuli [7]. Also relevant to the present work is how designers initiate the search process. Goncalves et al. studied how designers select keywords to initiate the search process [2]. Several behaviors were discovered, including searching for closely related terms to the design problem earlier in the task and more distantly related terms later in the task [2]. These search strategies are supported by related research on inspirational stimuli that suggests the importance of both analogically near and far stimuli on promoting beneficial design outcomes [8].

However, Ware suggests that the goal of a designer is not always defined, leading designers to use different search processes [9]. When a goal does exist, designers engage in active search, and otherwise passive search processes are used. Passive search is defined as the process during which designers have a goal to solve but do not have a fully defined search query [2, 9]. Though not intentionally searched for, stimuli discovered through passive search can be recognized by the designer as beneficial to their design and somehow related to the current problem [2]. In this work, we define active search as the goal-driven process of intentionally searching for a specific stimulus. Passive search instead results in the discovery and selection of stimuli that were not explicitly searched for.

In investigating designers' information seeking behaviors more generally, Damen and Toh found that information evaluated as helpful did not necessarily mean that designers leveraged this information during idea generation [10]. Later work by Damen and Toh suggested that designers are adept at *effectuating* readily available information sources, even those that may not evidently influence the outcome [11], and that designers applied diverse organizational strategies to best leverage information towards design goals [12]. These findings are useful for understanding why designers may select unexpected information: selected information may afford effectuation (i.e., use of existing resources) even when causal links to an outcome are not clear, or it may support organizational strategies that facilitate the designers' goals.

The present work extends upon the prior research reviewed here in two ways. First, we consider search processes using a multi-modal search tool. Prior work has focused on inspiration processes initiated by keyword or text-based searches, which require designers to engage in active search. By introducing non-text-based search inputs, as afforded by our multi-modal search tool, different ways of expressing search intent and pursuing a search goal can be explored. Second, while prior work focuses on the retrieval of inspirational stimuli that designers explicitly search for through active search, this work also considers designers' passive inspirational search processes leading to discovery of unintended stimuli. A deeper understanding of why designers select such stimuli could help illuminate how and why passively encountered inspirational stimuli shape design outcomes—or not.

Designers' Preferences for and Use of Inspirational Stimuli

Different features of inspirational sources can determine whether they are preferred or found useful by designers to support their design processes. For instance, the modality in which stimuli is presented can impact whether they are influential on the design process, such as in the difference between 2D versus 3D stimuli [13]. Designers tend to prefer visual information [14], which can lead to the generation of creative ideas [15] and increased idea novelty [16]. Further describing the nature of visual information, Wallace et al. suggested that students sought and were most influenced by highly resolved sketch stimuli rather than rough sketches [6]. Cai et al. suggested that while experts valued sketch stimuli for their contextual content, students valued

sketch stimuli for their real-life resemblance and direct connection to the task in question [7]. The analogical distance of the external stimuli to the designer's current problem or design space is also a relevant factor to consider, where far-field stimuli, despite being less obviously relevant to the problem at hand, can lead to idea novelty [17, 18]. Seeking distantly related stimuli is a strategy that designers intentionally employ to become "struck by inspiration" [2].

This paper extends on previous work by exploring how designers' preferences for inspirational stimuli may differ when stimuli is discovered *unexpectedly.* Much of previous work has described stimuli preferences when stimuli selection was intentional; here, we aim to uncover and understand motivations behind designers' selection of stimuli that are discovered randomly and unintentionally. The preferences designers have for unexpected inspirational stimuli can help explain designers' selections of inspirational stimuli. Designers' preferences for, e.g., visually represented and analogically distant design stimuli may give insight into their selection of stimuli that do not directly satisfy their search intentions. An understanding of how established findings describing designers' stimuli preferences and selections in active, intentional search align with their preferences in passive, unintentional search could offer deeper insight into the nature of search processes in design inspiration.

Methods

In this section, the cognitive study we conducted is presented, including details about the participants recruited, the design tool we developed, and the design task completed.

Participant Information

Participants were recruited via email solicitation among graduate students at the University of California, Berkeley, and industry professionals. Participants were required to have at least 1 year of Computer-aided design (CAD) experience. In total, 15 participants volunteered for the study, including 8 professionals and 7 students. Self-report experience with CAD tools ranged among students (3 males and 4 females) from <1 year to 9 years, and professionals (7 male and 1 female) from 3 to >10 years. Compensation of $20 was offered for participation in the 1-h study, consisting of a 30-min. design task and 30-min. interview. Findings from the interview are not reported in this paper. This study was approved by the Institutional Review Board (IRB) at the University of California, Berkeley.

Multi-modal Search Tool

Participants engaged with an AI-enabled multi-modal search tool during the cognitive study to complete a design task. The search tool uses a deep-learning approach to retrieve inspirational stimuli in the form of 3D-model parts based on the user's input query. To develop the search tool, deep-neural networks were used to model semantic, visual, and functional similarities between various 3D-model parts from the PartNet dataset [19], which consists of 24 object categories and 26,671 3D-model assemblies.

The result is a design tool that allows flexibility for designers to discover inspirational stimuli using several input modalities, including: (1) by text-based query, (2) based on another 3D-model part, and (3) based on the designer's current 3D-modeling workspace, composed of previously retrieved parts. Examples of keyword and part search inputs and results are shown in Fig. 1. In this example, the keyword search enables active search for the query "container", while the part search supports passive search, where the intention to encounter functionally related parts is made without specifically intending to find chair legs. Additional details regarding the development of this tool are described in our prior work [20].

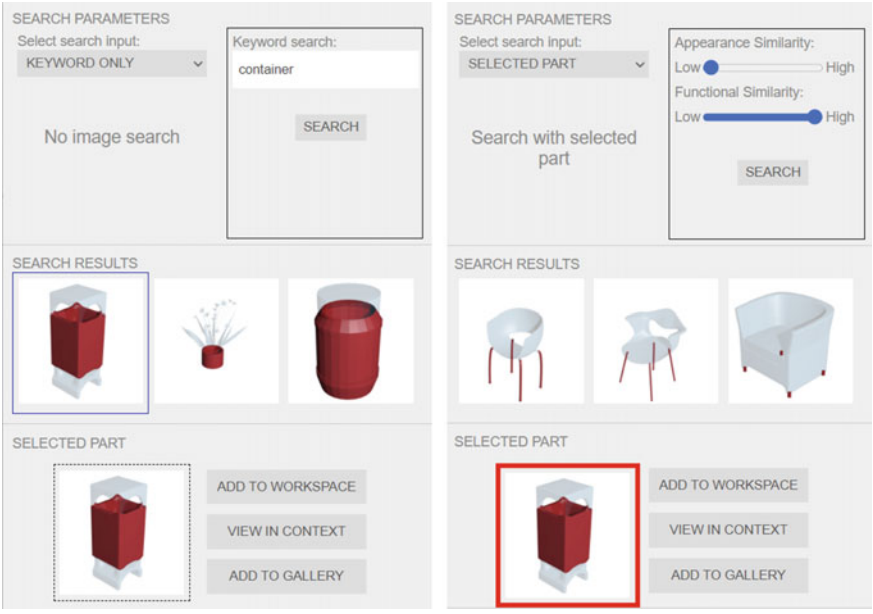

Fig. 1 Multi-modal search tool interface: Search results for (left) the keyword input "container" and (right) a part search of the selected container

Design Task

In the design task, designers were instructed to use the search tool to search for 3D parts to inspire solutions to the design of a "multi-compartment disposal unit for household waste". Designers began the task with a text-based query to retrieve parts to perform non-text searches. The study was facilitated using Zoom, which enabled screen and audio recording of participants' progress throughout the task. Screen recordings were used to capture how participants engaged with the search tool.

Instructions for following a think-aloud protocol were also provided, which directed participants to explain their interactions aloud, with particular attention to: (1) why the specified search type and input were used before executing a search and (2) whether the returned result is what was expected, or not, after executing a search. From prior work where the same design task was completed without think-aloud instructions, these prompts were specified to elucidate motivations behind previously observed search behavior during the task.

Identification of Search Behaviors from Task and Think-Aloud Data

The design task and think-aloud data were analyzed and classified into search behaviors based on definitions derived from Goncalves et al.'s description of the inspirational search process [21]. This process includes the formulation of search inputs, the (successful or unsuccessful) search for and selection of a stimulus, assessment of its correspondence to the designer's expectations, and the designer's choice to incorporate and adapt the stimulus to the problem at hand [21]. In the present work, the behaviors we are interested in identifying are how designers *evaluated* search results as expected or unexpected, and *selected* search results to be accepted or rejected from their designs. The criteria used to assign these behaviors are presented in Table 1 with representative examples from think-aloud data.

Two coders, each with at least three years of postgraduate design research experience, assessed the data using the classification scheme outlined in Table 1. Coder 1 manually transcribed think-aloud data from screen and audio recordings of the design task sessions. Coder 1 identified user interaction behavior and think-aloud quotations pertaining to the defined behaviors. A total of 235 searches were made throughout the study, an average of 15.7 searches per participant. To validate the framework, Coders 1 and 2 independently applied the defined codes to 15% of the data set. An interrater reliability of 84% was determined, suggesting that the developed coding framework was relatively consistent across coders. After resolving differences, Coder 1 coded the remainder of the dataset.

By identifying how search results were *evaluated* and *selected* by designers, we can explore the unexpected stimuli that designers accept and use in their designs. The

Table 1 Search behavior classification scheme from task and think-aloud data

Search behavior	Criteria for classification	Representative example
Evaluation (Expected)	Explicit acknowledgement that the result *is* what was searched for or preceded an 'accept' selection if no accompanying verbal statement given	"Yes, I like these features. This is providing what I'm looking for" (**P10**)
Evaluation (Unexpected)	Explicit acknowledgement that the result *is not* what was search for or preceded a 'reject' selection if no accompanying verbal statement given	"This is not what I was expecting – I was expecting to see more lids, whereas these are tabletops" (**P4**)
Selection (Accept)	Result is added to the designer's developing design in the 3D workspace or saved to their gallery of parts	"This is a shape that could possibly be used in my design. So, I'm going to add it to my gallery" (**P12**)
Selection (Reject)	Result *is not* added to the designer's developing design in the 3D workspace or saved to their gallery of parts. Designer continues to search again	"This is not what I was thinking, but this is a trashcan, for sure… I'm maybe more looking for a cabinet" (**P5**)

impact of incorporating unintentionally discovered stimuli on the design process is discussed through specific examples that emerged during the design task.

Results and Discussion

In this section, we present our preliminary findings related to the selection of unexpected inspirational stimuli and the effect of these stimuli on the design process. First, we identify these instances of design behavior by coding the data according to the classification scheme detailed in the previous section. Second, we present and discuss the high-level themes that emerge from these examples to propose motivations for designers' selection of unexpected inspirational stimuli.

Selection of Unexpected Inspirational Stimuli

Combined across all 15 designers, the numbers of searches categorized under each evaluation and selection behavior are reported in Table 2. In total, 156/235 (66.4%) searches retrieved results that were identified as unexpected. The high proportion of unexpected search results appears to be disproportionately true for searches made with 3D-part inputs (41/58, 70.7%) and 3D-workspace inputs (24/28, 85.7%), in

Table 2 Summary of search evaluations and selections by search input used

	Search input			
Search behavior	Keyword	Part	Workspace	**Total # of searches**
Evaluation (Expected)	*58*	*17*	*4*	*79*
Selection (Accept)	50	11	4	*65*
Selection (Reject)	8	6	0	*14*
Evaluation (Unexpected)	*91*	*41*	*24*	*156*
Selection (Accept)	11	4	6	*21*
Selection (Reject)	80	37	18	*135*
Total # of searches	*149*	*58*	*28*	*235*

comparison to keyword searches (91/149, 61.1%). Across search types, 149/235 (63.4%) searches produced results that were rejected by designers. Of the 156 searches with unexpected results, 135 (86.5%) were rejected and not incorporated into designers' ongoing work or saved for future inspiration.

Given the large proportion of rejected and unexpected results, two areas of further investigation are proposed. First, methods to improve the retrieval accuracy of AI-enabled design tools should be investigated, including the tool's ability to recognize the designer's search intent and goal from their input. A less obvious contribution is to encourage, through engagement of features within the design tool, the incorporation of these unexpected stimuli into the designer's ongoing idea. In the present study, 21/235 (8.9%) of searches were unexpected, but accepted by designers and integrated into their design ideas. As we showcase in the following sections, though they represent a small subset of the total searches conducted, these examples demonstrate the opportunity for unexpected stimuli to introduce exciting and beneficial design features during ideation.

Motivations for Selecting Unexpected Inspirational Stimuli

Introducing a Desirable, but Unanticipated Design Feature

The first motivation observed for selecting an unexpected result retrieved by the search tool was that it introduced a desirable, but previously unanticipated feature to the designer's concept. In two cases, designers were inspired to add wheels to their designs, though this is not what they initially sought. Participant P8, looking for different forms of containers through a part-based search with high functional similarity and low appearance similarity to a container lid, received the parts shown in Fig. 2a, including two sets of wheels. These were returned by the search tool because lids and wheels are visually dissimilar but share a common functional context in object assemblies including containers. Discovering the wheels, participant P8 noted:

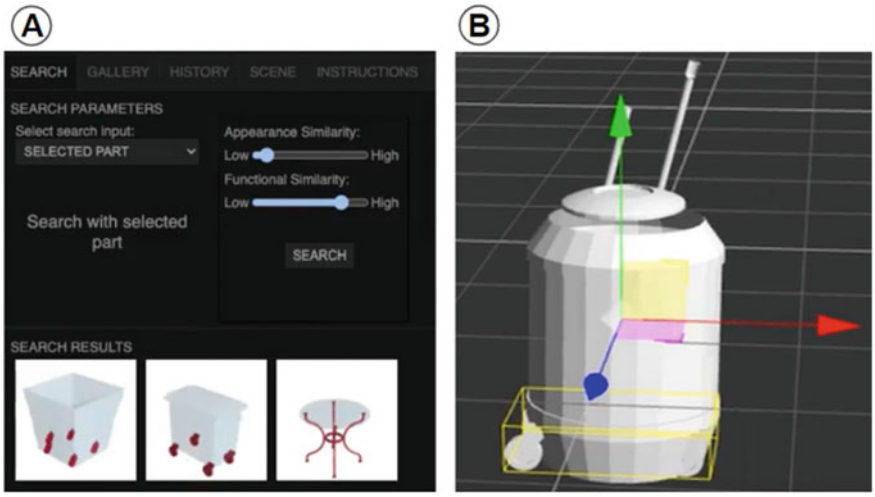

Fig. 2 An example of unexpected results introducing an unanticipated desirable feature (P8): **a)** unexpected wheel results returned by the search tool (left) and **b)** addition of the middle result to Participant P8's design (right)

"*Well now that I see it, I think it may be a good idea to have the unit movable, so I think castors would be something useful*". The resulting influence on their design can be seen in Fig. 2b, displaying that the wheels were subsequently added to the base of their disposal unit. In a second instance, participant P7, when looking for "*something similar to this drawer*" using a workspace-based search, was returned chair wheels (Fig. 3a). The search tool, recognizing visual similarity of the drawer to the seat in the chair assembly, returned chair wheels due to their shared context with the seat. After first remarking, "*well that's kind of funny*", the chair wheels were added to their design (Fig. 3b) after similarly acknowledging: "*Now we can add wheels to this and make it mobile, which is good*!".

In both examples, the effect of retrieving wheels was to introduce an unanticipated feature to their design, i.e., mobility. In the first example, wheels from an analogically near-field (as defined by Fu et al. [8]) object assembly (a different kind of container) were added, which may represent a more obvious transfer of unexpected stimuli to the design. The second example is striking as it demonstrates how even unintentional stimuli from a far-field domain (a chair) can be effectively applied towards introducing a desirable, but unanticipated feature to the design. The use of contextually unrelated stimuli is further relevant to the next motivation discussed.

Fulfilling a Searched for Purpose, in a Different Way

The second motivation identified for a designer's use of an unexpected stimulus was that it fulfilled the same purpose originally intended, but in a different way. Participant

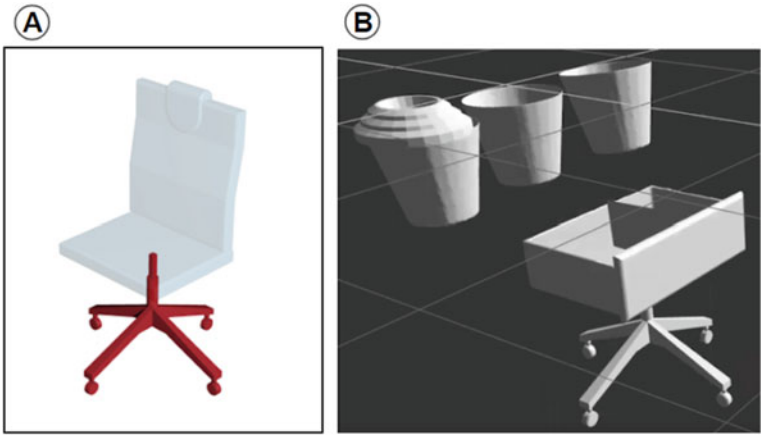

Fig. 3 An example of unexpected results introducing an unanticipated desirable feature (P7): **a)** Unexpected chair wheel results returned by the search tool (left) and **b)** addition of the part to Participant P7's design (right)

P4, upon retrieving three tabletop results (e.g., Fig. 4a) when searching for a lid to place on a rectangular trashcan found that "*Nonetheless, it's actually fitting what I'm looking for exactly*". In this example, although the object did not match what was searched for, its visual form suited the designer's needs for a cover they could scale to the size of their trashcan. In a similar example, Participant P7 searched for a "can" and was given a round base of a candle holder, as shown in Fig. 4b. While expressing that this is not what they were looking for due to its scale, they also stated, "*This one is maybe promising, I can maybe make it bigger…this looks like it has an opening*". Despite the size of the result, an acknowledged ability to scale it to the correct size made it useable to the designer. Finally, when looking for cylindrical shapes, Participant P14 was returned a chair seat (Fig. 4c). This result was identified as being potentially useful because, "*worst case, I can flip it… if I don't find anything, I can work with this shape which is resembling something that I might be looking for."* Reorientation has been proposed in prior research as a strategy to aid creativity [22]. In general, encouraging designers to consider object transformations such as rescaling or reorienting may assist their ability to discover more useful sources of inspiration from passive search processes.

Satisficing for a Result that Does not Meet Expectations

A final motivation discovered for designers to accept unexpected stimuli is a sense of satisficing for a result. Two distinct scenarios were observed: in the first, designers' search results included a previously rejected part, which may have strengthened the belief that a more relevant match did not exist. Secondly, even when acknowledging that a result is "*not quite what I was looking for*" (P15), the result was accepted. These

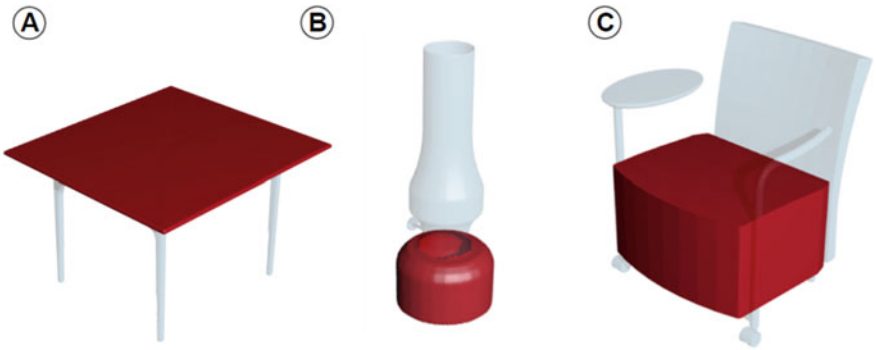

Fig. 4 Examples of unexpected results that fulfill the purposes of intentionally searched for parts: **a)** Tabletop scaled down to fit the top of a trashcan **b)** Candle holder base scaled up to serve as a can, and **c)** Chair seat reoriented to a container

examples reinforce that designers use readily available stimuli without knowing how they will directly influence ideas [11], suggesting that designers can tolerate an acceptable threshold of accuracy when using inspiration-retrieval tools.

Conclusion

In this paper, we presented the results of a cognitive study where designers searched for inspirational design stimuli to complete a design task. While searching, designers encountered many stimuli that did not meet their expectations. However, we also observed instances of designers using these unexpected stimuli in their design ideas to add new design features, fulfill their intended needs in a different way, or because designers satisficed for results. This work reveals the importance of the role of passive search in uncovering unexpected stimuli that can benefit designers' idea generation and proposes that design tools should encourage and support these unintended discoveries.

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