

LOOKING FOR INSPIRATION: UNDERSTANDING THE INFORMATION EVALUATION AND SEEKING BEHAVIOR OF NOVICE DESIGNERS DURING CREATIVE IDEA GENERATION

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ABSTRACT

Information usage is a key aspect of creative cognition and has been shown to influence design outcomes. The goal of this study was to investigate the information seeking behavior of student designers while validating a previously developed "Typology of Design Information" framework. Participants were asked to use and evaluate pieces of information during the idea generation process. Results show a discrepancy between the information that participants naturally sought out and their perceived utility (helpfulness) of the information. However, individually significant relationships between perceived utility and behavior were found with features generated by participants, suggesting that even though participants' perception of the utility of information pieces and their actual behavior are not related, both constructs have an identifiable influence on design outcomes. This study advances the Typology of Design Information framework by empirically exploring the link between the types of information used by novice designers and the ideas generated, and it illustrates that participants employ complex cognitive behavior when engaging with design information to generate novel ideas.

Keywords: Creativity, Conceptual design, Design cognition, Design education, Information management

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1 INTRODUCTION

“In a knowledge-based economy that is increasingly driven by the creation of value from information, design theory and methods should be more present to sustain these creative activities.” (Kazakci, 2015, p. 2). Indeed, the importance of gathering and identifying key pieces of information is recognized by the design community as crucial to the success of the design process, from the information-gathering stage of customer needs assessment to the design embodiment and realization stages (Ogot and Okudan-Kremer, 2004). Fundamental research argues that the acquisition and transformation of information is integral to the development of creative ideas (Wallas, 1926), with some claiming that the act of design itself is the process of transforming information into valuable knowledge (Mistree *et al.*, 1990). The strong link between information and creativity can be traced back to classic theories on associative memory that state that creative ideas are born out of the serendipitous combination of distantly related concepts to reveal ingenious and novel solutions (Fu *et al.*, 2013).

While the acquisition of information has traditionally been a competitive edge, information technology trends have increased the availability of information to such an extent that it is accessible to any designer to generate creative and competitive products (Kalay, 2006). Data driven information is increasingly valued over experience-driven assumptions to navigate these highly complex and uncertain design contexts (Bertoni *et al.*, 2017). Advances in engineering and computing have allowed us to generate and capture an unprecedented amount of data that could not be captured before the existence of such technology (Osman and Kazakçı, 2015). However, the practice of design has always included information beyond those directly related to the design problem, such as meta design cognition and personal and analogous experience. These are gaining importance in the face of emerging data-driven design tools (Corsini and Moultrie, 2017). Recent work has taken the first steps to organizing these relevant types of information into a framework (Lumbard *et al.*, 2018). This work seeks to build on this framework to better understand how designers navigate these varied forms of information in the early stages of the design process. This is important to examine because even though information can lead to the generation of new insights that enhance design creativity, it can also hinder the creative process by fixating the designer on prior ideas and limiting creativity in design (Jansson and Smith, 1991).

These prior works highlight the importance of systematically investigating the types information and their impact on the early phases of the design process. Although the influence of information has been investigated in many fields, these research streams are often disconnected and studied in isolation. This makes it hard to translate the wealth of knowledge on creative cognition into a consolidated understanding of how to characterize design information, or how to identify the most useful information for the appropriate stage of the design process. Additionally, research on strategies and tools for generating large quantities of original ideas is often more prescriptive than descriptive, or focused on building new theories about creative cognition. This imbalance must be addressed since scientific disciplines require both prescription-driven research that provides solutions to applied problems as well as description-driven research that enables a deep understanding of phenomena (Van Aken, 2004). Additionally, there is an increasing need for graduates who have both technical and creative design skills, highlighting the need for effective training for the next generation of innovation leaders. This necessitates a closer look at the ways in which novice designers utilize and evaluate the utility of information to develop creative solutions during design activities, as the theoretical underpinnings of current behavior and cognition must first be understood before they can be improved. Therefore, this study aims to explore the impact of different information types on the creative design process through an exploratory study with university students as novice designers. This research builds on a previously developed Design Information Archetypes Framework that seeks to develop a deeper understanding of information use in design education and practice (Lumbard *et al.*, 2018). This work contributes by serving as empirical validation for this framework and providing insights into how information during an early phase design activity is evaluated and utilized in idea generation. The next section summarizes prior work on the development of a preliminary Design Information Archetypes Framework.

1.1 Development of a design information archetypes framework

The previous section highlighted the need to systematically investigate the impact of information types in the early phases of the design process. As a first step in beginning to address these knowledge gaps, prior work developed a preliminary framework for classifying information used during design decision

making (Lumbard *et al.*, 2018). This “Design Information Archetypes Framework” aims to further understanding of the types of information used by designers based on data from interviews and focus groups, which were part of a larger field study conducted over a 5-year period. To capture the various forms of information utilized by designers during the design process, the typological approach of building theories was used, as discussed by Doty and Glick (1994). According to this framework, a theoretical understanding of applied phenomena can be captured through the development of dimensions and archetypes. In order to build theory based on typologies, Doty and Glick (1994) first recommend that dimensions are built to capture specific aspects of an entity. Archetypes are then understood as complex phenomena composed of multiple dimensions. Through the act of developing ideal types, a deeper understanding of the observed space is obtained.

Closely following this framework, several information dimensions were developed through a series of discussions, preliminary analysis of the transcribed interviews, reflective experiences gained during the field study, and review of related work. These information dimensions were refined using a rigorous coding process according to the principles of deductive content analysis (Mayring, 2004) conducted on the interview transcripts. Details about the development and support of each of these dimensions can be found in a prior publication (Lumbard *et al.*, 2018). In all, five main dimensions with two corresponding levels each were identified, and the details of each dimension are as follows:

- **Information Source:** This investigates the origin of information with respect to the individual or organization that generated the idea of the design. Novel designs can be developed using external information such as new technology or trends in the market (Hunter *et al.*, 2010), but expert designers also rely on internal information such as their own past experiences and their ability to recognize design problem patterns (Akin, 1990).
- **Abstraction of Information:** This focuses on the details provided by the information and the extent to which it deals with high-level concepts versus discrete real-life events. Designers engage with abstract information to maximize the effectiveness of their solutions (Ball *et al.*, 1997), while concrete information can help in simplifying complex problems (Christensen and Schunn, 2009).
- **Generality of Information:** This describes the generalizability of the information to other design tasks and projects. It captures whether information exhibits cross-cutting features (Li *et al.*, 2002) or are core paradigms specific to a particular domain (Osman and Kazakçı, 2015).
- **Effectuation of Information:** This explores the varied thinking styles of designers or design teams when addressing design problems. Decision-makers can generate effective solutions to identified problems by either using existing resources (effectuation), or by identifying a specific market need and working towards addressing that need using any resources necessary (causal) (Sarasvathy, 2001). Prior work stemming from this framework has shown that effectual and causal information play a complex role in influencing creativity in a design setting (Abid *et al.*, 2018).
- **Representation of Information:** This revolves around the form of communication used to deliver information during the design process. Designers typically share their ideas with other designers through emails with links to examples and short descriptions (Herring *et al.*, 2009). Others have also claimed that direct communication in the early stages has an impact on the creativity of the final product (Brown and Paulus, 2002).

While this initial Design Information Archetypes Framework can be used to build a theory about how information is used in creative design and to allow researchers to empirically test the impact of specific types of information on design outcomes, empirical validation of this framework is still needed to advance its predictive and explanatory capabilities. One important aspect of studying information utilization during design is designers’ own evaluations of relevant information early on during ideation. Self-reflections are an important tool to gain insight into the cognitive processes that designers employ during ideation. However, researchers have long noted discrepancies between people’s reported and actual behavior (Olson and Fazio, 2008), thus warranting the need for continued investigation. Given the ease and wealth of information available, the focus of this study is on understanding how designers prioritize and use information that is competing for their attention, and how those choices are reflected in the generated design features. Research that aims to fill these knowledge gaps can help strengthen the Design Information Archetypes Framework, which can then be used in education to teach design students how to effectively organize and leverage vast amounts of information to build creative and innovative products. In order to validate this framework, the current study will focus on empirically testing the impact of these information dimensions on novice designers’ information seeking behavior, the perceived utility of design information, and their design outcomes.

1.2 Research questions

The purpose of this study is to empirically investigate how novice designers (students) perceive and interact with certain types of design information during idea generation. Their observable behavior while seeking and utilizing information will be labeled as their information seeking behavior, although this will be used interchangeably throughout this work. In addition, since the design information used in this study is based on the previously developed Design Information Archetypes Framework (Lumbard *et al.*, 2018), this work will also serve to validate the theoretical framework using empirical data. To address this objective, the following research questions were developed:

- RQ 1: Is there a relationship between students' information seeking behavior and the perceived utility (helpfulness) of the design information?
- RQ 2: What is the relationship between students' perceived utility (helpfulness) of the design information and the features generated in their early phase concept ideas?
- RQ 3: What is the relationship between students' information seeking behavior and the features generated in their early phase concept ideas?

2 METHODOLOGY

2.1 Participants

A total of 12 undergraduate students were recruited from an introductory design course at a large metropolitan university in the United States. Students agreed to participate in a controlled class experiment as part of their learning experience and were not otherwise compensated for their participation.

2.2 Procedure

Students were invited to attend a 45-minute design study session in a university computer lab setting, which was specifically reserved for participants of this study. After introducing the purpose and procedure of the study, participants were asked to fill out an Informed Consent form. Once all questions were answered, participants were directed to the online web interface that provided an introduction to the study, background information about the design problem, and the goal of the design task. The design task was in a form of a hypothetical problem that required participants to generate innovative design solutions to the problem. Specifically, participants were provided with the following instructions: "*Your task is to develop concepts for a new, innovative, product that can froth milk in a short amount of time. The product should be able to be used by the consumer with a minimal instruction*". This design task was selected to represent a typical project in a first-year engineering design course, and to match the minimal engineering knowledge students have in these early courses. Students in these courses typically redesign small, electro-mechanical consumer products that are chosen to be equally familiar, or unfamiliar, to all students (Simpson and Thevenot, 2007). In order to ensure our participants were equally familiar with the product being explored, our design task went through pilot testing with first-year students prior to deployment.

Once the design task was read and understood, participants were given 15 minutes to review design information sheets through the interactive web interface. Each of the 10 clickable elements on the web interface were randomly ordered for each participant and contained sheets of information that were developed by the researchers to help the participants better understand the problem space. The design information sheets were specifically developed through pilot testing for this design task by the researchers using the Design Information Archetypes Framework described in Section 1.1. According to this framework, information can be classified under one of five information dimensions: (1) Effectuation of Information, (2) Source of Information, (3) Abstraction of Information, and (4) Generality of Information, (5) Representation of Information. Since each dimension consists of two levels, this led to the creation of 10 information sheets (5 dimensions x 2 levels) for this study. For example, two information sheets were created for the dimension "Abstraction of information"; one containing more abstract information (i.e. information about a strategic decision made by the hypothetical brand manager), and one that contained concrete information about the hypothetical design task (i.e. how to successfully froth milk). The full list of information sheets used in this study can be found at this link: <https://www.unomaha.edu/college-of-information-science-and-technology/bridge/research/resources.php>.

All interactions with the web interface were recorded for click-level analysis using screen capture software. This data was used to explore the behaviors of participants while they interacted with the different types of information during the design task. Once participants had reviewed the information, they proceeded to the brainstorming phase of the study. Each participant was given paper and pen and provided with 20 minutes to generate as many creative ideas as they could for an innovative milk frother. The students were instructed to sketch one design per each sheet of paper and to write notes or phrases to make their concept easy to understand. Note that during this ideation phase, participants were allowed to freely interact with the relevant design information and their interactions were not recorded.

After the brainstorming session, participants were asked to rate the helpfulness of each of the 10 information sheets with regards to the extent that each sheet of information helped them understand the space and generate innovative solutions to the design problem using a 5-point Likert type scale with 1 being not helpful at all and 5 being extremely helpful.

2.3 Metrics and data analysis

Once the study was completed, two independent raters were recruited to assess the features present in the 51 concept ideas created in the study using a 24-question Design Rating Survey (DRS), which can be found at this link: <https://www.unomaha.edu/college-of-information-science-and-technology/bridge/research/resources.php>. The first 20 questions on the DRS were used to help the raters classify the features each design concept addressed, similar to the feature tree approach used in previous studies (Toh *et al.*, 2012). The remaining 4 survey questions helped the raters identify the quality and technical feasibility of the design but were not relevant for analysis in this study. In order to investigate the content of the generated ideas based on the information the participants' looked at, idea features were extrapolated through analysis of the participants' generated ideas. While the rating process was able to identify the types of features present in the generated ideas to a high level of granularity, only the top-level features were considered for analysis. For example, if an idea was identified as being handheld with a plastic curved handle, only the handheld feature was considered for analysis to reduce the complexity and hierarchical nature of the data analysis. The **number of times each participant generated an idea that exhibited each of these features** was calculated and used for analysis. As these features are not mutually exclusive, it is possible for ideas to have overlapping features which would each be tallied separately. The features found in all ideas generated by the participants in this study are: Electrical (4) or non-electrical elements (47), rod (10) or no rod (40) present, externally (10) or internally (25) stored milk, handheld (3) or not (20), electrically (11) or manually (1) powered, and lastly, movement generated through stirring (5), shaking (4), steam (2), chemicals (1) or pumping (1).

In addition to identifying which features were present in the generated ideas, participants' information seeking behavior was captured through their interactions with the information sheets during the 15-minute information reviewing session. This was done by assessing the number of times each participant clicked on each information sheet during the study. Since participants varied in the number of times they clicked on information sheets (i.e. some participants quickly switched between multiple elements while others stayed longer on each information sheet), a normalized **Frequency Percentage** per participant was developed. This was calculated by dividing the number of times a participant clicked on an information sheet (frequency per information sheet) with the total number of times that participant clicked on all information sheets (total frequency for all information sheets).

Lastly, the extent of which each information sheet was perceived as helpful to participants was obtained at the end of the study using the **Perceived Helpfulness** metric, which assessed participants' ratings of how helpful each information sheet was using a 5-point Likert type scale (1. Not helpful at all – 2. Slightly helpful – 3. Somewhat helpful – 4. Very helpful – 5. Extremely helpful).

While the "Representation of Information" dimension was included as an information dimension block in the web interface and study, it was later removed from analysis. This information dimension would be challenging to investigate through a simulated design environment (such as the web interface built for this study), since it can be argued that all information presented to the participants in this study can be considered Asynchronous in nature. Thus, analysis of this information dimension was removed from this study.

3 RESULTS AND DISCUSSION

Preliminary analysis on the data indicate that the information sheets were used and evaluated differently by the participants. Totaling the number of times all participants clicked on each of the remaining 8 information dimensions shows that the Abstract information sheet was used the most (followed by Internal, Concrete and Domain Specific), while Effectual was clicked on the least often (see Figure 1). However, when looking at the perceived helpfulness of each information sheet, Concrete, Internal, and Domain Specific had the highest median values while Causal was rated the lowest (see Figure 1).

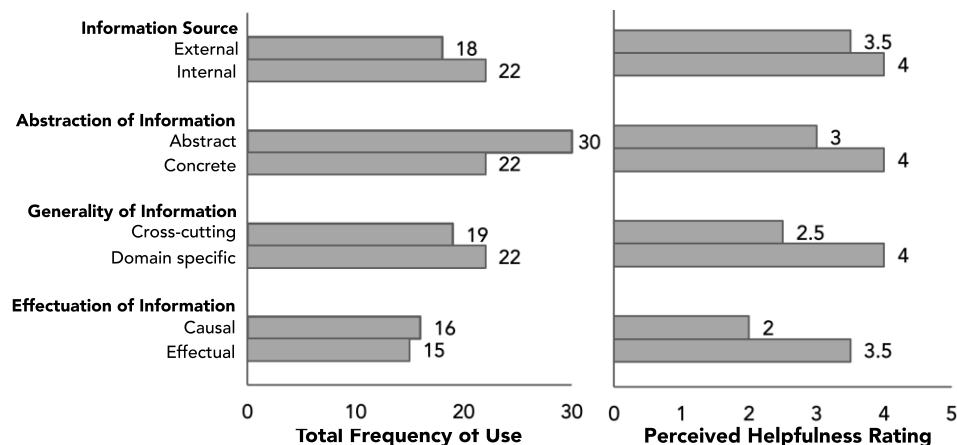


Figure 1: (left) Total number of times all participants clicked on each of the 8 information dimensions, and (right) participants' helpfulness rating (median) for each information sheet (5 is the maximum helpfulness score).

In order to address the research questions, three sets of Spearman Correlation Analysis were conducted. Spearman's rank-order correlation analysis was used due to the small sample size and the potential for non-linear relationships between the variables.

3.1.1 RQ 1: Is there a relationship between students' information seeking behavior and the perceived utility (helpfulness) of the design information?

A Spearman correlation analysis between the Frequency Percentage of each information sheet and the corresponding Perceived Helpfulness was conducted. The results revealed no significant results between the Frequency Percentage metric and the Perceived Helpfulness metric for each information sheet (see Table 1), indicating that the helpfulness rating provided by participants was not reflected in the number of times they clicked on that information sheet.

Table 1. Results of the spearman's rank-order correlation between the Frequency Percentage and the Helpfulness rating.

Spearman's Correlation Test between Frequency Percentage and Perceived Helpfulness Rating	Internal	$r_s = .211, p = .509$	External	$r_s = -.150, p = .643$
	Abstract	$r_s = -.147, p = .648$	Concrete	$r_s = -.190, p = .554$
	Domain specific	$r_s = .103, p = .750$	Cross-Cutting	$r_s = -.022, p = .946$
	Effectual	$r_s = -.238, p = .457$	Causal	$r_s = -.521, p = .082$

3.1.2 RQ 2: What is the relationship between students' perceived utility (helpfulness) of the design information and the features generated in their early phase concept ideas?

To address the second research question, a Spearman Correlation Analysis was conducted between the Perceived Helpfulness ratings and the Features generated in the ideas. The results revealed significant correlations for four relationships (see Table 2). No other relationships were significant, and for brevity, were not included in this paper.

Table 2. Significant results of the spearman's rank-order correlation between the Perceived Helpfulness ratings and the generated Features.

Feature	Perceived Helpfulness rating	Spearman Correlation
Externally stored liquid	Domain specific: Discusses the different types of milk frothers that exist on the market, including handheld models, steam machines, and electric jug frothers.	$r_s = -.713, p = .009$
Frothing by stirring	External: Discusses how frothed milk is produced, including how electric motors produce rapid motion needed to produce the micro bubbles in frothed milk.	$r_s = .621, p = .031$
	Cross-cutting: Discusses the modern design aesthetics used in kitchens, including the integration of smart home automation and Bluetooth technology in appliances.	$r_s = .660, p = .019$
	Causal: Discusses a growing segment of the population that have an interest in craft coffee beverages, including consumers using sophisticated methods at home.	$r_s = -.622, p = .031$

These results reveal a complex relationship between the perceived helpfulness of information sheets and the emergence of specific features in the participants' generated ideas. Further examination of the significant results show that the more helpful participants found information describing the growing customer segment (Causal), the less they generated ideas that included a stirring feature. Similarly, the more helpful they rated information describing other types of milk frothers (Domain specific), the less they incorporated the externally stored liquid feature (see Figure 2 for example ideas). On the other hand, the more helpful participants found information describing the milk frothing process (External) and kitchen aesthetics (Cross-cutting), the more they generated ideas incorporating a stirring feature, see Figure 3 for example ideas. While a logical relationship can be seen between the information sheet discussing the production of frothed milk using electric motors and the emergence of concepts utilizing the stirring motion, the other relationships are less obvious. This result indicates that participants are drawing on both semantically similar and distantly associated aspects of the information sheets as inspiration for idea generation, pointing to the use of associative memory that is highly personal and esoteric during the early phases of the design process.

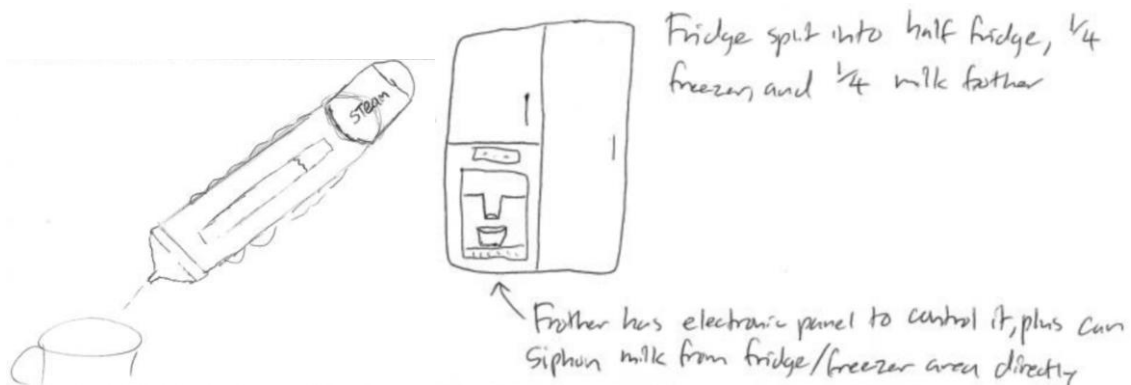


Figure 2: Example ideas generated by participants with the “externally stored liquid” feature.

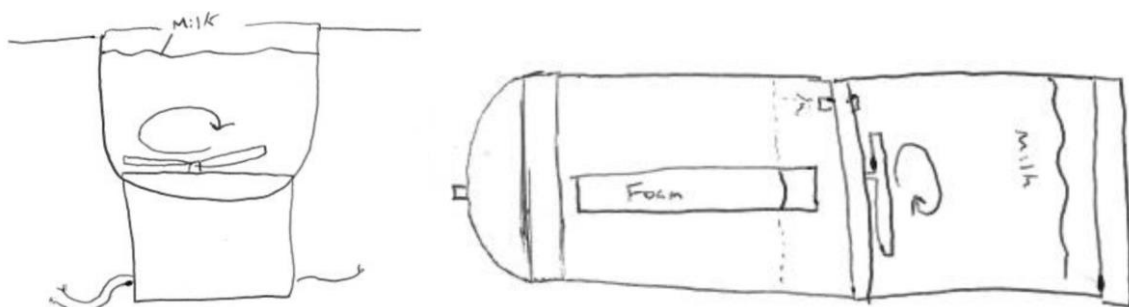


Figure 3: Example ideas generated by participants with the “frothing by stirring” feature.

3.1.3 RQ 3: What is the relationship between students' information seeking behavior and the features generated in their early phase concept ideas?

Spearman correlation analysis on students' information seeking behavior (as measured through Frequency Percentage) and the generated Features revealed significant results for six relationships (see Table 3). No other relationships were significant, and for brevity not included.

Table 3. Significant results of the spearman's rank-order correlation between the Frequency Percentage and the generated Features.

Feature	Frequency Percentage of Information Sheet	Spearman Correlation
No Electrical components	Causal: (see table 2)	$r_s = .711, p = .010$
Electrical components	Cross-cutting: (see table 2)	$r_s = -.664, p = .018$
Handheld	Cross-cutting: (see table 2)	$r_s = .702, p = .011$
	External: (see table 2)	$r_s = -.653, p = .021$
Internally stored liquid	External: (see table 2)	$r_s = .792, p = .002$
Externally stored liquid	Internal: Discusses existing small kitchen appliances developed by the company, the typical features and common failure points.	$r_s = .649, p = .022$

These results reveal complex relationships between the frequency that participants viewed certain information sheets and the emergence of specific features in their generated ideas. Specifically, increased viewing of one information sheet was often linked to the generation of certain features at the expense of others. For example, viewing more information on the milk frothing process (External) was related to less handheld features but more designs in which the liquid was stored internally. Viewing more information on kitchen aesthetics (Cross-cutting) was linked to less electrical components but more handheld features. The generation of less electrical components was also related to longer viewing of the customer segment (Causal). Lastly, more frequent viewing of information on the company's prior experience with developing small kitchen appliances (Internal), was related to more instances of the externally stored liquid feature.

4 IMPLICATIONS AND CONCLUSIONS

The main goal of this study was to shed light on the information seeking behavior of novice designers during the early phase of the idea generation process and the impact of information types on the design outcomes. One of the main findings of this study is that the information that participants naturally seek out during the design activity is not the same as the information that participants self-reported as helpful for idea generation. While participants were given the opportunity to reflect on how well each information sheet was able to aid them in their brainstorming process, the perceived utility of the information sheets did not correlate with the amount of times participants utilized the information sheet. This could indicate that other factors may be impacting their behavior such as participants' efforts to comprehend complex information, familiarity with the information sheets and the ability of participants to remember elements of the information sheets. Ongoing research is investigating the role of memory in this process and aims to develop guidelines for effective information utilization.

Another major finding of this work is that several significant relationships emerged between the helpfulness ratings and the types of features participants included in their generated ideas. A similar result was found between participants' information seeking behavior and the features found in their generated ideas. While participants' perception of the utility of information sheets and their actual usage of the information sheets are not related, both constructs have an identifiable influence on the design outcome. Specifically, participants were found to draw upon both closely and distantly semantically associated aspects of the information sheets as inspiration for idea generation. That is, there was no evidence that participants were blindly utilizing the provided information sheets to generate ideas, but were likely viewing them through the individual lens of experience and knowledge. Thus, information gathering, interpretation, and utilization can be understood as the intersection of external sources of inspiration with the designers' internal ecosystem of knowledge, memory, and experiences. These findings highlight the complex nature of design cognition and the need for further research to better understand how designers extract, evaluate, and interpret information in the design process, as well as on how novices can apply this knowledge in their training.

While this study provides a starting point for evaluating information usage during the design process, several limitations should be noted. First, in order to systematically study how novice designers use and perceive information, participants' information seeking behaviors during the idea generation phase was not considered for analysis. Future work should explore information utilization in more naturalistic settings where information dimensions overlap to form archetypes, and where participants move fluidly between information utilization and idea generation. The impact of memory on how designers process information should also be investigated in order to shed light on how external sources of information interact with existing design knowledge, and its role on design creativity. This is especially important with regards to this work, as the Design Information Archetypes Framework consists of 10 information dimensions. This number of concurrent sources is likely to exceed the limit of the participant's working, or short term, memory (Jonides *et al.*, 2008; Miller, 1956). This would most likely influence participants' behavior with the information pieces, as well as their helpfulness ratings. However, this situation is similar to the real world in the sense that there is an abundance of available information. Indeed, part of a designers' skillset, and even their expertise, is their ability to diagnose the relevance of information and consequentially ignore or incorporate it into their designs (Shanteau, 1992). The search for and selection of stimuli has been found to require different levels of cognitive effort (Gonçalves *et al.*, 2016), and research that is further investigating this issue is in progress.

Additionally, the mode in which the information is presented to the designers could play a role in their cognitive processing of that information. With regards to inspirational material, both novice and professional designers were found to prefer visual representations over textual ones (Gonçalves *et al.*, 2014). The information sheets provided in this study consisted of both text and images. While it is unlikely that the preferences between information sheets are fully explained by presentation mode, it is possible that there are differences in perception regarding the visual versus textual content by the participants. Similar work undertaken in this direction is seeking to isolate the effects of presentation mode from the information dimensions themselves, and future work is encouraged to take this into account as well. Lastly, this study sought to address the relationship between information usage and perceptions of information utility with regards to concept generation. The scope of this issue is such that one study by itself cannot fully answer it. Therefore, further research with different prompts, expert designers, and different student populations will help increase the validity of the findings and contribute to our knowledge of the complex role that information plays in design cognition.

In sum, the results of this study serve to empirically validate the Design Information Archetypes Framework, which aims to enable a more systematic investigation of the influence of information types on design outcomes. To advance this framework, this study explored the empirical link between the types of information used by designers and the ideas generated during the early phases of design. While prior research has explored each of these information sheets and their impact on design outcomes individually, this study contributes to design knowledge by providing a more complete picture of the information gathering phase when designers are often quickly filtering through and interpreting a wealth of relevant information. This study simulated this practice by representing the range of information that can influence the design process using the framework. With the increasing availability of data-rich design tools, the volume and variety of this information can quickly overwhelm the designer and reduce the effectiveness of the conceptual design process. Thus, this study provides a starting point for a systematic investigation of this information-rich process and contributes to the development of effective information processing strategies and methods for design education.

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