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FROM INFORMATION TO IDEAS: HOW DESIGNERS STRUCTURE INFORMATION TO SUPPORT IDEA GENERATION

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ABSTRACT

Design can be seen as a series of decisions that are informed by information that the designer has gathered from the environment and transformed into actionable knowledge. The sheer volume and variety of available information compels designers to impose structure upon the desired information, which in turn may affect subsequent design activities. To better understand how information may inform design decisions, this study investigates the relationship between designers' information organization behaviors and their generated ideas by recruiting eight professionals (four from software design and four from graphic design) for individual 3-hour design sessions. They were asked to generate ideas for a design problem (reducing pedestrian accidents in Nebraska) using the provided information. Results reveal that designers structured the information in three different ways (Clusters, Relations, and Nests), and both designer background and organizational strategy display different roles in the features generated in their ideas.

Keywords: Early-phase ideation, design cognition, knowledge structures, information organization strategies

1. INTRODUCTION

Innovation can be viewed as a process by which large amounts of design related information are consumed to then produce a variety of design outputs, some of which will be 'creative' [1]. Design outputs come in many forms. In engineering design, typical design outputs are conceptual sketches, prototypes, and fully implemented artefacts. These design outputs are an important means for designers to address a problem, so much so that certain design disciplines, such as graphic design, have been described as not just "the production of the visual communication; it is the modification of people's attitudes or abilities in one way or another" [2, p. 25]. The importance of problem solving skills in design is acknowledged by research [3] and graphic design job advertisements [4], which frequently call for idea generation and problem solving skills in addition to technical visual design skills. The approach of design as a form of problem solving is well acknowledged in the literature [5]. Indeed, the nature of design is such that design problems are often ill-structured [6], requiring designers to (re)structure and (re)construct the problem-solution space throughout the design process [7]. With the rapid growth of information due to technological advancements such as big data and cloud computing, designers must also balance the amount of information that is involved in the design process. As a source of inspiration, more information may promote creativity by increasing the number of analogies that a designer could draw upon [8,9]. However, information abundance can also lead to information overload [10,11].

Thus, successful design relies on the tailored application of experience-backed procedures and knowledge structures to project-specific requirements [12]. This process of negotiating and (re)organizing the problem-solution space is especially important in the early phases of the design process. For example, designers' ability to reorganize their own knowledge basis was found to be related to more innovative ideas [13]. To better understand the role of information on the tailoring of design cognition to a specific design project, this study set out to qualitatively investigate the relationship between experienced designers' information organization strategies and their generated ideas in an experimental setting.

1.1. Design Cognition

The process of (re)organizing the problem and the solution is supported by designers' expertise, which also helps them transform declarative knowledge into procedural knowledge and recognize solutions [14]. These cognitive processes are supported by experts' more comprehensive knowledge structures, which are able to support more complex reasoning about the design at various levels of abstraction. In constrast, novices are often unable to develop such inferences and remain at one (low) level of representation [15]. To facilitate the extensive knowledge structures that experts have accumulated over time and experiences, knowledge is connected and structured around core concepts. This conceptual framework intertwines factual and procedural knowledge in a way that provides a structure to interpret incoming information and communicate new and existing solutions [6]. The involvement of various cognitive processes suggest that there is more to the design process than the transformation of large amounts of information into creative solutions to problems [16].

As all new creations are based on one's previously acquired knowledge, the way in which prior knowledge is organized, accessed, and exploited is fundamental for understanding creative thought involved in generative tasks. Indeed, prior research has shown that the designer's ability to structure information around their own knowledge is connected to design outcomes [13]. For example, designers have been found to rely on analogies and associative processes to generate successful outcomes, and conceptually distant information has been used as inspiration for creative breakthroughs [17,18].

In addition to the development and application of relevant knowledge structures, the retrieval of information from these knowledge structures during design activities is equally important [19]. Although long-term memory may be unlimited in terms of storing information, the time or effort that is required to retrieve relevant information is not. Through experience, experts have acquired extensive knowledge that affects how they structure information. This, in turn, affects their abilities to remember, reason, and solve problems [19].

Experts have also developed mental shortcuts that they can (sub)consciously employ to increase the efficiency and effectiveness of their design processes and solutions [20]. Regardless of experience, designers are still subject to various biases that can affect their work such as design fixation, which may limit the designers' ability to consider a wide range of potential solutions [21,22]. One factor that designers can use to guide their thinking is the information that is available to them, such as details about the problem and project-specific requirements.

1.2. Information in the Design Process

Information plays an important role in design cognition and design processes for its influence on design outputs. The abundance and complexity of design information compels designers to develop strategies to adequately manage information and reduce complexity in design [23]. The different ways in which design teams structure information also affects information recall, communication patterns, and behaviors [24,25]. For example, designers have developed numerous retrieval strategies to acquire information [26], build rich collections of design information that lead to concrete design outcomes [27], and use readily available and historical design information to support learning and improving on past designs [28]. As such, meaningfully structured information is an important enabler of design success and innovation [28].

This is not to say that information or its organization is static. Designers' information needs dynamically evolve and adjust according to many interconnected factors [29] such as the current stage of the design process [30], the design task [24], and characteristics of the information itself [31]. For example, in addition to specific information about the design context and user characteristics, information pertaining to consumer needs and product requirements is especially important when the designer is concerned with understanding the end goals of the design engagement [32,33]. Such a requirements gathering activity is more closely associated with the early stages of the design process than the later stages where the designer may be more concerned with evaluation and refinement than conceptualization.

As the value of design information is influenced by characteristics of the information itself and the ways that designers' structure that information [34], understanding how information is or may be structured is central to understanding design engagements [23]. It is not just how *much* information designers have, but rather, *how* they use information during the design process that truly predicts successful outcomes. Since design cognition relies on a combination of domain knowledge, or expertise [35,36], and effective application of required processes [37], the way that designers structure information during design activities is of central importance to the field of design cognition.

1.3. Research Objectives

The ability to structure and leverage information to develop actionable design outcomes is crucial throughout the design process. Some of these processes and outcomes may be visible, but the majority of these organizational processes are cognitive in nature. Understanding how designers navigate this interaction between their internal cognition with the available external information can provide insight into what strategies might support successful design processes. Research on the information organization strategies of designers is needed to extend the existing body of work on design processes. Furthermore, research conducted with practicing designers will shed light on the complex processes employed in the field and add to our understanding of how experienced designers engage with information during design engagements. Therefore, this work is guided by the following main research objective:

Understand how designers' information organization strategies are related to the ideas they generate during early-phase design activities.

Specifically, this research goal will be addressed by 1) analyzing how designers organize and discuss relevant information prior to idea generation, 2) relating the strategies for organizing information to their generated ideas.

This study focuses on increasing understanding of both designers' reasoning process of developing organization strategies and the resulting scheme for organizing information to address the conceptual phases of a design task. This will add to our understanding of how designers employ their cognitive resources to manipulate information to facilitate the integration between old and new knowledge to generate creative solutions.

2. METHODOLOGY

An in-depth qualitative study was conducted with a total of 8 practicing designers with between 3 to 17 years of experience. Most were employed by small to medium software design and development companies in a U.S. midwestern metropolitan area (see Table 1), while two also taught at the university (from a different department) where the research took place. All participants were identified through the authors' professional networks and through snowball sampling. Only designers who had obtained at least 3 years of software design experience (through educational training, certification, or job training) *and* currently engage in design activities as their primary function in their full-time jobs were recruited for this study.

While the power of probability sampling is to select a "truly random and statistically representative sample that will permit confident generalization from the sample to a larger population" [38, p. 169], the goal of purposeful sampling is to select information-rich cases for an in-depth study to gain deeper insight into issues of central importance to the research [39]. Purposeful sampling has been used in numerous studies in cognitive science [40,41] and engineering [42] to uncover valuable insights on complex phenomena and human experience through a detailed analysis of in-depth protocol studies on behavioral patterns, performance, and reflections. In this study, specific cases (experienced designers) were chosen that intensely manifest the phenomenon of interest (routinely structuring information to facilitate the design process).

TABLE 1. RELEVANT DESIGNER CHARACTERISTICS

Designer	Design Experience	Title & ~years in current position	Organization Size & Sector
D1	8 yrs	User experience lead, 3 yrs	~ 51-200, mobile development & integration
D2	7 yrs	Product designer, <1 yr	~ 51-200, managed hosting and web design
D3	3 yrs	CTO, <1 yr	~1-50, custom software development and design
D4	6 yrs	CEO, 3 yrs	~1-50, custom software development and design
D5	17 yrs	Graphic design instructor, 7 yrs	~1000-5000, educational institution
D6	15 yrs	Graphic design assistant professor, 14 yrs	~1000-5000, educational institution
D7	5 yrs	Graphic designer, 3 yrs	~1-50, print, signage & marketing services
D8	8 yrs	E-learning designer, <1 yr	~1-50, digital marketing solutions

2.1. Procedure

The designers were invited to attend a 3-hour individual design session in a quiet and controlled environment. An overview of the full study can be found in Figure 1. Only the relevant aspects for this study will be discussed.

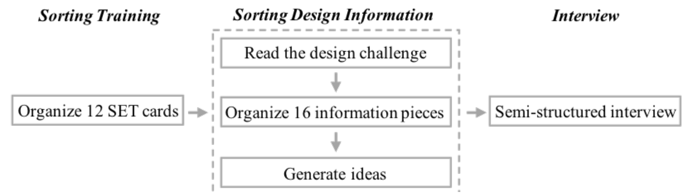

FIGURE 1. OVERVIEW OF THE STUDY PROCEDURE

2.1.1. Introduction and Information Organization. After a brief introduction to the purpose and procedure of the study, informed consent was obtained from all designers. The designers were then introduced to the design challenge of developing solutions for reducing pedestrian accident rates through a written design prompt that described the motivation and background behind the problem domain. The design task was: "*Your task is to develop concepts for a new, innovative product or system that will reduce pedestrian accident rates due to distraction from mobile devices*.". This task was intentionally open ended so the participants could generate any ideas they wanted regardless of complexity or scope. Once this task was understood and any questions were answered, the designers were provided with 15-minutes to familiarize themselves with 16 design information sheets. The design information sheets were specifically developed and pilot tested for this study (for more information see [43]). The full list of information sheets used for this study can be found at: https://www.unomaha.edu/college-of-information-science-and-technology/bridge/research/resources.php. During this stage, the designers were explicitly instructed to not yet start ideation but instead to focus on understanding each of the provided information sheets. Next, the designers were asked to organize these information sheets in a way that made sense to them using any organizational schemes, annotations, and reasoning that they wanted to while verbalizing their thoughts and using the whiteboard and markers to visualize it. Once the designers had completed their organization of the information sheets, they were asked to provide a high-level explanation and overview of the reasoning behind the organizational scheme to the researchers.

2.1.3. Idea Generation. Once the designers had explained their organization of the information sheets, they were given paper and pens to sketch their conceptual solutions to the problem. No specific directions were provided for how the designers could generate ideas, although the instructions to "generate as many ideas as possible" are typical for brainstorming techniques [44]. To reduce pressure on the designer, the researchers physically left the room during this time and the designers were free to brainstorm as many ideas as they could to address the design challenge. Once 20 minutes had passed, the researchers re-entered the study room and asked the designers to walk the researchers through their ideas while describing how they were related to the information sheets. A short interview was conducted to conclude the study, which was analyzed for reoccurring patterns and themes using inductive content analysis.

3. ANALYSIS OF ORGANIZATIONS AND IDEAS

Throughout the study, the designers were videotaped and audio-recorded. The researchers analyzed these to better understand the designers' visual organization and to gain insight into their thinking patterns and organizational strategies. Additionally, two independent raters assessed the 74 generated concept ideas using an 18-question Design Rating Survey (DRS) developed in previous work [45], which can be found here: https://www.unomaha.edu/college-of-information-science-and-technology/bridge/research/resources.php. This DRS is based on the assessment of features in each design using the Shah et al. [46] novelty and quality metrics. The first 15 questions on the DRS were used to help the raters classify the features each design idea addressed, similar to the feature tree approach [47]. The remaining three survey questions pertained to the technical feasibility of the design ("Can the concept be technically developed?"), plausibility of implementation ("Is the concept easy to execute?") and likeliness to reduce pedestrian accident rates if implemented ("Does the concept reduce pedestrian accidents?"), similar to the process used by [48].

One independent coder assessed all 74 concept ideas, and a second coder coded 27% of the ideas with an overall inter-rater reliability score of 84%. Any disagreements were settled in a conference between the two raters as was done in previous studies investigating creativity [47]. After the rating process, the features were aggregated into fewer features of higher granularity to facilitate analysis. This resulted in one high level distinction between whether the idea was aimed at creating or modifying a device versus changing the environment. If the idea was device related, the features were grouped into three subgroups: Device type (Standalone, Wearable or Handheld), Focus (Tracking, or reducing distractions), and Feedback (Visual, Audio, or Tactile). If the idea was environment related then it could be further broken down into four features (alerting pedestrians, alerting vehicles, redirecting pedestrians, or redirecting vehicles). An overview of how often each of the identified features occurred across all ideas can be found in the stacked bar graph displayed in Figure 2A and B.

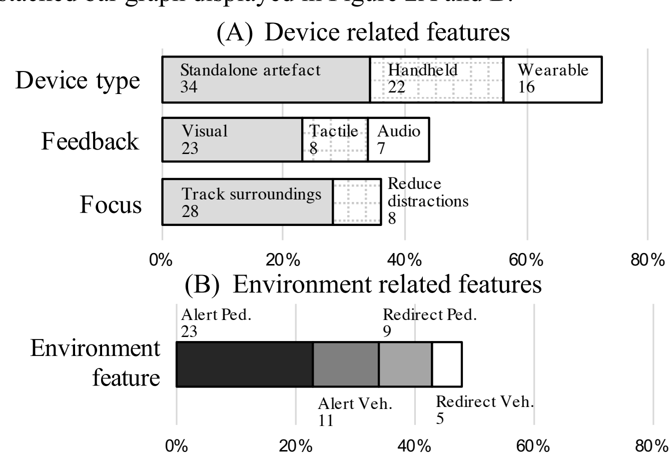

FIGURE 2A AND 2B. PERCENTAGE OF HOW OFTEN EACH FEATURE OCCURRED IN THE 57 DEVICE RELATED IDEAS (A) AND 46 ENVIRONMENTALLY RELATED IDEAS (B). PED. STANDS FOR PEDESTRIANS, VEH. STANDS FOR VEHICLES.

3.1. Designer Background and Idea Features

Prior to addressing the main goal of investigating the relationship between information organization strategies and idea generation, a preliminary analysis was conducted to understand how the designers' occupational backgrounds influenced the types of ideas that they generated in this study. Four designers (D1-4) are from the software design space while the other four (D5-8) have a graphic design background. An overview of how often each feature occurred per designer background can be found in Table 2, p.8.

3.1.1. Software Designers. The four software designers generated 53 ideas that would be technically feasible to execute, with 81% likely to reduce pedestrian accident rates if implemented and 33% that might plausibly be implemented.

Generally, the ideas were more focused on creating or modifying a device (64%) than the environment (40%), with 2 ideas incorporating both aspects (4%).The majority of the devices were standalone artefacts (42%), followed by handheld devices (22%) and wearables (21%). These devices typically included tracking features (36%) over distraction reducing features (4%). Device to human feedback was mainly visual (26%), although there were some with auditory (9%) or tactile components (9%). Other features not otherwise captured were found in 10% of the ideas: A system that flips the pedestrian back up when they fall, a defense hoop around the pedestrian, protection when bumping into things, and a self-driving hoverboard. The environmental ideas mainly focused on alerting pedestrians to obstacles or vehicles (21%), with some ideas incorporating features that alerted vehicles to distracted pedestrians (8%), redirected pedestrian (8%) or vehicle traffic (4%). Lastly, 27% of these ideas incorporated features not otherwise captured by the rubric: Automatic braking system for joints, fence between walkway, gamification, hazard highlighting street lights, incentive programs, lights on the wall, plastic ring around poles, road signs for drivers and pedestrians, smart clothing (T-shirt), solar charged lights on the ground and lights that turn red when pedestrians are present.

Combining these most frequently occurring features together results in a 'representative' idea that encapsulates the archetypal concept that software designers generated. Namely, the concept of a standalone device that tracks the environment and provides visual feedback (see Figure 3 left). For the environment-related ideas that would be any idea that alerts pedestrians to vehicles or obstacles (see Figure 3 right).

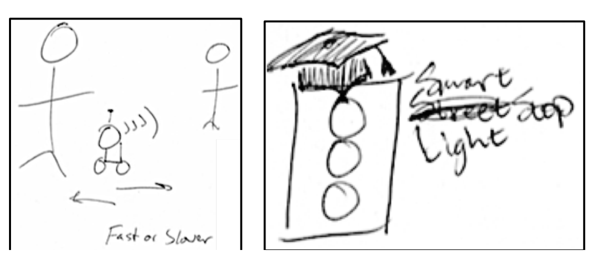

FIGURE 3. EXAMPLE OF A REPRESENTATIVE DEVICE-RELATED IDEA (LEFT) AND ENVRONMENT-RELATED IDEA (RIGHT) BY THE SOFTWARE DESIGNERS

3.1.2. Graphic Designers. The four graphic designers generated 21 ideas that would all be technically feasible to execute, 91% would likely reduce pedestrian accident rates if implemented, and 53% might plausibly be implemented. The ideas were generally more aimed towards changing the environment (62%) than creating or modifying a device (38%), with no ideas incorporating both elements. The majority of the devices were handheld devices (29%), followed by standalone artefacts (14%), and wearables (5%). The emphasis was on features that reduced distractions (19%) over tracking features (10%). Device to human feedback was visual (14%) or auditory (5%), with no ideas incorporating tactile feedback. The other device feature (5%) contained shoes and tech devices on laces. The environmental ideas focused mainly on alerting pedestrians (29%) or vehicles (19%), and redirecting pedestrian (14%) or vehicle (10%) traffic or behavior. Other environmental idea features were incorporated in 29% of the ideas: Implementing laws, (un)locking the car, making it personally relevant to users, connecting to campus change agents, providing flags to increase pedestrian visibility at crossings, and implementing incentive programs.

Combining these most frequently occurring features results in a 'representative' idea that encapsulates the archetypal concept that graphic designers generated. Namely, the concept of a handheld device that reduces distractions and provides visual feedback (see Figure 4 left). For the environment-related ideas that would be any idea that alerts pedestrians to vehicles or obstacles (see Figure 4 right).

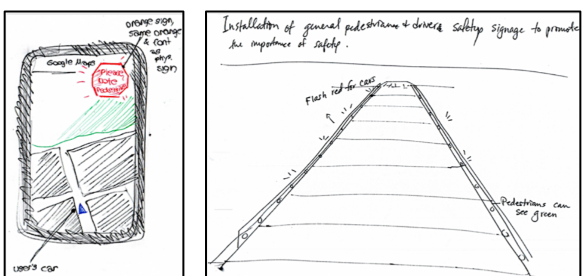

FIGURE 4. EXAMPLE OF A REPRESENTATIVE DEVICE-RELATED IDEA (LEFT) AND ENVRONMENT-RELATED IDEA (RIGHT) BY THE GRAPHIC DESIGNERS

3.2. Information Organization Analysis

To better understand the relationship between how designers organize information and the ideas they generate, the visual organizations of the information sheets were first analyzed for common strategies. The identification of each strategy resulted from both authors visually inspecting each organization for patterns that appeared to be similar to the patterns found in other organizations. The analysis of the visual organization of the information sheets revealed three patterns of how the designers structured the information that was presented to them: Clusters, Relations, and Nests (see Figure 5, 6, and 7). This paper focusses only on the resulting strategies. For a discussion on how the designers arrived at each strategy see [43].

Two designers (D1 and D2) followed a cluster forming pattern in which they grouped all the related information sheets together in categories of 2 to 5 information sheets (see Figure 5). Both designers created five categories, which D1 extended with three additional categories of information pieces that they felt were missing from the available information, but considered to be necessary for the design challenge. They were the only designer to express a need for more information.

Relations forming was the second pattern to emerge (see Figure 7). Here, the two designers (D3 and D6) utilized a more relational approach in which they indicated which information sheets could be categorized together, as well as how these information sheets were related to each other. For D3, this relationship took on a scale-like quality in which information sheets could be organized relative to each other along a quality.

The remaining four designers (D4 D5 D7 D8) extended the relations forming approach by adding a hierarchical component (see Figure 6). These designers created layers in which one or more information sheets were nested within another information sheet or category. For example, D4 created a child category 'Dangerous Driving' within the parent category 'Driving'. This child category was also a parent category for one information sheet ('Distracted Driving') whose other half ('Causes of Distraction') belonged to a different parent category ('Generic Info/Capabilities'). In turn, the information in other parent category informed other categories (as visualized by the arrows) and even formed a bi-directional information stream with the 'Client' category.

Taken together, each of these groups of information structuring strategies appear to build in complexity and sophistication. For example, the clustering pattern of information structuring is the least complex, while the relational information structuring pattern builds on this baseline by incorporating a relational element that captures the more abstract knowledge structures that designers are utilizing. Going further, the nesting information structuring pattern is the most complex of all, building on the categorical and relational nature of the information structures and applying a hierarchical or nested structure to the information pieces in order to represent a higher level of understanding of the information space.

3.3. Relationship between Organizational Strategy and Generated Ideas

To understand how the strategies are related to the generated ideas, the ideas were grouped by strategy and their features were analyzed similar to the analysis of the domain background in section 3.1.

Grouping the designers by visual information organization strategy resulted in an unequal number of designers per strategy, and unequal number of ideas per strategy. Therefore, to facilitate better understanding of the resulting patterns, the number of times a feature occurred was normalized by the total number of ideas in that strategy to create an occurrence percentage. An overview of how often each feature occurred per strategy can be found in Table 2, p.8.

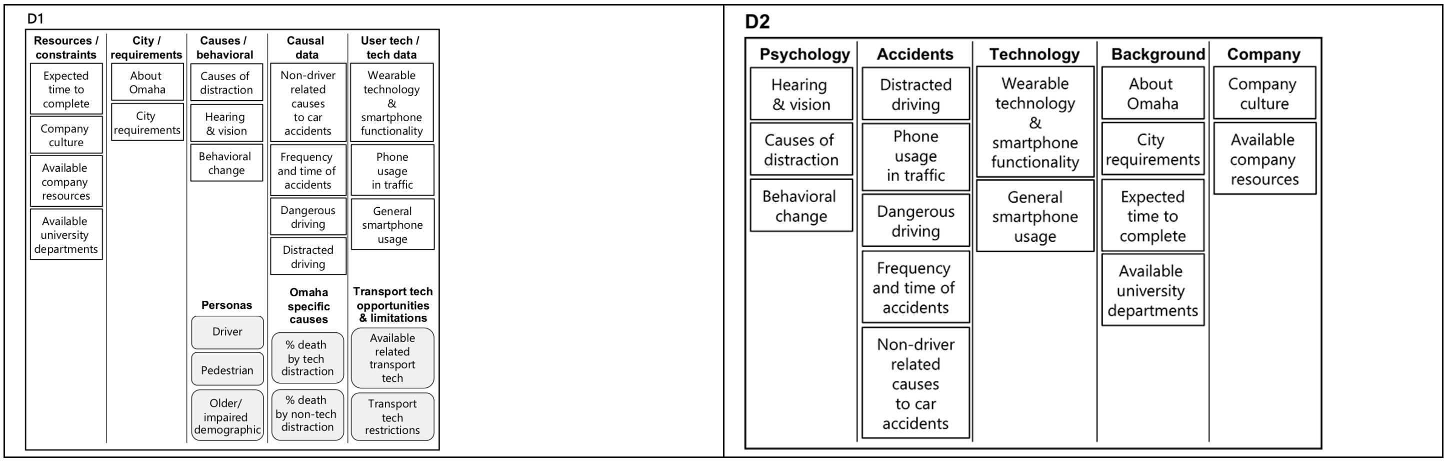

FIGURE 5. VISUAL ORGANIZATION OF THE TWO DESIGNERS USING THE CLUSTERS STRATEGY

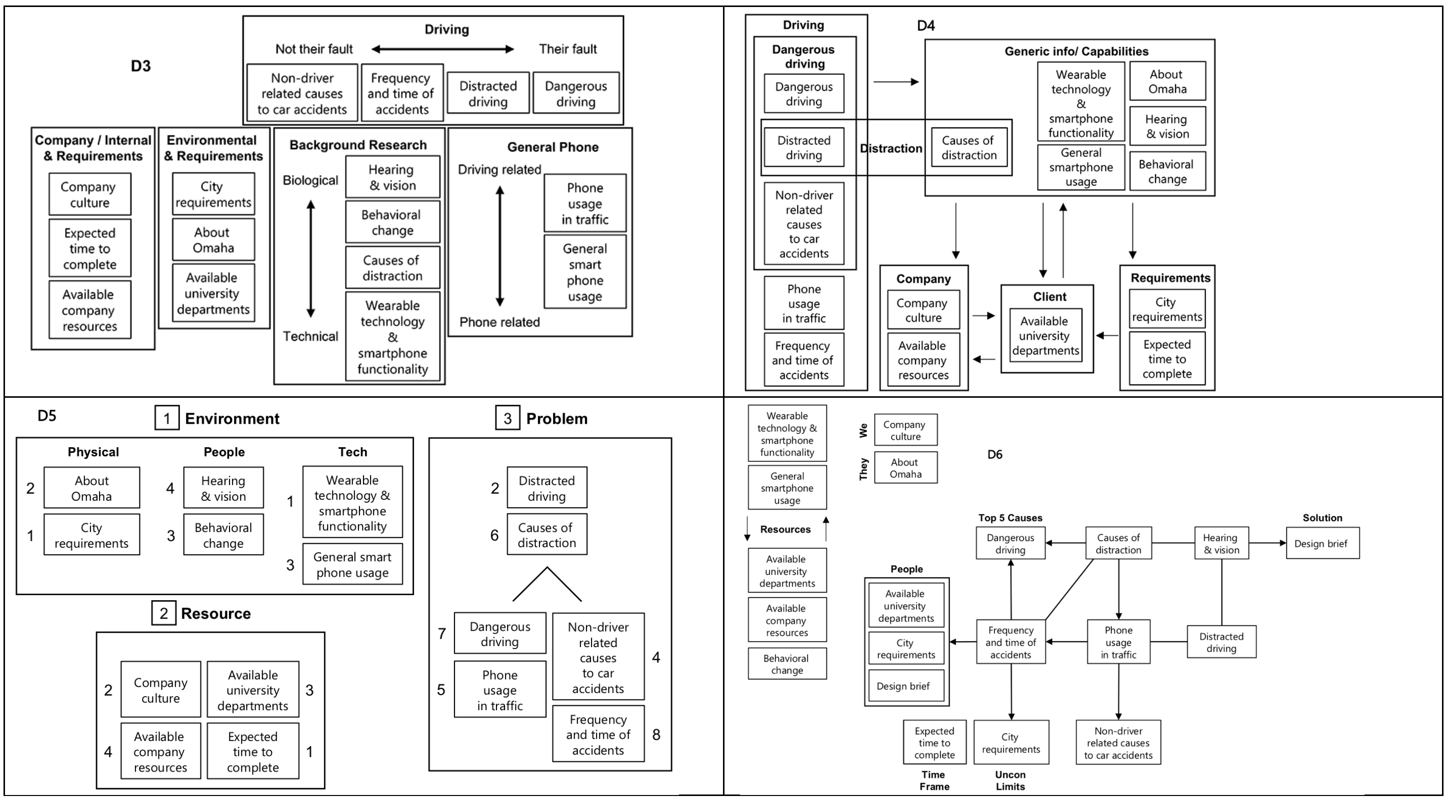

FIGURE 6. VISUAL ORGANIZATION OF THE FOUR DESIGNERS USING THE RELATIONS STRATEGY

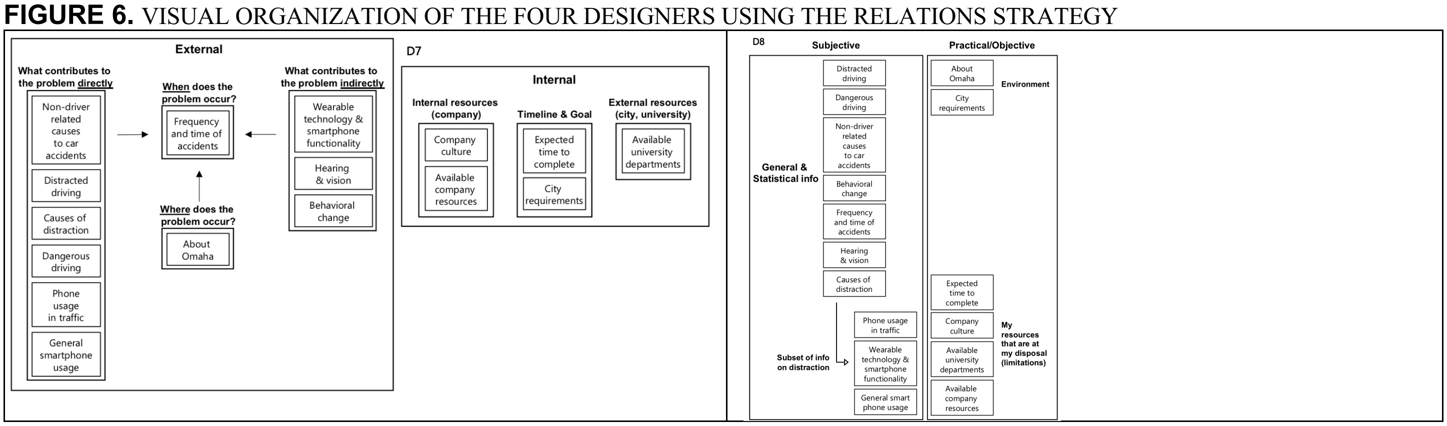

FIGURE 7. VISUAL ORGANIZATION OF THE TWO DESIGNERS USING THE NESTS STRATEG

3.3.1. Clusters. The two designers with this strategy generated 12 ideas that were all deemed technically feasible to execute and would likely reduce pedestrian accident rates if implemented. Of those ideas, 33% might plausibly implemented. Of all the generated ideas, the majority focused on changing the environment (75%), some were aimed at devices (33%) and 1 idea incorporated both aspects (8%).

The majority of the devices were handheld devices (25%), followed by standalone artefacts (8%). None of the ideas incorporated wearables. None of the ideas were aimed at reducing distractions while 25% incorporated a tracking element. Feedback was mainly visual (33%) or auditory (17%), no ideas had tactile feedback components. None of the 4 device ideas incorporated features not otherwise captured.

The environmental ideas mainly focused on alerting pedestrians to obstacles or vehicles (33%), alerting vehicles to distracted pedestrians (25%), or redirecting vehicle traffic or behavior (17%). None of the ideas redirected pedestrian traffic or behavior. However, 58% of these ideas did incorporate other features: Gamification, incentive program, road signs for drivers and pedestrians, and solar charged lights on the ground.

Combining these most frequently occurring features together results in a ‘representative’ idea that encapsulates the archetypal concept that the designers generated using this clustering strategy. Namely, the concept of a handheld device that tracks the environment and provides visual feedback (see Figure 8 left). For the environment-related ideas that would be any idea that alerts pedestrians to vehicles or obstacles (see Figure 8 right).

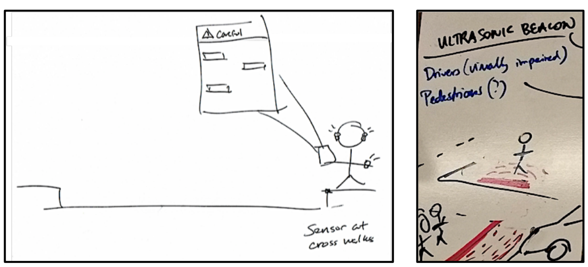

FIGURE 8. EXAMPLE OF A REPRESENTATIVE DEVICE-RELATED IDEA (LEFT) AND ENVRONMENT-RELATED IDEA (RIGHT) BY THE CLUSTERS STRATEGY APPROACH

3.3.2. Relations. The two designers with this strategy generated 29 ideas that were all deemed technically feasible to execute, 69% would likely reduce pedestrian accident rates if implemented and 66% might plausibly be implemented. The ideas were predominately focused on creating or modifying a device (21 on device (72%) versus 8 on device (28%).

The majority of the devices were standalone artefacts (52%), followed by wearables (24%) and handheld devices (21%). A tracking element was included in 35% of the ideas while 17% were aimed at reducing distractions. Feedback was fairly evenly distributed across visual (14%), tactile (10%) and auditory (7%). Other features were incorporated in 10% of the ideas: Defense hoop around pedestrian, self-driving hoverboard, and a trip prevention device.

The environmental ideas mainly focused on alerting pedestrians to obstacles or vehicles (10%), alerting vehicles to distracted pedestrians (7%), or redirecting pedestrian traffic or behavior (7%). None of the ideas redirected vehicle traffic or behavior. However, 58% of these ideas did incorporate other features: Implementing laws, (un)locking the car, making it personally relevant to users, automatic braking system for knee joints, campus change agents, hazard highlighting streetlights, and a red alert light when pedestrians are present.

Combining these most frequently occurring features together results in a ‘representative’ idea that encapsulates the archetypal concept that the designers generated using this Relations strategy. Namely, the concept of a standalone device that tracks the environment and provides visual feedback (see Figure 9 left). For the environment-related ideas that would be any idea that alerts pedestrians to vehicles or obstacles (see Figure 9 right).

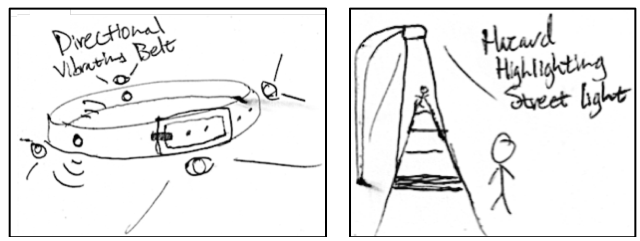

FIGURE 9. EXAMPLE OF A REPRESENTATIVE DEVICE-RELATED IDEA (LEFT) AND ENVRONMENT-RELATED IDEA (RIGHT) BY THE RELATIONS STRATEGY APPROACH

3.3.3. Nests. The four designers with this strategy generated 33 ideas that were all deemed technically feasible to execute, 91% would likely reduce pedestrian accident rates if implemented, and 33% might plausibly be implemented. There was even split between device-oriented ideas (52%) and environment-oriented ideas (52%), and one idea that incorporated both aspects (3%).

The majority of the devices were standalone artefacts (27%), followed by handheld devices (24%) and wearables (15%). A tracking element was included in 24% of the ideas while 3% were aimed at reducing distractions. Feedback was predominately visual (27%), but tactile (6%) and auditory feedback (6%) was also present. Other features occurred in 9% of the device ideas: Protection when bumping into things, and shoes and tech device on laces.

The environmental ideas mainly focused on alerting pedestrians to obstacles or vehicles (30%), followed by redirecting pedestrian traffic or behavior (15%), alerting vehicles to distracted pedestrians (9%), and redirecting vehicle traffic or behavior (6%). Other features were incorporated in 18% of the ideas: Fence between walkway, flags to increase pedestrian visibility at crossings, incentive program, lights on the wall, plastic ring around poles, and smart clothing.

Combining these most frequently occurring features together results in a ‘representative’ idea that encapsulates the archetypal concept that the designers generated using this Nests strategy. Namely, the concept of a standalone device that tracks the environment and provides visual feedback (see Figure 10 left). For the environment-related ideas that would be any idea that alerts pedestrians to vehicles or obstacles (see Figure 10 right).

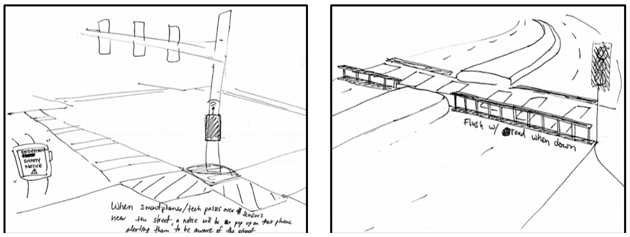

FIGURE 10. EXAMPLE OF A REPRESENTATIVE DEVICE-RELATED IDEA (LEFT) AND ENVRONMENT-RELATED IDEA (RIGHT) BY THE NESTS STRATEGY APPROACH

TABLE 2. PERCENTAGE OF FEATURES OCCURING ACROSS DIFFERENT STRATEGIES AND DESIGNER BACKGROUNDS. OVERALL NUMBER OF IDEAS AND THEIR EXPECTED FEASIBILITY, EFFECTIVENESS AND PLAUSIBILITY

	Designer		Strategy		
	Software	Graphic	Clusters	Relations	Nests
Total number of ideas	53	21	12	29	33
Technical feasibility	100	100	100	100	100
Likelihood to reduce pedestrian accident rates	81	91	100	66	91
Plausibility of implementation	33	53	33	69	33
PERCENTAGE OF FEATURES OCCURRING IN THE 57 DEVICE RELATED IDEAS					
	Software	Graphic	Clusters	Relations	Nests
Handheld	21	29	25	17	24
Wearable	21	5	0	24	15
Standalone artefact	42	14	8	52	27
Reducing distractions	4	19	0	17	3
Tracking surroundings	36	10	25	35	24
Visual	26	14	33	14	27
Audio	9	5	17	7	6
Tactile	9	0	0	10	6
Other device features	10	5	0	10	9
PERCENTAGE OF FEATURES OCCURRING IN THE 46 ENVIRONMENT RELATED IDEAS					
	Software	Graphic	Clusters	Relations	Nests
Alerting pedestrians	21	29	33	10	30
Alerting vehicles	8	19	25	7	9
Redirecting pedestrians	8	14	0	7	15
Redirecting vehicles	4	10	17	0	6
Other environment features	27	29	58	58	18

4. DISCUSSION

The main purpose of this study was to investigate the strategies experienced designers use to organize relevant information during a design task, and to investigate how these strategies are related to the ideas they subsequently generate. The main findings of this study are as follows:

- Designers with different backgrounds and strategies leaned towards different features in their generated ideas.
- Designers structured the information in three different ways: Clusters, Relations, and Nests.

By investigating how designers' information organization strategies were related to the ideas they generated, this study provides insight into how experienced designers interact with large amounts of information early in the design process. Specifically, the results indicate that, regardless of designer background or organizational strategy, all designers' ideas were primarily aimed at alerting pedestrians, which was the target audience and objective of the design brief. They also predominately relied on providing visual feedback to the user, even with the design brief stressing the importance of accommodating various disabilities.

With regards to designer background, the ideas generated by the software designers contained more standalone artefacts and were aimed more at tracking the surroundings, while the graphic designers showed an opposite pattern where they primarily generated ideas with features that more closely adhered to the design brief – i.e. handheld devices and reducing distractions. Interestingly, analysis of the dominant idea features also revealed a difference in problem framing choice between the software designers and the graphic designers, i.e. respectively oriented more towards tracking versus more distraction reducing. Extending this study to a more longitudinal setting would provide insight into how these differences would evolve as the designers further explored the problem and solution spaces [7]. Supplementing this work with field data could also extend understanding of how designers navigate complex information in team settings [49,50].

The formation and application of underlying principles are tied to the specific domain in which the designer has acquired the experience, meaning that, even between designers of similar training or job title, there is a certain measure of variability between designers [51]. These more specialized areas of expertise can be observed in the designers of this study as well, who operate in a wide variety of different industries and companies (see Table 1). It is likely that the information organization strategies utilized by the designers in this study are informed by these experiences, and replication of this study with a different set of designers will reflect such experiential differences.

Specific experiences have also been tied to problem-solving approaches. While the designers in this study could not be categorized into Lloyd & Scott's conjunctive versus deductive reasoning [52], they did exhibit problem framing behaviors and reasoning [53]. This is especially evidenced by the way that the designers resolved an apparent discrepancy between the design brief and the information sheets, which were respectively more focused on the pedestrian versus the driver. Upon told to 'use their best judgement of the situation', the designers chose to adhere more to the design brief than the information sheets, and generated ideas that were predominately directed at pedestrians. This decision can also be interpreted as the result of the designers cognitively constraining the search space, where the choice of constraints is motivated by several factors such as the designer's expertise and the design problem specifics [12].

The findings of this study provide further support for the importance of knowledge structures on idea generation [13,23]. Across the three strategies, it was more common for ideas to track the surroundings than reduce distractions. There seemed to be a relatively even spread between standalone versus handheld devices, with Clusters favoring handheld devices, Relations leaning towards standalone devices and Nests incorporating both features almost evenly.

This study employed visualizing ways of organizing information as a means for extracting and capturing knowledge structures that are vital to problem solving. As experts have more fully formed knowledge structures than novices [19], the use of experienced designers was instrumental in this process. The average experience of the designers in this study was 8.6 years of experience, with the software designers ranging between 3 to 8 years (average of 6 years) and the graphic designers ranging between 5 to 17 years (average of 11.25 years). Number of years can be an indicator of expertise as the exposure to a large amount of various problems and solutions in a domain supports the identification and accumulation of more abstract patterns about those problems, which is one of the key differences between experts and novices [27]. However, length of experience alone does not necessarily indicate better performance or choice of design strategy [54]. While this study provides descriptive insight into the ways that designers from different domains interact with large amounts of information early in the design process, the development of expertise or knowledge structures was beyond the scope of this study. Given the importance of expertise in the design process, more work is needed to investigate the formation and application of expertise. With regards to this line of work, open questions remain regarding what factors might influence the choice or development of these information organization strategies, how these strategies might evolve throughout the design process, and how these information organization strategies might impact the final design outcome rather than conceptual ideas.

This study builds on previous work investigating the types of information that designers use during the design process using reflective interviews [31], and how designers' approach, structure and organize information in a controlled setting [43]. The use of laboratory studies has been shown to provide valuable insights into design practice [55]. Simplifying the situation to one where an individual designer worked with study-specific information that was identical across participants enabled the researchers to reduce information diversity as a confound on the designer's information organization strategies. However, the study was conducted as a single moment in time and lacked client and user interaction, a situation that is not representative of everyday design experiences.

In addition to the aforementioned longitudinal and fieldwork research, this work would also benefit from a larger sample size and a wider variety of design disciplines. The small sample size in this study is the result of the intensity sampling method [39]. The purpose of this study was to gain insight into the strategies and reasoning employed by designers when engaging with large volumes of information early in the design process. This targeted, in-depth analysis required the use of prototypical designers with at least three years of experience working in the design space due to their ability to extract functional and structural aspects from inspiration sources and draw richer connections between the material compared to novice designers [56]. However, exploring how different levels of expertise and prior training in design domains impacts the knowledge structures of designers can provide useful insights into the development of design expertise.

5. CONCLUSION

This study provides preliminary support for the existence of shared underlying patterns in how experienced designers from different domains organize information in the early phases of the design process. The designers were found to display patterns in how they organized information, and these patterns were not exclusively tied to their background. The designers' information organization strategies were linked to specific features in their generated ideas, suggesting that the visual organizations are an indication of how the designers mentally structure the provided information and that this was related to their generated ideas. These findings contribute to the understanding of how designers' experience informs and interacts with information through existing knowledge structures.

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