BEYOND SEARCHING: UNDERSTANDING HOW PEOPLE USE SEARCH TO SUPPORT THEIR CREATIVE ENDEAVORS

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ABSTRACT

Yinglong Zhang: Beyond Searching: Understanding How People Use
Search to Support Their Creative Endeavors
(Under the direction of Robert Capra III)

Creativity is an essential part of people's daily life and work across a range of everyday tasks. However, little prior work has explored how people use search engines and information resources as part of their creative processes, and how systems might better support users' information needs when working on tasks that involve creative endeavors. In this dissertation research, I sought to investigate the types of information seeking tools and strategies that people currently use in practice when they engage in projects that involve everyday creativity. The dissertation includes two parts. In the first part, an online survey with 175 participants was conducted to get a general understanding of how people use search engines and other existing information tools to support their everyday creativity tasks, the types of creative process stages that are involved in their tasks, and how they use different tools to support different creative stages. To get a deeper understanding of people's behaviors and their creative processes, in the second part, I conducted a two-week diary study to investigate users' **in-situ search behaviors** in their design-related projects from different perspectives (e.g., types of information sought in a project, intents to use the information found online, strategies of using different resources or tools in creative processes, and challenges encountered in creative processes). At the end of this dissertation, I discuss the implications of this research and provide recommendations for future research and the future design of search systems.

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INTRODUCTION

Creativity and innovation are highly valued characteristics in different fields, such as science, commerce, education, and the arts. Sawyer (2011) argues that creativity will continue to increase in importance because of increased global competitiveness, shorter product development cycles, decreasing number of jobs that do not involve creativity, and growing demand for products of creative industries.

In addition to these social values, creativity has been regarded as a universal quality that helps people survive. As Richards highlighted in her seminal paper on everyday creativity (R. Richards, 2010, p.190):

> "Throughout our day, whether at home or at work, we humans adapt and innovate, improvise flexibly, at times acting from our 'gut feelings', at times from options we imagine and systematically try out, one after the other. Our creativity may involve anything from making breakfast to solving a major conflict with one's boss."

Over the past decade, much previous research has shown that creativity is a process that is trainable (Sawyer, 2011; Csikszentmihalyi & Getzels, 1988; Mumford, Mobley, Reiter Palmon, Uhlman, & Doares, 1991). David Kelley, the founder of IDEO[1], also noted in his book (2012, p. 2):

> "We've helped thousands of companies bring breakthrough ideas to market-from Apple's first computer mouse to next-generation surgical tools for Medtronic to fresh brand strategies for The North Face in China. And we've also seen that our methods can produce a new creative mindset in people that can dramatically enhance their lives, whether they work in the fields of medicine, law, business, education, or science."

In education, Stanford d.school gives us a great example of showing the feasibility of teaching people this method (design thinking) to help them develop their creative abilities.

[1] `https://www.ideo.com/`

In the realms of human-computer interaction (HCI), Shneiderman is one of the earliest scholars who advocated the importance of supporting people's creativity using information technologies. In 1999, he published a paper emphasizing the significance of developing user interfaces that support creativity. In the paper (Shneiderman, 1999), he described ways that information tools and interfaces could support users during phases in a creative process and proposed a framework for helping to design interfaces to support creative work.

Seeking to develop tools for supporting humans' creativity, much research has been carried out in the past twenty years. However, it has been recently pointed out that there are several limitations in the creativity-related research in HCI. By reviewing 998 creativity-related publications in the ACM Digital Library, Frich and his colleagues (2018) have found that many creativity-related HCI research has suffered from several shortcomings. Firstly, much prior research did not provide a clear definition of creativity and explain how it is studied. As the authors point out, "**we recommend looking to the well-established tradition of psychology-based creativity research to ground and inform HCI researchers' definition and delimitation of creativity**" (2018, p. 1243). Secondly, many prior studies focused on new tools, often developed by the researchers themselves, and investigated them in controlled experiments. Frich and his colleagues have emphasized that it is important to "**shift our efforts to studying in-vivo use of creativity support tools, not just the ones we build ourselves, but the ones that most creative practitioners employ in practice**" (2018, p. 1243). The research presented here is an answer to this call in the context of how people use search engines and other information resources in support of their everyday creative projects.

In the area of information search and retrieval, to the best of my knowledge, very few other efforts have been made to investigate how to design search systems and information tools for supporting creativity in the area of information search and retrieval. Shneiderman has highlighted opportunities to support creative processes by using search engines in his several papers (Shneiderman, 1999; Shneiderman et al., 2006; Shneiderman, 2007). White (2016) also points out the importance of investigating creativity in the fields of information retrieval and information science. Although prior work has explored ways to support serendipity in the area of information retrieval (Toms, 2000; Beale, 2007; Rahman & Wilson, 2015), it should be noted that creative processes and serendipity are very different.

Considering the popularity of search engines (such as Google, Bing, Yahoo, Baidu, etc.), we should also realize that search engines could be one of the best existing platforms for supporting users' creativity. According to the data reported by statista[2], in 2017, the number of internet users in the United States is approximately 286.94 million, and the total number of search engine users in the United States is around 230 million. That is to say, more than 80% of internet users use search engines in 2017. If search engines could be designed and improved to support users' creativity, a large number of people would benefit from the tools.

Seeking for a better understanding of how people use search engines to support their everyday creative tasks, I conducted this dissertation research to investigate the types of information seeking tools and strategies that people currently use in practice when they engage in tasks that involve everyday creativity. The dissertation research includes two parts: **a survey study** and **a diary study**. In the first part, an online survey with 175 participants was conducted to get a general understanding of how people use search engines and other existing information tools to support their everyday creativity tasks, the types of creative process stages that are involved in their tasks, and how they use different tools to support different creative stages. To get a deeper understanding of people's behaviors and their creative processes, in the second part, I conducted a two-week diary study to capture participants' behaviors, thoughts, and experiences during the start, middle, and end of a creative process in their design-related projects.

The impacts of this dissertation research are twofold. Firstly the findings of this research help the fields of information science and information retrieval understand what kinds of information needs are essential to people's design-related creative projects. Secondly, this research identifies problems and challenges that users face when searching for information to support creative tasks and informs the design of future search system features and tools to help support these types of search.

[2] `https://www-statista-com.libproxy.lib.unc.edu/`

CHAPTER 1

CONCEPTUAL BACKGROUND

1.1 Creativity

1.1.1 Definitions of Creativity

For the past several decades, many different definitions have been proposed to characterize the nature of creativity. In literature, the definitions of creativity can be classified into two different brackets: "big-C" and "little-c". In sociocultural approach, creativity is regarded as "the generation of a product that is judged to be novel and also be appropriate, useful, or valuable by a suitable knowledge social group" (Sawyer, 2011, p.12). In the research on "big-C", scholars attempt to understand creative genius and identify which creative works might last forever (Simonton, 2000). Creative genius always refers to a small group of people who have made a considerable contribution to a product that has been widely viewed as a masterwork in an established domain of creative achievement (Simonton, 2000). For instance, examples used in the research on big-C included the winners of the Pulitzer Prize in fiction (such as Robert Olen Butler, Michael Chabon, Oscar Hijuelos, Toni Morrison, and Anne Tyler) or people who have entries in the Encyclopedia Britannica longer than 100 sentences (such as Winston Churchill, Albert Einstein, Sigmund Freud, Franklin Roosevelt, Leo Tolstoy, and Queen Victoria) (Kaufman & Beghetto, 2009).

Unlike the sociocultural approach (big-C) assuming that only certain people can be creative, the individual approach looks more at everyday creativity which is seen as central to human survival and must be found in everyone (R. Richards, 2010). From the perspective of individualists, creativity is defined as "a new mental combination that is expressed in the world" (Sawyer, 2011, p.7). Richards (2010) has proposed that the construct of **everyday creativity** can be operationally defined based on two crucial criteria: originality and meaningfulness. Specifically, if a product or an idea wants to be deemed creative, first of all, it has to be novel and rare in a particular reference group. If a similar product has been created, this product should not be considered creative. In addition

Table 1.1: Four Levels of Everyday Creativity. Adapted from Sanders and Stappers (2012).

Level	Motivated By	Purpose	Example
doing	productivity	"getting something done"	organizing my herbs and spices
adopting	appropriation	"making things my own" or "make it fit better"	embellishing a ready-made meal
making	asserting my ability or skill	"make with my own hands"	cooking with a recipe
creating	curiosity	"express my ability"	dreaming up a new dish

to meeting the first criterion, a creative product must be socially meaningful: comprehensive to others and not random or idiosyncratic. Without the second criterion, there would be no way to differentiate eccentric or schizophrenic thoughts from creativity. It should be noted that in little-c and everyday creativity, creative outcomes do not have to be original on a global scale. As Richards noted, "our concern lies mostly with the benefits and possibilities for us personally, as we go through our day, while discovering how experience can be different if we live life more openly and innovatively" (R. E. Richards, 2007, p.5). In the research of design (Sanders & Stappers, 2012), everyday creativity has four levels: doing, adapting, making, and creating (see **Table1.1**).

1.1.2 Four P's of Creativity

In addition to "big-C" and "small-c", another important concept that should be noted here is the four P's of creativity: creative product, creative persons, creative process, and press (Rhodes, 1961; Runco, 2004b). In creativity research, "big-C" or "small-c" determine the magnitude of the creativity that is expected to investigate in a study, while the four P's framework shapes the angles from which the creativity is investigated.

Creative product Creative products do not just mean physical objects (such as machines, appliances, or structures), but also include processes, productions (such as works of arts, musical compositions, etc.), distributed systems, and services. The primary goal of the prior research on the creative product was to understand how creative products were generated (Benton, 1978; Weisberg, 1993; D. Cropley & Cropley, 2010, 2010). Considering that products are usually countable and available for judging, some authors have claimed that investigating products is the most objective approach to understand creativity (Kozbelt, Beghetto, & Runco, 2010). It is worth noting that creative products are not completely separated from the other "P" 's. Instead, creative products reflect the operations of other less observable P's such as motivation, personal properties (creative

persons), or social factors (Kozbelt et al., 2010).

Creative persons In studies on creative persons, the main goal is to characterize individuals who are creative. One of the most widely adopted approaches to investigating individuals is examining their personality. In the prior research, many efforts have been made to investigate the influences of personality on creativity (Prabhu, Sutton, & Sauser, 2008; Beeman & Bowden, 2000; Bowden & Jung-Beeman, 2003; Burch, Pavelis, Hemsley, & Corr, 2006; Dunbar, 1993; Feist, 1998; Fuster, 2002; Perrine & Brodersen, 2005; Reuter et al., 2005; Roberts & Mroczek, 2008; George & Zhou, 2001; Peterson & Pang, 2006; Rubinstein, 2003; Tierney & Farmer, 2002). In Feist (1998)'s functional model, it has been well explained how personality traits (cognitive traits, social traits, and motivational-affective traits) mediate the relationship between brain and creative thought and behavior (see in **Figure 1.1**).

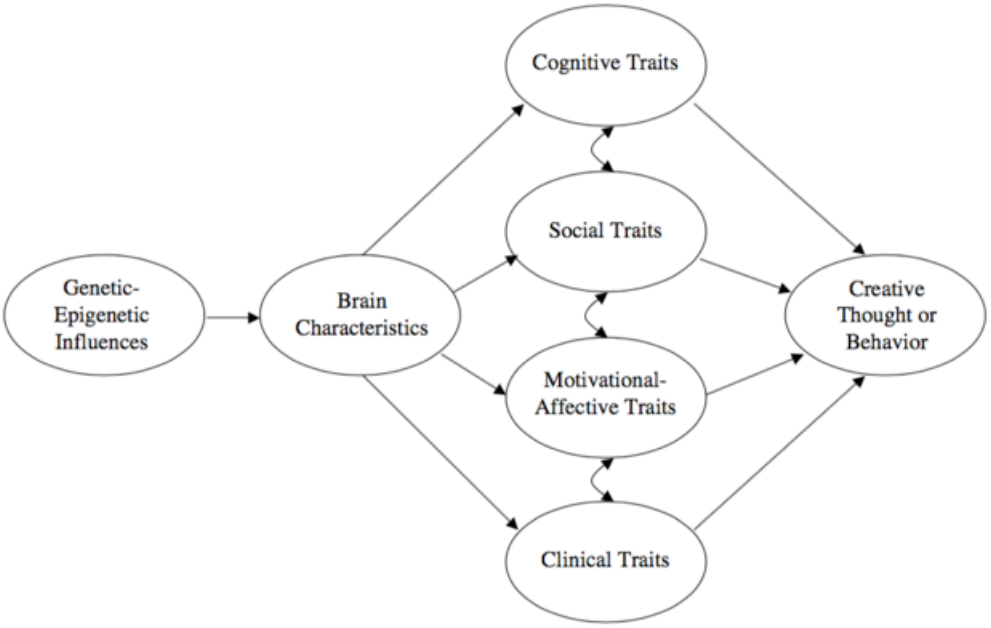

Figure 1.1: Functional model of the creative personality. Adapted from Feist (2010)

Creative processes Different from the research on creative persons that mainly focused on the personality aspect, studies on the creative processes investigate characteristics of mental mechanisms that occur when individuals are involved in creative activities. This approach is based on the broadly agreed-on notion that the existing knowledge is fundamental to creativity at all levels. The qualities

of creative outcomes are influenced by the extent of individuals' knowledge as well as the ways that they access and combine elements of that knowledge (A. J. Cropley, 1999; Feldhusen, 1995, 2002; Mumford & Gustafson, 1988).

Press As aforementioned, four P's of creativity usually interact with each other. The expression of personality, for instance, often depends on the setting or climate where an individual resides. The primary goal of research on the press[1] is to identify places or press factors and to investigate interactions between persons and these environmental factors. The factors that have been examined in previous research includes **national culture** (Hofstede, 2001; Ng, 2001; Lubart, 1999; Woodman, Sawyer, & Griffin, 1993), **external environment** (Isaksen & Treffinger, 2004; Florida, 2002; De Soto, 2000; Puccio & Cabra, 2010), **organization culture** (Olive & Cowling, 1996; Martins & Terblanche, 2003), **organizational structures** (Puccio & Cabra, 2010; Holt, 1987; Martins & Terblanche, 2003), and **climate and culture** (Isaksen, Ekvall, Akkermans, Wilson, & Gaulin, 2007; Ekvall, 1983).

1.1.3 Domains of Creativity

In creativity research, there is a topic that has been debated for more than a decade: Is creativity domain-specific or domain-general? A prevailing view of this topic is that creative people are not creative in a universal way, and they are creative in a particular domain (Csikszentmihalyi, 1988). Please note that in realms of creativity and psychology, domains are defined "a set of symbolic rules and procedures" (Csikszentmihalyi, 1996, p.27). Gelman (1994) considered domain as "a body of knowledge that identifies and interprets a class of phenomena assumed to share certain properties and to be of a distinct and general type". These definitions all agree with that domains include an internal, symbolic language, representations, and operations on these representations (Sawyer, 2011).

In creativity research, many efforts have been made to quantify the domains of creativity. For example, Carson and his colleagues (2005) have identified three types of creativity, such as expressive creativity (visual arts, writing, and humor), performance creativity (dance, drama, and music), and scientific creativity (invention, science, culinary). Similarly, in a study of 241 colleague

[1]Press refers the climate and the environment in which the *Person* works in to create the *Product*.

students (Kaufman & Baer, 2005), nine rated areas of creativity were grouped into three factors: empathy/communication (interpersonal relationships, communication, solving personal problems, and writing); hands-on creativity (arts, crafts, and bodily/physical); and math/science creativity (math and science).

Some authors have argued that creativity should not be assumed either domain-general or domain-specific. Kaufman and Baer (2005; 2004) have proposed a hierarchical model of domains that consists of both domain-general and domain-specific elements. In their model, there are four levels. The basic level is the initial requirements of being creative, which is called **domain general**. For example, intelligence is one of the domain-general factors that impact creative performance across all the domains. In the second level, there are several defined **general thematic areas**. Within each general thematic area, the third level, **domain**, is conceptualized for referring to a more limited range of creative activities. In the general thematic field of Artistic/verbal, for instance, there are several sub-domains such as playwriting, fiction, poetry, and so on. The fourth level is **micro-domains** that refers to more specific tasks.

1.2 Creative Process

1.2.1 Four-stage Models

In 1926, Wallas (1926) created one of the earliest creative process models by examining four different stages in a creative process, such as preparation, incubation, illumination, and verification. In the **preparation stage**, individuals define and set up a problem by consciously drawing on their education, analytical skills, and problem-relevant knowledge. During **incubation stage**, individuals take a break from the problem or work consciously on other problems. It should be noted that although people do not consciously work on the problem in the incubation stage, their brains are continuing working on it unconsciously. It has been understood that many associations or idea combinations occur during this stage. After taking a break, individuals enter the **illumination stage** at which they might feel sudden enlightenment. Hypothetically, the illumination phase is very delicate and is easily disrupted by outside interruptions or the time pressure of generating ideas. Following the illumination stage, the fourth stage is **verification** where individuals evaluate, redefine, and develop their creative ideas.

Wallas' model has a very far-reaching impact on creativity research. Based on this model, many

variants emerged. For example, Amabile (Amabile, 1988) has created a five-stage model by combining Wallas' model and her componential model of creativity. In her componential model, three identified individual characteristics are crucial to creativity: domain-relevant skills, creativity-relevant skills, and task motivation. By incorporating the three components, Amabile's model hypothesizes that a creative process involves five stages (task presentation, preparation, idea generation, idea validation, and assessment), each of which (except Stage 5) is influenced by at least one of the individual components (shown in **Figure 1.2**)

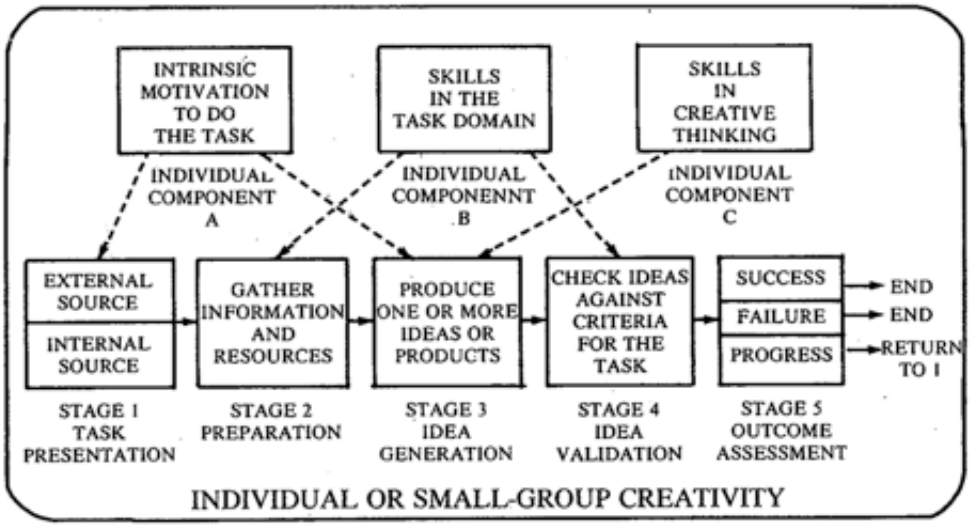

Figure 1.2: Model of individual or small-group creativity. Adapted from Amabile (1988).

Regarding the stages proposed in the models, some authors argued that it was necessary to differentiate a problem-finding or problem-formation stage from the preparatory phase (Getzels & Csikszentmihalyi, 1977; Osborn, 1995). For instance, Isaksen and Treffinger (1985) claimed that "mess finding"[2] should be the first stage in a creative problem-solving process so that the problem can be defined. Moreover, others suggested distinguishing problem finding from problem posing and problem construction. Mumford, Reiter-Palmon, and Redmond (1994) explained that *problem finding* is to notice what is not right, not good, or lacking, *problem posing* is to express a problem, and *problem construction* is to develop a detailed representation of a problem.

[2] A stage during which individuals attempt to identify a problem by probing their interests, experiences, and personal concerns.

Others suggested that a "frustration" stage should be added between the preparation and incubation stages. Goleman, Kaufman, and Ray (1992) and Sapp (1992) explained that when individuals were solving a challenging problem, their brains might reach the limit on dealing with this problem, therefore evoking the incubation stage.

However, individuals might not feel sudden enlightenment after the incubation stage. The "frustration" stage might happen between the incubation and the illumination stages, which could either make individuals accept a less-than-optimal solution or to move in a new direction (Sapp, 1992).

1.2.2 Dynamic Models

Not all scholars agree with Wallas' approach to theorizing the creative process. Some authors criticized that the discrete stages in these four-stage models are too "superficial". The creative process should be conceptualized as a dynamic blend of processes that co-occur recursively (Eindhoven & Vinacke, 1952; Ghiselin, 1963; Goleman et al., 1992). Guilford (1979) advocated that researchers should make more efforts to examine subprocesses that play crucial roles in the creative process. Some subprocesses have been identified in previous research, including problem definition and redefinition, divergent thinking, synthesis, recognition, analysis, and evaluation (Guilford, 1950, 1979).

To address the limitations above, several models have been developed, in which subprocesses of creativity were given additional attention. Finke, Ward, and Smith (1992) have developed the Geneplore model to characterize the development of novel and useful ideas. This model hypothesizes the entire creative process as a cluster of fundamental cognitive processes that collectively influence the probability of a creative outcome in a variety of ways. In this system, novel and useful ideas result from an interplay of a **generative process** and a **exploratory process**. Specifically, the fundamental generative process includes several subprocesses (Smith, 1995), such as retrieving various types of information (eg., specific category exemplars, general knowledge, images, source analogs) and combining concepts and images (Baughman & Mumford, 1995; Finke, 1990; Hampton, 1987; Murphy, 1988). The exploratory process involves such subprocesses as modifying, elaborating, and evaluating the creative potential of the ideas created in generative processes (Finke et al., 1992).

Mumford (1991) proposed a complex model by including eight unique core processes: problem construction, information encoding, category search, the specification of best-fitting categories, combination and reorganization of best-fitting categories, idea evolution, implementation, and

monitoring (show in **Figure 1.3**). Different from all the models aforementioned in this chapter, Mumford's system is constructed at an information-retrieving level, which assumed that information is stored and interpreted in categorical structures that are either procedural or declarative. According to Mumford's model, individuals selectively apply the core processes and cycle between them. Some findings have indicated that some of these processes (eg., problem construction, information encoding, category selection, and category combination) explain the variances in creative performances on problem-solving tasks (Mumford, Baughman, Supinski, & Maher, 1996).

1.2.3 Eight-stage Framework of Creative Process

In more recent work, Sawyer developed an integrated framework based on models proposed in previous studies, including eight stages of the creative process (Sawyer, 2011, p.90):

1. Find and format the problem
2. Acquire knowledge relevant to the problem
3. Gather a broad range of potentially related information
4. Take time off for incubation
5. Generate a large variety of ideas
6. Combine ideas in unexpected ways
7. Select the best ideas, applying relevant criteria
8. Externalize the idea of using materials and representations

Find the problem In this eight-stage framework, the first phase is to find and format the problem. There are several benefits regarding adding this phase to a creative process model. Firstly, problem finding and formatting stage differentiates the creative process from the standard problem-solving process that has been examined in the realm of psychology. Unlike many standard problem-solving tasks that have been extensively studied in psychological studies, creative problem solving typically occurs in an ill-defined situation in which the goals, information, and resources of a task or problem are not specified (Mumford et al., 1991).

Secondly, including problem finding and formatting increase the ecological validity of the model. In the real world – whether in the arts, science, education, or business – many problems people face are rarely well defined.

Lastly, finding and formatting a problem is extremely important for a creativity task. Much creativity research has found that exceptional creativity more often occurs when people work in fields where problems are not specified in advance (Sawyer, 2011; Csikszentmihalyi, 1996; Moore, 1985; van Andel, 1994; Arlin, 1975). In other words, a big part of success is to figure out how to formulate a good question.

Acquire knowledge After the problem is defined and formulated, the second stage is to acquire knowledge related to the problem. At this stage, a person has to become familiar with prior work and has to internalize the symbols and conventions of the domain. Without sufficient deep domain knowledge (not just remembering facts and procedures), it is extremely difficult for a person to combine existing elements and create a new combination. Some work has suggested that it may take as much as ten years of deep involvement in a domain for creative people to make "breakthroughs" (Gardner, 1993; Ericsson, Nandagopal, & Roring, 2005).

Including the second stage in the creative process also reflects a belief held by many researchers – creativity is not based on chance. **Creativity is never based on chance**. In the previous research, Andel argued that "serendipity" could result in a significant discovery (van Andel, 1994). This argument ignores the crucial roles of domain knowledge and learning in creativity. Sawyer's second stage suggests that facilitating learning in a creative process is very important for supporting individuals' creativity.

Gather related information Sawyer's third stage is to gather a broad range of potentially related information. In addition to gaining deep domain knowledge, individuals have to stay constantly aware of the environment and to absorb information from wide a variety of resources (Sawyer, 2011). However, this process is easier said than done due to several reasons.

We may not "see" the irrelevant, or less relevant, information that our brains do not expect to read. It has been found that more than half of the information that we saw has never been sent to the visual cortex of our brain (Sawyer, 2011). Several higher brain regions that are responsible for

thinking and creativity will "tell" visual neurons how to filter the incoming information from our eyes by infusing additional information to our visual cortex (Sawyer, 2011). This finding disputes what we used to believe that visual information from our eyes was processed upwards, through the visual cortex, into the higher brain regions. This result also suggests that without raising users' awareness of the information provided, merely displaying this information to users will not help them gather a broad range of potentially related information. They might just unconsciously ignore it.

Incubation After defining a problem and acquiring all the information for understanding the problem, our brain might need to take a while to search for new and appropriate combinations and creative solutions to the problem (Sawyer, 2011). Several studies had been carried out to explain the effects of incubation on creativity. However, individuals benefit from incubation only if they work hard on a problem at the first three stages, and then continue to work hard on it after incubation (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1994; Sawyer, 2011). Some authors claim that the primary goal of incubation is to give minds a rest so that individuals will be less fixed on incorrect solutions (Seifert et al., 1994; Langley, Simon, Bradshaw, & Zytkow, 1987; Sawyer, 2011).

Generate ideas After the incubation stage, the next step is to generate a large variety of ideas. The quality of this stage is largely influenced by individuals' knowledge and existing concepts. To correct people's belief that "think outside the box" is the best way to generate creative solutions or insights, Sawyer (Sawyer, 2011, p.90) has pointed out "creativity is not about rejecting convention and forgetting what you know". Although "outside" hints might open up a new problem-solving area, people still need relevant expertise and prior knowledge to figure out how to solve the problem in the "new" domain. Gaining more expertise and knowledge from different domains is a helpful way to prepare individuals for more and better insights.

Combine ideas Ideation is not the last step of the creative process. To come up with creative solutions or creative ideas, individuals have to combine the generated ideas unexpectedly. In prior creativity research, some useful strategies have been identified to support idea combinations, such as conceptual combination, metaphor, analogy (Ward, 1994; Ward, Dodds, Saunders, & Sifonis, 2000; Ward, Patterson, & Sifonis, 2004). Sawyer (2011) has pointed out that creative combinations can also derive from structure mapping that allows people to use the complex structure of one concept

to restructure the second concept. Remote combinations[3] have also been shown to result in a more creative work in previous studies (Wisniewski, 1997; Poze, 1983).

Conceptual transfer, which is also known as metaphorical or analogical thinking, has been found to facilitate more emergences of creative ideas as well. Metaphors refer to a type of conceptual combination which is generated by mapping a vehicle concept onto a topic concept (Mumford, Baughman, Maher, Costanza, & Supinski, 1997). In a real-world setting, people might not be aware of source problems that can be used in metaphorical thinking or might have trouble mapping features or information from the source problems to the problem that they seek to solve. Mumford and his colleagues (1997) have found that metaphor instruction contributes to the quality and originality of the creative combination.

Select the best ideas After generating creative insights, people have to select the best ideas by applying some relevant criteria. After all, many creative insights may turn out to be wrong ideas. At this stage, critical thinking, also known as convergent thinking, plays an important role in evaluating creative ideas. By reviewing the literature on idea evaluation, some authors have identified twelve criteria that people use when they evaluate ideas (Blair & Mumford, 2007):

- Risk (high probability of incurring a loss)
- Easy to understand (clear meaning without a lot of ambiguity)
- Original (unusual; novel; unique; uncommon)
- Complete description (provides detailed steps needed to make the idea work)
- Complicated (involves intricate details)
- Consistent with existing social norms (popular and consistent with societal norms)
- High probability of success
- Easy to implement (not difficult to implement)

[3]Combining concepts that are very different and further apart

- Benefit many people
- Produces desired social rewards
- Time and effort required to implement (time and effort required during implementation)
- Complexity of implementation (many steps likely required)

Generally speaking, idea evaluation is a very complicated process, which demands a great amount of cognitive effort. Findings of previous research have indicated that there is a close relationship between generating ideas and evaluating ideas. Creative people are usually good at both generating ideas and evaluating their ideas (Runco, 1994, 2003, 2004a). Unfortunately, in HCI, the importance of supporting idea evaluation has not been given sufficient attention.

Externalize ideas Different from all the models aforementioned in this chapter, Sawyer's model includes a stage of externalizing the idea. Some authors argue that in the real world, particularly in practical domains such as technological invention and entrepreneurship, having a good idea is not enough to become a creative person (Mumford, Baughman, & Sager, 2003; Policastro & Gardner, 1998). "Successful" creative people know how to execute their ideas, predict others' reactions and response to them, identify the necessary resources to make the ideas successful, and to develop plans for implementing the ideas and adjusting their plans (Grant, 2016; Sawyer, 2011; John-Steiner, 2000). Most creative people externalize their idea before it is fully formed, and externalizing an idea often results in other ideas and follow-on ideas. That is why IDEO instructs their designers to "be visual," "get physical," and that "the space remembers" (Boynton & Fischer, 2005; T. A. Kelley, 2001).

1.3 Information Seeking and Search

1.3.1 Information needs

In the area of information science, information needs have been explored from different perspectives (Case, 2007, p. 81-85): "seeking answers" (e.g., Tylor's typology of information needs (Taylor, 1968)), "reducing uncertainty" (e.g., Belkin's hypothesis of the anomalous state of knowledge (Belkin, 1980) and Kuhlthau's ISP stage framework (Kuhlthau, 1991)), and "making sense" (e.g., Dervin's sense-making theory (Dervin, 1998)). Although the research noted above has considered information needs from different perspectives (e.g., subjective vs. objective), much research has investigated

information needs based on three dimensions: "the nature of information", "why people seek", and "what they use it for" (Case, 2007, p. 87). In the context of information retrieval, research has also been conducted to understand how information needs trigger people to search for information using search systems (e.g., Ingwersen's integrated IS&R research framework ("The Integrated IS&R Research Framework", 2005) and Cole's theory of information need for information retrieval (Cole, 2011).

In the area of library science, several efforts have been made to understand the information needs of artists. For example, by interviewing four artists (a sculptor, painter, fiber artist, and metalsmith), Cobbledick (Cobbledick, 1996) found that they had different kinds of information needs (e.g., inspiration, technical information, specific visual information, information about trends and events in the art world, and business information). Inspired by Cobbledick's work, other similar studies have been conducted to investigate the information-seeking behaviors of artists (Van Zijl & Gericke, 2001; Frank, 1999; Cowan, 2004) and art librarians (Layne, 1994; Stam, 1995). Regarding the limitations of the research aforementioned, Cowan (Cowan, 2004) noted that all the studies focused on a particular group of people who worked in academia and who were library users. In this case, the library had been assumed to be the primary place where artists sought information related to their work.

In the area of human-computer interaction (HCI), Sohn, Li, Griswold, and Hollan (Sohn, Li, Griswold, & Hollan, 2008a) developed a taxonomy of 16 broad information needs based on data analyzed from a diary study (see Table 1.2). They identified contextual factors that could influence users' information needs (time, activity, conversation, and location) in the context of mobile search. In another diary study of mobile information needs, Church and Smyth (Church & Smyth, 2009) identified three sub-classes of information needs: local explicit, local implicit, and directions.

In more recent work, Church et al. (Church, Cherubini, & Oliver, 2014) ran a large-scale diary study and developed categories of daily information needs based on the taxonomy proposed by Dearman, Kellar, and Truong (Dearman, Kellar, & Truong, 2008) including persons, organizations, offerings, events, environmental conditions, news&trivia, finding, availability, and guidance.

1.3.2 Search Intents

Search intent refers to the reasons for issuing a specific query ("why people search" (Case, 2007, p. 87)). In prior research, many efforts have been made to understand and categorize users' search

Category	Subcategory
Persons (Information about a specific person, pet or oneself)	1. Well-being 2. Personal queries 3. State of an asset 4. Contact information 5. Appointments & Action items 6. Remember past experiences and events
Establishment & Organizations (Information about a specific business, association, society, civil department, organization, ect.)	1. Properties 2. Operating procedures & Laws 3. Contact information
Offerings (Information about a specific product or service provided by a single establishment or organization)	1. Properties & Quality 2. Pricing 3. Catalogue / Menu
Events (Information about a specific activity, function or event (in particular meetings) of importance that involve people)	1. Logistic & Work agendas 2. Pricing 3. Progress & Outcomes
Environmental Conditions (Conditions of the physical environment that currently or could in the future impact the inquirer)	1. Weather 2. Traffic
News & Trivia (Seeming random, inquisitive thoughts, pop culture references, news items, definitions, foreign language references)	1. Trivia & Pop culture 2. Definitions 3. Foreign language 4. News
Finding (Information required to identify or locate a person, animal, establishment & organization, an offering, an event or an asset as well as information related to distances and timing)	1. Name 2. Locate 3. Distance 4. Time 5. Intangible
Availability (Information required to identify when a person is available; an organization, establishment and event (not meetings) are accessible,and an offering or asset is obtainable)	1. Scheduled 2. Circumstantial
Guidance (Knowledge required to perform an action and inform a decision)	1. instruction 2. Advice, Opinion & Recommendations

Table 1.2: Categories of Information Needs. Adapted from Church et al. (2014)

intent. For instance, Jansen, Booth, and Spink (Jansen, Booth, & Spink, 2007) conducted a large-scale log analysis and identified three types of search intents (Jansen et al., 2007): informational, navigational, and transactional. In more recent research, Mitsui and his colleagues summarized 20 different intentions in searching tasks (Mitsui, Liu, Belkin, & Shah, 2017; Mitsui, Shah, & Belkin, 2016). Different from the aforementioned studies that primarily focus on investigating users' intents behind search queries in *searching tasks*, some research also seeks to examine intents behind people's information needs. For instance, Church and Smyth examined the intents behind the mobile information needs and found that these intents not only involved achieving the goal of finding information about a topic, but also included the goal of managing people's own personal information

(Church & Smyth, 2009).

1.3.3 Information-based Ideation Behavior

Information-based ideation behavior (IBI) is the process in which individuals integrate acquired knowledge with prior knowledge to seek a new understanding or to create new ideas (Bates, 2010). Related to this, Kerne has noted that the finding and using of information can facilitate individuals in generating new ideas that can lead to creativity (Kerne, Smith, Koh, Choi, & Graeber, 2008; Kerne et al., 2014). In prior work, several efforts have been made to understand IBI in specific situations. For example, Makri and Warwick(Makri & Warwick, 2010) examined how architects look for inspiration by seeking and using the information on the Web. They highlighted the importance of supporting architects' information use behaviors, communication behaviors, and the use of multimedia materials (Makri & Warwick, 2010). In a more recent study, Makri and his colleagues developed a framework to describe game designers' "information behavior undertaken specifically for the purpose of generating and developing ideas" (Makri, Hsueh, & Jones, 2019, p.776). In this "purpose-focused" framework, several specific types of information acquisition behavior (e.g., "seeking", "encountering", "monitoring", "examining", "immersing", "unblocking") and use behaviors (e.g., "interpreting", "collecting", "externalizing", "communicating") were identified.

1.3.4 Information Seeking Process

Information seeking and searching have been extensively explored in the fields of information science and information retrieval. Over the past several decades, some theories, models, and frameworks have been proposed to describe, explain, and predict humans' information seeking and searching behaviors in a variety of contexts.

Standard models Considering the activities and strategies in information seeking, Sutcliffe and Ennis (1998) have created a framework to explain and predict users' information seeking process. In this system, there are four main activities in the entire information seeking process, including problem identification, articulating needs, query formulation, and evaluation results. Each of those is assumed to be collectively influenced by users' knowledge of the domain as well as the IR system.

Concerning the strategy component of the model, Sutcliffe and Ennis (1998) claimed that each activity aforementioned was composed of specific strategies that dictated user action that might be either physical or cognitive. Additionally, there are two types of strategies in the model: general

strategies and consultation strategies. **General strategies** refer to plans formed by users in the search process, such as determining the approach in the problem identification phase, deciding when to terminate information searching, and evaluating the usefulness of the found results. When users' knowledge is not enough to solve a problem or to find the information they need, they might adopt **consultation strategies** by consulting an external source of knowledge (like a human expert, or a computer-based information retrieval system).

Similarly, Shneiderman and his colleagues (1997) proposed to use a four-phase model to characterize user behaviors in text searches, including formation (identifying information needs and search goals), action (starting the search), review of results, and refinement. The four phases correspond to the four activities proposed in Sutcliffe and Ennis's framework (1998).

In more recent work, Marchionini and White (2007) have created a model to describe the information seeking process. In their system, there are seven critical components, involving "recognizing a need for information, accepting the challenge to take action to fulfill the need, formulating the problem, expressing the information need in a search system, examination of the results, reformulation of the problem and its expression, and use of the results" (Hearst, 2009, p. 65).

Dynamic model In some standard models of the information-seeking process, it has been hypothesized that information needs are static and the information-seeking process is linear in that users successively refine their queries until they find documents relevant to the original information need (Hearst, 2009, Chapter 3). Bates (1989) has argued the linear process did not represent actual behaviors of information seeking and searching. As people interact with the search system, their information needs might change.

To address this issue, Bates proposed a berry-picking model (1989) by highlighting such claims as (1) searchers' information needs and their queries continuously change as they read and learn from the information encountered through the searching process, and (2) searchers' information needs are satisfied by multiple documents or bits of information that were found along the way. Bates (1989) also noted that the new information encountered generates a new conception of the query by providing people with new ideas and directions to follow.

Stages in ISP	Feelings Common to Each Stage	Thoughts Common to Each Stage	Action Common to Each Stage	Appropriate Task According to Kuhlthau Model
1. Initiation	Uncertainty	General/ Vague	Seeking Background Information	Recognize
2. Selection	Optimism			Identify
3. Exploration	Confusion/ Frustration/ Doubt		Seeking Relevant Information	Investigate
4. Formulation	Clarity	Narrowed/ Clearer		Formulate
5. Collection	Sense of Direction/ Confidence	Increased Interest	Seeking Relevant or Focused Information	Gather
6. Presentation	Relief/ Satisfaction or Dissappointment	Clearer or Focused		Complete

Table 1.3: Six-stage model of information seeking process. Adapted from Kuhlthau (1991)

Information stage models Some efforts have also been made to investigate how the information seeking process develops over periods of time. For example, Kuhlthau (1991) has found that in complex information-seeking tasks, searchers go through different stages concerning their knowledge of the information and their attitudes toward the tasks. Based on findings of her numerous field studies, Kuhlthau (1991) developed a six-stage model of the information-seeking process that incorporated three aspects: the affective, the cognitive, and the physical (see **Figure 1.3)**.

Strategic models Some prior studies have also attempted to explain the information-seeking process regarding a series of strategies. In the context of information search, strategies refer to combinations of tactics utilized to complete information search tasks (Hearst, 2009, Chapter 3). Bates (1979) has claimed that there are two essential tactics in an information-seeking process: (1) monitoring the process of the current search; and (2) weighing the cost and benefits of performing the current action or anticipated actions. Russell and his colleagues (1993) have also carried out a study to model the activity of monitoring tactics in terms of a cost structure analysis. In a more recent study, some authors have identified a possible latent factor structure of the costs of the information-seeking process (Y. Zhang & Gwizdka, 2016). This study suggests that the cost of information seeking is very likely to be associated with two distinct aspects of the search process:

exploration and validation processes.

Extending the cost structure analysis method, Pirolli and Card (1998) developed on information foraging theory that has had an impact on many studies on information seeking. Information foraging theory describes and predicts how users seek, gather, and use online information. In the information foraging theory, searchers have to make tradeoffs between two questions (Ng, 2001): (1) what gain can I expect from specific information (such a Web page)? and (2) what is the likely cost in terms of time and effort of discovering and consuming that information?

1.3.5 Information Search

Exploratory search For the last ten years, different types of searches have been extensively examined. In the fields of information science and information retrieval, exploratory search is defined as "a specification of information seeking, which describes the activity of attempting to obtain information through a combination of querying and collection browsing" (White & Roth, 2009, p .10). Comparing to the standard search (like, fact-finding), White argues that exploratory search behaviors are more likely to be driven by curiosity which includes complex cognitive activities associated with knowledge acquisition and the development of intellectual skills (2009). In exploratory search, users acquire knowledge, internalize it, and then apply the knowledge in new domains (White & Roth, 2009).

Marchionini (2006) has also suggested that learning and investigation are the critical components of the exploratory searches. Based on the theory of Bloom's taxonomy, Marchionini has developed a well-known model that characterizes exploratory search behaviors at an intellectual level (shown in **Figure 1.4**). In this model, users are assumed to engage in multiple types of searches. Some activities may be overlapped. For instance, looking up activities can be embedded in learning or investigating activities.

Focused search Unlike exploratory search, focused search is defined as a process in which "people query the document collection, examine search results and documents in close proximity to search results, and extract relevant information to meet their goals" (White & Roth, 2009, p. 17). The typical activities of focused search include specifying and reformulating queries, examining search results, and extracting information from the results. In a focused search, people are likely to have a clear sense of their information goals and know how to achieve these goals.

To illustrate the relationship between exploratory search and focused search, White has proposed a framework (shown in **Figure 1.5**). White's system assumes that the search process begins with exploratory searching, followed by focused searching. In the exploratory search stage, users might feel uncertain regarding the problems that they intend to solve. The uncertainty is very likely to decrease as the exploratory search process continues. Meanwhile, users' understanding of their problems might change during the exploratory search stage. After users have a clear goal and develop a plan to achieve it, they start focused searching to attain the goal.

Leisure search In addition to exploratory search and focused search, some other types of searches have been considered in recent studies. For example, Wilson and Elsweiler (2010) have proposed a new searching task scenario, called causal-leisure searching, to characterize users who browse information without explicit information need to solve. The authors argue that most of the studies on exploratory search investigate the behaviors of users who have already know their information needs. However, in everyday life, users might be unclear about their goal, technology, or domain of information. Different from task-oriented exploratory search, casual-leisure searching is more likely to be motivated by hedonistic reasons. In Wilson and Elsweiler's work (2010), four characteristics of causal search tasks have been identified:

1. The encountered information is usually "secondary importance to the experience of finding" (2010, p. 3).

2. The success of causal search tasks does not necessarily result from "finding the information being sought" (p. 3).

3. Casual search tasks are more likely to be driven by a specific mood or state.

4. "Causal search tasks are frequently associated with under-defined or absent information needs" (p. 3).

In a more recent study, Ye and Wilson (Ye & Wilson, 2014) have found different patterns regarding users' search behaviors by comparing causal (low importance) sessions and non-causal (high importance) sessions. Specifically, users read more pages in a causal low-importance session than in a non-causal high-importance session. Additionally, their analysis indicated that a casual

low-importance session was more likely to occur in the evening (17 pm - 21 pm), while a non-casual high-important session is prone to be found during the day (8 am - 16 pm).

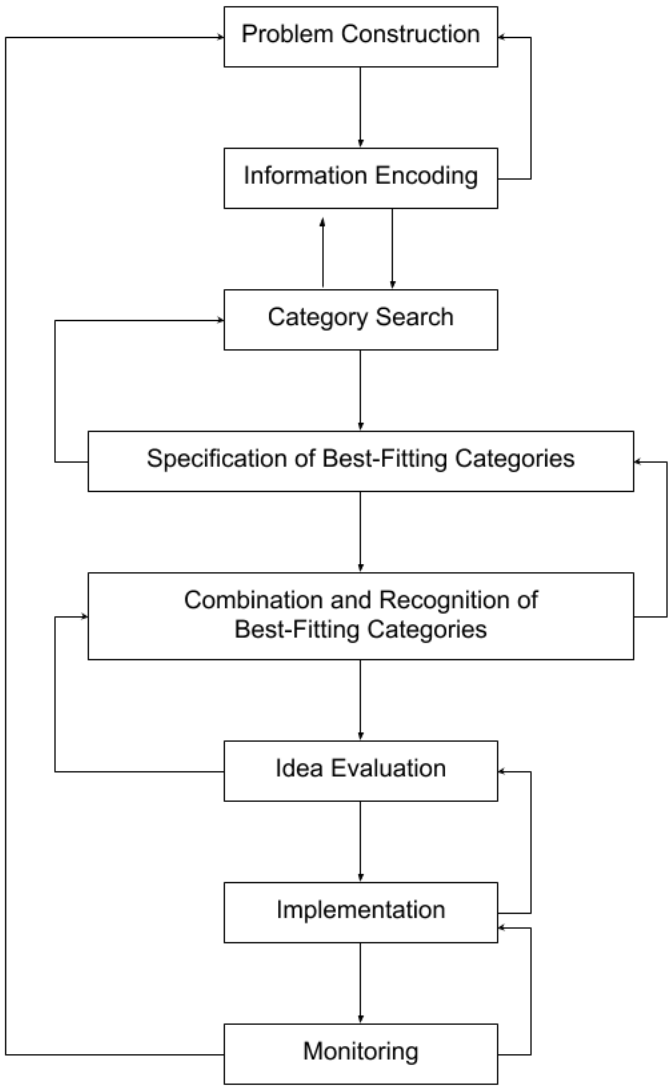

Figure 1.3: Mumford's creative process model. Adapted from Mumford (1991).

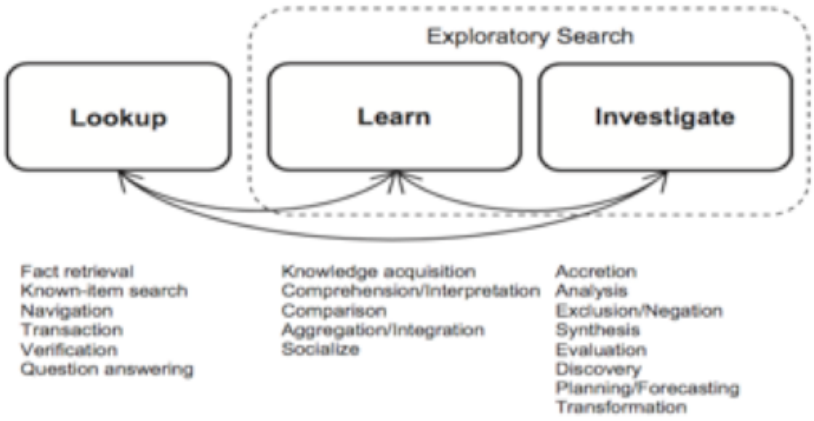

Figure 1.4: Model of exploratory search. Adapted from Marchionini (2006).

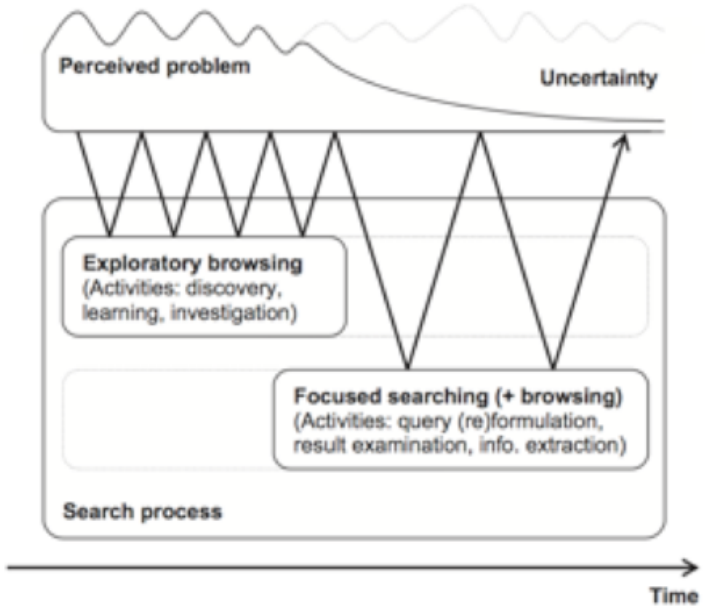

Figure 1.5: Model of search process. Adapted from White (2009).

CHAPTER 2

RELATED WORK

2.1 Information Seeking and Artists

In the area of library and information science, some studies had been conducted to understand artists' information-seeking behaviors in their work. For example, by conducting in-depth interviews with four artists (a sculptor, painter, fiber artists, and metalsmith), Cobbledick (1996) identified five kinds of information needs of artists:

1. Inspiration information
2. Specific visual information
3. Technical information
4. Information about trends and events in the art world; and
5. Business information

To obtain the information they needed in their work, artists made substantial use of libraries, print materials, and interpersonal resources. Similar to Cobbledick's work, some other studies had been conducted in the past 20 years to investigate the information-seeking behaviors of artists (Van Zijl & Gericke, 2001; Frank, 1999) and art librarians (Layne, 1994; Stam, 1995). Regarding the limitations of the research aforementioned, Cowan (Cowan, 2004) noted that all the studies focused on a particular group of people who worked in academia and who were library users. In this case, the library had been assumed to be the primary place where artists sought information related to their work. In more recent research, Medaille (2010) conducted a survey study to explore the information needs and behaviors of practicing theatre artists. In this study, it had been found that theatre artists mainly sought information for six purposes (2010, p. 336):

- "understanding a work's historical, cultural, and critical background;"

- "finding sources of inspiration;"
- "learning about contemporary or historical theatre productions, artists, and events;"
- "learning technical or process information;"
- "finding performance materials;"
- "and furthering career goals".

Medaille has claimed that information seeking and gathering played a critical role in the theater artists' creative processes and creative products. However, this study did not show the details regarding how information seeking could be applied by artists to support their creative process.

In the area of Human-computer interaction, Torrey and his colleagues (2009) conducted an interesting study to understand how people use online search to navigate and find information about craft that involves a physical artifact (for example people working with electronics, cell phones, or other computer-related hardware). In their study, they found users had troubles with keyword search in certain situations (2009, p. 1374), such as

- when users were "not familiar with a technique, a tool, or a material";
- when they could not "effectively constrain their results to meet their goals";
- when they were not able to describe tools, materials, and techniques due to their unfamiliarity of an activity;
- and when they had trouble constraining search results to "a particular aesthetic style, standard for quality, or the scale of their project".

2.2 Serendipitous Search

In the fields of information science, there are few studies carried out to investigate how to support creativity using search engines. However, many efforts have been made to investigate and design ways to deliberately induce serendipity.

"Serendipity" was named by Horace Walpole in 1754 based on the tale of The Three Princes of Serendipity and a camel story (van Andel, 1994). In information science and information retrieval, serendipity has been regarded as a valuable part of creativity, discovery, and innovation. In 2000, Toms (Toms, 2000) proposed four possible approaches to supporting serendipitous retrieval:

1. Enhance chance or "blind luck" by a random information node generator;

2. Enhance chance by providing personalized information that is more likely to meet the user's expectation;

3. Enhance anomalies and exception by using poor similarity measures;

4. Support reasoning by analogy.

Several systems or tools have been developed to support serendipity in web browsing. For instance, Beale (Beale, 2007) developed two systems for supporting users' serendipity by using ambient intelligence, which can incorporate information about the user's actions and environment. The first system was a tool for interactive data exploration and the second was a tool that incorporated a user's web browsing interactions to "look ahead" to find additional pages of possible interest. In a more recent study, Rahman and Wilson (Rahman & Wilson, 2015) have developed a search engine that could match search results with recorded Facebook "Like" data. This novel search system did not re-rank SERP results based on interests specified by participants, but it would highlight results to provide a secondary notion of potential relevance to ranking.

However, some authors have argued that focusing on the "chance encounters" aspect of serendipity will not necessarily result in significant discoveries or support creativity. As André, scraefel, Teevan, and Dumais noted in their paper, "discovery is never by chance" (André, m.c. Schraefel, Teevan, & Dumais, 2009, p. 305). A system could increase users' chances of encountering the "dots" of information that might result in discoveries, but knowing how to connect these dots is a different story. Without sufficient domain knowledge and expertise, it could be challenging for people to synthesize and make use of this encountered information.

It is worth noting that the research on creativity has demonstrated that creativity is never based on luck or chance. Domain knowledge and expertise are fundamental to creativity. A very primary difference between creativity and serendipity is that creativity is one of the psychological traits that humans have, whereas serendipity is a phenomenon that occurs randomly. Moreover, creativity is a process that is trainable, whereas the nature of serendipity makes it untrainable and unpredictable.

2.3 Frameworks of Creativity in Human-computer Interaction

2.3.1 Four-phase Genex Framework

In the realm of HCI, Shneiderman is one of the earliest researchers who advocated the importance of supporting people's creativity by using information technologies. In 1999, Shneiderman advanced to define a four-phase Genex framework based on the creative process model developed by Csikszentmihalyi (1996). In this system, four crucial stages had been proposed to support creativity (Shneiderman et al., 1997):

- **Collect** (learning from previous works stored in digital libraries, the web, etc);
- **Relate** (consulting with peers and mentors at early, middle and late stages);
- **Create** (exploring, composing, evaluating possible solutions);
- **Donate** (disseminating the results and contributing to the digital libraries).

In addition to the four-phase framework, Shneiderman identified several opportunities to use existing tools to support a creative process (Shneiderman, 1999). He suggested to:

- Improve search engines to support exploratory search;
- Use communication tools (Email, listservs, newsgroups, and threaded discussion) to facilitate consulting with peers and mentors;
- Use visualization tools to support the sensemaking of data and processes;
- Support thinking free association by using concept maps or mind maps
- Use office software (e.g., Microsoft Office, Adobe) to support composing artifacts and performances.

Some of these suggestions were adopted. For instance, Microsoft and Google both have launched features to help users explore the designs of their slides. By clicking "design ideas" (in PowerPoint) or "Explore" (in Google Sides), for instance, users will see the suggested templates that are automatically generated based on the structures of the slides that the users created.

2.3.2 Design Principles of Creativity Support Tools

In more recent work, Shneiderman has proposed a set of principles for designing creativity support tools, such as (2007, p. 26):

- "Support exploratory search"
- "Enable collaboration"
- "Provide rich history-keeping"
- "Design with low threshold, high ceilings, and wide walls."

Support exploratory search: Recall what is mentioned in Chapter 2, being aware of previous and related work as well as looking for potentially relevant information is important in creative processes. However, traditional key-word search cannot perfectly meet users' creative needs. As Shneiderman noted, "Google is great for fact finding, and it can be helpful for exploratory search projects, but there is much room for improvement" (2007, p. 26). The author has suggested that designing a faceted search interface, supporting dynamic queries, and providing rich mechanisms for organizing search results are possible approaches to supporting users to explore their related work and to seek for potentially relevant information.

Enable collaboration: The second strategy to support creativity is to facilitate collaboration. Shneiderman (2007) has pointed out that collaboration at an early stage is crucial for users to define a problem and to set up a goal in a creative process. The primary challenge in collaborations at this stage is to handle the rejection, ridicule, and rip-off that many innovators fear (2007). He suggests that supporting users to express their uncertainties in a safe environment is very important for developing trust in collaborations. Additionally, accurate records and safe exchanges are worth being considered in designing creative support tools.

Provide rich history-keeping: Shneiderman (2007) claims that rich history-keeping feature benefits discovers and innovators who use either structured or free-form thinking. The saved tracking information in users' work trails of a task can support users to compare and modify the alternatives in their task (2007). Supporting rich history-keeping is also a possible way to support the idea combination and idea selection stages in a creative process.

Design with low thresholds, high ceilings, and wide walls: The last principle included

in the paper (Shneiderman, 2007) is to consider the difference between experts and novices regarding their user needs. As Shneiderman has noted "(creativity support) tools should be easy for novices to begin using, yet provide ambitious functionality that experts need" (2007, p. 27). Multilayer interface design, for instance, is a possible way to satisfy this principle. Many search engine interfaces have been designed with two (novice and advanced) layers, which "allow novices to begin the first layer and move up as their experience increases and needs require" (Shneiderman, 2007, p. 27).

2.4 Cognitive Theory of Creativity Support Tools

Some other well-developed frameworks are also worth mentioning. Davis and his colleagues (2013) have proposed a novel theory to characterize people's creativity by incorporating and altering three classic theories that have been widely used in the area of HCI. In the new theory, there are three components: embodied creativity, situated creativity, and distributed creativity, which corresponds to embodied cognition, situated cognition, and distributed cognition. To illustrate the relationships between the three components and the three existing theories, before I introduce each component, I will review its counterpart.

2.4.1 Embodied Cognition and Embodied Creativity

In Wilson's seminal paper (2002, p. 626), he has claimed that embodied cognition is different from traditional cognitive theories concerning six distinct aspects, such as:

- "Cognition is situated."
- "Cognition is time pressured."
- "We off-load cognitive work onto the environment."
- "The environment is part of the cognitive system."
- "Cognition is for action"
- "Off-line cognition is body-based"

The six arguments indicate that humans' cognition is not entirely isolated from environments. Instead, it is hinged on their perceptions, actions, and interactions with environments. Inspired by this theory, Davis and his colleagues (2013) create embodied creativity and argue that the cognitive mechanisms that are involved in a creative process are also shaped and facilitated by interactions

with environments. For example, Sketching helps people in different areas (such as artists, designers, engineers) to explore and develop their ideas (Davis et al., 2013).

2.4.2 Situated Cognition and Situated Creativity

Situated cognition was first investigated in the area of educational psychology. Situated cognition theory argues that activities and environments are integral to cognition and learning (Brown, Collins, & Duguid, 1989). In this theory, it is assumed that "knowledge is situated, being in part a product of the activity, context, and culture in which is developed and used" (Brown et al., 1989, p. 1). In the field of Human-computer Interaction, situated cognition is applied to the investigation on how a tool, as an extension of humans' body, is incorporated into their cognition and activities. For example, chopsticks can be considered as an extension of people's hands that help people get food.

Based on the situated cognition theory, Davis and his colleagues develop situated creativity to characterize "a continuum between consciously focusing on a tool and automatically using that tool as an extension of the body based on real-time feedback of the creative task." (2013, p. 21)

2.4.3 Distributed Cognition and Distributed Creativity

Distributed cognition focuses on the organization of cognition by considering interactions between people, objects, and internal and external representations (Hollan, Hutchins, & Kirsh, 2000). The theory of distributed cognition assumes that cognitive processes "may be distributed across the members of a social group", "may involve coordination between internal and external (material or environmental) structure", and "may be distributed through time in such a way that the products of earlier events can transform the nature of later events" (Hollan et al., 2000, p. 176). Crowdsourcing is a good example that shows how distributed cognition theory works: leveraging the wisdom of crowds to complete some complex tasks that are difficult to accomplish by individuals.

Similar to distributed cognition, distributed creativity is used to describe "how the technical and conceptual skills required to create and explore artistic forms rapidly can be offloaded onto CSTs (creativity support tools) to different degrees" (Davis et al., 2013, p. 17).

Davis and his colleagues' work offers a unique way to look at the relationships between creativity, technologies, and environments. Instead of focusing on creative processes, this theory interprets people's creativity in a novel way: the embodied creativity highlights the importance of designing (physical) interactions in creativity support tools (CSTs), the situated creativity implies the significance of improving usability in CSTs, and the distributed creativity suggests the critical role of

collaborations in CSTs.

2.4.4 Framework of Emotions and Creativity

The third framework that will be introduced is regarding impacts of emotions on creativity. As an integral part of creative processes, ideation is influenced by emotions in some previous studies. According to de Rooij's findings (2015), the adaptive change, as one part of emotions, influences the execution of the idea generation process.

In the appraisal theory of emotion, several factors have been found that influence the adaptive changes. For instance, a goal-conductive situation results in positive emotions, while a goal obstruction situation causes negative emotions (Fridja, Ortony, Sonnemans, & Clore, 1992; Osborn, 1995; Lazarus, 1991; Scherer, 2001). It has also been found that goal-relevance is a moderator factor that adjusts the intensity of a resulting emotion based on the relevance of a situation to a person's goals (Kreibig, Gendolla, & Scherer, 2012).

Based on the appraisal theory of emotion, de Rooij and his colleagues (2015) develop a framework to explain the impact of emotions on creative ideation (see in **Figure 2.1**). This framework assumes that generating original ideas (creative ideation) is goal-conductive while generating unoriginal ideas (regular ideation) is goal-obstructive. When individuals generate more original ideas, they are more likely to experience a positive emotion during the ideation stage. The resulting positive emotion hypothetically "drive a positive feedback loop between appraising originality, positive emotion, and generating original ideas" (2015, p. 268).

The main contribution of de Rooij's work is identifying a different way to support people's creativity by manipulating the emotion-creativity link. The findings of their study also demonstrate the importance and necessity of including emotional design when we develop creativity support tools.

2.5 Examples of Creative Support Tools

2.5.1 Support Ideation

There are many different approaches to supporting ideation. For example, in-person brainstorming is one of the most widely used tools to conduct a collaborative idea generation (Osborn, 1995). The traditional approach in brainstorming is to write down as many ideas on post-it notes and then put them on whiteboards or walls. The primary limitation of this technique involves the difficulty to update and curate these physical notes.

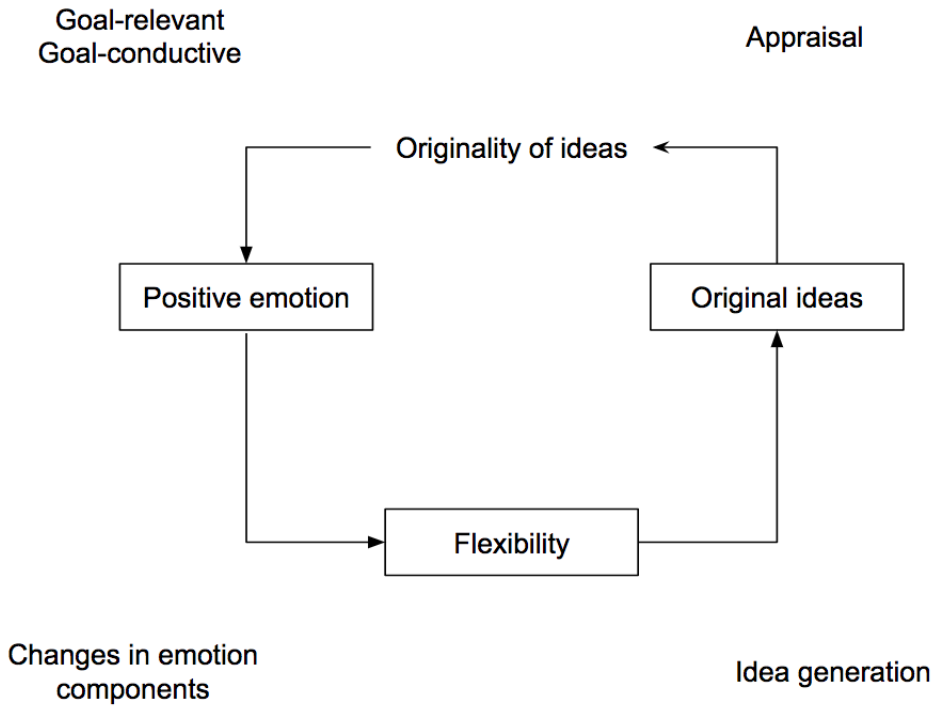

Figure 2.1: Framework of emotion and creativity. Adapted from de Rooij (2015).

To address this issue, different types of digital whiteboards and table-top systems have been developed (Guimbretière, Stone, & Winograd, 2001; Gumienny, Gericke, Wenzel, & Meinel, 2013; Hailpern, Hinterbichler, Leppert, Cook, & Bailey, 2007; Bailin, 2012; Hilliges et al., 2007). Many of the systems attempted to support users with context stimuli which can facilitate sparking novel associations in brainstorming. For instance, ***Idea Expander*** (H.-C. Wang, Cosley, & Fussell, 2010) was able to automatically select and recommend pictorial stimuli based on the group's conversation in a brainstorming. Similarly, ***InspirationWall*** (Andolina, Klouche, Cabral, Ruotsalo, & Jacucci, 2015) could automatically generate keywords to support ideation in a brainstorming session by using speech recognition to monitor users' discussion. In more recent work, Andolina and his colleagues (2017) developed a new system, called ***Crowdboard***, to support smaller crowds to join in-person ideation in synchronous creative sessions.

Another way to support ideation is to leverage distributed creativity. In recent studies, an increasing number of papers have shown their attempts to make use of crowdsourcing in the idea generation phase. The main advantage of utilizing crowdsourcing in ideation is the expediency of collecting a large number of ideas in a short time (Boudreau & Lakhani, 2013). However, everything

comes with a price. Although this technique is usually cheap to get a large number of ideas, the quality of the generated ideas is poor. The low-quality ideas ironically make the idea selection very costly (Buskirk, 2010).

Some studies have been carried out to explore different ways to make the best use of crowdsourcing to support ideations. For example, some authors (Yu, Kittur, & Kraut, 2016) asked non-experts to find distant domains that were potentially useful in identifying some inspiring examples to solve particular problems.

2.5.2 Support Design Process

The design process has been facilitated in a variety of ways. For instance, Dow and his colleagues (2013) used crowdsourcing techniques to improve the stages of an innovation process (such as need-finding, ideating, testing, and pitching) in a classroom. In a different example, some researchers developed a novel tool, called ***CrowdCrit***, which leveraged the power of crowdsourcing to support the generation and visualization of high-quality visual design critique (Luther et al., 2015). In a more recent study, Kim and her colleagues (2017) have created an online creative community, which is called ***Mosaic***, to facilitate the in-process work-sharing process in an artwork. Using this platform, artists could share their reflections on how they improved their creative process. Their findings suggest that sharing the creative process contributes to an excellent collaborative environment that might result in creative growth.

In the domains of visual arts, much research has also been carried on to understand how artists and designers used tools to facilitate their creative processes as well as designing tools to support their creative work. For example, Zhang and Candy (2007) identified five communication models by analyzing the interaction between artists and technologists, including face-to-face mode (used to exchange knowledge, plans, and progression), computer-assisted model (used to demonstrate technical knowledge), interactive-artifact-assisted mode (used to gain feedback and suggestions), proposal-assisted mode (used to present requirements), and drawing-assisted mode (used to explain ideas/solutions not accessible under other modes).

In a similar study, Nakakoji and her colleagues (2002) had conducted a case study to investigate two participants (a visual interaction designer and an expert programmer) who collaboratively developed a series of interactive software tools. In this study, the authors analyzed the uses of representations during the participants' work processes: what the interaction designer and the

programmer collected, represented, interacted-with, and reflected-on in their individually working (IW) phase. The findings of this study indicated that the two stakeholders both saved the generated representations even if they were not useful for the current task. As they denoted in the study, such representations would be re-used as part of their later creative tasks.

To support musicians' work, Wu and Kinns (2017) developed two interactive musical systems for supporting non-musicans' creative process and learning in music-making. Based on the findings of their user study, they summarized several key implications for designing creativity support tools for novices, such as learning the sound, playing live, catalyzing insights, and scaffolding composition.

In the intersection of computational creativity and creativity support tools, some efforts have been made to understand how AI systems could stimulate people's design process and how these systems could be used to support people's creative work. Norton and his colleagues (2011) have developed DARCI (digital Artist communicating intention) system to create original images through a process perceived as creative. As an AI system, DARCI has been trained to evaluate its own created artifacts (images) and modify images to match different adjectives. In another example, by using a computational model of Perceptual logic to learn artists' styles through collaboration, Davis and his colleagues (2011) have developed a computational collaborative art program (PERLOGICART) to support the processes of making artworks.

2.5.3 Support Creative Thinking Using Visualization

Shneiderman has noted the opportunity of using visualization to support human creativity (1999; 2006; 2007). In 1999, Nakakoji and her colleagues (1999) created two systems, IAM-eMMA and EVIDII for supporting designers to find visual images in creative design tasks. Specifically, IAM-eMMA could retrieve images related to a design task and infer the "rationale" behind a designer's choice of the images based on knowledge-based rules that were constructed by other designs. EVIDII could provide designers with some visual representations of the relationships among designers, images, and words by allowing them to associate affective words and images. Based on the findings of their user study, they have suggested that a visual system developed for supporting to design creative tasks needs to rely on "the design knowledge that (1) is contextualized, (2) is respectable and trustful, and (3) enables 'appropriation' of a design task." (1999, p. 170) They have also shown that (1) "computer systems can help designers in their creative design by using visual images"; (2) "delivery of images is helpful as long as the delivery is based on the 'rationale' that the designers consider meaningful";

and (3) "Mechanisms for supporting collective creativity need to be carefully designed so that they will not deprive them of the feeling of having the design activity their own" (1999, p. 171).

To support children's creative thinking, Resnick has developed "kindergarten approach to learning" that supports a "spiraling cycle of Imagine, Create, Play, Share, Reflect, and Back to Imagine" (2007, p. 1). Based on this approach, Resnick and his colleagues have developed a new programming language, called Scratch[1] for helping children develop their creative thinking.

In the research on creativity, it has been found that a high tolerance of ambiguity is associated with creative personalities (Guilford, 1957). Specifically, individuals with a high tolerance for ambiguity are more likely to remain open and to continue working through a complex situation longer. The openness and the prolonged endurance of working in a complex situation may increase these individuals' chances to discover a novel solution (Sternberg & Lubart, 1995; Zenasni, Besançon, & Lubart, 2008).

Inspired by this finding, Dove and Jones (Dove & Jones, 2014) advanced to explore ways of utilizing visualization tools to stimulate creative thinking in collaborative design workshops. In their study, the levels of the ambiguity of the visual coding have been controlled. In the condition with less ambiguous visual encoding (IV1), the visualization interface was designed based on familiar elements, such as bar charts, linear timelines, bubble charts, and area charts, whereas in the condition with more ambiguous visual encoding (IV2), some more abstract elements were included which provide a class of possible interpretations and gave people multiple options for exploration. Their findings indicated that increasing ambiguity in the visualization, which was used by participants to explore and to understand the context of a design problem, had a negative impact on creative performances. The authors also pointed out that there was little evidence indicating that the ordering or learning effects existed in the study. They suggested that individual differences might have an interactive effect on the ambiguity of visual encoding. For example, it was found that the ideas generated by workshop 2's are more novel and appropriate in IV2 condition than in IV1 condition in their study.

In another example, Wei and Hurango (2017) developed a visual schema, ECT (Emotion-Centric Timeline) that could support analysts and designers in their learning and developing an emotional

[1] `https://scratch.mit.edu`

design for games by visualizing the progression of emotion and narrative-driven games. However, this novel visual schema has not been evaluated in the study.

Kerne and his colleagues (2017) created a novel tool that enables users to collect multimedia contents (such as text, images, and videos) during web browsing. The canvas provided by the tool allows users to "think by free association" (Shneiderman, 1999) to discover and interpret the relationships among these collected contents. Moreover, this tool allows users to assemble, shift perspective, sketch, write, and exhibit. These interactions have been found helpful in supporting creative visual thinking in a different study (Lupfer, Kerne, Webb, & Linder, 2016). One of their user studies has shown that the tool's zoomable user interface helps users with creating "multiscale curation space contexts", which "stimulated intensive and extensive curation of their prior work" (Kerne et al., 2017, p. 389). It was also shown that using this tool to teach participants (students) free-form web curation could effectively increase their creative engagement.

2.5.4 Support Feedback

In the creative processes, having high-quality feedback is important for people to evaluate and select ideas. In prior research, some efforts have been made to investigate ways to enhance the positive effects of feedback on creative work. For example, Wu and Bailey (2016) have investigated how two cues of feedback providers (*efforts*: energy that providers invest in writing feedback; *expertise*: the levels of providers' domain knowledge) could influence the perceived quality of feedback. Their study found that the two cues could impact the perceived quality of feedback when the cues were negative. In another example, Yen and her colleagues (2017) ran a crowdsourced experiment to test the effects of combining a reflection activity and reviewing external feedback for an interactive design task. The results of their study suggested that designers' interactive processes could be enhanced by a lightweight, explicit reflection.

Considering that content creators are less receptive to feedback with negative valence, Wu and Bailey (2017) developed a novel technique to address this issue by ordering a set of feedback based on its valence. In their user study, it was found that content creators' affective states and their perception of feedback could be improved by showing them negative feedback last.

To support design work, Xu and his colleagues (2014) created a novel system Voyant that helped designers get perception-oriented feedback on their design from a non-expert crowd. The user studies carried on had shown that the crowd feedback system contributed to the improved design

by prompting deep and cosmetic changes. Additionally, Voyant provided designers an easy way to analyze relations between the crowd's perception of design and the visual elements within it.

2.5.5 Support Embodied Creativity

As aforementioned, our cognitive processes involved in creativity are influenced by our perceptions, actions, and interactions with environments. The free-form web curation tool (Kerne et al., 2017; Lupfer et al., 2016) mentioned above is a good example of demonstrating how well-designed interactions (such as sketching, note-taking, or dragging) could facilitate users' thinking as well as their creative processes.

In another example, researchers designed a physical design tool, called ***Tile Cards***, which included a set of 110 design cards and a workshop technique (Mora, Gianni, & Divitini, 2017). The finding of this study has indicated that Tile Cards help non-experts quickly generate ideas by supporting them to explore the combinations of user interface metaphors, digital services, and physical objects.

More recently, several interesting studies have been conducted to explore novel ways to help users understand their bodies in relation to their creativity. For instance, by using the real-time biofeedback of users' heart rate variability (HRV), Loudon and Zampelis (2017; 2017) developed a novel technique to improve people's level of attention and relaxation that is believed to be associated with creativity. In another study, Feltahm and Loke (2017) used a pressure mediated sound-generating surface to explore kinds of somatic awareness and aesthetic engagement of walking which is argued to be a source of creativity and exploration. Their data analysis detected an awareness of tempo and rhythm during the step cycle that might be linked to internal focus as shifts in attention and bodily organization.

CHAPTER 3

SURVEY STUDY

Note: this chapter is a slightly modified version of a full paper that you had accepted to CHIIR 2019 (Y. Zhang & Capra, 2019).

To the best of our knowledge, very few efforts have been made to investigate how to design search systems for supporting creativity. With this goal in mind, we must first understand what kinds of creative tasks people perform in their life and work, how they conduct the tasks, and what opportunities there are for search systems to support their needs. In this preliminary study, we are particularly interested in understanding people's *everyday creativity*, which R. Richards defines based on two crucial criteria: originality and meaningfulness (R. Richards, 2010). Incorporating these two criteria in the context of information searching, we broadly define *creative tasks* as tasks in which people attempt to use information technology to create something original and meaningful. This definition has an intentionally broad scope, with the "something" being able to refer to both physical and non-physical things (e.g., an idea or a project).

To gain a better understanding of how people use search engines and information tools to support their creative process, we conducted an online survey (N=175) using the Amazon Mechanical Turk (MTurk). Our survey asked participants to think of a time recently when they were trying to create something and went online to look for useful resources or information. We asked participants to type a detailed description of their task, to indicate what computing devices they used as part of the task, what information tools they used, and to indicate which (from a list of) creative process stages (e.g., figuring out goals, creating ideas, combining ideas, etc.) were involved in their task. We also asked about their satisfaction using particular tools to support particular creative process stages.

We grounded our survey questions and analysis in prior research on creativity. One way that creativity has been studied is in terms of different *domains*. We analyzed the participants' responses using a set of everyday creativity domains developed by Jauk, Benedek, and Neubauer (Jauk et al., 2014): visual arts, performing arts, music, literature/writing, arts & crafts, cooking, and science &

engineering.

Creativity is also understood to be a process that involves multiple *stages*. We used a set of creative process stages identified by Sawyer (Sawyer, 2011): find goals, look-up information, explore, create ideas, combine ideas, select ideas, and put ideas into practice (execute).

In this preliminary study, we present the results of our survey and address the following research questions:

- **RQ1: What kinds of creative tasks do people perform in their everyday life and work?** To address this, we analyzed participants' task descriptions and categorized them based on a set of *creativity domains* from prior work (Jauk et al., 2014).
- **RQ2: How are computing devices and information tools used by participants to support their creative tasks?** For devices, we report on participants' use of desktop/PCs, smartphones, tablets, and other devices to support their tasks. For information tools, we report on the use of search engines, images, videos, and social media sites.
- **RQ3: How is information search used as a part of a creative process?** We examine how seven different creative process stages (e.g., find goals, create ideas, combine ideas, etc.) identified from prior work (Sawyer, 2011) were involved in our participants' tasks, and show how different information resources and tools were used to support each stage.
- **RQ4: What are the opportunities for search engines to support the creative process?** We present Bayesian regression models to investigate: how the domain of the task influenced the creative stages involved, how the creative stages influenced the resources/tools used, and how satisfied participants' were using particular tools to support creative stages.

Based on our results, we present a set of implications about how IR systems can better support users engaged in creative tasks.

3.1 Methodology

To explore how people use search engines and online resources to support their everyday creative tasks, we conducted an online survey. In this section, we describe how we recruited our participants and give details about our survey.

3.1.1 Participants and Recruiting

We recruited participants to complete our survey by posting Human Intelligence Tasks (HITs) to the Amazon Mechanical Turk (MTurk) crowdsourcing platform. To encourage a diverse sample, we used several techniques. First, we posted our recruitment HITs in small batches on different days and times across a one week period. Second, when posting different batches, we included different terms in the "keywords" field of the HIT (for keyword list, see **Appendix A.1**). The HIT keywords are often used by MTurk workers to search for HITs to work on, so by using different terms we hoped to attract a more diverse sample of participants who were doing tasks that involved creativity. Each day, we posted five groups, each of which included nine HITs. Each group was posted using a different set of keywords, but the survey itself was identical for all participants.

We posted our HITs with the following requirements for the MTurk workers: (1) location in the United States, (2) HIT approval rate greater than or equal to 95%; and (3) age > 18. We configured MTurk and our survey software (Qualtrics) to prevent participants from taking the survey more than once. Participants who completed the survey and entered a valid completion code into the HIT were paid $1.50 USD through the MTurk platform.

3.1.2 Survey Design

The survey began with a brief demographic questionnaire (e.g., age, gender, education, field of employment). Then participants responded to the main part of the survey – the creative task questionnaire. At the end of the survey, we also included a creative achievement questionnaire that is not analyzed in this study.

Creative task questionnaire: We asked participants to think of a time recently when they were trying to create something and went online to look for useful resources or information. Focused on this task, we asked participants a series of questions (for full text, see **Appendix A.2**):

Q.1: Describe the task – We asked participants to type a written description of the task into a textbox. Also as part of Q.1, we asked participants to categorize the domain(s) of the task they described. To make it easier for participants to identify categories, instead of showing the eight high-level domains identified by Jauk et al. (Jauk et al., 2014), we showed participants a list of 18

more specific categories[1] derived based on previous research (Carson et al., 2005; Kaufman & Baer, 2005; Jauk et al., 2014) as well as from our own pilot testing. Participants were instructed to select all categories that applied to characterize their task.

Q.2: Describe how they approached the task – Using another open-ended question, we asked participants to describe how they approached the task (e.g., how they started, what resources they used, what strategies they used to find information).

Q.3: Indicate computing devices used for the task – To gain insight about what different computing devices were involved, we asked them to indicate if they used any of the following: desktop/PC, smartphone, tablet, smart TV, voice assistant (e.g., Siri, Alexa, Google Home), or other (please specify).

Q.4: Indicate information resources/tools used – We also asked which of the following information resources were used to support their task: search engines, videos, images, social sites (e.g., Pinterest, Instagram, etc.), other (please specify).

Q.5: Creative processes stages – Based on the answers to Q.4, we created a loop in the survey that dynamically asked a set of questions to capture the relationship between each information resource and stages of the creative process outlined by Sawyer (Sawyer, 2011, p.90):

For which of the reasons below did you use *<option selected in Q.4>* in the task (choose all that apply, or not applicable):

- **Find goals**: figure out my goal (what I want to create/design or which problem I want to address/solve)
- **Look up**: look up information relevant to my goal
- **Explore**: explore (gather a broad range of potentially related information) about my goal
- **Create ideas**: create a large variety of ideas that may achieve my goal
- **Combine ideas**: combine some ideas that I have already had

[1]Visual arts, music, dance, sports, education, architectural design, entrepreneurial ventures, creative writing, humor, inventions, scientific inquiry, theater & film, culinary arts, crafts, product design, presentation, report writing, graphic design, and other.

- **Select ideas**: select the best ideas from all the new ideas that I have created
- **Execute**: figure out how to put my ideas into practice to achieve my goal

For example, if in Q.4 a participant chose both search engines and social sites they would see two separate **Q.5** questions, one asking about the reasons for using search engines and another asking about the reasons for using social sites. Throughout the study, we will refer to the creative process stages as: find goals, lookup, explore, create ideas, combine ideas, select ideas, and execute.

Q.6: Satisfaction/experience with information resources for each stage – We embedded a second-level loop in the survey to investigate participants' satisfaction with each information tool used for each creative stage. For example, we asked: "How satisfied were you with using *images* to *create ideas*?" Participants were asked to evaluate a resource/tool only when they reported using it.

3.2 Data Analysis

Qualitative coding: In the survey, we asked participants to select from 18 domains to categorize their creative tasks. We thought that providing a large set of 18 domains would help participants identify relevant categories. However, in some cases, there was variation in how participants interpreted and applied the categories. For our analysis, we decided to re-categorize the data using eight domains we adapted from Jauk et al. (2014, shown in Table 3.1). The two authors independently reviewed participants' responses to Q.1 and Q.2 and assigned one of the eight domains. After this initial round of coding, the Cohen's Kappa for inter-coder agreement was $\kappa = 65.9\%$. After this, the authors independently re-coded the 47 responses they had disagreed on in the first round. The overall inter-coder agreement after the second round was 85.2%. Following Bradley's suggestion (Bradley, Curry, & Devers, 2007), we resolved the remaining 15 cases by discussion and consensus.

Quantitative analyses: Following the call of Tetsuya Sakai (2017) at SIGIR 2017 and Kay, Nelson, and Hekler (2016) at CHI 2016 advocating the use of Bayesian statistics, all the statistical inferences in our study are based on Bayesian inference. In our Bayesian analysis, a No-U-Turn sampler[2] was used; in each model, we ran Stan (http://mc-stan.org/) with six chains, each of which

[2]Different from Markov chain Monte Crlo (MCMC) algorithm that requires researchers to specify two parameters: a step size and a number of steps L, No-U-Turn estimates the number of steps L by using "a recursive algorithm to build a set of likely candidate points that spans a wide swath of the target distribution, stopping automatically when it starts to double back and retrace its steps" (Hoffman & Gelman, 2014, p. 1). Additionally, No-U-Turn algorithm

had 8000 iterations. Details of our Bayesian analysis are provided in Appendix A.3.

Responses and data quality: Based on our MTurk HITs, a total of 175 participants provided responses to our survey (86 female, 86 male, 2 other, 1 no answer). The age ranges of our participants varied broadly: "18-24 years old" (n=20), "25-34 years old" (n=75), "35-44 years old" (n=48), "45-54 years old" (n=19), "55-64 years old" (n=9), and "65-74 years old" (n=3). Most of our participants were employed (n=151, 86%) and came from 22 different fields.

Before we conducted our data analysis, we checked the quality of the survey data. Our manual review showed that all participants provided thoughtful responses to Q.1 and Q.2. The total length of Q.1 and Q.2 ranged from 22 words to 624 words (M = 138.09). Across all the questions, participants spent on average 24.31 minutes completing the survey. Based on our review, participants spent sufficient effort on the survey and we did not omit any responses.

3.3 Results

3.3.1 Descriptive Statistics

Recall that our survey questions asked participants to describe a particular creative task they had done recently and to answer questions about the domain of the task, the devices used, the information resources/tools used, and the creative process stages that were involved. In this section, we present descriptive statistics about the participants' responses to these questions.

Creative task domains: As shown in Table 3.1, in response to Q.1 and Q.2, the everyday creativity tasks that participants described were distributed across the eight domains we examined. The variety and richness of participants' task descriptions was particularly striking and illustrates the complex information seeking that is required to support everyday creative tasks.

Devices used: In Q.3, participants noted the use of (possibly multiple) computing devices in their creative tasks. Desktop/PC was the most frequently used platform (163 of 175 responses, 93%), followed by smartphones (n=70, 40%), and then tablets (n=26, 15%). Devices such as Google Home (n=3) and Smart TVs (n=2) were mentioned by only a few participants. Using Bayesian logistic regression models, we examined whether this distribution differed based on task domain and did not find any notable differences.

uses primal-dual averaging to estimate the step size parameter (Hoffman & Gelman, 2014).

Domains (count)	Task activities (count)
Visual arts (35)	Painting/sculpture (4), Photography design (1), Interior design/renovation (14), Graphic design (10), Character/logo design (5), Architectural design (1).
Perform arts (2)	Making movie/film (2).
Music (5)	Making music (5).
Literature (15)	Nonfiction writing (5), Fiction writing (10).
Arts and Crafts (54)	Making tools (5), Making cards (5), Making furniture (13), Making jewelry (4), Making decoration or gift (11), Clothing (8), Gardening/landscape work (4), Craft other (4).
Cooking (16)	Cooking (16)
Science & engineering (28)	Academic writing (2), Technical problem solving (14), Programming (5), Website development (4), Building a scientific product (3).
Everyday/other (20)	Learning how to do/use something (5), Non-technical problem solving (15).

Table 3.1: Activities and Domains of Creative Tasks

We also investigated different *combinations* of platforms that participants reported using. The most common scenario was that a desktop/PC was the only platform used for a task (n=92, ∼53%). However, scenarios that included combinations of two and three devices were very common, being reported in 74 of the 175 responses (∼42%). The frequencies included: desktop only (92), desktop + smartphone (46), desktop + smartphone + tablet (12), desktop + tablet (8), other combinations (8), smartphone only (7), tablet only (2). These results suggest that task resumption across devices and sessions (Y. Wang, Huang, & White, 2013) is an important part of supporting creative tasks.

Resources/tools used: In Q.4, participants indicated the (possibly multiple) tools and information resources (search engines, images, videos, social sites) they used to accomplish their creative tasks. Figure 3.1 shows how frequently each tool was used for tasks in each domain. Overall, search

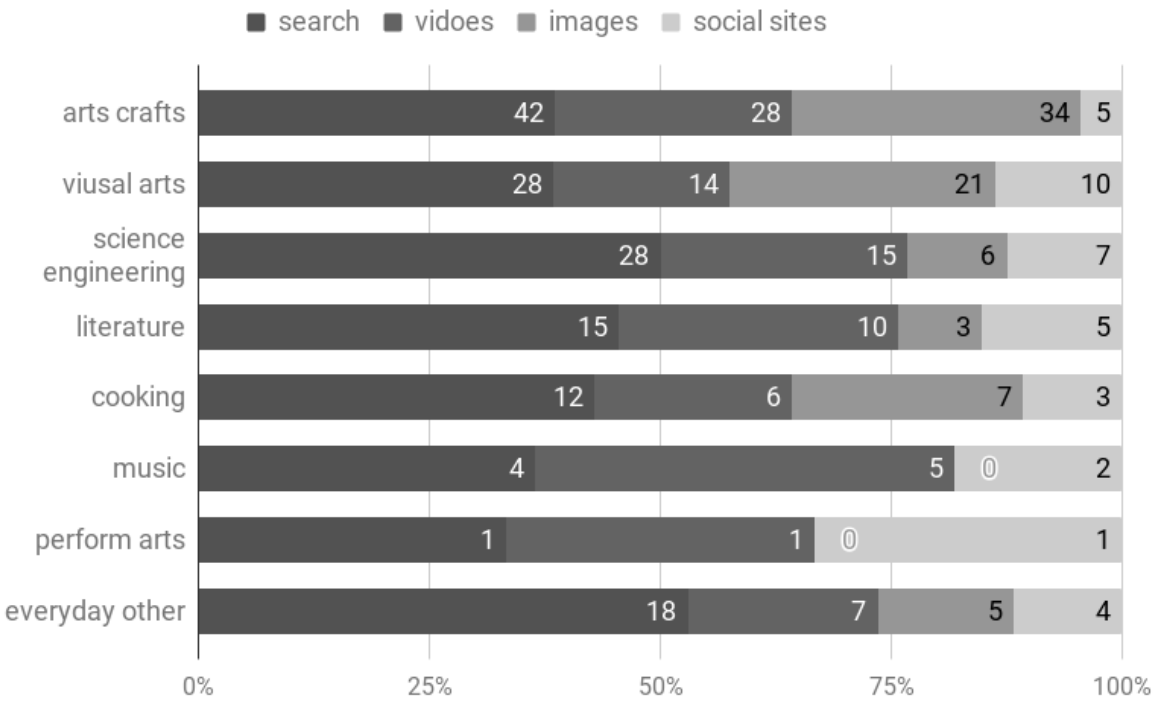

Figure 3.1: Use of Tools across Different Domains.

engines were the most frequently reported tools. Videos were also frequently used, especially in arts & crafts tasks. Images were commonly used in both visual arts and arts & crafts tasks. We also note that tools were used in combinations; approximately 69% of participants used at least two different tools in their creative tasks.[3]

Creative stages involved: Figure 3.2 shows the creative stages that participants reported as being part of their tasks (from Q.5). Among the stages, **look up** (look up information relevant to the goal, (n=151, 86%)) and **explore** (gather a broad of range of potentially related information about the goal, (n=131, 75%)) were the most frequently involved stages in our participants' creative tasks. However, all stages were commonly used, with even the least frequent (**select ideas**) being used by 33% (n=57) of our participants. These results show the complexity of creative tasks and illustrate how they may differ from fact-finding and comparative search tasks. Similar to exploratory

[3]The frequencies of tools reported included: search only (39), search + videos (32), search + images (27), search + videos + images (19), search + videos + social (14), search + videos + images (9), images only (8), videos only (7), videos + images (5), search + social (4), images + social (4), search + images + social (4), social only (2).

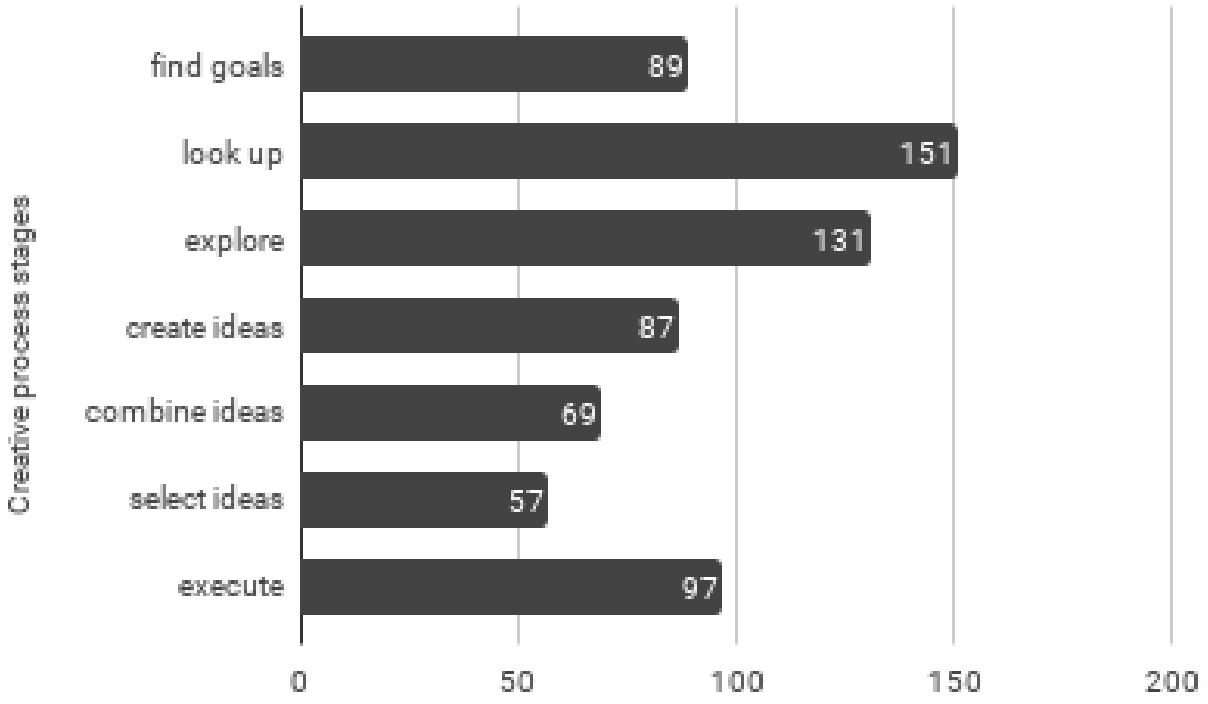

Figure 3.2: Creative Process in Creative Tasks.

search, the creative tasks reported by our participants involved exploration, learning, and synthesis.

Descriptive statistics summary: Our results show that participants reported tasks that involved multiple creative process stages, and that they used multiple information resources/tools and computing devices to support their tasks. These results also suggest that the participants used resources/tools differently when doing tasks in different domains. To explore these potential differences, we conducted a set of regression analyses (Section 3.3.2).

3.3.2 Relationships of Domain, Stage, and Tools

In this section, we explore relationships between the task domains, resources/tools used, and the creative stages. We present analyses of (1) how different task domains involve different creative stages, (2) how different creative stages involve the use of different resources/tools, and (3) users' satisfaction using different resources/tools to support particular stages.

		Model 1: Find goals	Model 2: Look up	Model 3: Explore	Model 4: Create ideas	Model 5: Combine ideas	Model 6: Select ideas	Model 7: Execute
Intercept	**Mode**	-0.02	**2.59***	**1.26***	-0.35	**-0.87***	**-1.17***	0.03
	HDI	[-0.56, 0.44]	**[1.74, 3.82]**	**[0.65, 2.19]**	[-0.91, 0.14]	**[-1.77, -0.23]**	**[-2.07, -0.55]**	[-0.48, 0.52]
Visual Arts	**Mode**	0.04	-0.80	-0.18	**0.85***	0.75	0.47	0.20
	HDI	[-0.74, 0.76]	[-2.26, 0.42]	[-1.31, 0.71]	**[0.09, 1.67]**	[-0.15, 1.76]	[-0.52, 1.44]	[-0.48, 1.01]
Cooking	**Mode**	0.08	-1.01	0.09	-0.08	0.33	0.86	-0.27
	HDI	[-0.92, 1.02]	[-2.68, 0.43]	[-1.13, 1.48]	[-1.15, 0.86]	[-0.78, 1.57]	[-0.19, 2.13]	[-1.24, 0.71]
Arts crafts	**Mode**	0.43	**-1.37***	0.02	**1.10***	0.76	0.47	0.52
	HDI	[-0.25, 1.09]	**[-2.67, -0.29]**	[-1.03, 0.89]	**[0.33, 1.77]**	[-0.06, 1.75]	[-0.32, 1.50]	[-0.19, 1.17]
Literature	**Mode**	-0.85	-0.05	-0.39	0.28	-0.13	-0.18	-0.68
	HDI	[-2.09, 0.10]	[-1.84, 2.21]	[-1.53, 0.99]	[-0.81, 1.22]	[-1.32, 1.17]	[-1.50, 1.13]	[-1.71, 0.37]
Music	**Mode**	0.40	0.61	1.39	-0.95	-1.72	-1.57	-0.24
	HDI	[-1.14, 1.99]	[-1.95, 6.27]	[-0.78, 7.16]	[-2.96, 0.84]	[-7.72, 0.47]	[-7.29, 0.73]	[-2.04, 1.18]
Perform arts	**Mode**	-0.01	0.42	-0.85	0.27	0.62	0.79	-0.11
	HDI	[-2.42, 2.39]	[-2.85, 5.72]	[-3.66, 1.53]	[-2.11, 2.74]	[-1.86, 3.31]	[-1.62, 3.61]	[-2.36, 2.47]
Science & engineering	**Mode**	0.36	-0.13	-0.06	-0.23	0.73	0.22	0.43
	HDI	[-0.47, 1.15]	[-1.63, 1.65]	[-1.13, 1.06]	[-1.07, 0.61]	[-0.20, 1.83]	[-0.74, 1.36]	[-0.37, 1.26]
Everyday/other	**Mode**	-0.29	0.15	**-1.06***	-0.94	-0.36	-0.26	0.17
	HDI	[-1.26, 0.57]	[-1.47, 2.43]	**[-2.24, -0.05]**	[-2.09, 0.08]	[-1.70, 0.73]	[-1.38, 1.02]	[-0.72, 1.08]

Note: * indicates that the null value (zero) is rejected.

Table 3.2: Creative process stages across different domains of creative tasks. Each column shows results for one Bayesian logistic regression model with the eight domains as predictor variables. The predicted outcome is a binary variable that indicates whether the stage was included in the task or not. Cells marked in bold show domains that had an effect in that model. The mode values show the log odds increase/decrease. $\hat{R}$ of all the models were less than 1.1 for all the parameters.

How different task domains involve different creative stages We wanted to investigate how different task domains (e.g., arts & crafts) might involve different creative stages (e.g., create ideas, look up). To investigate this, we developed seven Bayesian logistic regression models (see Equation A.1 in Appendix A.3), one for each creative stage. In each model we included eight dummy variables corresponding to the task domain (e.g., visual arts, cooking, etc.) as predictors. The predicted (binary) outcome for each model was whether that particular stage was included in the task (1) or not (0).

The results of the Bayesian logistic regression analysis are shown in Table 3.2. Each **column** shows results for one of the models. Following Kruschke's (Kruschke, 2014) suggestion, we report the *mode* and 95% *high-density interval (HDI)* for each parameter. In Bayesian regression the *mode* indicates the log odds increase or decrease and the *HDI* provides a function similar to a confidence interval in null hypothesis testing (but must be interpreted differently; see details in **Appendix A.3**). In Bayesian inference, there is no p-value; instead, *to interpret the results, the null value (zero) of a coefficient is rejected if its 95% HDI excludes zero* (Kruschke, 2014). In other words, when the HDI of a coefficient does not include zero, then we have high confidence that this variable has an effect on the model.

In Table 3.2, the domains (e.g., visual arts, cooking, etc.) that had an effect in a model are shown in bold and marked with a "*". For each model (stage), the highlighted domains are the ones that were more predictive of that stage. The estimated potential scale reduction factors ($\hat{R}$) of all the models were less than 1.1 for all the parameters, which indicates that the Bayesian models converged well (Brooks & Gelman, 1998).

Description of the results – Three of the models in Table 3.2 show interesting results (Models 2, 3 and 4). There is evidence that (1) the look-up stage was less likely to be included in arts & crafts tasks (log odd decreased 1.37 in Model 2); (2) the explore stage was less likely be included in everyday/other tasks (log odds decreased 1.06 in Model 3); and the creating ideas stage was more likely to be involved in tasks related to visual arts and arts & crafts (log odds increased 0.85 and 1.10, respectively in Model 4).

		Intercept	Find goals	Look up	Explore	Create ideas	Combine ideas	Select ideas	Execute	σ
Model 1:	**Mode**	0.33	-0.97	**2.03***	0.58	0.68	-0.52	-0.18	0.33	**1.01***
search	**HDI**	[-1.52, 2.24]	[-2.01, 0.09]	**[0.95, 3.30]**	[-0.52, 1.71]	[-0.41, 1.75]	[-1.58, 0.54]	[-1.32, 1.00]	[-0.71, 1.45]	**[0.04, 3.49]**
Model 2:	**Mode**	**-1.30***	0.19	1.06	-0.07	0.14	0.02	-0.43	**0.82***	**0.33***
Videos	**HDI**	**[-2.61, -0.06]**	[-0.50, 0.88]	[-0.02, 2.08]	[-0.89, 0.73]	[-0.59, 0.88]	[-0.67, 0.78]	[-1.23, 0.41]	**[0.09, 1.57]**	**[0.01, 1.63]**
Model 3:	**Mode**	**-1.54***	0.45	**-1.27***	**1.66***	**0.93***	0.36	-0.48	-0.01	**0.84***
Images	**HDI**	**[-3.39, -0.11]**	[-0.27, 1.26]	**[-2.50, -0.24]**	**[0.63, 2.70]**	**[0.12, 1.73]**	[-0.44, 1.18]	[-1.40, 0.39]	[-0.84, 0.85]	**[0.19, 2.59]**
Model 4:	**Mode**	**-2.72***	0.04	0.11	0.37	**0.98***	0.57	0.13	0.36	**0.69***
Social sites	**HDI**	**[-4.56, -1.09]**	[-0.86, 0.90]	[-1.23, 1.63]	[-0.77, 1.51]	**[0.07, 1.98]**	[-0.30, 1.53]	[-0.80, 1.09]	[-0.56, 1.33]	**[0.08, 1.8]**

Note: * indicated the null value (zero) is rejected

Table 3.3: Use of tools to support the creative process. Each row shows results for one Bayesian regression model with the seven creative stages as predictor variables. The predicted outcome is a binary variable that indicates whether the tool was used in the task or not. Cells marked in bold show stages that had an effect in that model. The mode values show the log odds increase/decrease. $\hat{R}$ of all the models were less than 1.1 for all the parameters.

How different creative stages involve the use of different resources/tools To understand whether the creative stages (e.g., find goals, look-up) could be used to predict the use of specific tools, we created four Bayesian random effects logistic regression models, one for each tool (search, videos, images, social sites). In each model, the predicted outcome is a binary variable that indicates whether the particular tool was used in the task. The predictor variables are seven binary variables corresponding to the seven creative stages (e.g., find goals, look-up, etc.). Also in each model, we included random effects to control for the influence of domains on the use of a tool (for instance, images might be generally more likely to be used in the domain of visual arts than in other domains).

The results of the random effects logistic regression models are shown in Table 3.3. In Table 3.3, each **row** shows results for one of the models. According to the results, there is evidence that (1) when participants were doing tasks that included the need to *look-up* relevant information, the log odds of using search engines increased 2.03 in Model 1, whereas the log odds of using images dropped 1.27 in Model 3; (2) when participants tried to *explore* potentially relevant information, the log odds of using images increased 1.66 in Model 3; (3) when participants attempted to create ideas, the log odds of using images and of using social sites increased 0.93 in Model 3 and 0.98 in Model 4, respectively; and (4) when participants attempted to put ideas into practice (*execute*), the log odds of using videos increased 0.82 in Model 2.

These results show that participants used different resources and tools to support different stages of their creative processes and provide practical data about what types of information may be most useful to users during different creative stages. While it is not surprising that users would make use of different tools for different stages, our results show *which* specific tools were the most relevant to specific stages. These findings suggest opportunities for search systems to predict a users' stage and use this information to help show specific types of content (for example, to use queries and interaction history to determine domains and possible stages).

Users' satisfaction of tools to support stages

		Model 1: Find goals	Model 2: Look up	Model 3: Explore	Model 4: Create ideas	Model 5: Combine ideas	Model 6: Select ideas	Model 7: Execute
Intercept	**Mode**	6.53	6.21	6.26	6.05	6.04	6.15	6.34
	HDI	[6.07, 7.04]	[5.87, 6.56]	[5.86, 6.72]	[5.4, 6.74]	[5.57, 6.50]	[5.44, 6.82]	[5.62, 7.1]
Search	**Mode**	0.27	**0.50***	0.15	0.20	0.00	0.17	-0.04
	HDI	[-0.18, 0.77]	**[0.16, 0.79]**	[-0.22, 0.52]	[-0.39, 0.81]	[-0.47, 0.43]	[-0.56, 0.79]	[-0.55, 0.53]
Videos	**Mode**	0.36	0.32	**0.46***	0.61	0.08	0.29	0.46
	HDI	[-0.31, 0.96]	[-0.05, 0.72]	**[0.03, 0.97]**	[0.00, 1.47]	[-0.43, 0.64]	[-0.47, 1.10]	[-0.07, 1.01]
Images	**Mode**	0.38	0.08	0.06	0.47	**0.54***	-0.48	0.18
	HDI	[-0.21, 0.96]	[-0.39, 0.54]	[-0.35, 0.49]	[-0.22, 1.09]	**[0.04, 1.11]**	[-1.29, 0.22]	[-0.43, 0.89]
Social sites	**Mode**	**-0.94***	**-0.84***	**-0.75***	**-1.35***	-0.65	-0.03	-0.69
	HDI	**[-1.74, -0.27]**	**[-1.42, -0.30]**	**[-1.23, -0.17]**	**[-2.34, -0.37]**	[-1.33, 0.03]	[-1.20, 1.31]	[-1.44, 0.10]
σ_υ	**Mode**	**1.01***	**0.91***	**1.31***	**1.38***	**0.64***	**0.95***	**1.73***
	HDI	**[0.23, 1.55]**	**[0.54, 1.3]**	**[0.88, 1.77]**	**[0.88, 2.01]**	**[0.01, 1.09]**	**[0.07, 1.50]**	**[1.22, 2.34]**
σ_ω	**Mode**	0.06	0.05	0.05	**0.09***	0.07	0.11	0.11
	HDI	[0, 0.73]	[0, 0.48]	[0, 0.61]	**[0.01, 1]**	[0, 0.72]	[0, 1.03]	[0, 1.24]

Note: * indicated the null value (zero) is rejected

Table 3.4: Satisfaction with using each tool in different creative process stages. Each column shows results for one Bayesian ordered probit regression model with the four resources/tools as predictor variables. The predicted outcome is an ordinal variable that indicates satisfaction score of the tool. Cells marked in bold show recourses/tools that had an effect in that model. The mode values show the latent variable, μ increase/decrease (see Equations A.3 in Appendix A.3). $\hat{R}$ of all the models were less than 1.1 for all the parameters.

To investigate participants' satisfaction with using each tool for different stages (Q.6), we developed seven Bayesian random effects ordered probit regression models, one for each stage (e.g., find goals, look-up, etc.). Ordered probit regression is recommended when the outcome is ordinal values, especially when the values are not normally distributed (Kruschke, 2014). In each model, the predicted variable is an ordinal variable that indicates the satisfaction score of the tool. The predictors of each model are dummy variables corresponding to the tool that was evaluated. In addition to including the random effects associated with domains, we also included random effects in each model to control the impacts of repeated measurements (different tools could be evaluated by the same participant multiple times).

The results of the ordered probit regression models are shown in Table 3.4. Each **column** shows results for one of the models. The results of the table show that *across different domains and different participants* there is evidence that participants were likely to feel more satisfied with (1) using search engines when they attempted to look up information (Model 2), (2) using videos to explore potentially relevant information (Model 3), and (3) using images to help combine their ideas (Model 5). Based on the results of Model 1, 2, 3, and 4, we also found that people were likely to feel less satisfied with using social sites across several creative process stages (finding goals, look-up, explore, and create ideas). The findings in Table 3.4 also suggest that there were random effects that resulted from the repeated measurements by participants (σ_v). This is not surprising, and indicates expected individual biases in using ratings. Table 3.4 also shows that the random effects associated with the domains of the creative tasks (σ_ω) were very weak, indicating little overall effects of domains on satisfaction with the tools.

3.4 Discussion

In this study, we used well-established psychology-based creativity research to ground definitions of creativity, creative processes, and creative tasks in the context of information search. Our findings provide insights about (1) how people use search engines and information resources to support their everyday creativity tasks, (2) the ways that creative process stages that are involved in their tasks, and (3) how they use different information resources to support different creative stages. In this section, we summarize our findings and discuss implications for future research.

With respect to **RQ1** (What types of tasks?), we found that participants looked for information to support a wide range of creative tasks (see Table 3.1), suggesting many opportunities (and challenges)

for search systems to support everyday creativity. Considering **RQ2** (What computing platforms and information tools were used?), we found that in 42% of the tasks (n=74), combinations of devices were used, illustrating the importance of cross-session and cross-device search task resumption (Y. Wang et al., 2013) in order to support creative tasks. Search engines were frequently used in all the task domains and images played a frequent role in arts & crafts and visual arts tasks. Videos were also commonly used, especially in arts & crafts, science, and literature/writing.

RQ3 addressed the creative process stages involved in our participants' creative tasks. For this question, our results show several interesting findings. First, we found that all of the creative stages we investigated were commonly involved in our participants' tasks. The look-up and explore stages were involved in 86% and 75% of tasks respectively, and even the least common stage (select ideas) was reported in 33% of the tasks. Second, we found that most of our participants' tasks involved *multiple* creative stages – 73% involved at least three different stages.[4] Consistent with prior work on task-based search (Kelly, Arguello, & Capra, 2013), these results indicate that system awareness of the searcher's ongoing task and task-stage is important for search systems to provide stage-appropriate information.

RQ4 considered the relationships between task domain, creative process stages, and information resources/tools. Our Bayesian logistic regression models found that the look-up stage was less likely to be included in arts & crafts tasks, the explore stage was less likely in everyday/other tasks, and that the creating ideas stage was more likely in visual arts and arts & crafts tasks. Second, we examined whether different stages involved the use of different information resources/tools. Our regression models found that when doing tasks that involved the look-up stage, participants were more likely to use search engines and less likely to use images; that the explore stage increased the use of images, and that the creating ideas stage increased the likelihood of using images and social sites. Finally, we examined participants' satisfaction using different tools to support different stages. Our results showed that participants were likely to be more satisfied with using search engines to look-up information, using videos to explore potentially relevant information, and using images to help combine ideas. Participants were less satisfied with using social sites across several

[4]**Number of stages included in a task (number of unique tasks)**: one-stage (18), two-stages (29), three-stages (34), four (29), five (21), six (17), and seven-stages (25).

stages (finding goals, look-up, explore, create ideas). These results illustrate the importance of understanding users' current tasks and task stages, and point to *specific opportunities* for task-aware search systems to assist users with task- and stage-appropriate information in creative tasks.

Creative tasks: In the most of the tasks we analyzed, searching for information was not the ultimate goal, but was part of a process to achieve the creative goals of the task. Several of the creative stages we investigated are components of other types of information seeking tasks (e.g., look-up). However, several stages are more characteristic of creative tasks (e.g., create ideas, combine ideas). In this sense, creative tasks may be viewed as different from "regular" problem solving tasks. For example, Mumford et al. has concluded that creative tasks may differ from standard problem-solving tasks in that they require both convergent and divergent thinking, more cognitive effort, and may involve combining/reorganzing existing knowledge (Mumford et al., 1991). Based on these perspectives, we see opportunities for future IR research to address users' needs in different creative stages (e.g., see work on "create" tasks by Kelly, Arguello, Edwards, and Wu (Kelly et al., 2015)).

3.5 Implications

Below we discuss implications of our work in terms of developing search systems to support creative tasks and future research.

(1) Systems should support cross-device search. In our survey, 47% of the creative tasks were performed across different platforms, suggesting the importance of support for continuing searches across devices. One possible way to support cross-platform creative tasks is to facilitate rich history-keeping and re-finding. Although many search engines currently support cross-platform history features, there are still challenges about how best to support users. For instance, most existing browsers display search history in chronological order, which may make it difficult for users to uncover and make sense of relationships between the information encountered, different creative stages, and keep track of different creative tasks that may be worked on in parallel. Future work should explore approaches to support making use of search history and saved content across different platforms, stages, and projects.

(2) Images and videos play important roles. Our results show that images and videos were an important resource for many creative searches and that they were frequently used in conjunction with search engines. In addition, our results show that the use of resources/tools differs across

creative process stages (Table 3.3). This suggests that creativity can be supported through a better understanding of how to mix and rank different types of vertical content on a search result page based on users' task domain and creative process stage. For instance, in our study, participants were more likely to use videos in the execute stage (figure out how to put my ideas into practice to achieve my goal). One possible reason is that for many people, it is easier to learn procedural knowledge from videos than from textual materials. This is consistent with prior work that has shown that participants searched for videos to learn procedural knowledge about craft techniques and skills (Torrey et al., 2009). Furthermore, research from learning science has suggested that some types of knowledge are easier to learn with certain media formats than others (e.g., introducing complex topics is easier to learn with videos) (Mayer & Moreno, 2003; Berk, 2009). Future research should explore how search engines can better support users to learn different types of knowledge (e.g., declarative vs. procedural knowledge) by optimizing multimedia search results. Our results suggest that users search for information that is not only relevant, but also easy to learn and apply.

(3) There are specific opportunities for task- and stage-aware support. Our results show that for particular creative stages, participants were more likely to use certain tools (e.g., there was increased use of images for the creating ideas stage). In addition, participants had a higher probability of feeling satisfied using certain tools for particular creative stages (e.g., using images to help combine ideas). These findings illustrate opportunities for systems to support users' in particular types of creative tasks and stages.

Interestingly, Table 3.4 (Model 3) shows that no specific tool was preferred for the "explore" stage. Shneiderman suggested that facet-ed search interfaces, dynamic queries, and rich mechanisms for organizing search results are possible approaches to supporting users in exploration stages (Shneiderman, 2007). In addition to supporting the "look up" and "explore" stages, tools could be designed to integrate with search processes to support ideation. For example, Kerne et al. (Kerne et al., 2017) created a novel tool that enables users to collect multimedia content (such as text, images, and videos) as they search.

As our findings suggest, creative tasks are often longitudinal, multi-stage, and multi-session tasks. Search system support for these tasks may benefit not only from traditional methods for session identification, but also from *stage identification* to understand and classify the users' current creative stage. Moreover, information needs may change as users move from one task stage to another. Future

work is needed to better understand the relationships of users' information needs across different creative stages.

CHAPTER 4

DIARY STUDY – METHODOLOGY

4.1 Research Questions

The preliminary research (see **Chapter 3**) provides insights into how people use search engines and other existing information tools to support their everyday creativity tasks, the types of creative process stages that are involved in their tasks, and how they use different tools to support different creative stages (see Table 4.1). However, the survey study presented in Chapter 3 did not provide an in-depth understanding of how the creative processes were carried out, why people used these tools/resources to support their creative stages, where they spend their time in the processes, and at which point they might struggle.

To get a deeper understanding of these questions, in the second part of the dissertation research, I conducted a diary study to understand users' in-situ search behaviors in their creative tasks. Instead of investigating **all** the creative domains and tasks were identified in the survey study, this diary study focused on the design-related projects which broadly refer to the projects in which people try to design solutions to the problems or challenges by using different creative processes (e.g., design thinking). The following research questions were addressed in this diary study:

- **RQ1. What types of information are people searching during their design-related creative projects?** RQ1 looked at information needs from the perspective of "*the nature of information*" (Case, 2007, p. 87). Specifically, in this dissertation, we were interested in understanding the **types of information** that people seek in their design-related projects.
- **RQ2. What intents do people have to use the information they seek in their creative processes?** RQ2 investigated participants' **intent to use** the information that they find. In this question, we sought to gain a deeper understanding of participants' information needs by investigating "what they use it for" (Case, 2007, p. 87) in their projects.
- **RQ3. What kinds of tools/resources do people choose in their creative stages?**

	What we found	What we don't know
Creative tasks	8 domains in creative tasks 26 task activities	- -
Computing Platforms	Many creative tasks (58%) involved using more than one device.	How did they switch between different devices in their tasks?
Tools/resources	Search engines frequently used in all the creative tasks. Participants had strategies to choose and use tools/resources to support each of their creative stages.	- Why did they choose and use certain tools/resources to support their creative stages?
Creative stages	Participants' creative process varied across different creative domains. The user experience of using a particular tool changed across different creative stages.	What were the sequences of participants' creative stages? At which points (stages) do people struggle in their creative process?

Table 4.1: Summary of Survey Study findings

In the preliminary study, it has been found that search engines were frequently used in combination with other resources. In RQ3, several statistical models were developed to investigate participants' strategies to use search engines along with other tools/resources (e.g., video sites, image sites, Q&A sites, and social media sites). Different from the survey study, this diary study provided a longitudinal dataset about participants' strategies to use different resources or tools during the two-week period.

- **RQ4. Why do people choose a certain tool/resource to get information in their creative processes?** To contextualize the results of RQ3, in RQ4, I identified participants' reasons for using certain tools/resources to obtain information in their creative stages.

- **RQ5. What kinds of problems do people encounter when they use the tools/resources to support their creative processes?** In RQ5, I categorized the information-seeking challenges that participants faced when they were working on their design-related projects. Examining this research question helps to identify possible ways to improve search engines to better support people's design-related creative tasks.

4.2 Methods

4.2.1 Diary Studies

Diary studies are known for their high ecological value as they are carried out in situ, which minimizes the effects of observers and participants (Czerwinski, Horvitz, & Wilhite, 2004; Carter

& Mankoff, 2005). As Carter and Mankoff (2005) highlighted, while researchers in laboratory studies can collect objective data about participants' activities, they do not necessarily gain a good understanding of the events that are important to the participants. Regarding the shortcoming of diary studies, the primary issue is that this research method can invoke a "Heinsberg-Style" challenge: for example, journaling might add to the interruption of the flow of daily events (Czerwinski et al., 2004).

Elicitation studies and feedback studies Depending on how diary data are captured and analyzed, diary studies can be divided into two different types: **elicitation studies** and **feedback studies**. In elicitation studies, researchers use media captured by participants in their diaries as prompts for discussion in an interview, whereas in feedback studies participants are asked to answer predesigned questions about events that participants report (Carter & Mankoff, 2005). Carter and Mankoff (2005) have also pointed out that in feedback studies, participants are expected to provide information about an event once they perceive it, while participants in elicitation studies are only asked to capture some aspects of an event when it occurs and provide information about it later in interviews.

Because feedback studies require participants frequently to report events or information that they see, participants could be overburdened easily when the number of events reported is too large (Czerwinski et al., 2004; Carter & Mankoff, 2005). One way to mitigate this problem is to ask participants to rapidly capture prompts that are comparatively easy to record (e.g., photograph). Despite this limitation, it should be noted that comparing to elicitation studies, feedback studies have much higher accuracy due to questions being asked at the time of the event (Czerwinski et al., 2004). Considering that people search many times per day, in the dissertation **I combined the feedback approach and elicitation approach in my study so that the relevant information or event will be close to the point in time where the participant experiences it.**. Specifically, I used the daily forms for recording information at the time of the event and used a retrospective stimulated exit interview to gain additional insights from participants' projects.

Diary entries One of the challenges in designing diary studies is to find a reliable way to record entries. In the field of HCI, many different approaches and tools have been explored to log users'

activities and feedback during diary studies. For instance, some studies had been done by using **voicemail** to log participants' answers to questions every day (Daskalova, Bentley, & Andalibi, 2017). However, as Sohn, Li, Griswold, and Hollan argued in their paper (2008b), voicemail works well for instructed responses, but it can be less effective when researchers attempt to log structured responses.

Spreadsheets and structured forms are efficient tools for participants to log detailed information regarding their activities (Schuler, Grandhi, Mayer, Ricken, & Jones, 2014; MaKay & Watters, 2008). For instance, Schuler et al. (2014) asked participants to use an activities overview sheet to record all the details (such as date, time/duration of the event, event details, and so on) about the coordination of their social group-activities. In another example, Czerwinski et al. (2004) asked participants to use Microsoft Excel spreadsheets to track the process of their daily work tasks and how the tasks switched.

Some researchers also used **text messaging** to record participants' diary entries. For instance, Sohn et al. (2008b) asked participants to compose text messages in a predefined way which could help the participants subsequently answer a set of questions. In the study, participants were asked to send all the messages to text messages or email messages. The sent messages were then reformatted and posted on a website for participants to review later.

As aforementioned, **photographs** have been a widely used tool for recording diary entries due to the ease of use. Clark-Ibáñez (2004) has also pointed out that photos could hold participants' attention to help with structuring interviews. She highlighted that it was critical to allow participants to review and remove photos before elicitation interviews because participants would have vastly different reasons for taking photos that were about similar objects. The review process can help participants provide more accurate information in the interviews.

In the diary study for my dissertation, I asked participants to use structured forms[1] and/or photographs to log detailed information regarding their creative processes.

[1]In the diary study, participants used Microsoft forms to record their entries.

4.2.2 Content Analysis

Qualitative content analysis Content analysis has been widely used to identify patterns, themes, biases, and meanings in a particular body of material, such as written documents, photographs, motion pictures, videotape, and audiotapes (Bogdan & Biklen, 1998; L. Richards & Morse, 2012). There are several characteristics of qualitative content analysis, including (1) the flexibility of utilizing inductive or/and deductive methods in the data analysis, and (2) the ability to extract manifest and latent content meaning. Different from the grounded theory which is widely used to generate a substantive theory in social science, content analysis focuses more on extracting categories from the data (Cho & Lee, 2014). According to Berg's findings, conducting content analysis typically involves the following steps (Berg, 2001, p. 240):

1. Transcribing the data into textual material (e.g., field notes, transcripts, image sequences) that can be "read".

2. Analytically developing codes and/or inductively identifying codes that are affixed to sets of notes or transcript pages.

3. Transforming codes into categorical labels or themes.

4. Sorting materials by using these categories and then identifying similar phrases, patterns, relationships, and commonalities or disparities.

5. Examining sorted materials to isolate meaningful patterns and processes.

6. Considering identified patterns in light of previous research and theories, and a small set of generalizations is established.

Quantitative content analysis Depending on the degree of analysis, content analysis can be qualitative, quantitative, or a combination of both. Quantitative content analysis frequently involves counting the textual elements and providing a means for identifying, organizing, indexing, and retrieving data. However, some authors have criticized that heavy quantitative content analysis might exclude all the contextual accounts of information that are not in the form of numbers. As Berg and Lune have emphasized, it is important to combine both approaches in content analysis: "the descriptions of quantitative analysis show how researchers can create a series of tally sheets to

determine specific frequencies of relevant categories" and "the references to qualitative analysis show how researchers can examine ideological mind-sets, themes, topics, symbols, and similar phenomena, while grounding such examinations in the data" (2001, p.355).

Units and categories One crucial step in content analysis is to decide what to examine and count. The units of analysis include different levels, such as words or terms, themes, paragraphs, items, concepts, and semantics (Berg, 2001). In content analysis, categories can be developed and determined inductively, deductively, or by a combination of both. In an inductive approach, the dimensions or themes are derived from the data (documents), whereas in a deductive approach, a categorical scheme is usually suggested by a theoretical perspective and assessed by the data (Berg, 2001).

Open coding Open coding is widely used in content analysis. The primary purpose of open coding is to identify meanings that exist in the text or that are supported by it (Selltiz, Wrightsman, & Cook, 1976). It is advised to conduct open coding based on four basic guidelines (2001, p.366):

- "Ask the data a specific and consistent set of questions": researchers have to make sure that data is pertinent to the original objective of the research study.
- "Analyze the data minutely": open coding is just an initial coding procedure, which is used to include many categories, incidents, and interactions. When researchers eventually saturate the document with repetitious codes, it is time to stop the open-coding process.
- "Frequently interrupt the coding to write a theoretical note".
- "Never assume the analytic relevance of any traditional variable such as age, sex, social class, and so forth until the data show it to be relevant": these variables should not prohibit researchers from intentionally using certain variables deductively.

4.2.3 Bayesian Analysis

Bayesian basics Bayesian Analysis is based on the famous Bayes'rule:

$$f(\theta|x) = \frac{f(x|\theta)f(\theta)}{f(x)} \tag{4.1}$$

In the equation 4.1, $f(x|\theta)$ is the **likelihood** of data x given a parameter θ, which maps each conjecture "onto the relative number of ways the data could occur, given that possibility" (McElreath, 2018, p.33). $f(\theta)$ is the **prior** distribution of a parameter (the initial set of plausibilities). $f(\theta|x)$ is the **posterior distribution** of θ having observed x.

The most critical part of performing the Bayesian analysis is to specify priors. In the literature, priors can be specified in certain ways. If a previous estimate exists (from prior similar studies), the existing estimate can be used as a prior. Otherwise, flat prior (e.g., uniform prior) is commonly used as a weakly informative prior, which is used to keep from inferring strong associations between variables (McElreath, 2018; Kruschke, 2014). A. Gelman, Jakulin, Pittau, and Su (2008) have also suggested using Cauchy distributions as the default **weakly informative default priors** for intercept and coefficients in logistic regression models.

Applications of bayesian analysis in user research In the previous research, Sakai (2017) and Kay et al. (2016) have provided thorough explanations why the Bayesian approach is superior to a frequentist approach and why people should consider using the Bayesian approach in IR evaluation research and user studies. Particularly, as Kay et al. (2016, p. 4522) summarized, Bayesian techniques can benefit user studies in certain ways:

- "allows more precise comparison of novel conditions against known conditions"
- "draws more reasonable conclusions from small-n studies"
- "shift the conversation from ***Does it work?*** to ***How strong is the effect?***, ***How confident are we in this estimate?***, and ***Should we care?***"

In addition to the advantages above, it has been shown that Bayesian inference can address issues regarding sampling intentions that are likely to be found in user studies (Kruschke, 2014). For example, in this proposed dissertation study, I collected data in two weeks. When p values are computed, however, it is theoretically assumed that researchers did not intend to fix the duration of collecting data (Kruschke, 2014). In other words, p values might be different as the sampling intention changes (Kruschke, 2014). Unlike the frequentist inference, Bayesian analysis does not have these issues because "the Bayesian interpretation of data does not depend on the covert sampling

and testing intentions of the data collector" and the "likelihood function captures everything we assume to influence the data" (Kruschke, 2014, p. 314).

Information to collect	Questions in Screening Questionnaire	Criteria
Project type	Q.2. Please briefly describe the creative project that you will be working on. Q.3. Please select the area that can best describe your project. Q.6. What is the context for this creative project (e.g., work, school, personal hobby)?	Design-related
Creativity level of the project	Q.4. Please select the option that can best describe your motivation to do the project. Q.5. Please indicate which following activities that you might include in your project. Q.8. Have you done similar projects before? If so, please briefly explain your prior experience.	Creating or making level
Project timeline	Q.1. What is the timeline for the project?	2 - 3 weeks
Tools and devices	Q.7. How will the project involve finding and using information or resources on the Internet to support the goals of the project? Q.9. Please select all the tools that you will need to use in the project. Q.10. Briefly describe any information resources, search engines, databases, or social media/networks that you might use to get information that you will need for this project. Q.11. Please select all the platforms that you might use in your project.	Use search engines

Table 4.2: Information Collected from Screening Questionnaire

4.3 Study Design

4.3.1 Participant Recruitment

For the diary study in this dissertation research, participants were recruited from the University of North Carolina at Chapel Hill (UNC) who were planning to work on design-related creative projects in the near future. The recruitment process included two parts: a screening questionnaire and a screening interview. Firstly, we sent out an invitation email to UNC students via UNC email lists (see the email template in **Appendix B**). Students were asked to fill out a screening questionnaire (which was attached to the email) if they agreed to:

- Be available to meet on campus during May 2019;
- Use Firefox when working on the project;
- Share their browser history when working on the project;
- Work on the project at least three days per week for two weeks.

Screening questionnaire The screening questionnaire link was open from April 23 to May 23, 2019. In total, 33 students submitted responses. In the screening questionnaire, questions were

asked to decide whether a participant should be invited to the diary study (see in **Table 4.2**). Each response was evaluated by two researchers (my advisor and I) using the following criteria:

- **Whether the participant is familiar with creative processes** (e.g., does this participant know about design thinking?);
- **Creative stages involved in the task**. The task should include the **ideation process** (create ideas or/and combine ideas) and the **test process** (evaluate ideas or/and execute stage).
- **Flexibility of the project** (e.g., is this project NOT a school project or an assignment that has to meet certain requirements);
- **Tools or devices that would be used in the project** (e.g., will the participant need to search for information as part of the project?).

Screening interviews After the initial evaluation, 16 students were invited to participate in screening interviews. Each screening interview session lasted 15-20 minutes. During each interview session, three questions were asked (shown in **Table 4.3**) to confirm that these participants' projects could meet these criteria listed above. Based on candidates' interview responses and their answers to the open-ended questions, my advisor and I discussed and selected 15 participants for participating in the diary study.

Questions	Intentions
Would you please describe what you will be working on this project?	Understand project, its timeline/deadline, and requirements.
Would you please describe your plan to do this project?	Check whether this project would involve ideation and evaluation processes.
Would you please briefly describe the tools and devices that you will use in the projec?	Make sure that the participant would use search engines in the project.

Table 4.3: Questions designed for screening interview

4.3.2 Diary Study Design

The diary study itself included three parts: 1) an introductory interview, 2) the two-week diary period, and 3) an in-depth interview. The interview stages for each participant were conducted individually.

Diary study setup

Before each introductory interview, a diary study toolkit was set up for each participant, including:

- A **Firefox account** to be used only for the diary study;
- A link to a **useful information form** to be used to record any time when a participant find useful information that helps the project move forward;
- A link to a **trouble form** to be used to record any time that the participant runs into problems, obstacles, or frustrations about finding information related to the project;
- A link to a **daily review form** to be completed at the end of each day the participant work on the project;
- A link to a **Frequently Asked Questions document** to be used to resolve some common questions that the participant might encounter during the diary study;
- **Written instructions** about how to log into the Firefox account in Firefox browsers.

To protect participants' privacy, each participant was asked to use a separate Firefox account provided as part of the study when he or she was working on a project. Each account was registered with a shared UNC Email address established for use by the researchers in this study. Each participant was assigned their own Firefox account that only they and the two researchers could access.

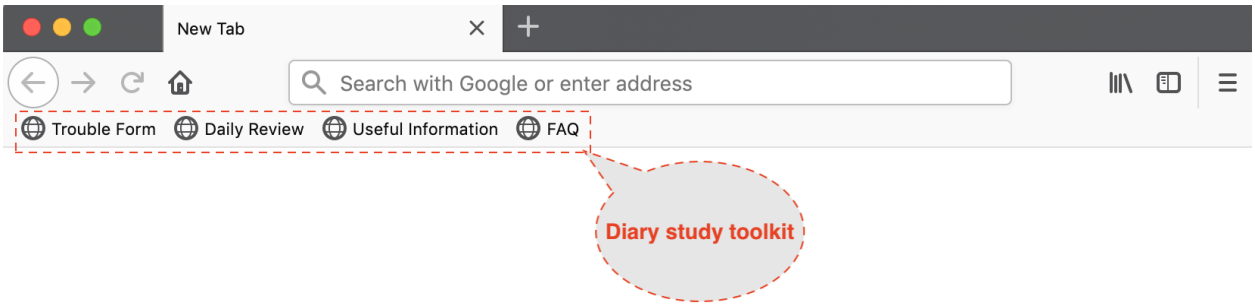

Figure 4.1: Diary Study Toolkit in Firefox Browser

Introductory interviews

The introductory interview was conducted in person at our lab in Manning Hall and lasted 30-45 minutes. The primary goals included:

- Asking participants to walkthrough each questionnaire/form to make sure that they understand each question;
- Asking about their availability for answering the daily review questionnaires; we tried to customize the time to send out an email to each participant.
- Helping them understand how their work is awarded in the study;
- Showing participants how to into the assigned Firefox account in their Firefox browsers;
- Making sure that they know what they need to complete in the entire diary study.

Diary study workflow

Each diary study session started in one day after the introductory interview. Please note that participants started their two-week period at different times that were worked out in coordination with the investigator to ensure they would be actively be working on the project and be able to complete diary entries during the period. During the diary study session (two-week period), participants were asked to log individual entries and provide a daily review (see the workflow in **Figure 4.2**).

In the diary studies, participants had to work at least six days across the two-week period. If participants worked on the project on a specific day of the two weeks, they were asked to fill out (1) the ***useful information form*** any time that they found information that helped move their project forward, and (2) the ***trouble form*** any time that they ran into a problem, obstacle, or frustration about finding information related to their projects.

Specifically, in the ***useful information Form*** (see full text in **Appendix D.1**), participants were asked to record:

- URL of the information;
- Their creative stage when they found the information (multiple choices);

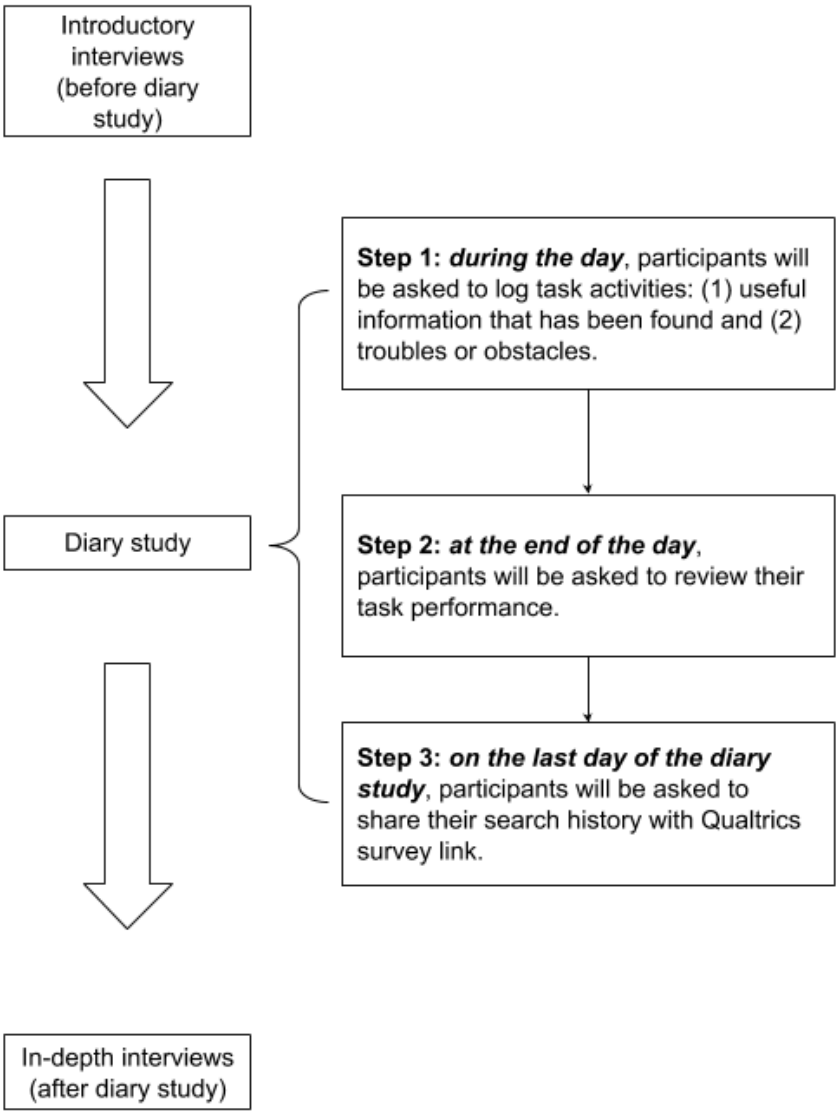

Figure 4.2: Diary study workflow

- The information resource that they used to find the information (multiple choices);
- The platform that they used to find the information (multiple choices);
- Why this information was helpful in the project (open response);
- How satisfied they were with using this information resource that they reported (multiple choices).

In the ***trouble form*** (see full text in **D.2**), participants were asked to record:

- Creative stage(s) when they encountered a problem/obstacle (multiple choices);
- To describe the problem they encountered (open response);
- How they worked around the problem, if they figured out how to solve the problem (open response);
- The platform that they were using when they encountered a problem/obstacle or felt frustrated (multiple choices);
- Information resource that they were using when they encountered a problem/obstacle or felt frustrated (multiple choices);
- How satisfied they were with using this information resource that they reported, if applicable (multiple choices).

Please note participants could report "No problem to report" in the trouble form if they did not encounter a problem, obstacle, or frustration about finding information related to their projects during the entire day.

The primary reason for asking participants to log this information was to get a better understanding of the contexts of participants' project activities and their information needs.

In the ***daily review form***, participants were asked fill out a questionnaire hosted by Qualtrics (See full text in **Appendix E**). In this questionnaire, at the end of each day they worked on their project, participants were asked to provide the following information about the work they had done on their project today:

- What they had done for their project today (open response).
- All the platforms that were used to look for information (multiple choices);
- All the creative stages they engaged (multiple choices);
- All the tools that were used to support each creative stage they engaged (multiple choices);
- How specific tool(s) were used to support a certain creative stage (open response);
- If they did not use search engines, reasons for not using search engines to support a certain activity/creative stage (open response);
- All the app(s) that were used to switch between different devices (multiple choices);
- Reasons for using a specific tool or app to support switching between different devices if applicable (open response);
- The biggest technical and nontechnical challenges they encountered during their work on the project today (open response);
- How the information they found before [today] helps what they did [today] and why (open response);
- How they saved, organized, or preserved what they found for the possible use in feature (open response);
- How they will use the information that they found [today] in the future work that they will do next time (open response).

The diary review questionnaire was designed to capture the information that might be missing in the individual entries (e.g., how people switched their devices during the project). On the last day of the diary study, participants were asked to export their browser history[2] and share the history file by uploading it to the researcher using a UNC Qualtrics form.

[2]Firefox history is stored in the places.sqlite file which can be located and exported by following the instructions from: https://support.mozilla.org/en-US/kb/profiles-where-firefox-stores-user-data. A guide was sent to participants to help them export their browser history.

In-depth interviews An in-depth interview was scheduled 1-2 workdays after the diary study session. Retrospective methods (Russell & Chi, 2014) were used to inquire about participants' behaviors in the diary study. Each in-depth interview session lasted between 90 to 120 minutes. Prior to the interview, queries, titles of web pages, and URLs were extracted from the browser history. During the in-depth interview, we reviewed the query history with each of the participants. The titles of the web pages they clicked on were also shown to help them recall their behaviors in their projects. Additional details about the pre-processing and interview steps are given below.

Browser history data prepossessing: before the in-depth interview, the browser history data was analyzed and prepossessed in the following steps:

1. Slice the entire dataset by days (S_1, S_2, ... ,S_n)
2. Within each subdataset, S_i (i = 1, 2, 3, ..., n),
   - extract all the queries (q_{i1}, q_{i2}, ... ,q_{ij});
     - for a query, q_{ik}, extract all the webpages[3] recorded by the browser between issuing q_{ik} and $q_{i(k+1)}$: D_{ik} (k = 1, .2, ..., j);
     - Upload the q_{ik} and D_{ik} to a JSON file: J_{ik};
3. Group all the individual JSON files

Diary study data preprocessing: the participant's diary study data were extracted and grouped by days. The following information was shown to participants during the interview session:

- The creative stages indicated by the participant (Q.2 in **Appendix E**);
- The tools that the participant used to support each stage (Q.3 in **Appendix E**);
- The challenges reported by the participant‘ (Q.6 **Appendix E**);
- The participant's notes about what they accomplished for the project each day (Q.1 **Appendix E**).

[3]Each webpage data include a title and a URL.

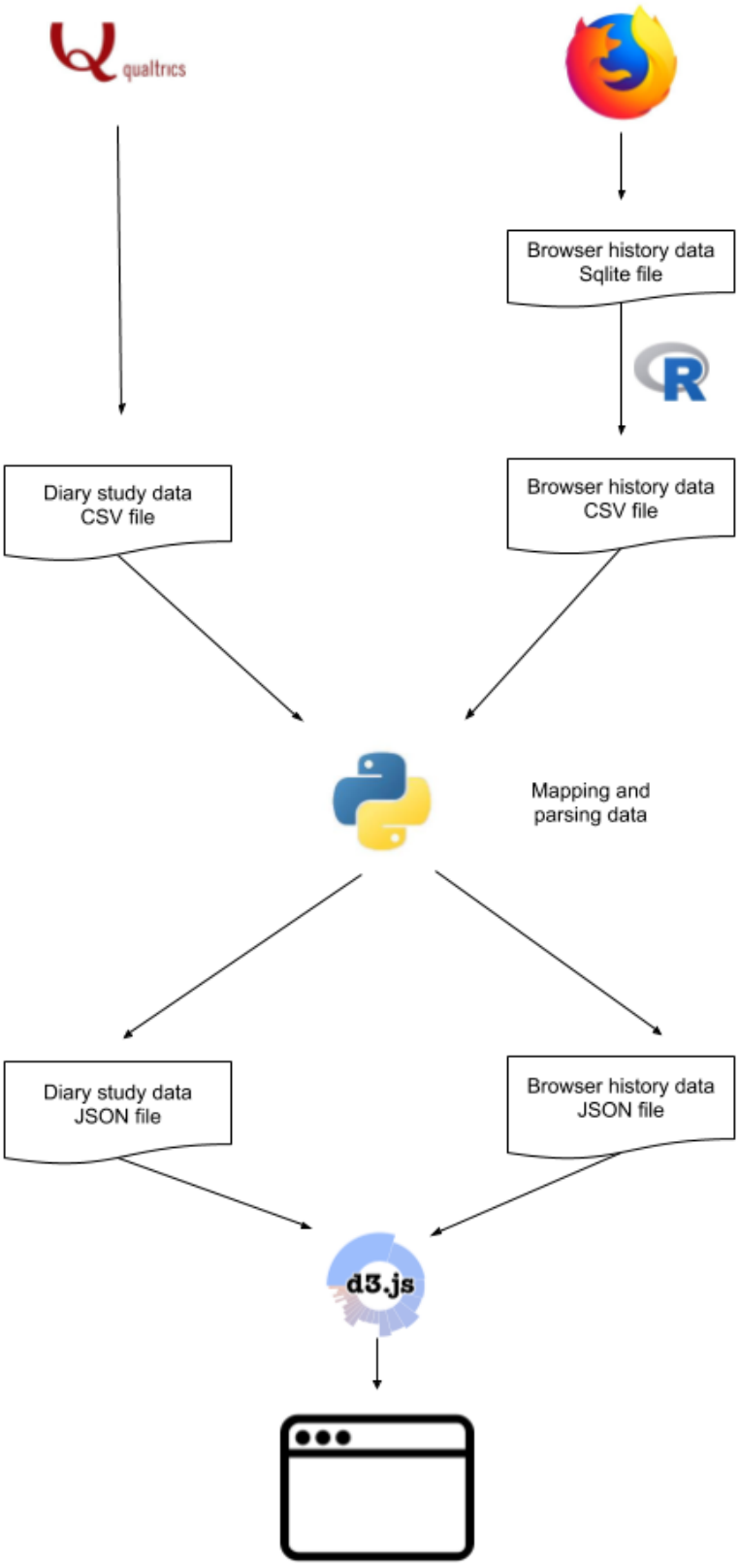

Figure 4.3: Pipeline of Processing Diary and Log Data

The extracted diary study data (summaries) were stored in a JSON file. The data extraction and mapping processes were being handled by using Python and R scripts (see the pipeline in **Figure 4.3**). A tool was designed to support participants to review the log data and diary study data in the interview (see the interface in **Figure 4.4**).

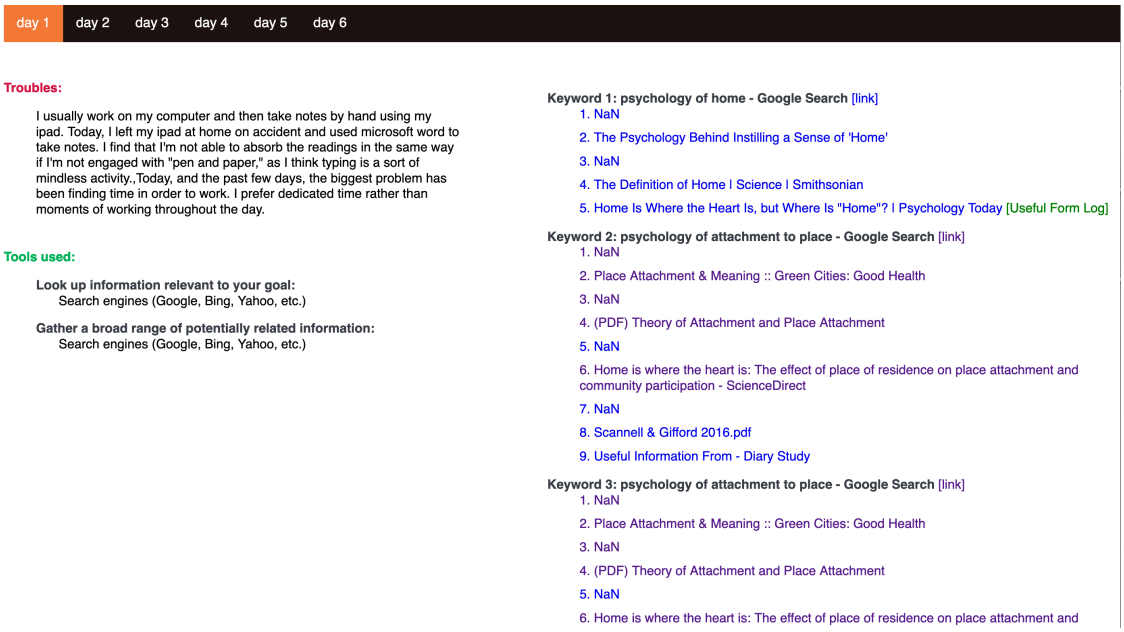

Figure 4.4: Interface of Visualization Tool

To avoid the *false memories effect*, I followed Russell and Chi's suggestions to avoid (1) "cueing the participant to pay special attention to the behaviors that are the focus of the study", (2) asking "value statement questions", and (3) "asking for global affective responses from experience in the past" (2014, p. 389). Specifically, in the interviews, I asked the following questions:

- Q.1.1. Would you please use these keywords and the webpages you clicked to show me what you did in your project during Day N? If you did not remember that you searched using a keyword, that is totally fine. We can skip that keyword.
- Q.1.2. While you were searching these keywords, what kinds of information did you look for?
- Q.1.3. Did you find any information that you need If not, why?
- Q.1.4. Here are the activities/creative stages that you reported in your diary data; now thinking about your creative stages, would you please group these keywords based on the stages that

you were at when you search each of them? You can use this tool (Qualtrics questionnaire) to arrange all the keywords.

- Q.2.1. As you reported that you used [tools] in your project, would you please tell me why you needed these tools to support this activity/stage?
- Q.2.2. [If search engines were not used to support the stage], why did not you use search engines to support this stage?
- Q.3.1. Did you do anything to save, organize, or preserve what you found on **[Day N]**? If so, please describe how you did?
- Lastly, before we move on to the next Day, could you please say something more about any challenges or troubles that you met during Day N.

At the end of the interview, participants were also asked to explain (1) how they used the tools or apps to switch devices in their project; (2) why they chose these tools; and (3) any troubles that they encountered in the switching process.

4.4 Data Quality Control

4.4.1 Document Creative Processes

The diary study data largely depended on participants' creative efforts. A creative task could turn out to be a regular work task if the person did it routinely. As screening criteria shown in **section 4.3.1**, each of the creative projects were expected to include both the ideation process and the test process. To examine if/how these aspects were present in their projects, I asked participants to share two artifacts (e.g., image, video, document) to illustrate their creative processes and the progress that they had made on their project. Specifically, **the first artifact** was used to document how they generated different new ideas in their projects, and **the second artifact** was used to record how they selected the new ideas that they had generated in the project. Participants were informed that the artifacts could be pictures, images, documents, or videos that they had worked on as part of the project. Participants were asked to submit the two artifacts by Day 7 and Day 14, respectively.

4.4.2 Incentivization

The approach to incentivizing participants has also been designed deliberately in this study. In prior research (Sohn et al., 2008b, 2008b), it has been found that increasing compensation might encourage participants to make up diary entries. To address this issue, in this diary study, choose not to award participants based on the number of diary entries that had been logged. Instead, all the participants got a flat pay-rate payment $80 **if they meet all the following conditions**:

- Document work on their projects for at least three days per week by completing the following subtasks:
  - Complete at least 1 helpful information form;
  - Complete at least 1 trouble information form;
  - Complete the diary review form.
- Share with us the two artifacts;
- Upload their Firefox account browser history;
- Participate in the last interview.

A "bonus" system was designed to motivate participants to provide high-quality responses in this research. Specifically, each of the participants will be told that they have eligibility for the "high-quality bonus"[4] ($40) at the end of the study if they provide "high-quality responses" (genuine and thoughtful response). All the participants were told that the bonus would be evaluated based on the following criteria:

- Spend considerable efforts on the project;
- Be able to capture most of the helpful information and troubles related to the project;
- Be able to clearly explain answers with sufficient details.

At the end of the first week, I sent feedback to each of the participants regarding the quality of their diary entries. **If a participant's performance was below what was expected (e.g.,**

[4]We planned in advance to give all participants the bonus if they completed the entire diary study.

missing some questions in the daily review questionnaire or if they did not provide much detail in their answers), I would provide guidance on how to improve the quality of the response in order to get the bonus in the feedback. This feedback was designed to help them write more informative responses, not to influence their creative process or their use of particular resources.

4.4.3 Check in with Participants

During the diary study, I monitored the participants' work every day. If some participants' responses were difficult to understand, I would send a follow-up email to ask them to clarify the responses. If some participants did work on their project two days in a row, I would remind them by Email.

Coding schemes	**Datasets (Questions included in data analysis)**
Scheme 1: RQ.1 and RQ.2	Q.1 and Q.3 in Appendix D.1
Scheme 2: RQ.4	Q.4.2 and Q.4.3 in Appendix E
Scheme 3: RQ.5	Q.2 in Appendix D.2 Q.6.1 and Q.6.2 in Appendix E

Table 4.4: Datasets used in developing the initial coding schemes

4.5 Data Analysis

4.5.1 Qualitative Analysis of Diary Data

To analyze the qualitative data (open-ended questions) of participants' diaries, I followed the six-step workflow suggested by Berg (2001):

1. **Step 1:** Reading and being familiar with data;
2. **Step 2:** Open coding and creating initial categories;
3. **Step 3:** Collapsing similar or dissimilar categories into broader higher-level categories;
4. **Step 4:** Reviewing all the categories;
5. **Step 5:** Defining and naming all the categories.

In the qualitative analysis, firstly, I completed the **step 1-3** and generated initial coding schemes to analyze **RQ.1**, **RQ.2**, **RQ.4**, and **RQ.5**. **Table H.1** shows the datasets used for developing the initial coding schemes. To standardize the coding process, I also developed specific rules for applying codes (see **Table 4.5**). The coding unit in the analysis was the response to each open-ended question. Specifically, **In step 3**, a deductive approach was used to group the lower-level categories of the types of information in **Scheme 1**[5]. An inductive approach was used to collapse similar lower-level categories into broader higher-order categories in **Scheme 1 (usage intents part)**, **Scheme 2**,

[5]After engaging in several rounds of reading participants' responses, I found the scheme of everyday information needs developed by Church et al. (2014) covered many aspects of the types of information sought by our participants. Inspired by their work, I used their categories as a starting point to group the lower-level categories of participants' information needs.

Coding schemes	Datasets	Coding rules	# of unique labels allowed to assign
Scheme 1	Q.1 and Q.3 (Appendix D.1)	1. Type of information: the type of information indicated in the answer of Q.3; If a participant did not clearly indicate the type of information found, the coder should use the URL in Q.1 to chacaterize the type of information; 2. Usage Intents: intents indicated in the answer of Q.3	One or more lower-level categories
Scheme 2	Q.4.2 (Appendix E)	1. Create stage: the stage shown in the question of Q.4.2; 2. Reason for using a resource: the resource and the reason for using it indicated in the answer of Q.4.2.	Only one stage One or more lower-level categories
	Q.4.3 (Appendix E)	1. Create stage: the stage shown in the question of Q.4.3; 2. Reason for not using search engines: reasons indicated in the answer of Q.4.3	Only one stage One or more lower-level categories
Scheme 3	Q.2 (Appendix D.2)	Challenges: challenges indicated in Q.2	One or more lower-level categories
	Q.6.1 (Appendix E)	Challenges: challenges indicated in Q.6.1	One or more lower-level categories
	Q.6.2 (Appendix E)	Challenges: challenges indicated in Q.6.2	One or more lower-level categories

Table 4.5: Rules applied in the qualitative coding process: this table shows the dataset(s) used in developing each coding scheme, the rules applied to code each coding unit, and the number of unique codes allowed to be applied to the coding unit.

and **Scheme 3**. Each coding scheme includes one lower-level category (examples) and one or more higher-order categories (themes).

Secondly, the second coder was invited to independently code all the data (see **Table H.1**) by applying the coding schemes and the coding rules that I developed. During this coding process, the second coder was asked only to use the lower-level categories to code each data point. After the second coder coded all the data, we calculated Cohen's Kappa for the initial inter-coder agreement (see **Table H.1**). The inter-coder agreement results show the lower bound[6] of the agreements in our qualitative analysis. Cohen's Kappa was calculated based on the agreements of the parent category of the lower-level categories (examples). Since **Q.6.1** and **Q.6.2** (daily review questionnaire) covered all the challenges reported in **Q.2** (trouble form), Cohen's Kappa of **theme 3** was calculated based on the agreements of codes to **Q.6.1** and **Q.6.2**. Following Bradley's suggestion (2007), we resolved all the disagreements of our codes by discussion and consensus.

After resolving all the disagreements, thirdly, the second coder and I iterated over **step 4 and**

[6]Some disagreements resulted from blunders (e.g., assigning a wrong label or forgetting assigning a label).

Scheme	Sub-schemes	Cohen's kappa statistic
Scheme 1	Information needs	0.75
	Intents	0.62
Scheme 2	Resources	0.86
	Reasons for using a resource	0.62
	Reasons for not using search engines	0.63
Scheme 3	Challenges	0.79

Table 4.6: Cohen's kappa statistic for initial inter-coder agreement

5. We reviewed each coding scheme to make sure that all the lower-level categories were grouped and named in a meaningful way.

Lastly, my dissertation advisor and I had several rounds of in-depth discussions and finalized the coding schemes. See the final coding schemes in **Appendix H**. **Only the highest-level categories (categories) are presented in Chapter 5**.

4.5.2 Qualitative Analysis of In-depth Interview

As described before, the questions asked in the interviews were similar to those included in the daily review questionnaire. In this dissertation research, the main purpose of the in-depth interviews was to get ***more insight*** and understand why participants chose and used particular tools and information resources to support their creative processes (RQ.4) and what challenges they met in their projects (RQ.5). In this sense, instead of developing new coding schemes to analyze in-depth interviews, my advisor and I decided to use **Scheme 2** and **Scheme 3** as a starting point to analyze the in-depth interview transcripts. If any new categories or themes were found in the interviews, I would update the two coding schemes accordingly. Only one new category, "communication", was identified and added in scheme 2: in **P2**'s interview, she noted that she used Instagram to share her work in public. As we expected, the coding schemes (2 and 3) developed from diaries cover most of the categories revealed in the in-depth interview; however, the in-depth interview data provide more insights and more profound explanations about the categories or themes.

4.5.3 Quantitative Analysis of Daily Review Questionnaire

RQ3 asks, "What kinds of tools/resources do people choose in their creative stages?". To address this question, we used Bayesian random-effect logit regression models[7] was developed to analyze participants' responses to **Q.4.1** in **Appendix E**. Due to the small sample in this diary study, the Frequentist approach can suffer from some issues, such as extreme inferences obtained by using maximum likelihood (A. Gelman et al., 2008) and inflated Type-I error rates for fixed effects (McNeish, 2017). In **Chapter 6**, I will discuss more the reasons for using Bayesian analysis by comparing the approaches.

[7]In the Bayesian analysis, a No-U-Turn sampler (Hoffman & Gelman, 2014). In each model, I ran Stan (`http://mc-stan.org/`) with six chains, each of which had 10000 iterations.

CHAPTER 5

RESULTS

5.1 Characteristics of Participants and Creative Projects

Fifteen participants were selected to participate in the diary study. Eleven participants completed the entire study (4 participants dropped out). Most the participants had a background of art and design (see **Table 5.1**). During the two-week period, each of the participants worked on their own projects. Based on participants' answers in the screening questionnaire, most the creative projects were motivated by either **curiosity** or **asserting their abilities or skills** (see **Figure 5.1**). According to Sanders and Stappers's research (2012), these two motivations are the key drivers to the highest levels of everyday creativity: **creating** and **making** levels (see more detail in **Table 1.1**). This result indicates that the projects brought by our participants to the diary study were prone to involve top levels of everyday creativity (creating and making levels).

Regarding the contexts of these creative projects (personal hobby, school project, or work), our screening questionnaire data showed that more than half of the projects were about participants' personal hobby and were prone to be motivated by their curiosity (see **Figure 5.1**). In the screening questionnaire, it has also been found that most of our participants had done similar projects before and had a related experience that provided them the necessary domain knowledge, skill, and abilities to conduct their projects. This finding suggests that most of our participants had a good experience level for the goals of our diary study. Please note that our goals were to investigate how people used information resources to support their **creativity**, not to focus on how they learned a brand-new skill.

To get an understanding of how resources distributed across our participants, I analyzed and clustered the URLs logged by Firefox. Before analyzing the log data, I removed all the links/URLs

P#	Major	Project
2	Arts	Making digital collages about a city after hurricane.
3	Arts	Making a multiple color and layered woodblock print.
4	Arts	Creating a custom typography and a poster.
5	Arts	Create abstract art work by programming re-used technology.
6	Arts	Creating abstract portrait of a family as a gift.
9	Media	Internship projects in a creative agency.
10	Media	Writing narrative nonfiction stories about sea level rise.
11	Biology	Creating and selling her art works.
12	Psychology	Writing a manuscript for a historical fiction novel/novella.
13	Psychology	Designing a board game based on family member's life.
14	Arts	Designing series of animations using Photoshop and Illustrator.

Table 5.1: Participants and their projects

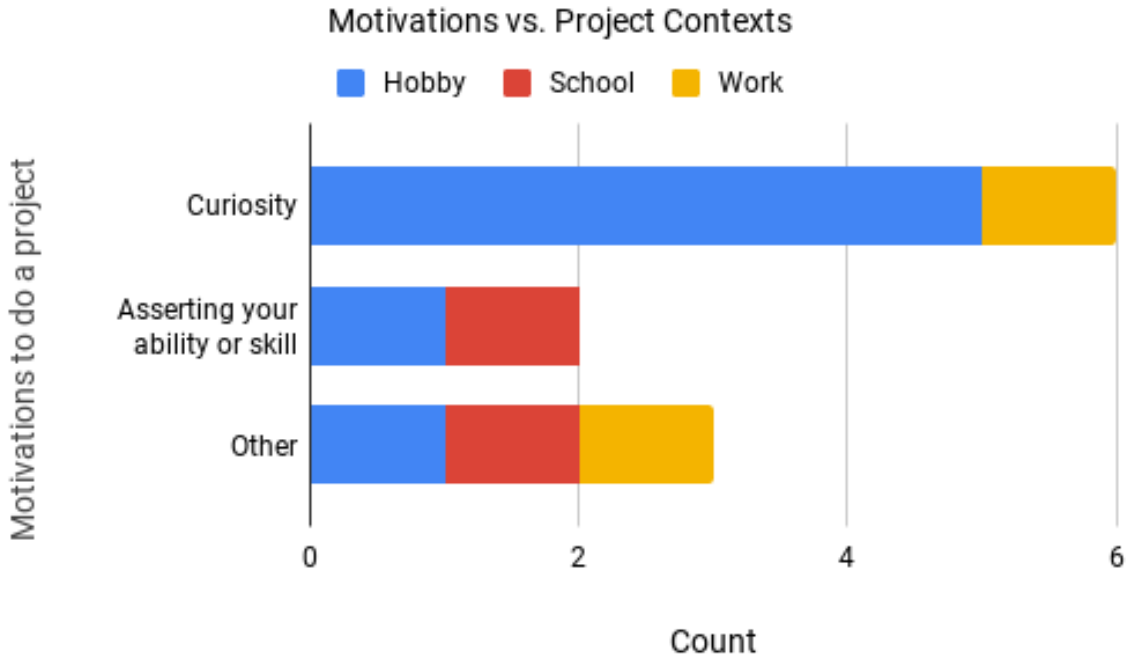

Figure 5.1: Motivation to do a project

generated by the diary toolkits (e.g., OneDrive link, Qualtrics link, and certain Google Drive links[1]). After cleaning the log data, there were 3626 unique links visited by our participants. To categorize the 3626 unique links, I first extracted the domain of each URL and then manually coded the themes of these domains. In total, there were 487 different domains extracted from the browser log data, and the identified categories (total # of unique URLs > 10) are shown in **Table 5.2**.

[1]Some documents (e.g., FAQ document) in the diary toolkit were hosted by Google drive in the diary study

	P2	P3	P4	P5	P6	P9	P10	P11	P12	P13	P14	Total # of unique URLs per domain
search engines	21.2%	60.4%	18.4%	52.7%	56.6%	24.1%	32.4%	15.4%	37.0%	14.5%	60.4%	1074
products/online tools/services	9.7%	0.9%	41.5%	0.9%	4.1%	50.7%	1.8%	1.2%	0.0%	36.6%	5.9%	775
images	17.5%	9.0%	9.3%	0.0%	5.4%	10.9%	0.0%	18.7%	0.0%	3.5%	1.0%	257
organization websites	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	39.5%	0.9%	0.0%	2.1%	5.9%	256
shopping	0.5%	10.8%	1.7%	5.1%	2.3%	1.1%	0.0%	24.2%	0.0%	14.3%	0.0%	204
videos	0.0%	2.7%	0.6%	21.9%	23.1%	0.3%	0.2%	16.9%	8.7%	0.8%	3.0%	204
Google-related products	0.0%	0.0%	4.4%	2.7%	0.0%	2.9%	6.1%	20.8%	0.0%	0.0%	0.0%	154
online knowledgebase	0.9%	4.5%	1.5%	5.1%	1.8%	0.9%	0.2%	0.3%	52.2%	6.9%	0.0%	127
magazine/news	5.1%	0.0%	4.2%	2.1%	0.9%	1.4%	7.1%	0.0%	0.0%	2.3%	3.0%	106
forums	0.0%	0.0%	0.2%	0.6%	0.0%	0.3%	0.0%	0.0%	0.0%	10.8%	5.9%	67
social media websites	0.5%	1.8%	2.5%	2.4%	0.0%	0.2%	3.7%	0.0%	0.0%	2.7%	2.0%	62
personal website/portfolio	14.7%	6.3%	1.9%	0.9%	1.4%	0.3%	0.0%	0.0%	0.0%	0.4%	1.0%	59
university/education	2.3%	0.9%	0.2%	0.6%	0.0%	2.7%	3.9%	0.0%	1.1%	0.0%	0.0%	51
gallery/exhibition/show	12.9%	0.0%	0.0%	2.7%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	45
online training/coaching	0.0%	0.9%	5.9%	0.0%	0.9%	1.5%	0.0%	0.0%	1.1%	0.0%	2.0%	44
blog	0.0%	1.8%	0.6%	0.3%	2.3%	0.5%	0.0%	0.3%	0.0%	4.0%	1.0%	37
library websites	11.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	34
product Q&A/blog	0.5%	0.0%	3.6%	0.0%	0.5%	0.3%	0.0%	0.0%	0.0%	0.0%	7.9%	29
entertainment	0.0%	0.0%	2.8%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	14
academic journal	1.4%	0.0%	0.0%	0.3%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	12

Table 5.2: Categories of the domains visited in diary study: this table shows the top categories (total # of unique URLs > 10).

5.2 Types of Information & Usage intents

RQ1 asks, "What types of information do people need during their creative projects?" To address this question, we analyzed diary entries provided by participants on their ***useful information form*** (Q.1 and Q.3 in Appendix D.1). Based on their responses, we identified six types of information as shown in **Table 5.3**: (1) procedural knowledge (instructions), (2) domain knowledge, (3) finished examples, (4) tips/opinions/recommendations, (5) information about specific topics, and (6) inspiring information. Each of these will be elaborated in the following sub-sections.

Info Types	Description	Examples
Procedural knowledge (instructions)	User manual (software or apps)	*"The page [Adobe user manual] I found told me how to create animations in Illustrator. This is something that I was previously unaware of and although I knew it was possible to do, I struggled with it. I figured out from this page the file type I can export the animation as."* - P14
	Textual - steps	*"This [article] has step-by-step information through the prototype process as well as links to other related resources, like for production."* - P13
	Videos - demonstration	*"The information [a video] I found was how to make a gradient for a block print. This will be helpful when executing the same technique on my second layer of my print."* - P3
Domain knowledge	Declarative knowledge of a domain	*"I wanted more information on [domain knowledge related to mythology], especially what their equivalent to [specific topic]. This determined my setting for the first section of my story, and helped me have a more accurate story."* - P12
Finished Examples	Finished examples of other people's related work	*"This [a website about vegetarian environment health] is an example of what I want one of my stories to look like, and it provides a good framework of how I can shape my own ideas into a tangible product"* - P10
Tips/opinions/ recommen-dations	Tips, opinions, recommendations about a specific topic	*"I finally got my question answered of the amount of prints that I should bring of each design. She [the YouTuber] recommended 10 prints of each design. This is helpful for me because it allows me to have an idea of what I should buy, how many different types of prints I should have, and then how I am going to price them"* - P11
Information about speicific topic	About a person	*"I found this link after searching for contemporary collage artists or photographers. I think this has great leads to narrowing down my artistic kindreds."* - P2
	About a product or service	*"Google answered my question about the type of bit I should be purchasing in order to drill a hole through glass without breaking it."* - P5
	About a specific business/ organization/establishment	*"This information is about hydrogreography and planning for the City of Washington, which will help inform my research and discuss the city's history in my writing."* - P10
	About a place or location	*"Google images of maps of NC, SC and Georgia. I'm thinking of making the game board that shape since those are the 3 states my Dad has lived in, where we have family and where he thrifts."* - P13
Inspiring information	Information that motivates people	*"I mainly used this as visual inspiration for clothing and appearances, as well as a motivation booster, since the voice-over of the myth is accompanied with classical art."* - P12

Table 5.3: Types of information sought in design-related projects: this table shows the types of information that participants reported in their *useful information forms*.

RQ2 asks, "What intents do they have to use the information they seek in their creative processes?" To address this question, we characterized the *usage intent* behind each type of information in the diary question (Q.1 and Q.3 in Appendix D.1). Different from prior studies (Mitsui et al., 2017, 2016) which have focused on "search intents" (intents to search for information), this dissertation focuses on participants' *intents to use information*. For example, in the useful information form, instead of asking participants to explain why they searched for each piece of information, we asked them to describe *how the information they found could help their project move forward*. We choose this focus on usage intent in order to address RQ2. The answer to this question will provide us a deeper understanding of people's information needs: "*what they use it for*" (Case, 2007, p. 87). In

our qualitative data analysis, we identified seven categories of usage intents (shown in **Table 5.4**): (1) to learn how to do something, (2) to seek inspiration, (3) for ideation (e.g., generate new ideas), (4) to evaluate and select ideas, (5) for project planning (e.g., conducting research to plan a project), (6) to make a purchasing decision, and (7) to keep motivated.

Intent	Description	Examples
Learn/figure out how to do something	Figure out how to design something, learn how to use a new technique, feature, skill, or tool, improve design process/skill/technique, or use a tool or technique	"*The page I found told me how to create animations in Illustrator. This is something that I was previously unaware of and although I knew it was possible to do, I struggled with it. I figured out from this page the file type I can export the animation as.*" - P14
Seek inspiration	Process of collecting information that might be used to generate their own ideas.	"*lots of individual types of collectables that will be useful in the future when I'm trying to come up with specific items and information about those items to include in the game.*" - P6
Ideation	Process of creating their own ideas by using all the information that they already have	"[I] saw *textures overlaid on type, [which] helped me integrate it into my project idea*" - P4
Idea evaluation and/or selection	Process of evaluating and/or selecting idea(s)	"*I looked up more specifically Thai Kozo paper to find out more about it, and this resource had a great description of the paper and it's qualities. This information reinforced my idea to use Thai Kozo paper in the final print.*" - P3
Plan a project	Process of developing a design/project plan	"*I found information about one of the people I would like to talk to, and this brief summary of her work informs me about her expertise and what I might like to ask her, which helps... preparing me for my interviews.*" - P10
Purchase something	Buying something that is needed in the project	"*This will help me move forward because I can purchase the gesso this week and start the painting.*" - P6
Keep motivated	Motivate themselves to continue working on the project	"*...it [this video] inspired me to keep going. Working full time and doing other duties in just my normal life... is a lot of work, and I haven't been dedicating a lot of time to… drawing*" - P11

Table 5.4: Usage intents behind each type of information: this table shows participants' intents to use the type of information that they reported in their *useful information forms*

5.2.1 Procedural Knowledge - Instructions

Types of information. Procedural knowledge refers to knowledge of "how to do it" (McCormick, 1997). In this dissertation, we defined procedural knowledge to refer to instructions on how to do something. Our participants described looking for a variety of types of procedural knowledge to support their creative projects. These included articles describing steps in a process, videos demonstrating how to do something, and online manuals/help for an application. Participants described two main genres for procedural knowledge: **texts** (articles or software manual) and **videos**. In addition, they distinguished how these two formats can differ in the amount of detail provided:

> *"A demonstration is they don't tell you steps but they just show you and when you look at steps or you look at paper types, it's more … This is a weird thing to put into words. They're similar but they're not … From here [articles], I can get definitive steps. They tell me exactly what they did versus like a video. Someone might not totally explain what they're doing and might just do it [in videos]."* [**P3-interview**]

Usage intents. Not surprisingly, procedural knowledge was largely associated with the usage intent to learn how to do something:

> *"The page [Adobe user manual] I found told me how to create animations in Illustrator. This is something that I was previously unaware of and although I knew it was possible to do, I struggled with it. I figured out from this page the file type I can export the animation as."* [**P14-diary**]
>
> *"This [article] has step-by-step information through the prototype process as well as links to other related resources, like for production."* [**P13-diary**]
>
> *"The information [video] I found was how to make a gradient for a block print. This will be helpful when executing the same technique on my second layer of my print."* [**P3-diary**]

Procedural knowledge was also used to **evaluate and select ideas**. Particularly, videos helped facilitate the idea evaluation and selection process in participants' projects. By watching videos, participants could predict and evaluate potential outcomes **if a certain method or technique was performed in their projects**. For example, Participant 3 mentioned in her diary:

> *"I am now at the printing phase of my project and was curious on hand burnishing prints onto thicker paper. I know hand burnishing was ideal for thinner papers from prior knowledge, but found in this video that it can be just as successful on thicker weight paper. This is helpful to my project as I select a paper to use for the printing process."* [**P3-diary**]

Some other less frequently occurred intents were also identified in our analysis. For example, Participant 11 searched procedural knowledge to look for inspiration and Participant 13 looked for procedural knowledge to help plan a project.

The importance of procedural knowledge in design has also been identified in prior research which investigated how people searched "how-to" knowledge in craft projects (Torrey et al., 2009).

5.2.2 Domain Knowledge

Types of information. Domain knowledge is "the searcher's knowledge of the search subject or topic" (Wildemuth, 2004, p. 247). In our analysis, we found many examples of participants looking

for information specifically related to the *background, theory, and history of the topic of their creative project. For example, participants looked for information about mythology, art theory, game design theory, historical knowledge, and psychological theory related to their projects.* Interestingly, most of the domain knowledge our participants sought was non-art and non-design related. Most of our participants had an art or design background and had sufficient knowledge about how to design something. The knowledge that participants searched for was more likely to be the new "domain" that they wanted to explore and include in their projects.

Usage intents. One important thing we learned from our participants is that **design is both object and experience**. We found many participants' projects were developed around a meaningful "story". To craft the stories behind their designs, participants searched for related domain knowledge to help themselves understand and decide which stories they wanted to tell in their work. For instance, as **P3** and **P6** wrote in their diaries:

> "*Initially for my project, I was considering making a multi colored block print for either a moth or something botanically related. However, after my friend and I got into a conversation about native American folklore and it's influence on illustration, I became interested in the legend of [name of legend]. After reading the legend from the URL posted above, I have decided definitively that I want to make a multi colored linocut on this legend.*" [**P3-diary**]

> "*This website had an additional piece of information about the sunflower and it's ability to remove toxins from soil and its heliotropism and phototropism. Those terms mean the sunflower turns toward the sun. This will help me move forward because I [In her project, she created a portrait of her mom and give it her dad as a gift] can use this knowledge to make the sunflowers turn toward my mother to symbolize her role in our family as the life giver and source of power.*" [**P6 - diary**]

We also observed that the "story craft" process itself could involve certain creative activities. In our study, we observed that domain knowledge was used for specific purposes, such as **learning or figuring out how to do something**, **generating ideas (ideation), and planning a project**:

> *"I wanted more information on Titans [domain knowledge related to mythology], especially what their equivalent to Mount Olympus was. This determined my setting for*

the first section of my story, and helped me have a more accurate story." [**learn/figure out how to do something: P12-diary**]

"I was curious about the [a bird]'s symbolism in other cultures, so I went about researching that. It was interesting to me how in a lot of cultures, the [bird name] has a negative connotation whereas in Native American culture it has a positive one. In regards to my project, the positive and negative connotations are reminiscent of a yin-yang format and I may possibly integrate that into my key block. This overall helps with the format in which I want to arrange my imagery." [**ideation: P3-diary**]

"This paper has a great overview of the science of carbon sequestration. A lot of my project is storytelling with science mixed in, so this source will help my project move forward by giving me a solid basis in the science." [**plan a project: P10-diary**]

Additionally, some participants reported using domain knowledge to **evaluate and test ideas** and **seek inspiration**. For instance, **P13** searched knowledge about game mechanics and definitions to help herself narrow down her design ideas:

"This is a wikipedia type page with a list of game mechanics and definitions and descriptions of them as well as how they apply to board play and card play. This will help me understand terms that I read about on other sites about different game mechanics and to narrow down the kinds that might be best to include in my game." [**P13-diary**]

It is also interesting to note that **P6** described searching domain knowledge (art physiology) to get inspiration for their artwork:

"It was another blog [domain knowledge related to art physiology] that helped me think about art from the bigger perspective of how it makes people feel. It will help me move forward because I have been so focused on the techniques that I hadn't exercised the thoughts for why I am doing the art." [**seeking inspiration: P6-diary**]

In the area of information search and retrieval, extensive research has been conducted to understand the role of domain knowledge in search tasks (X. Zhang, Liu, Cole, & Belkin, 2015; Liu, Liu, & Belkin, 2016; Mao, Liu, Kando, Zhang, & Ma, 2018). However, to the best of our knowledge,

few studies have attempted to understand how people use domain knowledge to achieve their creative goals in their tasks or projects (e.g., story crafting).

5.2.3 Finished Examples

Types of information. Another type of information sought by our participants to support their creative tasks were **examples** of finished projects completed by other people. Finished examples can provide a tangible illustration of what a project using a particular technique might look like, or how it might function.

Usage intents. Our participants described using finished examples for multiple reasons. For instance, we observed that participants used examples to **rule out some options or ideas when they evaluated and selected ideas**. As **P6** wrote down in her diary:

> *"After doing some landscape practice I decided that a watercolor portrait won't capture the details I want. I searched for and found images of watercolor people. I can move forward using this information because I was able to rule out what I thought might be the design choice."* [**P6-diary**]

Finished examples could also help participants **explore and collect other people's ideas** (seeking inspiration). These ideas could then serve as the raw materials for participants to generate their ideas in the ideation process (Sawyer, 2011, p. 114). In **P13**'s project, she searched for "*illustrated map of [US state]*", "*cool vintage map*", and "*similar styled maps for [names of two states]*" to seek the inspiration of design:

> "*Googled 'illustrated map of [US state]' and found a cool vintage map in Google Images. Followed the link to this website that I then searched for similar styled maps for [other US state names]. They serve as inspiration if I can't put them together in a high-quality way.*" [**P13 - diary**]

In addition to seeking inspiration, **figuring out how to design something** was another intent when participants looked for finished examples. As **P10** wrote in her diaries:

> "*This [a website] is an example of what I want one of my stories to look like, and it provides a good framework of how I can shape my own ideas into a tangible product*" [**P10-diary**]

A few participants also used finished examples to **facilitate their ideation processes**. **P6**, for example, in her diaries mentioned that while she painted the portrait of her Mom, she searched "*girl on bike images*" to brainstorm and generate her design ideas:

> "*Several quick images searches uncovered multiple girl on bike images that remind me of my Mom's pic. It will help moving me forward to get an image in my mind of combined pic with right pose.*" [**P6-diary**]

In the field of information retrieval, providing support for finding finished examples has not been explored much outside the context of image search. However, researchers in HCI have recognized the critical role of examples in people's creative work and explored different ways to support using examples in creative processes (Kulkarni, Dow, & Klemmer, 2014; Lee, Srivastava, Kumar, Brafman, & Klemmer, 2010; Siangliulue, Arnold, Gajos, & Dow, 2015; Swearngin et al., 2018).

5.2.4 Tips, Opinions, or Recommendations

Types of information. Tips, opinions, and recommendations were another commonly sought type of information in our participants' creative projects. Similar to procedural knowledge, tips, opinions, recommendations might include steps, instructions, or guidance to help participants perform a technique or use a tool in their projects. However, different from procedural knowledge, tips, opinions, and recommendations also include other people's experiences and reflections which provide participants additional insights.

Usage intents. Participants used tips, opinions, and recommendations to help **learn or figure out how to do something**:

> "*The information that I found was helpful was that the artist is using acetate to transfer imagery from their first block onto the second one. I was searching for a solution for this, so that I can have all of my different colored blocks register (i.e., line up in the final product) perfectly. This is a useful technique that I was previously unaware of and will consider in making my block tomorrow after I do more research.*" [**P3-diary**]

Others' experiences and reflections included in tips/opinions/recommendations can also help participants to **evaluate and select a specific design idea** or to **plan their projects**:

> "*This is a shorter blog post that talks about just a few game mechanics (a few new ones not included on other sites I've looked at), specifically in why they work well in different*

games. This will be helpful in deciding what to include and why." [**idea evaluation and section: P13-diary**]

"*... I [P11 attempted to came up with plan to design something for selling] finally got my question answered of the amount of prints that I should bring of each design. She [the maker of the video] recommended 10 prints of each design. This is helpful for me because it allows me to have an idea of what I should buy, how many different types of prints I should have, and then how I am going to price them ...*" [**plan a project: P11-diary**]

Similar to the tips, opinions, or recommendations identified in our study, feedback can help people evaluate and select ideas in people's creative work. In the area of HCI, the role of feedback in creative work has also been investigated. Specifically, studies have been conducted to investigate how designers seek feedback from online design communities (Chan, Dow, & Schunn, 2015; Crain & Bailey, 2017; Xu & Bailey, 2012). This is an interesting area for exploration in the context of supporting creative tasks and information-seeking activities to support creative tasks.

5.2.5 Information about a Specific Topic

Types of information. Participants reported looking for information about specific topics (e.g., people, locations, products, services, these tools) related to their projects. We discuss these below.

Information about a person

Usage intents. Participants searched for specific information about a person's work/research experience, background, or contact information for different purposes. Firstly, information about a person's work/research experience, background, and work was important for our participants to conduct their research. By researching other people's work, participants could narrow down the scope of their ideas (**idea evaluation and selection**):

"*I found this link after searching for contemporary collage artists or photographers. I think this has great leads to narrowing down my artistic kindreds.*" [**p2-diary**]

Our participants also noted that examining other designers or artists' work might help them generate ideas (**ideation**), just as **P5** wrote down in his diaries:

"*This URL links to an artist talk by [name of famous photographer]. This talk generates new ideas for the production of my project and linked me to a multitude of different artists who work in a similar way.*" [**P5-diary**]

In our data, we also found that uses of the information about a person were sometimes tied to the specific requirements of a project. For instance, **P6** searched [famous composer]'s work because Chopin was her Mom's favorite composer and she wanted to figure out how to "*space the sunflowers to mimic a piece of [famous composer] music*" in her painting (**learn/figure out how to do something**):

"*[famous composer] was my Mom's favorite composer. This is one of the pieces I remember her listening to. I realized I might be able to space the sunflowers to mimic a piece of [famous composer] music.*" [**P6-diary**]

In another example, **P11** watched her favorite artist's YouTube channel to figure out how to **plan her project**:

" *...I used my favorite artist's YouTube channel, and watched some of her videos. It helped me move forward since I found a lot of very useful information through her that allowed me to figure out prices and what kinds of companies and turn around times I might have for products.*" [**P11-diary**]

In **P10**'s project, she looked for a local expert on wetlands to answer some science-based questions which gave her ideas to design her work (**seek inspiration**):

"*I found a website for [name of a wetland center], which I didn't know existed! I was looking for [an] expert on wetlands to answer some science-based questions I have, and this is a perfect source of that information that will inform my project and give me ideas/opportunities to make my infographics.*" [**P10-diary**]

Information about a product or service

Usage intents. In our study, most of the design-related projects involved using physical tools, software/apps, or materials to ***create*** something. Seeking information (e.g., price, properties, or quality) about a product or service could help participants make good design decisions by

supporting certain types of creative activities. In **P3**, for example, she searched information about the characteristics of "*Kozo paper*" to evaluate and select the paper in her wood-printing project (**select and evaluate ideas**):

> "*I looked up more specifically Thai Kozo paper to find out more about it, and this resource had a great description of the paper and it's qualities. This information reinforced my idea to use Thai Kozo paper in the final print.*" [**P3-diary**]

The descriptions or instructions of "*gloss medium*" also helped **P6** to figure out "*how to use it*" to make "*the bicycle to be shiny and man-made*" in her painting (**learn/figure out how to do something**):

> " *As I looked at the painting, the bicycle looked organic like the grass and sunflowers. I wanted the bicycle to be shiny and man-made, so I started searching and reading about gloss medium. I had heard of it but didn't know how to use it. Now I can after reading about it.*" [**P6-diary**]

In a more particular case, we found that **P11** searched the product information about tables to help **plan out her project**:

> "*I cant believe I found this! I found the exact measurements for the table, which I normally would think that this is something I would find online. This helps my project move forward because now I can begin to plan out how I want my table to look, what kind of things I can display, and how I can display it. I also found the prices for additional people at my booth, and how many chairs I will be provided, which is all helpful general information for my table and possible helpers that might come to work with me at my booth.*" [**P11-diary**]

In the same project, **P11** also searched for several products to **seek inspiration** on ways to package, price, and sell the items she designed:

> "*Another thing that I did not think about is if I want to package my artwork and how. I was thinking that I might want to go with a recyclable option such as these! This helps my project to move forward by giving me ideas on how to package (which will go*

into pricing my items), and possibly sell them and make them look cute for other people wanting to buy them!" [**P11-diary**]

Lastly, it is not surprising that information about products and services helped participants decide what tools or materials to buy in their projects (**purchasing something**):

"*Google answered my question about the type of bit I should be purchasing in order to drill a hole through glass without breaking it.*" [**P5-diary**]

Information about a business/organizations and location/place

Usage intents. In certain types of projects, participants had to search for specific information about business/organizations or a location. For instance, **P10** sought to write several narrative nonfiction stories about sea-level rise in specific locales, and in the project, for instance, she searched for information about "*hydrogreography and planning for the City of [name]*" to help plan the research in her writing:

"*This information is about hydrogreography and planning for the City of [name], which will help inform my research and discuss the city's history in my writing.*" [**P10-diary**]

In another example, **P13** searched "*maps of [3 US states]*" to help design her game board:

"*Google images of maps of [3 US states]. I'm thinking of making the game board that shape since those are the 3 states my Dad has lived in, where we have family.*" [**P13-diary**]

5.2.6 Inspiring Information

Types of information & usage intents. In our study, we uncovered several information needs that were rarely mentioned in previous research. For instance, **P11** and **P12** searched for inspiring information to motivate themselves to continue working on their projects:

"*While this video didnt really have any information about my project, it inspired me to keep going. Working full time and doing other duties in just my normal life with a family is a lot of work, and I haven't been dedicating a lot of time to myself and drawing. This helped me in a way that motivated me to keep drawing, keep working at my project,*

and allowed me to come up with more ideas of what to possibly draw and sell at my booth."
[P11-diary]

"*I mainly used this as visual inspiration for clothing and appearances, as well as a motivation booster, since the voice-over of the myth is accompanied with classical art.*"
[P12-diary]

The influences of affective factors are not new to the research on creativity. Several efforts have been made to understand how people's emotions can influence their creative processes. Based on the the appraisal theory of emotion (Fridja et al., 1992; Osborn, 1995; Lazarus, 1991; Scherer, 2001), for instance, de Rooij et al. developed a framework to explain how emotions influence the execution of the idea generation process in people's creative work (de Rooij et al., 2015). This is also an interesting area for future work related to search system support for creative tasks.

5.2.7 Summary of Information Needs and Usage Intents

	Learn/figure out how to do something	Seek inspiration	Ideation	Idea evaluation and selection	Plan project	Purchase something	Keep motivated
Procedural knowledge (instructions)	7	1	0	2	2	0	0
Domain Knowledge	3	2	2	5	2	0	0
Finished Examples	5	5	2	3	0	0	0
Tips, opinions, or recommendations	5	1	1	2	2	1	0
Information about a specific person	1	3	1	1	2	0	0
Information about a specific product or service	1	1	0	1	1	0	0
Information about a specific business, association, society, civil establishment or organization	0	0	0	0	3	0	0
Information about a specific place or location	2	0	0	0	1	0	0
Inspiring information	0	0	0	0	0	0	2

Table 5.5: Information needs and intents: this table shows the occurrences between each information need and different usage intents. The number in each cell refers to the number of unique participants. For instance, there are seven participants searched for procedural knowledge to learn/figure out how to do something.

To summarize the findings regarding information needs and usage intents, we created **Table 5.5** to illustrate the occurrences between each type of information and different usage intents. **The**

number in each cell refers to the number of unique participants. **Table 5.5** indicates that a certain type of information needs can be linked to multiple different usage intents. That is to say; the same information might be searched and used for different reasons.

5.3 Resources

5.3.1 Tools/resources Used in Creative Stages

RQ3 asks "What kinds of tools/resources do people choose in their creative stages?" To address this research question, we analyzed participants' responses (multiple choices) to **Q5** on the ***daily review form*** (Appendix A). Specifically, we developed seven Bayesian logistic regression models (see **Equation 5.1**), one for each creative stage, for understanding our participants' strategies of choosing and using the resources (e.g., search engines, videos, images, Q&A sites, and social media sites) to support a certain creative stage.

$$\begin{aligned} \mu_i &= logistic\left(\beta_0 + \omega_{[participant[i]]} + \sum_j \beta_j x_{ij}\right) \\ y_i &\sim Bernoulli\left(\mu_i\right) \\ \omega &\sim Normal\left(0, \sigma_\omega\right);\ \sigma_\omega \sim Cauchy^{+}\left(0, 5\right) \\ \beta_0 &\sim Cauchy\left(0, 10\right);\ \beta_j \sim Cauchy\left(0, 2.5\right) \end{aligned} \tag{5.1}$$

In each model, we included five dummy variables corresponding to the resource as predictors. The predicted (binary) outcome for each model was whether that particular stage was included in the task (1) or not (0). In **Equation 5.1**, β_0 is the intercept of the logistic regression model, x_{ij} is the predictor j for participant i. $\omega_{[participant[i]]}$ is the random effect specified to control the effects of repeated-measures in the diary study for participant i. Since the question (**Q.4.1** in **Appendix E**) was modified and different from the question used in the preliminary study (**Q5** in **Appendix A**), we did not use the results (posterior distributions of β) from the preliminary study to specify the prior distributions in **Equation 5.1**. Instead, we used Cauchy distributions as the default **weakly informative default priors** for the intercept, $\beta_0 \sim Cauchy\left(0, 10\right)$ and coefficients, $\beta_j \sim Cauchy\left(0, 2.5\right)$ in our random-effects logistic regression models (A. Gelman et al., 2008). Normal distribution was used to specify the prior distribution of the random effect $\omega \sim Normal\left(0, \sigma_\omega\right)$ and half-Cauchy distribution, $\sigma_\omega \sim Cauchy^{+}\left(0, 5\right)$ was used as the prior distribution for the scale parameter, σ_ω.

		Model 1: Find goals	Model 2: Look up	Model 3: Explore	Model 4: Create ideas	Model 5: Combine ideas	Model 6: Select ideas	Model 7: Execute
Intercept	**Mode**	**-2.95***	**-1.39***	**-2.17***	**-2.79***	**-3.85***	**-3.95***	**-0.98***
	HDI	**[-7.63, -1.79]**	**[-1.94, -0.87]**	**[-5.06, -1.31]**	**[-4.54, -1.88]**	**[-9.38, -2.31]**	**[-10.15, -2.36]**	**[-1.56, -0.43]**
Search	**Mode**	3.05	**1.56***	-0.36	-0.81	**-2.09***	-0.79	-0.72
	HDI	[-0.32, 27.74]	**[0.17, 3.24]**	[-1.73, 1.40]	[-2.41, 1.04]	**[-4.10, -0.31]**	[-2.88, 1.30]	[-1.81, 0.46]
Images	**Mode**	0.80	-0.39	0.13	1.12	0.17	0.03	**-1.10***
	HDI	[-0.73, 2.19]	[-1.56, 0.73]	[-1.09, 1.32]	[-0.52, 3.21]	[-1.77, 2.11]	[-1.78, 1.70]	**[-2.49, -0.02]**
Q&A	**Mode**	**1.81***	-0.54	-2.10	-0.14	-1.48	-0.98	0.28
	HDI	**[0.18, 3.38]**	[-2.14, 0.80]	[-29.33, 0.80]	[-2.62, 1.84]	[-25.18, 1.83]	[-21.72, 2.72]	[-1.00, 1.54]
Social sites	**Mode**	-0.13	-0.37	-0.88	-0.16	0.70	1.07	-0.27
	HDI	[-2.62, 1.72]	[-2.19, 1.01]	[-3.44, 0.72]	[-2.66, 1.66]	[-1.55, 2.75]	[-0.70, 2.92]	[-1.58, 1.02]
Videos	**Mode**	1.15	0.99	-0.82	0.26	-0.41	-2.33	-0.61
	HDI	[-0.29, 2.58]	[-0.03, 2.17]	[-2.49, 0.59]	[-1.61, 2.07]	[-2.57, 1.48]	[-20.47, 1.04]	[-1.80, 0.43]
σ	**Mode**	**0.25***	**0.1***	**0.09***	**0.3***	**0.49***	**0.77***	**0.39***
	HDI	**[0.01, 1.37]**	**[0.01, 0.87]**	**[0.01, 0.9]**	**[0.04, 2.66]**	**[0.02, 2.74]**	**[0.02, 3.2]**	**[0.01, 1.17]**

Table 5.6: Strategies of using resources in a creative stage. Each column shows results for one Bayesian logistic regression model with the five resources as predictor variables. The predicted outcome is a binary variable that indicates whether the stage was included in the task or not. Cells marked (*) in bold show domains that had an effect in that model. The mode values show the log odds increase/decrease. $\hat{R}$ of all the models were less than 1.1 for all the parameters.

The results of the random effects logistic regression models are shown in Table 5.6. In the table, each **column** shows results for one of the models. The resources that had an effect in a model are shown in bold and marked with a **"*"**. For each model (stage), the highlighted resources are the ones that were more predictive of that stage. In Bayesian regression, the *mode* indicates the log odds increase or decrease, and the *HDI* provides a function similar to a confidence interval in null hypothesis testing (but must be interpreted differently). In Bayesian inference, there is no p-value; instead, *to interpret the results, the null value (zero) of a coefficient is rejected if its 95% HDI excludes zero* (Kruschke, 2014). In other words, when the HDI of a coefficient does not include zero, then we have high confidence that this variable has an effect on the model. The estimated potential scale reduction factors ($\hat{R}$) of all the models were less than 1.1 for all the parameters, which indicates that the Bayesian models converged well (Brooks & Gelman, 1998).

According to the results, there is evidence that: (1) when participants used Q&A sites, they were more likely to be in the "find goals" stage; (2) when participants used search engines, they were more likely to be in the Look up stage, and less likely to be in the "Combine Ideas" stage; and (3) when participants used images, it's less likely that they were in the "execute" stage (trying to put their ideas into practice.

Please note that the question we asked in our survey study is different from the one asked in our diary study:

Example - survey study:

> Q.5. For which of the reasons below did you use **search engines** in the task (Choose all that apply)?:
>
> - Figure out my goal (e.g., what to create/design; what problem to address/solve)
> - Look up information relevant to my goal
> - Explore (gather a broad range of potentially related information) about my goal
> - Create a large variety of ideas that may achieve my goal
> - Combine some ideas that I already had
> - Select the best ideas from all the ideas that I have created
> - Figure out how to put my ideas into practice to achieve my goal

- Other (please specify)

Example - diary study:

Select all the tools that you used to **support figuring out my goal** today:

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, etc.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)
- Social sites (Facebook, Twitter, Reddit, etc.)
- Q&A Sites (Quora, Yahoo answer, AOLAnswers, Stackoverflow, etc.)
- Other (please specify)

In this sense, the results from our survey study and diary study were not comparable. But, it should be noted that Q&A sites play an important role in our participants' projects, and in our survey study we did not consider Q&A sites.

5.3.2 Patterns of Creative Stages

Recall that during in-depth interviews we asked participants to group their keywords based on the stages that they were at when they searched each keyword. Considering that participants might not remember all the queries, we allowed participants to mark the queries that they did not remember or those that were irrelevant to their projects. After removing these marked queries, we analyzed the sequences of participants' creative stages that involved online searching (e.g., Google, Google images, Pinterest, Reddit). The result is shown in **Figure 5.2**.

Figure 5.2 indicates that the patterns of the creative stages that involved online searching differed among participants. As can be seen from the larger number of queries, **P5** and **P9** were more likely to search information online to support their creative stages than **P2**, **P11** and **P12**. In **Figure 5.2**, it is also shown that certain creative stages were more likely to include online searching, such as lookup, explore, and execute stages. Additionally, **Figure 5.2** also suggests that our participants' creative stages were non-linear, and the sequences of creative stages might be influenced by their strategies. For instance, in some participants' projects (e.g., P3, P4, P9, and P14), the **execute** stage occurred throughout the entire project.

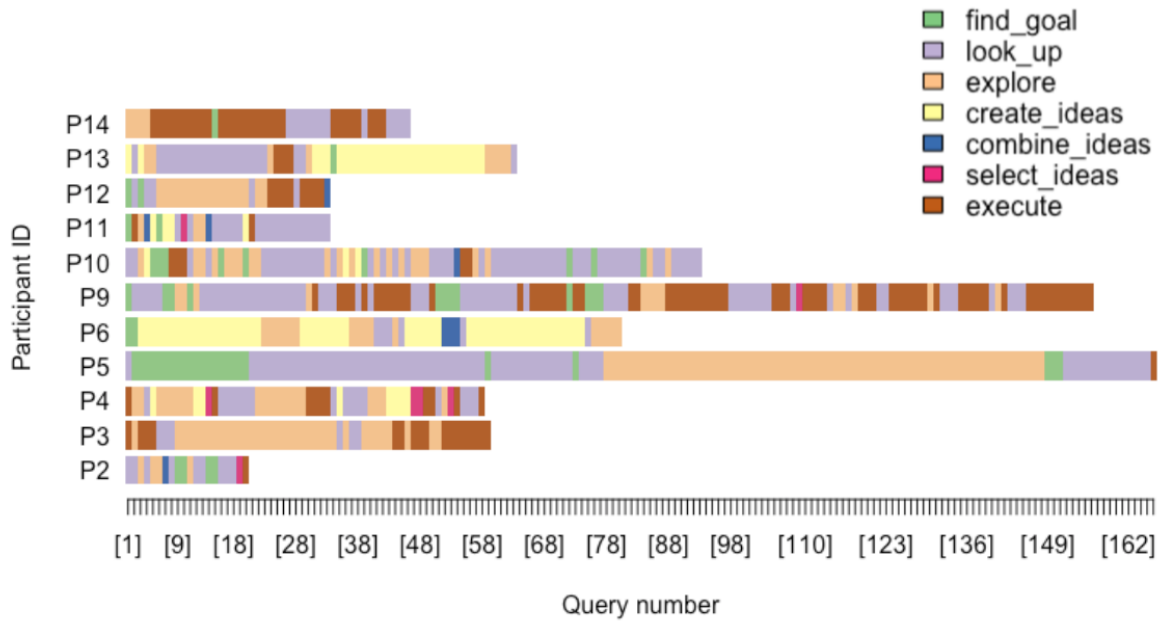

Figure 5.2: Sequences of creative stages that involved online searching: this figure shows the sequences of their creative stages that involved online searching in resources (e.g., Google, Google images, Pinterest, Reddit).

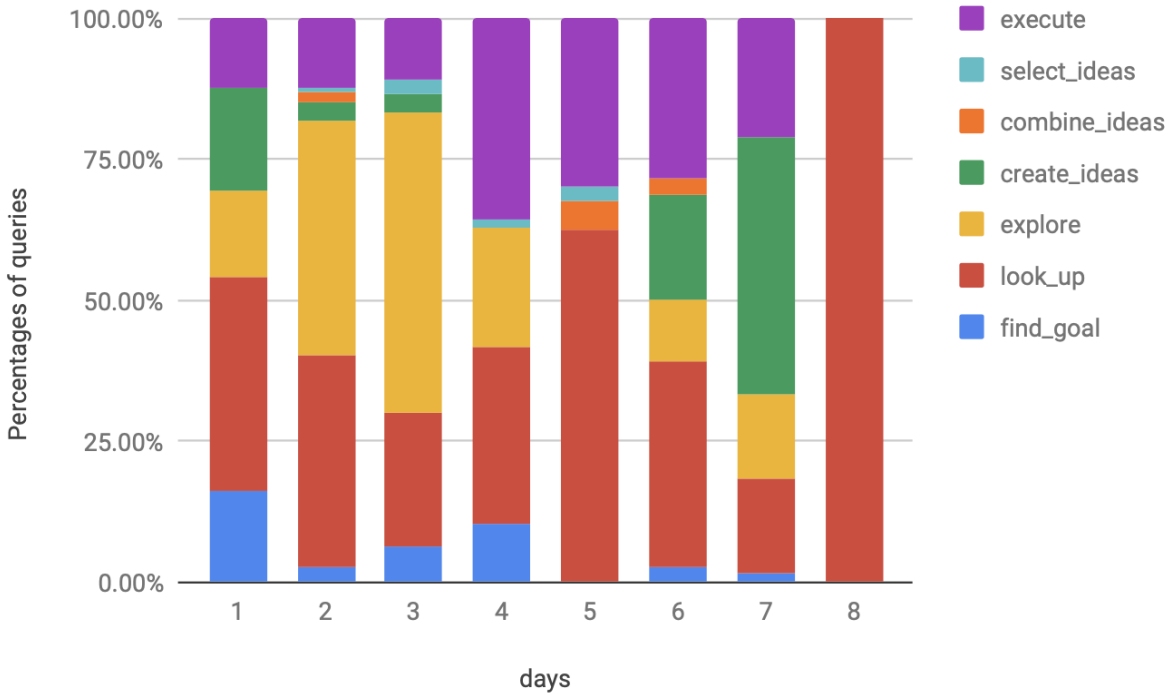

Figure 5.3: Frequencies of creative stages that involved online searching across different days: this figure shows how the patterns of the creative stages differed across different days.

Figure 5.3 shows how the patterns of participants' creative stages changed across different days. For example, in the first three days that a participant worked on their project, they issued many queries related to the **explore stage**. After the first three days, they issued more queries as part of the **execute stage**. Additionally, more queries were found to be associated with **create ideas** stage at the beginning (first 1 or 2 days) or the end (last 1 or 2 days) of participants' projects.

Regarding the findings shown in **Figure 5.2** and **Figure 5.3**, it should be noted these results ***only*** show the creative stages that involved online searching behaviors. For instance, no **create ideas** stage found during Day 4 and 5 in **Figure 5.3** does not necessarily mean that no participants generated their ideas during the two days.

5.3.3 Uses of Resources

RQ4 aimed to understand why people use a certain resource to support their creative processes. To investigate this question, we conducted a qualitative analysis on **participants' diaries** (Q.2 in Appendix D.2) and **in-depth interviews** (Q.6.1 and Q.6.2 in Appendix E). In the data analysis, we identified eight different resources/tools that participants used in their projects: (1) search engines, (2) video sites, (3) images sites, (4) images from search engines (image searches), (5) Q&A sites, (6) social sites, (7) blogs, and (8) shopping websites.

We also uncovered five common reasons for choosing a resource/tool (see **Table 5.7**): (1) to look for specific information[2], (2) to specifically support creative processes, (3) to support learning domain knowledge, (4) to supporting learning procedural knowledge, and (5) to manage information (e.g., saving and organizing the information found online).

It is worth noting that reasons for choosing resources/tools ***are not necessarily the same as*** the usage intents behind information needs. The two were identified from different datasets (see more detail in **Table H.1**). It should be pointed out that **the type of information sought and usage intents could influence how participants chose a particular resource or tool in their projects**. For example, if a participant wants to find finished examples (information need) to gather inspiration about how to design a logo (usage intent), this participant may choose Pinterest (resource) to support this creative process (the reason for using this resource). The reasons for choosing resources/tools often had similarities or connections to the usage intents. This indicates that: (1) our participants provided consistent data in the diary entries, and (2) the reasons for choosing a resource or tool can be used to infer people's information needs and usage intents. In the following subsection, I describe why people chose to use each of the resources in their design-related projects.

Uses of search engines

Reasons for using search engines. All participants used Google as their search engine when

[2]Please note this specific information does not include looking for or learning the information about declarative knowledge about a domain (e.g., mythology, art theory, game design theory, historical knowledge, psychological theory) and the information about procedural knowledge about instructions.

Themes	Description
Look for specific information*	Look for specific information about a tool
	Look for specific information about a person
	Look for specific information about a place
	Look for specific information about a product
	Look for specific information about a resoruce
	Look for specific visual information
	look for specific information for asnwering a question or knowing a topic
	Look for specific information about a company/organization
Specifically support creative processes	Combine ideas
	Create ideas
	Evaluate ideas
	Look for inspiration
	Select ideas
Support learning domain knowledge	Learn or look for declarative knowledge about a domain (e.g., mythology, art theory, game design theory, historical knowledge, psychological theory)
Support learning procedural knowledge	Learn or look for procedural knowledge about instructions
Managing information	Organize information

Table 5.7: Reasons for using resources: this table shows the reasons for using resources that were identified from *daily review questionnaire* and *in-depth interviews*. Please note *look for specific information* in this table (marked with *) does not include looking for or learning the information about declarative knowledge about a domain (e.g., mythology, art theory, game design theory, historical knowledge, psychological theory) and the information about procedural knowledge about instructions.

they conducted their projects. Most of our participants described using search engines **to look for specific information** and **to specifically support creative processes**:

> "*I used the search engines to call up broad swathes of information about the people and places I am interested in incorporating into my project so that I can better understand what they are and any recent news about them.*" [**looking for specific information: P10-diary**]

> "*From the information that I found on google to make my imagery, I combined that knowledge with what I learned about making a key block to make the initial block for my print. This would have been unachievable without the synthesis of these two ideas.*" [**specifically support creative processes: P3-diary**]

Some participants also reported using search engines to **support learning domain knowledge**.

For instance, **P12** used search engines to learn about the domain knowledge about "history of Greece" so that she could write an "accurate piece of fiction":

> "*It helped me find historically relevant information that I needed to start the beginnings of writing a historically accurate piece of fiction, as well as make relevant inferences on how the story would be different if a female character were guiding the helm, so to say.*" [**P12-diary**]

A few participants also used search engines to **learn procedural knowledge**. For example, **P2** searched for articles to learn how to write "a short artist bio" for her work:

> "*... I used search engines to find information on how to write a short artist bio since I find that when I typically write one, it turns into an artist statement-which are two totally separate things...*" [**P2-diary**]

Searching strategies. Revisiting **Figure 5.2**, we can see that **look up** and **explore** stages often occurred together. In participants' in-depth interviews, we also found a similar pattern that participants might start with broad searches[3] first and then progress to narrow searches **unless they had a piece of very specific information to look up**. Just as **P10** and **P12** explained, during broad searches, people might develop more specific information needs and generate new queries or pick up specific terms from webpages to lookup more specific information:

> "*... I think it was like ... I could do these broad topics and take the different avenues, and so like, have a broad topic and be like, oh, this is an interesting thing, and then use that as a search term, and so then that helped me be broad and then go specific, and then I could go back to the broad search term and find the next specific thing.*" [**P10 - interview**]

> "*It's very much like I start very broad in scope and then I just get more specific as I figure out what exactly. For example, today I went from very general life of women to, as I needed the nitty gritty, who is that person specifically. So it was able to do that, and*

[3]Broad searches refer to the search activities that people issue a broad query to find information. Broad searches might be exploratory search or lookup

then executing my idea, it was like I was writing and I wanted a word but I couldn't think of the right word so I googled it." [**P12-interview**]

It is also interesting to note that these specific queries/terms might be derived from other resources/tools. For example, **P5** developed his specific terms or information needs from watching a video:

"*The video [video about a specific artist] linked me multiple artists that I then researched further. This helped me process possible visual outcomes and formal strategies for the production of my project.*" [**P5-diary**]

In addition to issuing a more specific query, **P12** used the search results and links in the results as a path to narrow down the scope of her searches:

"*I pretty much started, you can't really tell this much in this first one because I just have a bunch of the same thing, but I honestly look at very general things. I don't google very specific things, so I google just like the full myth of [name of myth]. And in some of the ones that I looked at, maybe it was just like him getting fire, maybe it was just him and his relationship with the [name of second myth]. So I start with one search and then through the links, as I follow this link, and follow that link, I get more specific until I find the exact information that I want.*" [**P12-interview**]

However, when the scope of search results was too broad, people who are new to a domain might feel overwhelmed by the information provided by search engines. For example, as **P13**[4] explained in her diaries:

"*Had the Quora page that Google brought me to not been so helpful I probably would have used Google much more. As it was the first site it took me too had a ton of useful information to get me started. In the future as I may use Google to find more resources, but for getting started and the time I had today it would have been overwhelming to have more information or sites to visit.*" [**P13-dairy**]

[4]P13 has experience of design, but it was her first time to design a board game.

Reasons for not using search engines We also identified several reasons that participants noted for **not using search engines** from the qualitative analysis. Firstly, although search engines provide a broad range of information, **it is not always easy to synthesize the information collected from different resources and perspectives**:

> "*I think, honestly, probably if I really looked I could find everything that I really wanted to know but one of the things that I really, I don't know. I don't think I could ever really find on a search engine would just be like somebody's, I don't know. To put all into one spot I don't think I could find this just using a search engine. Would be like, this is my experience, this is what I did, this is what I wanted to do, these are all my things, these are all the pictures, these are all the videos. This is like... That's so much to just see on a search engine.*" [**P11-diary**]

Secondly, **people may not need to find more information in a certain stage of their projects**. There is no doubt that searching for information is an important part of the creative processes, but coming to certain cognitive activities (e.g., at the final stage of the decision-making process or combining ideas), what participants needed to do is to figure out ***how to use the information they found***:

> "*I used a search engine earlier in the process today. When it came to building the collage, or finishing it, I was solely using the research I had gained and Photoshop.*" [**P2-diary**]

> "*Search engines really didn't have much to do with determining the best ideas I had, since that was a decision I had to make with input from others (or on my own), and search results don't really come into play there.*" [**P4-diary**]

Thirdly, **people may just want to search for information within a specific resource**. In our study, we found that some participants skipped search engines when they already knew the exact resource where they wanted to look up:

> "*Since I know Pinterest and Instagram can offer me plenty of high-quality ideas, I would not have to use search engines. In addition, search engines usually generate broader results, including articles, videos, and photos. Here, I only need graphics.*" [**P9-diary**]

"*I technically used the search engine to find the Q&A [website]. For me to put something in practice it revolves around execution. I could probably find it via searching, but I want it faster. I want as few clicks to get to it.*" [**P6-diary**]

It is also interesting to note that people might **leverage the algorithms of search engines and use them to find certain information in a specific resource**, just as **P13** described in the interview:

"*Yeah. For the game. For what I was looking for. They were fine names, but not for what I was looking for. And Reddit is usually pretty clever with puns especially, but the Reddit search function is awful. It's terrible ... But if you use Google, and you include Reddit in the search, it works much, much better.*" [**P13-interview**]

Uses of videos sites

Reasons for using video sites. In the design-related projects, videos were primarily used to **support learning procedural knowledge**:

"*As I was thinking about on some past art projects, I wondered if there wasn't a way to make the canvas smoother. My past projects I have used store prepped canvas and it seems very bumpy. I decided to search for videos online that show how artists prep their canvas. I looked at a couple. My favorite gave me not only the tool and medium to use, but also a video of the technique.*" [**P18-diary**]

We also found that participants used videos to **specifically support creative processes**, **look for specific information**, or **support learning domain knowledge** in some cases. For instance, **P11** used video to help combine her ideas in her work (**specifically support creative processes**):

"*I used the YouTube video to pull all of my ideas together in one concrete setting. I.e. putting all of my plans into an organized video and list for me to kind of think through.*" [**P11-diary**]

P6 also used Videos to look for information about flatbed scanners in YouTube (**look for specific information**):

> "*I researched the history of the [specific technology] on google this brought me Wikipedia, Then to see visual examples I searched youtube, which provided a large array of at home videos of people experimenting.*" [**P6-diary**]

In a more specific project, **P12** watched videos to learn about "Prometheus myth" for helping her writing (**support learning domain knowledge**):

> "*I found a video essay that gives me more perspective on [name of myth] and gives me a fresh way to get the same information.*" [**P12-diary**]

Video sites vs. Search engines. Seeking to understand why our participants chose videos over other resources, we found that compared to textual documents provided by search engines, videos have several advantages. Firstly, as aforementioned, videos **provide more information in one spot where it has been better synthesized and more diverse**:

> "*There's also like through artists talks on YouTube, you can get like some more information that comes directly from that person than like other articles and magazines that are writing about their, their work without having like a book that they've written, or an article that artist that's written on hand.*" [**P5-interview**]

> "*I feel like the medium is different, so it can do different things. Not only do I get voiceover, but I can get my paintings and I can get my videos, of movies that have adapted Greek myth. So I feel like I can get a lot of different kinds of artistic interpretation in one go. Whereas in Google it's like, here's an article about it, and here is a PDF about it, and here is an encyclopedia thing about it. It's all different.*" [**P12-interview**]

Secondly, as **P6** described in her diaries, videos **can help people more easily learn "how-to" (procedural) knowledge in a visual way**:

> "*The bulk of my research today was within the making of the project. Youtube videos seemed to be more helpful because the accompanying visuals it provides.*" [**P9-diary**]

Thirdly, **P11** pointed out in her interview that videos **can provide "a personal touch of a human being" which can help her more easily evaluate the quality of the information they find**:

"*It's basically because it's just like it's so personal to hear someone talk about it. I don't mind reading and looking up documents, that's not an issue for me but I don't know, there's one thing of reading something somebody wrote and then there's another thing of just watching what someone did. And I just enjoy watching and listening to someone's work because you get to see people's personalities and you get to see their entire thought process.*" [**P11-interview**]

Lastly, video sites can **help people more easily find the information provided by individuals who have a similar background or interests**:

"*So, it would have more of this specific information that I wanted to find. To me when I started looking up ... what do I want to sell. I didn't want to sit there and read an article about it. ... nine times out of ten the people that are writing these articles or whatever are not the people I'm trying to get information from ... When I can just watch this video and this person sounds really excited. And they're ready to talk about what they want to sell, and it has more to do with I wanted to see what people were selling and I wanted them to talk to me about it.*" [**P11-interview**]

Reasons for not using video sites. However, not everyone liked using videos to collect information. In our data analysis, We also identified several reasons for not watching videos to find information. For instance, some participants considered watching a video as **an inefficient way to search the exact information that they want to find**:

"*I wouldn't say it's my first choice just because I think if I just had a ton of time, I would maybe be like ... Oh, let me just watch these videos for fun and learn things from them ... But since I was just like working on a project and I did have a timeline to be on, I was just like ... Okay, I just want to find out the things that I need as I go.*" [**P14-interview**]

"*If I have a very very very specific question then I'm just going to look it up [using search engines] because I don't want to spend my time [watching videos]. But a lot of the time I want to listen then.*" [**P11-interview**]

"*I get really impatient watching the videos actually. I find that if I watch a video on how to do something in YouTube I just get frustrated because it doesn't give me the exact information I want immediately. It's more of a roundabout way to get to the information that I want. ... whereas on a document I can use the command find [Control + F] and search for exactly what it is.*" [**P2-interview**]

"*I guess I ended up watching videos of people drilling through glass, but it was when I knew like that I had a direct question that I needed answered. Like just quickly what kind of bit do I use for this, and I don't want to like sit through*" [**P5-interview**]

Additionally, **it may be more difficult for people to make a quick relevant judgment on a video than on a document**. People can scan a document and make a quick relevant judgment, but for a video, people are unable to "scan" this video to figure out whether it addresses a topic that they want to know or not:

"*there was a couple of videos I think, that were like 20, 30 minutes long and if I... Okay, so, also another thing some people are just really cringe, if that makes sense. So, like on those videos I think that I watched maybe like five minutes ...*" [**P11-interview**]

Uses of images sites

Reasons for using images sites. **Images sites** (Pinterest, Instagram, Tumblr, Flickr, etc.) and **search engines** (image searches) were analyzed in our study. Overall, both were frequently used to **support creative processes** (e.g., browsing images for inspiration, evaluating and selecting ideas) by our participants:

"*I specifically used Pinterest as a source to gain inspiration and really browse the types of projects that have already been done. For example, I saw that people who did typographic illustration were often illustrating one of a couple things: either a) illustrating a word, a phrase, or a quote, or practicing with the alphabet. I used this image-searching to narrow down my idea and learn that I preferred quotes over other types, and it aided me in forming a more specific goal.*" [**P9-diary**]

"*I used google image and Pinterest for brainstorming and gathering ideas/inspirations and then I sketch them down. My sketches can sometimes be random ideas that pop into*

my mind. I tend to keep those because they might be useful in the developing process of this project." [**P9-diary**]

"*Pinterest provided a platform to view a wide range of photos of other multi colored prints. This in turn inspires my own creative process. For example, I was drawn to pins showing work centered around botanical or wildlife imagery. This helped narrow my intent on making several blocks on either moths or botanical.*" [**P3-diary**]

"*I wanted to add a rippling line to my animation... The search results mainly consisted of how to animate a ripple in water or waves, but I eventually figured out an idea by looking at the results in Google images.* " [**P14-diary**]

"*I also used Google to search for board game examples that might inspire me in order to pick the best design to create. I also used it to collect a lot of images to choose from in creating the board design.*" [**P13-diary**]

We also found that some participants used Pinterest as an information management tool to **save and organize images and other types of information**. For example, **P11** and **P2** used Pinterest to save and organize the ideas they collected from other people's work:

"*...I used Pinterest to save some ideas to my page in order to look back on later. Like set up ideas and other useful things.*" [**P11-diary**]

"*I collected images of artists that I already had saved to Pinterest that I felt were inspirations for my work more than other artists in order to create the Kindreds board...*" [**P2-diary**]

Search engines (image searches) vs. Image sites. Although both images searches and image sites could be used to support certain creative activities, their affordances were different. Typically, image searches are more likely to be used to look for a broad range of *regular images*, whereas image sites, particularly for Pinterest, were used to browse **high-quality images created by artists or professionals**. Participants chose between the two resources based on their needs (for example, how broad they wanted to explore):

"*...when you go look at Google images, they a lot of times will show ... people that don't make good art or good prints ... , versus Pinterest, there's people with talent. This takes a lot of talent to do versus something that's scratched together. This is wood engraving. Wood engraving's a very detail oriented process, so these are typically people that know what they're doing. This is very beautiful and labor intensive, so it's just more detailed...*" [**P3-interview**]

"*... On the first stage, I kind of want to get a broader idea. I would go to Google image to search for what this word means, and how do people see it. Then after I got into the design part, I want to know more about the layout, and also the geometry of some logo designs, I would go to Pinterest. And then Instagram is more like a personalized search engine for me, because I just remember it from my own experience what kind of designs I like, so I know what kind of accounts I want to go to draw inspiration from, so it's definitely different.*" [**P9-interview**]

Uses of Q&A sites

Reasons for using social Q&A sites. Different from the preliminary study, this diary study separated Q&A sites from the social sites in the qualitative analysis. In our data, we identified several Q&A sites, such as Quora, Stack Overflow, Tool/software Q&A sites, and Q&A forums. Q&A sites were mainly used by our participants to get **answers to technical how-to questions (support learning procedural knowledge)** and **comments or suggestions from other professionals (support creative processes)**:

"*I watched multiple videos and researched many forums and articles detailing how to transfer imagery from one block to the next. A common trend in almost everything that I researched today, except in the videos that I watched on youtube who were of people already printing their finished blocks, had the common trend of making a key block and then transferring their imagery with that. This was concluded to be the most accurate method on the basis that it evolves with your carving.*" [**P3-diary**]

"*The expert responses on Quora also offered a lot of examples and suggestions which I was able to start sifting through and noting my favorites that might be possibilities.*"

[**P13-diary**]

"*Stack Overflow has got Q&A for artists that answer technical how to questions. I wanted advice on how to make watercolor trees in the background. While I was there I found much more on drawing skin and making likenesses that was even more valuable ...*" [**P6-diary**]

"*Adobe Support was also useful because Adobe is the creator of Illustrator, but there were a few times when I got frustrated because I couldn't always find the answer to my specific problems. However, it did help me most of the time because it has almost everything I could possibly need to know about Illustrator.*" [**P14-diary**]

It is also interesting to note that **P13** used forums to help herself understand or learn broad topics about broad game design:

"*Today I used the board game forum to start looking over posts by game designers about board game mechanics. I am very much at the place where I need at least a rough sketch of some rules or ideas for rules I'd like to implement so that I can start thinking about all the components I might need. And also so I can do short pilots testing different mechanisms. This is the area I know the least about and feel the least confident about this whole project – and it's key to making the game actually work and fun! So I'm probably going to spend a bit more time looking through these posts in the future as well.*" [**P13-diary**]

We also found **P4** used Q&A sites to look up specific information about a tool:

"*... As far as the Q&A sites went, I used some to see what programs were Windows accessible versus ones that weren't, since I was finding a lot that were for Macs only.*" [**P4-diary**]

Q&A sites vs. Search engines. Participants also noted differences between articles (blogs or related website) suggested by search engines and Q&A sites. As **P5** and **P6** explained in the interviews, Q&A sites, particularly forums, **can provide people access to the rich information exchanged and left by others online**:

"*Q&A sites are actually pretty useful in that there's just so many responses and then there are people responding to responses. So it's kind of this like system of checks that you can sift through and pull out what you can from it. But if you search something on Google, generally it'll be like an article written by one person.*" [**P5-interview**]

"*I just wanted to be professional. Like, how do other artists do it? ... So, I didn't want to search for a bunch of weird answers ... I wanted to go right to who talks about this, the artists do. So, I wanted to go right to that art site [Q&A sites].*" [**P6-interview**]

Uses of social sites

Reasons for using social sites. In participants' projects, social sites were mainly used to **ask for feedback from other people (e.g., family, friends, colleagues) to support creative processes**:

"*I had some ideas in place about my final story, so I used social sites to run them by other writers and to get feedback.*" [**P10-diary**]

" *I sent some ideas to some friends in a group chat [Facebook] and asked their opinions on the layouts, as well as color palettes to see which ones they liked best. Their responses helped me sort out the good ones from the bad, and helped me eliminate some ideas and palettes I was considering using. It helped me combine (sort of) two similar ideas as well.*" [**P4-diary**]

"*I use social media sites to communicate with my clients and my creative team to select the best ideas. My creative director also uses social media sites to give feedback.*" [**P9-diary**]

It is also interesting to note that **P10** used Facebook to find some **"on-the-ground" knowledge about a place or location**:

"*Yeah, so, if I'm reading research, it's all like academic, and it's often from people from the outside coming into a community, but this [Facebook] was people from the community talking about their community, so it's really... it's like what are the actual*

problems. It's like what people are talking about to their neighbors and what matters to them ..." [**P10-interview**]

Uses of Blogs and shopping websites

Reasons for using blogs and shopping websites. In the qualitative analysis, we identified two resources participants mentioned that were not included in our previous quantitative analysis: blogs and shopping websites. These two resources were used for specific reasons by our participants. For instance, **P6** used blogs to **support her creative processes by learning lessons from others work** and to **find information that could motivate herself to continue working on her project**:

"*One of the images was where a blog from the artist offered to tell you the top six things to do when drawing on toned paper or something like that. It was a catchy title and reminded me that I needed to refresh myself of toned paper properties. I looked for something like this blog so that I could take advantage of other people's lessons learned so that my art comes together smoother.*" [**P6-diary**]

"*I was feeling uneasy, but after reading the blog and realizing art is for yourself and others it helped to motivate me.*" [**P6-diary**]

Additionally, **P14** used a blog to support **learning procedural knowledge in her project**:

"*The blog posts were usually helpful because they usually had step by step instructions on how to use a tool in Illustrator, for example, or the keyboard shortcuts needed which help me achieve my project goals more easily.*" [**P14-diary**]

Shopping sites were primarily used to **look for specific information about a product**. For example, **P11** used the Amazon website to look up for items that she needed for her projects:

"*I used Amazon in order to look up information on some items that I would put on my booth in order to make an aesthetically pleasing setting and some items that I would use. For example, I looked up the button maker which allows me to make things to sell, and I get to see how much it might cost for me to do so ...*" [**P11-diary**]

Shopping sites vs. search engines. **P11** also explained why the information (about products) provided by search engines was not as rich as this provided by Amazon:

> "*A simple search doesn't really give me a broad range of things to look at in terms of pricing. However, sites like Amazon show me prices, colors, sizes, and a bunch of information about products that I am considering buying.*" **[P11-diary]**

Summary of resource uses

To summarize how resource uses were used by our participants (based on the qualitative analysis described in the sections above), we created **Table 5.8** to illustrate the occurrences between each resource and the reasons for using the resource. **The number in each cell refers to the number of unique participants who mentioned using the particular resource for the specific purpose**.

Resources	Look for specific information	Specifically support creative processes	Support learning domain knowledge	Support learning procedural knowledge	Managing information
Search engines	10	10	6	3	0
Videos sites	2	3	1	7	0
Images sites	0	6	0	0	2
Image Searches	0	6	0	0	0
Q&A sites	1	3	1	6	0
Social sites	2	4	0	0	0
Blog	0	2	0	1	0
Shopping websites	1	0	0	0	0

Table 5.8: Resources and reasons for using resources: this table shows the occurrences between each resource and reasons for using resources. The number in each cell refers to the number of unique participants. For instance, there are ten unique participants who mentioned using *search engines* for the purpose *to look for specific information*.

5.4 Challenges

In RQ5, we investigate the challenges and problems that participants encountered in their projects. Participants were asked to use the daily review form to log the challenges that they encountered when they worked on their projects. After a thorough analysis on the diary entries (Q.2 in Appendix D.2) and interview data (Q.6.1 and Q.6.2 in Appendix E), we identified common challenges grouped according to the following themes: **creative processes**, **search**, **time constraint/pressure**, **motivation**, **information organization**, and **resources**. These are described in more detail below.

5.4.1 Creative Processes

In the creative processes theme, one of the most frequently mentioned challenges was **figuring out their design options**. Particularly, figuring out **what to design** and **how to design something** was a common hurdle in our participants' project:

> "*A lot of my challenges for these days are going to come down to the technical act, where it's like, how do I want this scene to play out? How do I want the emotional beats of this moment to play out as? Is this in line for the character that I have been developing? It was a lot of making sure that everything seemed genuine to the characters that I had written ...*" [**P12-interview**]

> "*The biggest non-technical challenge today was refining my goal and figuring out what exactly I want to create and what steps I need to take to get there. I want to make an infographic but I'm still figuring out what kind of infographic to make.*" [**P10-diary**]

> "*I had a hard time figuring out a good layout or appropriate font for my logo. Although I was just trying out new ideas, not being able to create the right vibe for my logos is very frustrating.*" [**P4-diary**]

When participants had several different design options, **making a design decision** would become another challenge that some participants faced in their creative processes:

> "*My biggest technical challenge was deciding the best paper to use for my block prints.*" [**P3-diary**]

"*Thinking about how rules work together and making decisions about what rules to eliminate completely.*" [**13-diary**]

In addition, **P4** and **P13** also noted in their diaries that they **had trouble finding an efficient way to "prototype" their ideas for evaluation**:

"*Figuring out / finding the best quote I wanted to illustrate, as well as not being able to properly envision/sketch out my ideas because it's all in my own handwriting, so it's hard to see what the final composition would be like*" [**P4-diary**]

"*[the challenge is] Figuring out how to quickly make a lot of different representations of components to be able to test out different rules.*" [**P13-diary**]

The creative process is often not a straight line. Participants might have to deal with the fact that some of their design plans did not work. As **P3**, **P4**, and **P5** mentioned in their diary entries, they had to revise their ideas when they found the ideas did not work as they expected:

"*I changed my mind! LOL I thought I got the design I wanted using watercolor but when I tried it I realized that is not in my head [watercolor did not work].*" [**P3-diary**]

"*it is a challenge when the program I was planning on using didn't work out ... and feel challenged by having to now search for another way to execute my ideas.*" [**P4-diary**]

"*...Repeatedly watching videos made me question my initial interests ... I then returned back to deciding what I really wanted to do with this project. I returned to the work of [name of artist] an artist that works with the manipulation of digital technologies for inspiration. I watched youtube videos of installations of his work as well as videos of him discussing his concepts.*" [**P5-diary**]

5.4.2 Search

Regarding search, most searches were conducted on Google and a few on Pinterest. The biggest challenge with searching on Google was to **find the exact information sought**:

"*Just like I was talking about with the keywords ... sometimes random things would come up ... And so, I couldn't find what I actually needed, but nothing was super urgent or hindered my progress at all ...*" [**P10-interview**]

"*Yeah. you could obviously see from my keywords but I just couldn't really find exactly what I needed ... I just would search one thing and then the results would be kind of along the lines of it, but not exactly what I was looking for.*" [**P14-interview**]

"*how overwhelming, how much information there is, and figuring out, and then related to that, sometimes the information that's there isn't really relevant to my specific need or my specific game.*" [**P13-interview**]

"*Yeah, maybe on this day I was looking for something specific, and on the other days when it was a big broad search, I could find it, but when I wanted something very specific, maybe I didn't know the right words to say, or somehow I wasn't finding it.*" [**P6-interview**]

Aligning with the findings of several prior studies (Barry, 1994; Levitin & Redman, 1995; Miranda & Saunders, 2003; Y. Zhang, Zhang, Lease, & Gwizdka, 2014), this result suggests that the scope of the information need is essential to people's relevance judgments.

Regarding Pinterest, a few participants mentioned that they had trouble finding relevant information/images:

"*With Pinterest, I was worried about the reliability of the information. Like I mentioned with the recipes not working out right or finding something not related to my goal at all. So the Pinterest algorithm is one that if it cannot find what you want it will search for a bunch of unrelated things*" [**P2-interview**]

"*...On Pinterest it's based on the algorithm and what people tag, and sometimes people will be wrong about what they tag and so, it will show up completely irrelevant images when it's not at all what you're looking for.*" [**P4-interview**]

Additionally, P6 and P10 pointed out that they had trouble tracking search processes in their projects:

"*All right, so if I started here, and I was looking at pictures, images, then halfway through I might restart it again because I [didn't remember] ... It's like what was I back at? ... So, I might start it again ... So, I was just going back, and forth, back, and forth.*" [**P6-interview**]

> *"Yeah, so the non-technical challenge was like when I got to this point and realized when I search this key term, and how do these sites come up and realize that I wanted to spend at least an hour searching those, and I had five minutes, and it was like, okay, well, how can I preserve this search term and all these links without clicking on them and bookmarking them ... then I'll forget exactly... I'll be like, I never visited this site, why did I bookmark it. And so, sort of like tracking myself and figuring out how I preserved it, and I realized I could go into my search history and figure out what I had searched."* **[P10-interview]**

Query lengths & challenges in online searching. In this research, we also analyzed participants' browser logs to get a better understanding of participants' challenges in searching information. Considering individual differences in the lengths of queries issued by our participants, we standardized and scaled the lengths of the queries issued by each participant:

$$q_{ij}^{*} = \frac{q_{ij} - \mu_j}{\sigma_j} \tag{5.2}$$

In **Equation 5.2**, q_{ij} is the length of the ith query issued by Participant j, and μ_j and σ_j are the mean and sample standard deviation of the lengths of all the queries issued by Participant j (including queries issued using Search engines, YouTube, and Pinterest). q_{ij}^{*} is the scaled length of the the ith query issued by Participant j.

Figure 5.4 shows the mean of participants' scaled query lengths across different tools (e.g., search engines, YouTube, and Pinterest) and creative stages (e.g., find goal, lookup, explore, create ideas, combine ideas, select ideas, execute). Based on the results shown in Figure 5.4, the average lengths of queries issued in search engines were longer in **execute** and **lookup** stages than those in other stages. This finding indicates that our participants might need longer queries to specify the exact information they wanted to find during lookup and execute stages. Similarly, we found that participants issued longer queries when they attempted to explore on on YouTube.

In **Chapter 6**, I will discuss how our findings can inform the future design of search engines.

5.4.3 Time Constraint/pressure

We understood that our participants might be busy with their studies and school work during the diary study sessions. To help them feel less pressure due to the time constraint of the diary

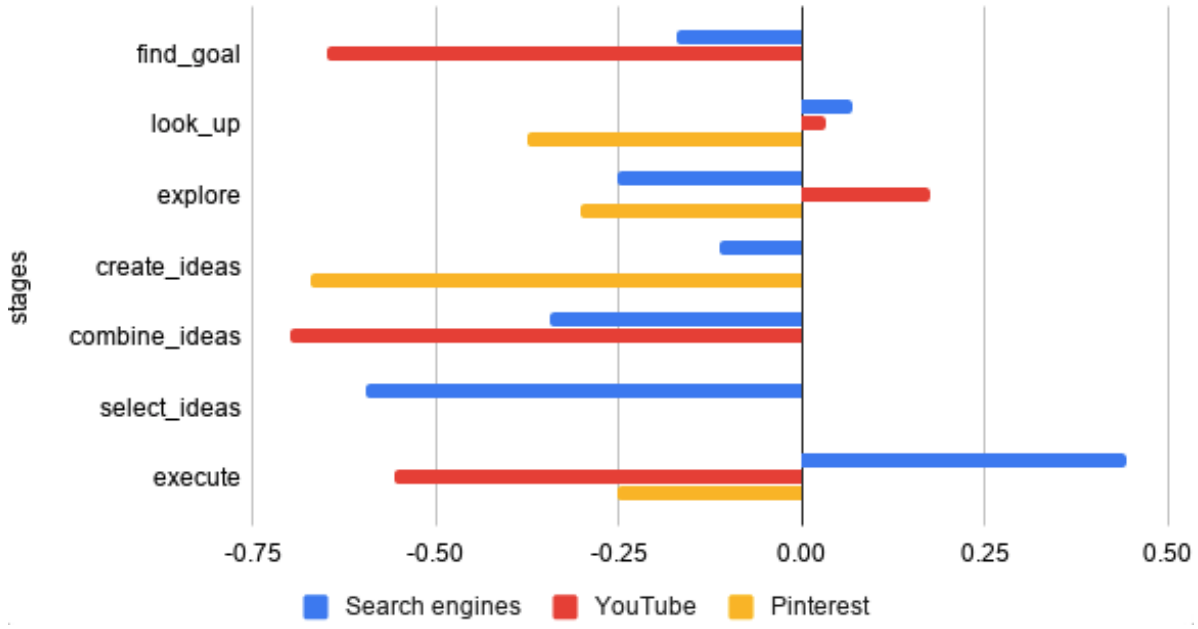

Figure 5.4: Mean of participants' scaled query lengths across different tools (resources)

study, we allowed participants to extend the deadlines of their sessions if they needed to. However, based on a variety of reasons, some participants still noted in participants' diaries, some participants still noted that they felt time constraints or time pressures related to their projects:

"*Finding time to work on the project has consistently been a nontechnical challenge...*" [**P13-diary**]

"*Its hard to balance working on this and working full time, but I am persevering and wanting to tackle this all head on!*" [**P11-diary**]

"*I felt time-pressed* to make the final product and it is a challenge to work when the program I was planning on using didn't work out ..." [**P4-diary**]

"*... creating the animation frames this way is very tedious and time-consuming; it takes a long time to make a simple frame using the pen tool. So carving a long enough period of time out to make significant progress is sometimes difficult and the process of creating the animation can be mentally frustrating because you create your initial frame, then you have to go through all these steps to copy that frame to a new one, change one tiny detail, and then do that all again. But don't get me wrong, I enjoy doing it, that's just one thing I wish I had a faster way of doing.*" [**P14-diary**]

Similar results about roles of time constraint/pressure in creative works have also been reported in several prior studies in creativity research (Amabile, Conti, Coon, Lazenby, & Herron, 1996; Amabile et al., 2002; M. Baer & Oldham, 2006; Karau & Kelly, 1992).

5.4.4 Motivation

Similar to time constraints/pressures, lack of motivation is another non-technical challenge that our participants noted having to overcome in their projects:

> "*The biggest non-technical challenge today was having enough energy to dive into the project. I had a busy day and was feeling intimidated by what I knew I needed to do to keep this project moving forward.*" [**P10-diary**]

> "*Low motivation and exhaustion were challenges for me today...*" [**P4-diary**]

> "*My biggest challenge on the non-technical side was forcing myself to sit and look at each artist individually from the list of names I have created.*" [**P2-diary**]

5.4.5 Information Organization

In the creative projects, participants not only searched for information but also saved and used it to help their projects move forward. **P13** and **P6** mentioned that they had challenges when they organized the information they found:

> "*Yeah, so the technical was trying to organize all that information and distill it down into what was relevant for what I was trying to, because a lot of these people are prototyping games because they want to pitch them and sell them, and I just want to play it.*" [**P13-diary**]

> "*Keeping track of the images in one place and remembering what I had explored on previous days. For example, I accidentally created a second folder for the images. Now some images are in one folder and some are in a second folder.*" [**P6-diary**]

5.4.6 Resources

Several issues regarding the quality of resources were also identified in participants' diary data, including **lack of professional resources**, **unreliable resources**, and **broken links**:

"*I find that resources on writing a good artist biography are typically scarce for the Art world. I have noticed that there are more research for hobby artists than there are for Fine Artists. While I found decent enough resources, I had to rely on a website called [name of site], which sells graphic designs and illustrations on household items or apparel. Not exactly the best source for when you're applying to put your work in a gallery, but I was able to make due.*" [**lack of professional resources: P2-diary**]

"*The biggest technical challenge for me today was navigating confusing websites. One of the most confusing was the [website name] - I kept getting transferred to different, older-looking sites that didn't look up-to-date or legitimate. That was difficult because I wasn't sure how to get to the information or if I could trust the source.*" [**unreliable resources: P10-diary**]

"*Encountering resources that were not academically credible. Searching provided tons of opinions.*" [**unreliable resources: P5-diary**]

"*Sometimes links were broken or didn't link to the specific information I thought they did. For example, there was a specific article on prototyping in a short amount of time, but the link only took me to another forum and not that article specifically. Trying to find information on specific game mechanics and not having successful searches.*" [**broken links: P13-diary**]

CHAPTER 6

DISCUSSION

This chapter includes two parts. In the first part, I briefly summarize the findings reported in Chapter 5; in the second part, I highlight the implications of this dissertation and demonstrate how this research can inform future research in the area of information search and retrieval.

6.1 Summary of Analysis Results

6.1.1 Types of Information and Usage Intents

In RQ1, we examined what types of information people need to support creative projects. Through qualitative analysis of participants' diary entries, we identified six main types of information that our participants described using in their creative tasks: 1) procedural knowledge, 2) domain knowledge, 3) finished examples, 4) recommendations, 5) specific information, and 6) motivating information. In their classic work on information seeking and use, Byström and Järvelin (Byström, 1995) outline three categories of information: problem information (properties of the problem), domain information (facts, concepts, and theories in the problem domain), and problem-solving information (how to solve problems) (Byström, 1995, p.195-196). Relating the information types our participants described in Byström and Järvelin's classifications, we find that *domain information* maps well to domain knowledge and specific information. *Problem-solving information* includes procedural knowledge, recommendations, and could also involve finished examples and motivating information.

In RQ2, we examined how participants' information needs in creative projects are connected to their intents to use the information they find. Through qualitative analysis, we identified seven categories of usage intents: 1) to learn to do something, 2) to seek inspiration, 3) for ideation, 4) to evaluate ideas, (5) for project planning, (6) to make a purchasing decision, and (7) to keep motivated. Several of these usage intents are common to other task types (e.g., learning to do something, planning, decision-making). However, seeking inspiration, ideation, and evaluating ideas are particularly characteristic of creative tasks and are associated with use cases that current search

systems are not well-equipped to support. For uses such as ideation and seeking inspiration, the searcher's goal is often to *generate new ideas*.

6.1.2 Resources and Creative Stages

In **RQ3** and **RQ4**, we investigated how and why different resources are used to support a particular creative stage. The results of the Bayesian analysis indicate that participants had strategies to choose and use specific resources to support their creative processes. For instance, when participants used Q&A sites in their projects, they were more likely in the stage of finding goals. When participants used search engines, they were more likely in the stage of looking up the information relevant to their goals and less likely to be in the stage of combining their ideas. When participants used image sites, they were less likely to be in the stage of trying to put their own ideas into practice.

The **Figure 5.2** also shows that the patterns of the creative stages that involved online searching differed across our participants. Based on the results shown in **Figure 5.2**, we found that participants' creative stages were not linear. Additionally, in **Figure 5.3**, it is shown that the patterns of participants' creative stages changed as they made progress across the days that they worked on their projects.

As to the reasons for choosing and using each resource, we identified several reasons. As **Table 5.7** shows, **search engines** were mainly used to look for specific information, support creative processes, and support learning domain knowledge. In certain situations, participants might not use search engines in their projects due to several reasons. Firstly, the information/results provided by search engines can be very broad, and participants might have trouble efficiently synthesizing them. Secondly, as aforementioned, in some cases, participants did not need to search for additional concepts or facts. Instead, what they needed is to figure out how to use the information that they had already found to help their projects move forward. Lastly, some participants reported not using search engines because they already knew the specific resource(s) that they wanted to look up (e.g., directly search in Youtube or Pinterest).

As to the reasons for using **videos**, we observed that videos were primarily used to support learning procedural knowledge. Some participants also used videos to support their creative process, look for specific information, or support learning domain knowledge. Compared to search engines, videos have some advantages. Firstly, the information provided by videos is usually well synthesized

and organized. Secondly, videos offer a visual way for people to better learn "how-to" knowledge. Thirdly, videos can provide "a personal touch of a human being" which can help people evaluate the quality of the information they found in the videos. Lastly, videos help people more easily find the information provided by the creators who share similar backgrounds or interests. It should be noted that compared to journalists who write and publish articles online, video creators (for example, YouTubers) are prone to have more diverse backgrounds. However, videos are not always useful. In our study, our participants described particular reasons for not using videos. For instance, watching videos might not be an efficient way for people to find the exact information that they are looking for. Also, it is more difficult for people to make a quick relevance judgment on a video than on a document.

Images sites and image search (e.g., Google images) were frequently used to support certain creative activities (e.g., looking for inspiration, evaluating and selecting ideas). Compared to the image search that provides access to a wide range of regular images, image-oriented sites (e.g., Pinterest) can provide more high-quality images created by artists or professionals.

Q&A sites were mainly used to look for answers to technical "how-to" questions and find comments or suggestions provided by other professionals online. As we pointed out in **Chapter 5**, many design-related projects involved using physical tools and software/apps to create something. Choosing an appropriate tool or technique is one of the several important things that participants had to figure out before they started their projects. Also, the comments or suggestions provided by other professionals could help participants evaluate their ideas to make a good decision. Compared to the articles that are written by one or multiple authors, Q&A sites, particularly forums, can provide people access to information that is shared, exchanged, and interacted with, and commented on by a group of people or professionals.

Regarding the **social sites**, some participants used them to get feedback from others (e.g., family, friends, colleagues). In our qualitative analysis, we also found that **blogs** were used to learn lessons from others' work, to find information that can motivate themselves to continue working on their projects, and to gain procedural knowledge. As to **shopping websites**, in some cases, participants noted choosing them over search engines because shopping websites can provide a broader range of information about a product or service.

6.1.3 Challenges

In **RQ5**, we examine challenges reported by our participants when they worked on their creative projects. Several themes emerged in our data regarding the challenges in creative projects, including **creative processes, search, time constraint/pressure, information organization, motivation, and resources**.

In the creative processes theme, some participants reported that they had trouble figuring out their design options, finding an efficient way to "prototype" their ideas, and making a design decision. Inaccurate evaluation of ideas or a wrong design decision might lead to failure of a design.

As to the search theme, the main issue with using search engines is finding the exact information that participants looked for. As our participants described, search engines can provide the information that is ***related*** to what they wanted to search, but not the ***exact*** information that they were looking for. For Pinterest, some participants could not find results that were related to their goals. Some participants also mentioned they have trouble tracking the searching process in their projects because they did not remember what they searched and read.

Regarding the information organization theme, participants described their troubles organizing and making sense of the information that they found and saved. Resource issues are another type of technical challenges faced by our participants. For instance, some professional resources (e.g., some artists' portfolios) might not be available online or not indexed by search engines. Some participants also found that specific resources or websites were not unreliable, and some links were broken.

Time pressure and staying motivated are a few of the non-technical challenges noted by our participants. Since diary study is an in-the-wild approach, this method provided us a chance to uncover some time constraint and time pressure issues that were that our participants encountered in their projects. Another non-technical challenge that participants noted was to keep motivated. Conducing a creative project is never an easy job, and participants might feel tired and even frustrated in their projects. These negative emotions could make participants less motivated.

6.2 Implications of Dissertation Research

6.2.1 Research on Information Needs and Intents

Different from many prior studies that attempted to understand people's information needs in a lab setting, we conducted in-situ research to investigate people's information needs in their own

projects over two weeks. In this longitudinal research, the information types identified largely overlap with the daily information needs reported in Church's large-scale diary study (Church et al., 2014). This finding suggests that many information needs found in our research could be applied to a more general context (beyond design-related projects). We also identified several information needs that were not covered in Church's research (Church et al., 2014), such as finished examples, inspiring information, and domain knowledge. In the field of information search and retrieval, information needs are often described at a high-level. For instance, Ingwersen and Järvelin ("The Integrated IS&R Research Framework", 2005, p. 295) identified eight different types of information needs from two different perspectives: **specific information needs** ("known item", "known data element", "known topical or contents", "factual") and **exploratory information needs** ("muddled item", "muddled data element", "muddled topical or contents", "muddled factual"). Compared to Ingwersen and Järvelin's categories, the information needs (types of information) identified in our study are more concrete. Focusing on more specific categories can make our research findings more actionable for the future design of search engines. It is also worth noting that the types of information revealed in our study can be either specific or exploratory, which largely depends on ***people's prior knowledge*** (how much they know about the topic or theme) and ***their goals*** (whether they want to explore or not).

As shown in our results, several types of information are essential in a design-related project. When people design something, they need to generate their ideas, externalize them, and transform them into an object by using different types of tools or techniques (digital, physical, or both). In the ideation process, examples of the finished projects play an essential role in providing inspiration to facilitate the ideation process. People might search for different formats of examples (e.g., texts, images, or even videos) to collect others' design ideas. When people seek to externalize and transform their ideas, procedural knowledge, and tips/opinions/recommendations smooth the process of creating objects that can best represent the ideas in their minds. Additionally, creative projects require a significant amount of mental efforts and can never be easy, which is why people might have to need inspiriting information resulting from their tiredness, frustration, and lack of motivation in their projects. Previous studies have made a considerable amount of efforts to help people search and learn domain knowledge; however, how people search and learn procedural knowledge, tips/opinions/recommendations, and examples is an area that would benefit from additional research.

Regarding intents, our research focused on the "**intents of using information**". In terms of Belkin's ASK (Belkin, 1980) and Dervin's sense-making model (Dervin, 1998), new ideas can be the possible outcome of information use. Understanding information use behavior has also been emphasized in the research on information-based ideation behavior (Makri et al., 2019). In our study, we show that understanding the intents of using information could better help us investigate people's information needs. As aforementioned, the same type of information can link to different usage intents. That is to say; the same information can be used for very different reasons in specific contexts. This finding suggests that when we study information needs, it is necessary to investigate them in context. Instead of just focusing on what people search, we also have to ***understand how people intend to use the information that they find*** in their tasks. A better understanding of the intents of using information can also inform the future design of search systems: if search systems can better predict how people will use the information that they search for, recommendations and results provided by the systems could be more relevant and useful.

6.2.2 Research on Searching as Learning

Many efforts have been made to investigate how search engines can be used for supporting people to learn knowledge. Findings indicate that people may have trouble finding the exact information that they look for due to several factors, such as the scope of a topic (Barry, 1994; Levitin & Redman, 1995; Miranda & Saunders, 2003; Y. Zhang et al., 2014), existing knowledge about a topic (Lancaster, 1979; Harter, 1992; Y. Zhang et al., 2014), and the availability of the resources related to a topic. In our diary study, we found that people may have trouble finding the exact information when they search for information about ***a very specific topic***, when they already ***knew much about the topic***, and when there are ***limited professional resources about the topic***. In this sense, the future research on searching as learning might also have to investigate ***how to help people quickly find the contents that they want to learn*** instead of only focusing the goals of learning (e.g., the types of knowledge that people want to learn). As our participants noted, sometimes, they knew what they wanted to learn, but they could not find the exact contents that could support the learning process.

Regarding the ***goals of learning***, the types of information identified in our research also suggest that people require different types of information or knowledge (e.g., tips/opinions/recommendations, procedural knowledge, domain knowledge, etc.) in their day-to-day life and work. Previous studies

have made a considerable amount of efforts to help people learn domain knowledge (X. Zhang et al., 2015; Wildemuth, 2004; Liu et al., 2016; Mao et al., 2018). However, how people learn procedural knowledge and tips/opinions/recommendation has not been given sufficient attention. It is also worth noting that finding, learning, and making sense of tips/opinions/recommendations can be very challenging (particularly when the tips/opinions /recommendations are contradictory):

> "*With printmaking, it's sort of like there's a lot of different ways and some people are like 'This is the best way' and other people are like 'Oh, no. Don't use this way'.*" **[P3-interview]**

As to the ***contents of learning***, it has been found that participants used different resources (e.g., images, videos, social sites, or Q&A) to find and learn information or knowledge. In our study, our participants sought to learn by using multiple types of resources, and their information needs could also evolve and move from one type of resource to another. For instance, a video that a person watched may help this person generate a new information need and motivate him or her to read more related articles. In this sense, it is necessary to consider multimedia learning processes in future research on searching as learning. We might consider how to make aggregated search results to support people's creative processes (e.g., mixing and ranking aggregated search results based on usage intents or creative stages). We could also find a novel way to include "*creative verticals*" in aggregated results. For instance, instead of slicing results in terms of media types (e.g., videos, books, images, news, and shopping), we could segment search results based on these "creative" information needs (e.g., procedural knowledge, finished examples, domain knowledge, tips/opinions/recommendations) identified in our research.

6.2.3 Redesigning Search Engine Result Pages (SERPs)

From our data, we find that our participants treat search engines as not just a resource but also a tool that leads people to a variety of different resources. Search engines are like an interactive "map" that lead to different types of resources (e.g., videos, images, articles, blogs, forums, etc.) where they can find the information they need:

> "*...I Google searched '[three word query]' and ... yeah, that video popped up ... I saw that and I just clicked on it from there, so Google served as a proxy to get me into YouTube to look at that information.*" **[P3-interview]**

"*I think it generally started with like a search engine search, but that kind of led me to videos, longer videos of people explaining the history of the [technology].*" [**P5-interview**]

"*... I rely very heavily on Google and occasionally YouTube to get my information ... I just feel like it's so convenient to have all these different formats of things in what I see. Because it shows you videos and pictures and articles, and everything that I could need in one spot. It just makes it super convenient.*" [**P12-interview**]

Just displaying relevant results in the "ten blue links" fashion may not help people easily make sense of the information on the "map". In our research, we found that participants used different types of resources in their projects to support their creative processes. There is no doubt that search engines provide people great access to these resources, but the information shown on SERPs might not be well synthesized and organized to some people. In future research, we can explore the different design layout of SERPs to learn how to group information or resources that can facilitate people's creative processes. Additionally, our results showed that video sites, particularly Youtube, are a good place for people to get a variety of information that has been synthesized by the video creators. Future research can also examine how to mine the video contents and use the extracted information to inform the way to synthesize search results.

6.2.4 Improving Search Algorithms

One of the challenges faced by our participants was to find the exact information that they were looking for. The roots of this problem involve three aspects.

Firstly, we note that our participants were not amateurs, and most of them had design/art training before. That is to say, the information sought by our participants was less likely to be general questions (e.g., "how to use photoshop", "how to paint", "how to take a good photo"). Their questions were usually very specific to a particular topic or technique in a domain that is sought by a specific group of people. In this sense, the bias in the datasets that are used to train search algorithms may make it difficult for existing commercial search engines to provide much helpful information in certain cases.

Secondly, people do not have much control over the scope of the information returned by search engines. The only way they can change the scope is to issue different queries. However, generating a high-quality query is not always an easy job. Sometimes, this process requires a lot of effort and

time. For instance, as **P10** stated:

> "*The biggest technical challenge was figuring out how to be* ***both specific and broad in my search terms****, because I wanted to gather a wide range of information but still have it be relevant to my topic.*" [**P10-diary**]

Thirdly, the existing commercial search engines (e.g., Google, Bing, Yahoo) do not give people a way to specify and express their own relevance criteria explicitly. The relevance criteria are inferred by machine learning algorithms that map people's queries to some criteria predefined by search engine companies. However, this mapping process is not always accurate, and the algorithms may misread what people exactly want. For example, existing search engines may have a difficult time to infer people's existing knowledge (what people already know) on a topic that can influence their relevance judgments and information needs (Lancaster, 1979; Harter, 1992; Y. Zhang et al., 2014):

> "*...there were issues because sometimes it was hard to find the answers to my specific questions. I really wanted to find out how to easily duplicate or copy/paste a layer onto a new layer, but I kept getting results on how to copy and paste onto the same layer, which I already knew how to do...*" [**P14-diary**]

In the future, we could think more about how to help people easily "zoom in" and "zoom out" of the scope of search results by improving the design of search algorithms. From the perspective of personalized search, for instance, we could explore ways to put users in the loop and give them more control over the search algorithms. As an example of this, in our study, **P2** noted that they annotate the metadata of Pinterest so that she and others could get more accurate search results from Pinterest:

> "*... I'll add information so that the image is more accurate when somebody else searches it ... So if somebody has just saved an image by [names of artists], I'll go in, find the title and the year that that work was made. Not only for myself but so that somebody else could search it using those keywords.*" [**P2-interview**]

In future research, similarly, we can explore ways to design a new feature that allows people to "input" their criteria. For instance, we could design a new SERP that can allow people to mark the

results that they already know, and search algorithms can use this "input" information to rerank the results on SERPs. It should be noted that some early studies were conducted to explore ways of designing browsers that could collect feedback from users in situ (Claypool, Le, Wased, & Brown, 2001; J. Y. Kim, Teevan, & Craswell, 2016; Fox, Karnawat, Mydland, Dumais, & White, 2005). In the future, it is worth revisiting and continuing this research.

6.2.5 Design of Creativity Support Tools

Support seeking inspiration

Our participants reported looking for finished examples to seek inspiration in their projects. Although the finished examples can be articles, images, or videos, images were the primary resource that participants used to search for examples. Search engines do a good job of helping people find a variety of images, but there is still room for improvement. For instance, it is still challenging for people to quickly narrow down the scope of the images that they want to search for. Besides, our participants noted that when they wanted to search for images that were related to design work and arts, search engines might not provide many high-quality results.

Another challenge related to image search is tracking and saving images that have been already viewed. Different from reading articles, browsing images could be very quick and people can browse many images in a short period. When using search engines to browse images, people may just look at them without clicking them. That is to say; many viewed images might not be logged in the browser history. For example, P6 noted that she had to download images and save them in her desktop so that she could go back to review them later:

> "*I find it so important to save the images since by scanning them a few days later they evoke different thoughts than the first time, so I save images I like to a file. I probably have 20 images now for this project*" **[P6-diary]**

It may help streamline people's creative processes if search engines can be designed to help people save and organize and review the images that they browsed.

Support seeking indirect feedback

In the field of creativity support tools, several novel systems were developed for providing users a platform to seek direct feedback from experts (Y. W. Wu & Bailey, 2017; Yen et al., 2017; Xu et al., 2014) to evaluate their ideas. In our research, we found that participants primarily used

two ways to get feedback regarding their work. To get ***direct feedback***, participants mainly used Facebook or social media apps to ask their friends, family, and colleagues to provide comments or suggestions on their ideas and work. As to ***indirect feedback***, participants searched for the tips/opinions/recommendations that can be ***analogous to*** participants' work or ideas and used them to help with evaluating ideas. opinions To the best of our knowledge, in the fields of information search and retrieval, few efforts have been made to understand how to support people find ***useful*** tips and opinions. To achieve the goal, search systems need to learn how to do analogy mining and provide "analogical results" (not just relevant) to people. For instance, in the area of HCI, some related work has been done to explore ways to design and implement models that can support people to find useful analogies in large datasets (Kittur et al., 2019; Chan, Chang, Hope, Shahaf, & Kittur, 2018; Gilon et al., 2018; Hope, Chan, Kittur, & Shahaf, 2017; Yu, Kraut, & Kittur, 2016).

Support information use

Information searching is an important component of people's creative projects. Across different creative stages, our participants had different information needs and searched for different resources to help their project move forward. However, only searching for information would not help their projects to get done. Our participants also had to make use of the information found online to "create something". Prior work has considered dimensions of information usage. For example, in Belkin's ASK (Belkin, 1980) and Dervin's sense-making model (Dervin, 1998), new ideas can be a possible outcome of information use. Understanding information use in the context of ideation has also been explored by Makri et al. (Makri et al., 2019). In our diary and interview data, we identified several common approaches that participants used to ***save, organize, and preserve*** the information for the use in the future (see Figure 6.1).

It should be pointed out that notes-taking played an important role in our participants' projects. Our participants described taking digital notes, paper notes, or both to help themselves save and use the information that they encountered:

> "*I took down a few notes within Microsoft word that stood out to while watching the video as well as some other project ideas ...* " **[P5-diary]**

> "*I kept a Google doc open for notes and ideas, and I also copied links there that I may*

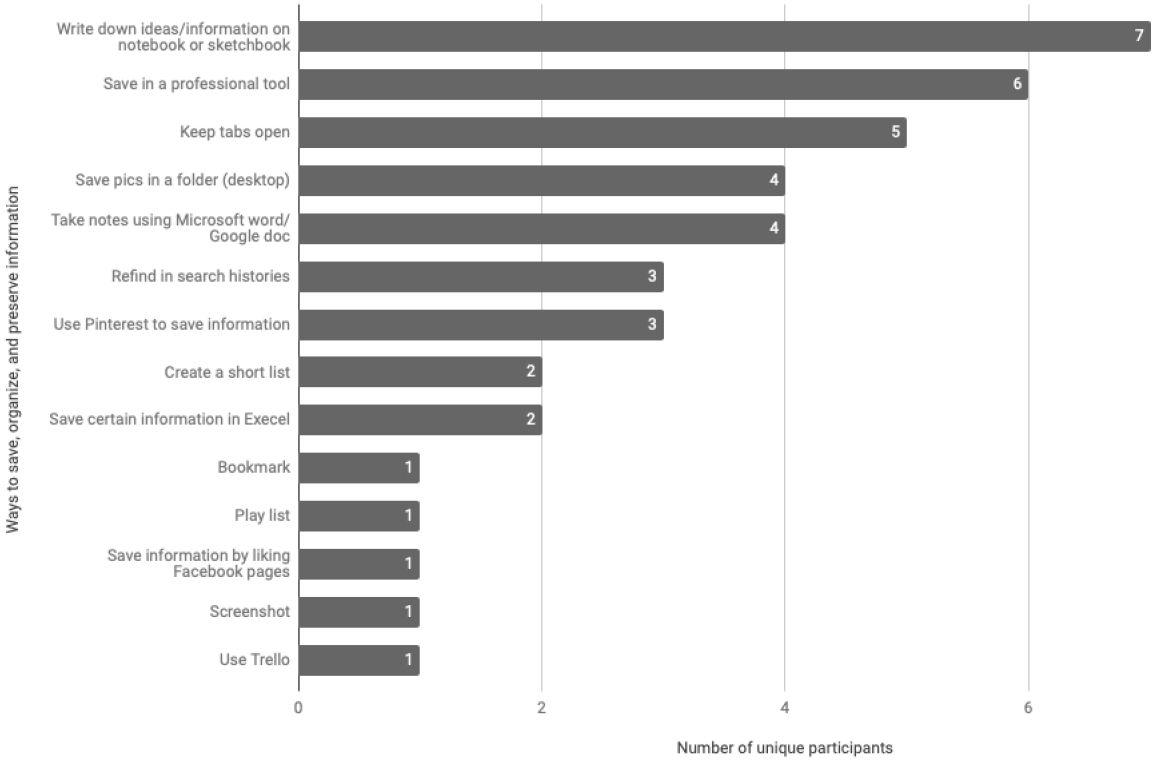

Figure 6.1: Ways to save, organize, and preserve information for the use in future: approaches were identified from participants' diary data

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use at a later date. For instance, I saved the link to [name of site] so I can explore their maps and data later." [**P10-diary**]

"*That's really just my way of being able to access that information no matter what device I'm using. So let's say I don't have my computer with me, but I have my iPad reader and I'm wanting to just read and take notes on the Notes app. I can have both those apps open at the same time and take handwritten notes.*" [**P2-interview**]

This finding also suggests that supporting note-taking during searching is necessary, and just as **P6** wrote down in her diary:

"*I wish there was a tool that would annotate on the actual web pages and take a screenshot and save in OneNote. I could probably figure out how to do that if I tried, but to me I want to work on the art not figuring out new tech. I scribbled down gesso and joint knife so that I wouldn't forget to buy them tomorrow.*" [**P6-diary**]

6.2.6 Bayesian Analysis for Small-n Studies

An additional contribution of this dissertation is that we used a Bayesian approach to analyze the quantitative data in this dissertation. Weakly informative priors were used to specify prior distributions to ***regularize extreme inferences that are obtained using maximum likelihood***. The key idea behind weakly informative priors is that "*a typical change in an input variable would be unlikely to correspond to a change as large as 5 on the logistic scale (which would move the probability from 0.01 to 0.50 or from 0.50 to 0.99)*" (A. Gelman et al., 2008, P.1363).

In the frequentist framework, when a random-effects model is fitted on a dataset with level-2 sample sizes[1] below 50 by using traditional maximum likelihood estimation, the estimates of both variance components and standard errors of fixed effect can be downwardly biased, which can cause inflated Type-I error rates for the fixed effects (McNeish, 2017). Particularly, once the level-2 sample sizes drop below 25, it is almost certain that the data suffer from the small sample biases (McNeish, 2017). Although **Restricted Maximum Likelihood** (REML) can improve the performance of a random-effects model when it is fitted on a dataset with small level-two sample sizes (Ferron, Bell, Hess, Rendina-Gobioff, & Hibbard, 2009; McNeish & Stapleton, 2016), the inflated Type-I error rates for fixed effects can not be resolved entirely (Kenward & Roger, 1997). To address the small sample biases, a Bayesian approach is suggested in some prior research (Muthén & Asparouhov, 2012; Van De Schoot, Broere, Perryck, Zondervan-Zwijnenburg, & Van Loey, 2015).

In this quantitative analysis, we used Bayesian and Frequentist. For Frequentist approach, lme4 package was used to run a random effect logistic regression model. Restricted Maximum Likelihood (REML) was used to estimate parameters. approaches to develop two sets of random effect logistic regression models, respectively. Before fitting models, all binary predictor variables were standardized with "*a mean of 0 and to differ by 1 in their lower and upper conditions*" (A. Gelman et al., 2008, P.1363). To check the precision of the estimates of our regression models, we generated the **High-Density Intervals** (95% HDIs) for Bayesian models and **Confidence Intervals** (95% CIs) for Frequentist models, shown in **Figure 6.2 - 6.8**.

Overall, Frequentist models had poor performances. Specifically, Frequentist Models 1-5 suffered

[1]Level-2 sample sizes refer to the number of the clusters or groups in the data. For example, in our study the level-2 sample sizes equal to the number of the participants (11).

from a singular fit issue in our study, which means these models were too complex to be justified by our dataset. To avoid the issue, it is suggested to either simplify the model (Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017) or use a Bayesian approach to specify weakly informative priors (Chung, Gelman, Rabe-Hesketh, Liu, & Dorie, 2015; A. Gelman & Hill, 2006). In our cases, the singular fit issue results from the random-effect variance estimates of (nearly) zero. However, it will not be a reasonable choice to remove the random effect components to simplify frequentist models, since our research is longitudinal research with repeated measurements.

Additionally, because of the small sample sizes in our study, some estimates in the Frequentist models had extreme inferences that were obtained using Restricted Maximum Likelihood (REML). For example, the CIs of the intercept and "search engines" variable in **Model 1** (**Figure 6.2**) were extremely large, which indicates a large uncertainty underlying the estimates. **It should be noted that HDIs and CIs are computed in different ways, and we did not compare the ranges of HDIs with those of CIs**.

Regarding the conclusions drawn from Frequentist and Bayesian approaches, there were two differences. In **Model 2** (**Figure 6.3**), the frequentist model rejected the null value (zero) of ***videos*** variable was rejected (95% CI = 0.05, 2.18; $p = 0.04$), whereas the Bayesian model did not (95% HDI[2] = -0.05, 2.15); in **Model 7** (**Figure 6.8**), the Bayesian model rejected the null value (zero) of **images** variable (95% HDI = -2.51, -0.01), whereas the Frequentist model did not (95% CI = -2.39, 0.09; $p = 0.07$). Considering the issues with frequentist approach mentioned above, we only reported the results of the Bayesian approach in **Chapter 5**.

[2]the *HDI* provides a function similar to a confidence interval in null hypothesis testing (but must be interpreted differently). In Bayesian inference, there is no p-value; instead, to interpret the results, the null value (zero) of a coefficient is rejected if its 95% HDI excludes zero (Kruschke, 2014).

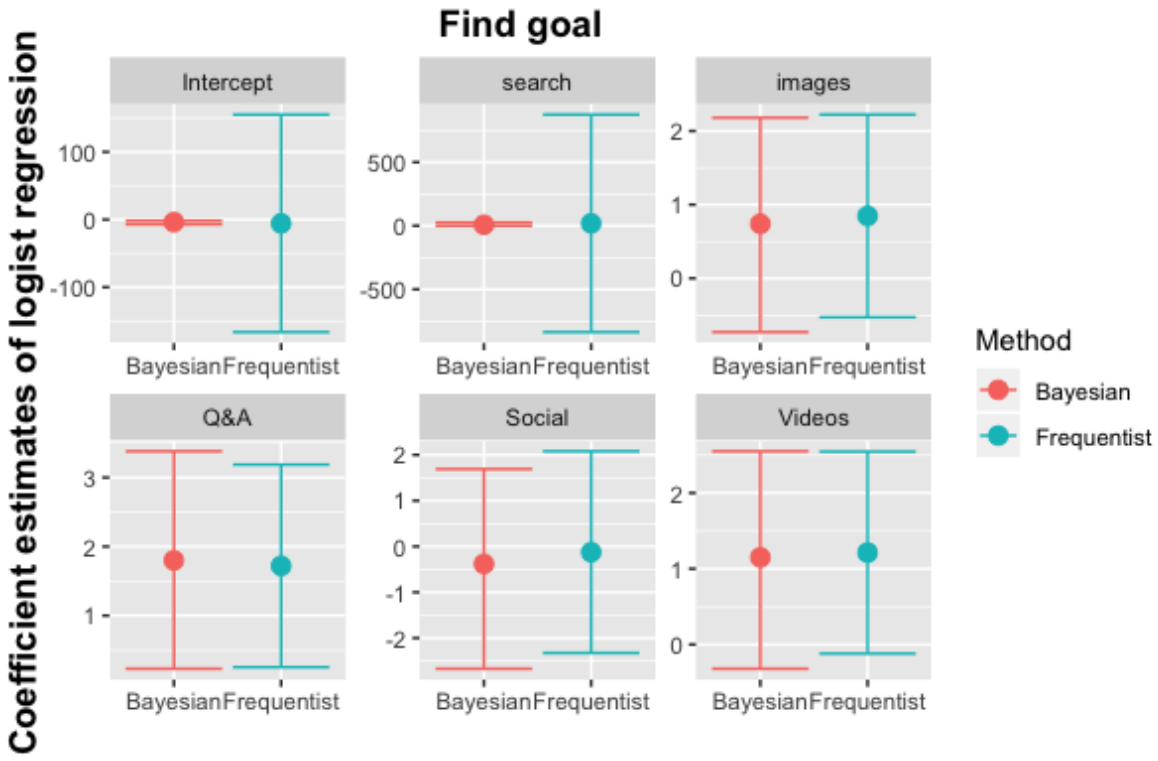

Figure 6.2: Model 1: Find Goal Stage

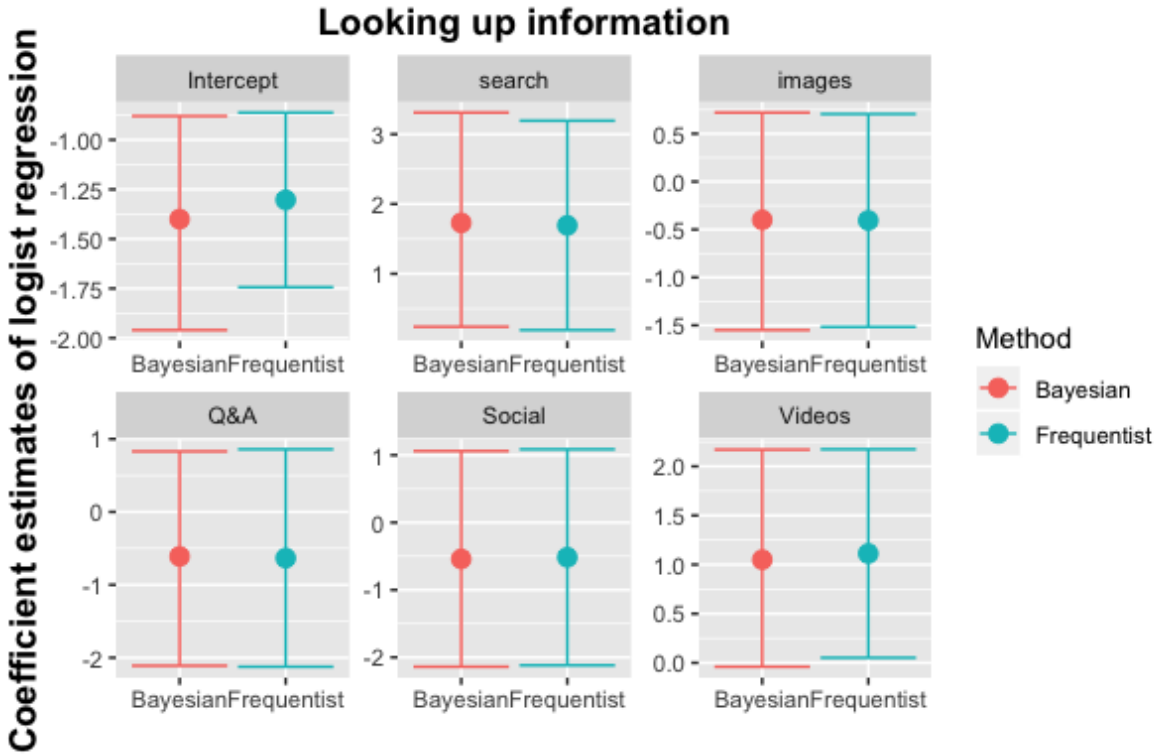

Figure 6.3: Model 2: Look-up Stage

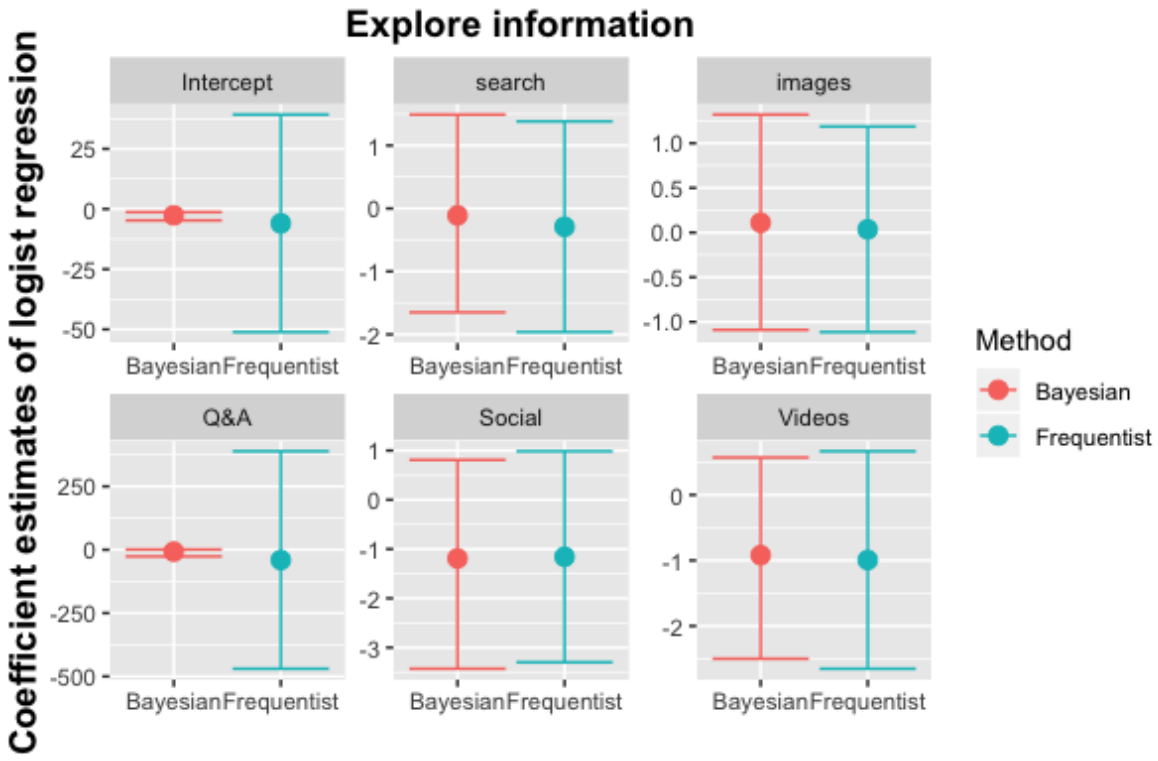

Figure 6.4: Model 3: Explore Stage

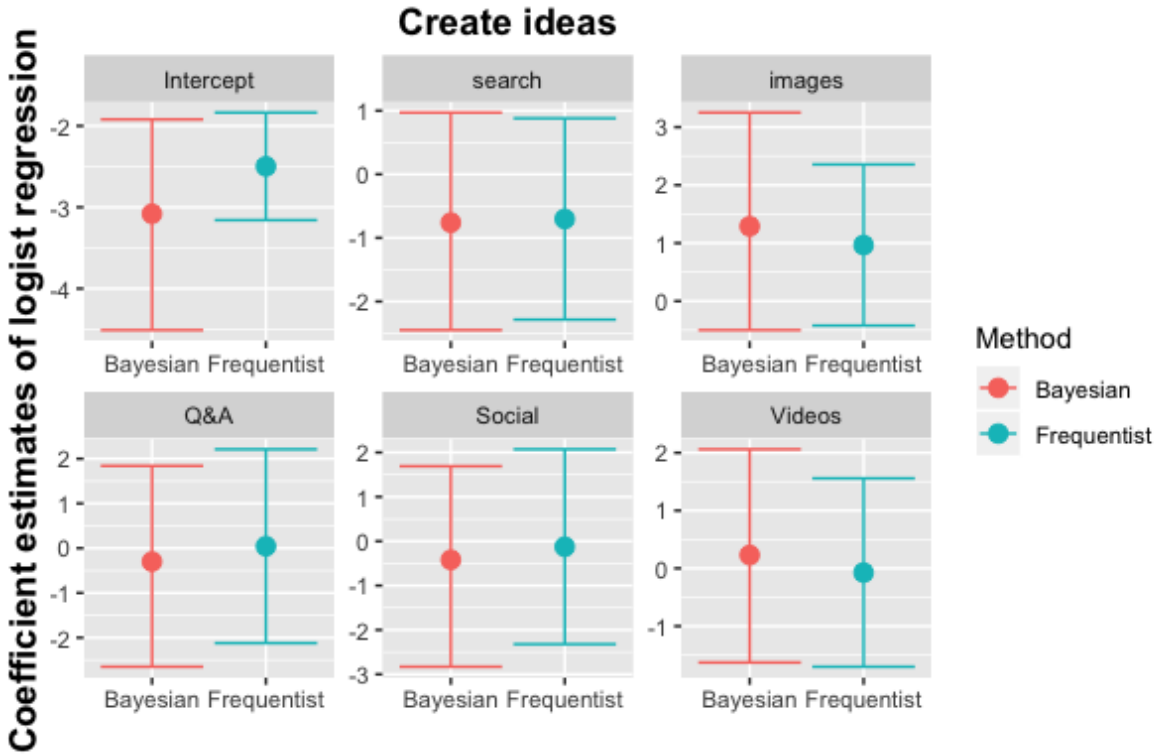

Figure 6.5: Model 4: Create Ideas Stage

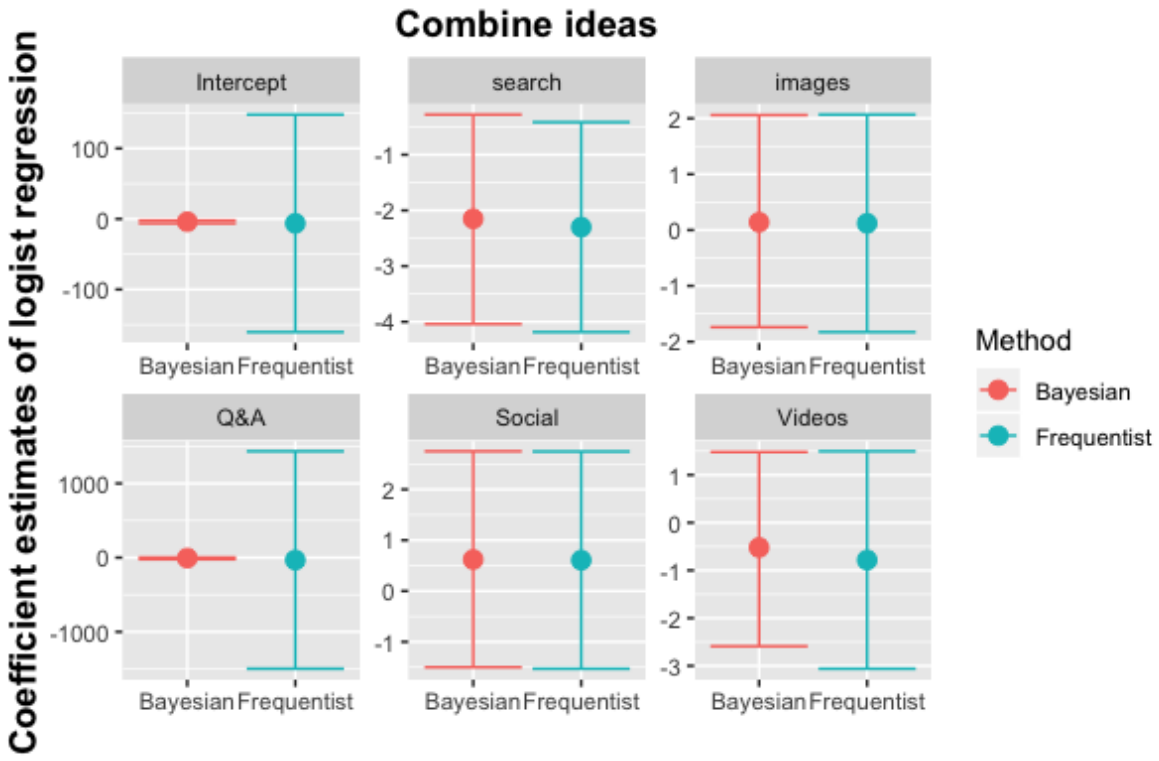

Figure 6.6: Model 5: Combine Ideas Stage

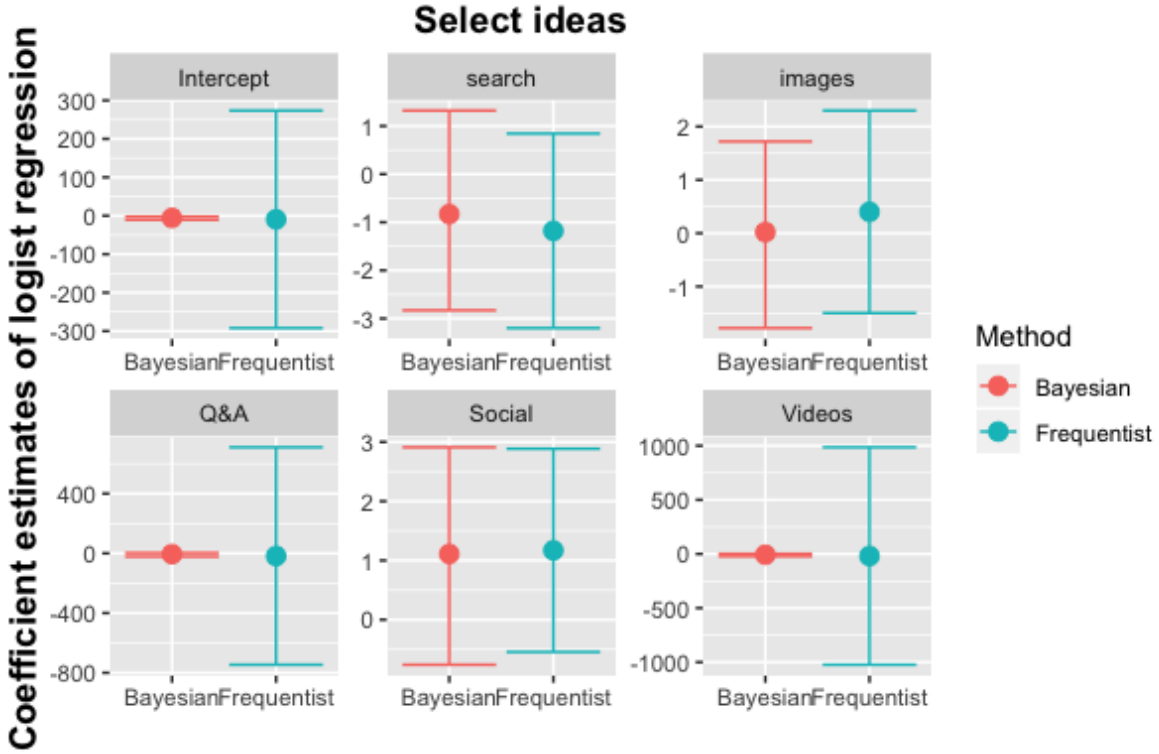

Figure 6.7: Model 6: Select Ideas Stage

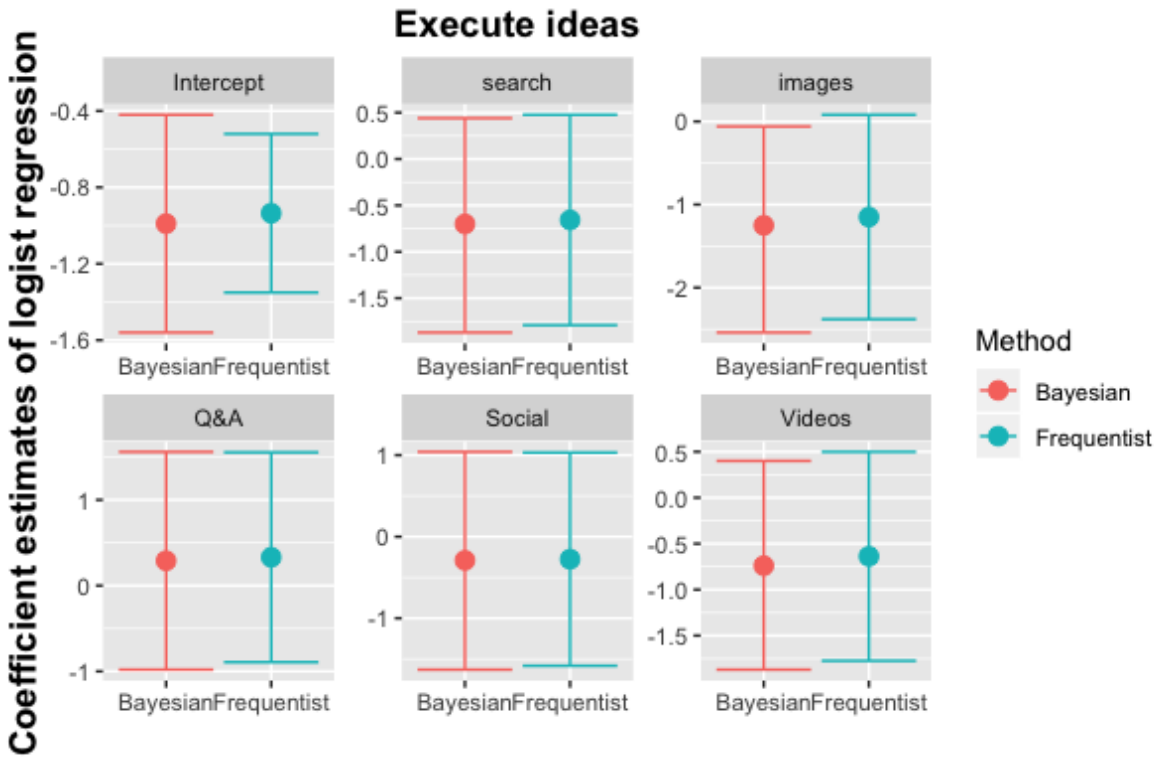

Figure 6.8: Model 7: Execute Stage

6.2.7 Diary Study in Research on Information Search and Retrieval

As aforementioned in Chapter 4, diary studies have high ecological value as they are carried out in situ, which minimizes the effects of observers and participants (Czerwinski et al., 2004; Carter & Mankoff, 2005). Compared to laboratory studies that have been widely used in the area of information search and retrieval, diary studies can help researchers have a better understanding of events that are important to participants a well as stages that are involved in participants' tasks. In the following paragraphs, I summarize some lessons that we learned from this dissertation research regarding conducting diary studies about information seeking and use.

Firstly, ***Motivation is important***. In order to collect reliable data in a diary study, it is necessary to make sure that participants have a motivation to conduct a task in the study. In this dissertation research, we asked participants to bring their own projects to the diary study and also used screening questionnaire and screening interviews to ensure that our participants had "meaningful" reasons for doing their projects. "Meaningful" motivations can drive participants to complete a diary study and offer more helpful insights in their log entries. Participants with low

motivation might either drop out in a study or provide low-quality entries.

Secondly, ***it is essential to provide a detailed diary study guide and make it easy to access for participants.*** Before a diary study session starts, a researcher should conduct onboarding interviews with all the participants and make sure that they understand what they need to do in the study and have no trouble using any tools to support the diary sessions. Additionally, it is important to share a digital copy of the diary study guide with participants. Participants might not remember all the detail that has been discussed in the onboarding interviews. If participants had any questions, the researcher should make sure that participants can easily find the digital copy of the diary study guide. In this dissertation research, a diary study guide and a FAQ document were placed in the bookmark bar of each participant's Firefox account. Whenever they had any questions regarding the diary study, they could check the two documents by clicking the bookmarks.

Thirdly, ***the questions used to collect information should be carefully designed***. A survey or questionnaire is commonly used for logging diary entries, but it is worth noting that survey or questionnaire questions should be specific enough to capture the information that is useful to the study and should be able to capture events or incidents that will repeat during a diary session. Different from a survey study that participants will answer a survey or questionnaire once, in a diary study, participants will answer the same survey several times. If a question asks something that will not change over a short period (e.g., attitudes, preferences), the response provided by a participant might be the same or similar during the entire diary study session.

Fourthly, ***participants need help with recalling details in the in-depth interview***. An in-depth interview is usually paired with a diary study so that researchers can get the maximum benefit of the diary entries. If researchers ask their participants to "recall" certain levels of details about the participants' tasks, it can be helpful to provide some concrete examples or information that can trigger participants' memory. In this dissertation research, when we asked participants to recall their search behaviors in their projects, we found that high-level diary data (e.g., creative stages included each day, summaries of what had been done each day, and challenges reported each day) and search logs (e.g., keywords searched each and webpages visited each day) could help participants recall what they did in their projects. Particularly, the visualization tool developed for this diary study helped participants easily tell the stories of the creative "journeys" in their projects.

Lastly, ***making sure that participants' performances are tracked***. By design, diary studies

often have low levels of "control" of variables. However, researchers can design some “homework” that can help track participants’ performances in their tasks. In this dissertation research, for example, participants were asked to provide some artifacts (e.g., documents, videos, or images) that showed their “ideation” and “evaluation” processes in their projects. Additionally, participants’ diary entries were tracked during their diary sessions. Specifically, if a participant did not work on a project two days in a row, I would check in with the participant.

CHAPTER 7

CONCLUSION

This dissertation work includes two parts: a survey study and an in-situ study (diary study). We grounded our research questions and analysis in prior research on creativity. Specifically, we focused on everyday creativity developed by Richards (2010) and used a set of creative process stages identified by Sawyer (2011) to understand people's creative processes.

In the first part, we conducted a survey study to explore the role that information search plays in supporting everyday creativity. We observed that people engage in information seeking to support an array of creative tasks across different domains and that they often use multiple devices and information resources/tools to support these activities. Our participants' tasks involved multiple creative stages that involved different, more divergent needs (e.g., create ideas) than other types of directed, convergent searching (e.g., find information). We found that search engines and other information resources/tools (e.g., images, videos, social media) are strategically used by people to support their creative processes, but there are opportunities to provide better support.

In the second part, we conducted a diary study to get a deeper understanding of how people use search engines and other digital resources to support their creative processes (e.g., information needs in people's design-related creative projects, their strategies of using different resources to support their creative processes, and the challenges they encountered).

Specifically, to understand our participants' information needs (**RQ1** and **RQ2**), we investigated our participants' information needs from two different angles: "the nature of information" and "what they use it for" (Case, 2007, p. 87). Based on the qualitative analysis, we identified seven different types of information sought by our participants, including procedural knowledge (instructions), domain knowledge, finished examples, tips/opinions/recommendations, information about specific topics, and inspiring/motivating information. Additionally, we identified seven different usage intents (e.g., learning how to do something, seeking inspiration, ideation, evaluating and selecting ideas, project planning, making a purchasing decision, and keeping motivated.) for describing participants'

intents to use each type of information in their projects.

To examine our participants' strategies of using different resources in their projects (**RQ3** and **RQ4**), we used quantitative and qualitative methods to analyze our datasets. The findings of our quantitative analysis (Bayesian analysis) have indicated that the usage of a particular resource can predict whether a participant is in a specific creative stage, for some stages (e.g., the usage of Q&A sites was predictive of being in the "Find Goals" stage). In our qualitative analysis, we have also investigated eight different resources/tools that participants used in their projects (search engines, video sites, images sites, images from search engines, Q&A sites, social sites, blogs, and shopping websites) and five common reasons for choosing a resource/tool (looking for specific information, supporting specific creative processes, supporting learning domain information, supporting learning procedural information, and managing information).

By deeply examining our participants' diary entries and in-depth interviews, lastly, we have uncovered several themes regarding our participants' common challenges faced in their design-related projects (**RQ5**): creative processes, search, time constraint/pressure, information organization, motivation, and resources. These challenges described by our participants provide insights that can inform future research on information needs and intents as well as the future design of search engines.

The implications of this dissertation research include three parts. From the theoretical perspective, our findings show: (1) the importance of considering people's usage intents in future research on information needs and (2) the necessity of examining the goals (e.g., the types of knowledge that people want to learn) and contents (e.g., resources used for supporting learning) of learning in the research on ***Searching as Learning***. From the design perspective, we also provide several recommendations for improving search engines to better support people's creative processes (e.g., looking for exact information, seeking inspiration, seeking indirect feedback, and using information). From the methodology perspective, this dissertation shows how a diary method can provide researchers an excellent opportunity to gain insights into how people use search engines to support their projects in their environments. By comparing Bayesian and Frequentist approaches in the quantitative data analysis section, we also show how researchers can benefit from the Bayesian approach when they face small-n sample issues.

Regarding the limitations of this dissertation study, firstly, all the participants were recruited from

the University of North Carolina at Chapel Hill. The findings of this research might be potentially biased by our participants' demographic backgrounds. Secondly, as pointed out in the Methodology chapter, this diary study only investigated design-related creative projects. In the future, it is worth examining the findings (e.g., different information types, usage intents, reasons for using different resources) in new contexts and different research problems.

APPENDIX A

Survey of Preliminary Study

A.1 Keywords of MTurk HIT Groups

Keywords used in the posting of Amazon Mechanical Turk (MTurk) HIT groups:

- **Group 1**: crafts, architectural design, culinary arts;
- **Group 2**: humor, theater, film;
- **Group 3**: invention, entrepreneurial ventures, product design;
- **Group 4**: visual arts, interaction design, visual design, graphic design;
- **Group 5**: writing, presentation, report writing, creative writing.

A.2 Survey Questions

Q.1. For this set of questions, please think about a time recently when you went online to look for useful resources or information to help you create something. For example: designing something, coming up with a solution to a problem, brainstorming for a project, creating a new recipe, working on a writing project, remodeling your house, and so on.

Q.2. Still focusing on the task you just described, please tell us about your creative process in the task. For example, you can tell us how you started this task, what sites or resources did you use, your strategies to find information or resources, and so on.

Q.3. Which of the following did you use to look for information in this task? Choose all that apply:

- Desktop or PC,
- Smartphone,
- Tablet,
- Smart TV (Apple TV, Roku, Play TV, etc.),
- Google Home or Alexa,

- other (please specify)

Q.4. Which of the following tools did you use as part of your search? Choose all that apply:

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, etc.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)
- Social sites (Facebook, Twitter, Reddit, Google+, etc.)
- Other (please specify)

Q.5. For which of the reasons below did you use *<option selected in Q.4>* in the task (Choose all that apply):

- **Figure goals**: figure out my goal (what I want to create/design or which problem I want to address/solve)
- **Look up**: look up information relevant to my goal
- **Explore**: explore (gather a broad of range of potentially related information) about my goal
- **Create ideas**: create a large variety of ideas that may achieve my goal
- **Combine ideas**: combine some ideas that I have already had
- **Select ideas**: select the best ideas from all the new ideas that I have created
- **Execute**: figure out how to put my ideas into practice to achieve my goal
- Not applicable

Q.6. How satisfied were you with using *<option selected in Q.4>* to: *<option selected in Q.5>*

A.3 Bayesian Analysis

In the Bayesian models, we adopted A. Gelman et al.'s suggestions by setting Cauchy distributions as the default weakly informative priors for **intercept** (β_0) and **coefficients** (β_j) (A. Gelman et al., 2008). The half-Cauchy distribution is used as the default prior for **scale parameters** (σ) (A. Gelman, 2006). Normal distribution is used as the priors for **random effects** (ω and υ).

High-density interval (HDI) is recommended to be used for the credible interval in Bayesian analysis (Kruschke, 2014, p.89). 95% HDI includes all the most credible values (ones with the highest probability density) of the parameter. It should be noted that HDI is different by definition from the CI, which is a limit that provides no distributional information about the parameter values (Kruschke, 2014).

A.3.1 Logistic Regression Model

$$\begin{aligned} \mu_i &= logistic\left(\beta_0 + \sum_j \beta_j x_{ij}\right) \\ y_i &\sim Bernoulli\left(\mu_i\right) \\ \beta_0 \sim Cauchy\left(0, 10\right);\ &\beta_j \sim Cauchy\left(0, 2.5\right) \end{aligned} \tag{A.1}$$

The sum-to-zero constraint ($\sum_j \beta_j = 0$) is added in the model.

A.3.2 Rand. Effects Logistic Regression

$$\begin{aligned} \mu_i &= logistic\left(\beta_0 + \omega_{[domain[i]]} + \sum_j \beta_j x_{ij}\right) \\ y_i &\sim Bernoulli\left(\mu_i\right) \\ \omega \sim Normal\left(0, \sigma_\omega\right);\ &\sigma_\omega \sim Cauchy^{+}\left(0, 5\right) \\ \beta_0 \sim Cauchy\left(0, 10\right);\ &\beta_j \sim Cauchy\left(0, 2.5\right) \end{aligned} \tag{A.2}$$

ω is the random effects in the model. The $domain[i]$ refers to the domain of the task that participant i conducted ($domain[i]$ = 1,...,8).

A.3.3 Rand. Effects Ordered Probit Regression

$$
\begin{aligned}
\mu_i &= \beta_0 + \upsilon_{[user.id[i]]} + \omega_{[domain[i]]} + \sum_j \beta_j x_{ij} \\
p(y_i = k \mid \mu_i, \boldsymbol{\theta}) &= \phi(\theta_k - \mu_i) - \phi(\theta_{k-1} - \mu_i) \\
\upsilon \sim Normal\,(0, \sigma_\upsilon);\ \omega &\sim Normal\,(0, \sigma_\omega) \\
\sigma_\upsilon, \sigma_\omega &\sim Cauchy^{+}\,(0, 5) \\
\beta_0 \sim Cauchy\,(0, 10);\ \beta_j &\sim Cauchy\,(0, 2.5) \\
\theta_k &\sim Normal(k + 0.5, 0.25)
\end{aligned}
\tag{A.3}
$$

In the model, it is assumed that there is a latent variable (μ_i) influencing participant's responses to an ordinal variable, y_i, through some "threshold concepts" that are modeled by a series of threshold values ($\theta_1, \theta_2, ..., \theta_{K-1}$, where K equates the number of ordered options in the ordinal variable). In the model, υ and ω are the random effects. ϕ refers to the cumulative distribution function. $Normal(k + 0.5, 0.25)$ is used as the prior for each threshold values ($k = 2, .., K - 2$) (Kruschke, 2014). To make the model determined, the two extreme thresholds are fixed to meaningful values on the outcome scale (Kruschke, 2014): $\theta_1 \equiv 1 + 0.5$ and $\theta_{K-1} \equiv K - 0.5$. The sum-to-zero constraint ($\sum_j \beta_j = 0$) is added to the model.

APPENDIX B

Recruiting Email Template

We are recruiting participants for a study about how people **use technology to support their creativity** in their day-to-day projects.

About you: you don't have to be an artist or professional designer, but you should be the person who is willing to use design or creative thinking to make a change in your work and life.

About your project: the project should be one that involves some aspects of creativity and/or design (such as UX/product/prototype design, scientific research, visual arts, arts and crafts, creative cooking, and so on). Your project could be your school project, research project, personal hobby, a portfolio that you are building for hunting jobs, or even your startup business plan.

To participate in our research, you have to agree with:

- **Using Firefox when working on the project**;
- **Sharing your browser history when working on the project (you will be able to remove any private or sensitive information)**;
- **Working on the project at least three days of a week (this study will last 2 weeks)**.

The goal of our study is to gather data about your thoughts and experiences during the start, middle, and end of a creative or design process. If you are selected to participate, during a two week period you will be asked to complete questionnaires and make diary entries about how you use technologies and information resources on the Internet to support your creative endeavor in your project. At the end of the two weeks, we will schedule an interview with you to review your diary entries and ask some questions about how you found and used online resources to help your work on the project.

If you are interested in participating in this project, please click the link below to fill out a short questionnaire. In the questionnaire, you will be asked to answer questions about your background and the project you plan to conduct. You will also be asked to provide your name and an email address where we can contact you. If you are selected for participation in the study, we will send you a follow-up email with more information. We anticipate the study starting on DATE and ending on

DATE. **Please note all the data collected in the questionnaire will not be shared outside of our research team.**

APPENDIX C

Participant Screening Questionnaire

Q.1. What is the timeline for the project?

- less than 1 week
- 1- 2 weeks
- 2-3 weeks
- 3 - 4 weeks
- 4 - 5 weeks
- more than 5 weeks

Q.2. Please briefly describe the creative project that you will be working on.

Q.3. Please select the option that can best describe your motivation to do the project:

- Curiosity (e.g., expressing your own ability)
- Asserting your ability or skill (e.g., making with your own hands)
- Appropriation (e.g., making something your own or making it fit better)
- Productivity (e.g., getting something done)

Q.4. Please select the area that can best describe your project:

- Solve a practical problem with an original technical trick
- Construct something which required scientific knowledge
- Write a computer program
- Design a website
- Create a photo-montage or photo collection
- Paint a picture/create a graphic
- Produce a sculpture
- Produce a blueprint for an interior redesign
- Tinker with an object
- Create an original decoration
- Design or sew clothing
- Cook an original dish/make up a new recipe

- Form a sculpture out of food

Q.5. Please indicate which following activities that you might include in your project:

- Figure out my goal (what I want to create/design or which problem I want to address/solve)
- Look up information relevant to my goal
- Explore (gather a broad range of potentially related information) about my goal
- Create a large variety of ideas that may achieve my goal
- Combine some ideas that I have already had
- Select the best ideas from all the new ideas that I have created
- Figure out how to put my ideas into practice to achieve my goal
- Other (please specify)

Q.5.1 Please briefly give us an idea of how the activities you checked above are involved in this project.

Q.6. What is the context for this creative project (e.g., work, school, personal hobby)?

Q.7. How will the project involve finding and using information or resources on the Internet to support the goals of the project?

Q.8. Have you done similar projects before? If so, please briefly explain your prior experience.

Q.9. Please select all the tools that you will need to use in the project:

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, ect.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)
- Social sites (Facebook, Twitter, Reddit, Google+, etc.)
- Other (please specify)

Q.10. Briefly describe any information resources, search engines, databases, or social media/networks that you might use to get information that you will need for this project.

Q.11. Please select all the platforms that you might use in your project:

- Desktop or PC,
- Smartphone,

- Tablet,
- Smart TV (Apple TV, Roku, Play TV, etc.),
- Google Home or Alexa,
- other (please specify)

Q.12. In the space below, please provide us with information about how we should contact you if we need to follow-up on your responses, or if you are selected to participate in the study.

- Name:
- Email:

APPENDIX D

Individual Entry Forms

D.1 Found Useful Information Form

Please use this form to record how you found the information that would help your project move forward.

Q.1. URL of the information.

Q.2. Indicate your workflow stage when you found the information:

- Figure out my goal (e.g., what to create/design; what problem to address/solve)
- Look up information relevant to my goal
- Explore (gather a broad range of potentially related information) about my goal
- Create a large variety of ideas that may achieve my goal
- Combine some ideas that I have already had
- Select the best ideas from all the new ideas that I have created
- Figure out how to put my ideas into practice to achieve my goal
- Other (please specify)

Q.3. Briefly describe the information you found and how it will help project move forward?

Q.4. What device did you use to find the information?

- Desktop or PC
- Smartphone
- Tablet
- Smart TV (Apple TV, Roku, Play TV, etc.)
- Google Home or Alexa
- Other (please specify)

Q.5.What type of information resource did you use to find the information?

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, ect.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)
- Social sites (Facebook, Twitter, Reddit, etc.)

- Q&A Sites (Quora, Yahoo answer, AOLAnswers, Stackoverflow. etc.)
- Other (please specify)

Q.6. How satisfied were you with using the information resource (that you checked above) to find the information

D.2 Experienced Trouble Form

Please fill out this form anytime you experience problems, obstacles, or frustration in finding information online related to your project.

Q.1. Indicate your workflow stage when you encountered the problem:

- Figure out my goal (e.g., what to create/design; what problem to address/solve)
- Look up information relevant to my goal
- Explore (gather a broad range of potentially related information) about my goal
- Create a large variety of ideas that may achieve my goal
- Combine some ideas that I have already had
- Select the best ideas from all the new ideas that I have created
- Figure out how to put my ideas into practice to achieve my goal
- Other (please specify)

Q.2. Briefly describe the problem you encountered.

Q.3. Did you figure out any solution or work-around to this problem? If so, please describe.

Q.4. Indicate the device you were using when you encountered a problem.

- Desktop or PC
- Smartphone
- Tablet
- Smart TV (Apple TV, Roku, Play TV, etc.)
- Google Home or Alexa
- Other (please specify)

Q.5. Indicate the information resource(s) (if any) that you used.

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, ect.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)
- Social sites (Facebook, Twitter, Reddit, etc.)
- Q&A Sites (Quora, Yahoo answer, AOLAnswers, Stackoverflow. etc.)
- None
- Other (please specify)

Q.6. How satisfied were you with using the information resource (1-7 rating scale)?

APPENDIX E

Daily Review Questionnaire

Thinking about the tasks that you have done for your project today, please answer the following questions:

Q.1. Please briefly describe what you have done for your project today.

Q.2. Indicate all the devices that you used to look for information on this task today:

- Desktop or PC,
- Smartphone,
- Tablet,
- Smart TV (Apple TV, Roku, Play TV, etc.),
- Google Home or Alexa,
- other (please specify)

Q.3. Which of the following activities did you engage in for your project today:

- Figure out my goal (e.g., what to create/design; what problem to address/solve)
- Look up information relevant to my goal
- Explore (gather a broad range of potentially related information) about my goal
- Create a large variety of ideas that may achieve my goal
- Combine some ideas that I already had
- Select the best ideas from all the ideas that I have created
- Figure out how to put my ideas into practice to achieve my goal
- Other (please specify)

Q.4.1. Select all the tools that you used to support **[selection in Q.3]** today:

- Search engines (Google, Bing, Yahoo, etc.)
- Videos (Youtube, Vimeo, ect.)
- Images (Pinterest, Instagram, Tumblr, Flickr, etc.)

- Social sites (Facebook, Twitter, Reddit, etc.)
- Q&A Sites (Quora, Yahoo answer, AOLAnswers, Stackoverflow. etc.)
- Other (please specify)

Q.4.2. Briefly describe how you used the tools checked above to support **selection in Q.3** today.

Q.4.3. **[If "search engines" is not checked in Q.4.1]:** Thinking specifically about search engines, please briefly describe why you did not use a search engine to help with **[selection in Q.3]**? This helps us understand the role of search engines in your creative work.

Q.5.1. **[If selecting more than one devices in Q.2]:** Please select all the tools that you used to switch between different devices in your project:

- Cloud services (OneDrive, Google Drive, iCloud, Box, etc.)
- Bookmark tools (browser bookmark, Pocket, etc.)
- Emails
- Time, task, project management applications (Asana, Basecamp, Workflowy, Todoist, Trello, ect.)
- None
- Other (please specify)

Q.5.2. **[If NOT selecting "None" in Q.5.1]:** Please briefly describe how you used these tools to switch between different devices in the project.

Q.6.1 What were the biggest **technical challenges** for you today to work on your project?

Q.6.2 What were the biggest **nontechnical challenges** for you today to work on your project?

Q.7. Did the information that you found before today help you today in your project? Please explain how it was helpful or why it was not helpful.

Q.8. Did you do anything to save, organize, or preserve what you found today for the possible use in the future? If so, please describe.

Q.9. How will you use the information that you found **TODAY** in the future work that you will do **TOMORROW/Next Time**?

APPENDIX F

In-depth Interview

F.1 Introduction

Thanks for coming back! Firstly, congratulations on completing your project! In this interview, I would like to ask you some questions to learn more from you about how you used various tools and information resources to support your project.

F.2 Review Creative Stages

- Q.1 Firstly, I would like to ask you to briefly describe your creative process in this project by using the materials that you shared with us.

F.3 Review Log Data and Diary Study Data

Awesome! Before you came to this interview, I processed your diary data and browser history and grouped them by day. All the data is shown on this webpage. The left part is the diary data that you logged on Day 1. The right side is the search history that you generated on the same day. Do you have any questions about the information shown on this interface?

Great! Now, I will ask questions to learn about what you did on each day of the diary study. Let's start with Day 1. Looking at this set of keywords:

- Loop (finish all the keywords):
  - Q.2.1. Do you remember these queries? If so, do you remember why you did these searches? **[Make sure participants explain why they needed to find this information in their projects.]**
  - Q.2.2. Did you find anything you needed when you searched these keywords? If no, why do you think you didn't find helpful information? .
- Q.2.3. Now thinking about the creative stages shown here (displayed on a monitor), would you please group these keywords based on the stages that you were at when you searched each of the keywords? Participants will be asked to use a Qualtrics questionnaire to group keywords on a second monitor.

- Q.3. Since you mentioned that you also used [tools] in your project, would you please tell me why you needed these tools to support each stage? (if applicable)
- Q.3.1. [If search engines are not reported in a certain stage], would you please tell me your reasons for not using search engines in the [creative stage]?
- Q.3.2. Did you do anything to save, organize, or preserve what you found on **[Day N]**? If so, please describe how you did??

F.4 Review Devises

Awesome, lastly, I would like to think about how all the devices you used in the project:

- Q.4. how did you use these tools or apps to switch devices in your project?
- Q.5. Did you encounter any troubles when you switched devices in the project?

APPENDIX G

Diary Study Instructions

Thank you for agreeing to participate in this study.

GOAL

The goal of this study is to learn about your thoughts, behaviors, and experiences when you use search engines and other digital tools to support your creative project.

DATES

The study will last for 14 days from **[date]** until **[date]**. You can work anywhere and anytime you wish. You don't have to work on your project every day, but we expect you to work on it at least three days per week so we will have enough information to learn from you. During the two weeks, we want you to work on your project as you normally would any other project.

DIARY STUDY TOOLS

As was already discussed, you will be asked to export your browser history that is relevant to your project on **Day 14**. In order to protect your privacy, we will ask you to use a separate Firefox account that we will provide when you are working on the project. In this way, we will not have access to your regular/private browsing history. **The Firefox account is registered with a shared UNC email address and we both have the access to the UNC Email account and the Firefox account**.

To help you document your thoughts and experience, we have designed a diary toolkit for you:

- A **Firefox account** to be used only for the diary study;
- A **useful information form** to be used to record times when you find useful information that helps your project move forward;
- A **trouble form** to be used to record problems, obstacles, or frustrations that you encountered when looking for information for your project;
- A **daily review form** to be completed at the end of each day you work on the project.

Instructions

- During this introduction, we will show you how to log into the Firefox account that we have

set up for you. We will also send you written instructions about the account in case you need them.

- During the study, **any day that you work on the project**, we ask you to use the forms to document your activities:
  - Any time that you find useful information related to your project, please fill out the ***useful information form***. This means that you may complete multiple useful information forms during a day;
  - Any time that you run into a problem, obstacle, or frustration about finding information related to your project, please fill out the ***trouble form***;
  - **At the end each day that you work on the project**, please fill out the ***diary review questionnaire*** to reflect on what you have done during the day.
- We know this sounds like a lot of forms, but each form should only take a few minutes to fill out and the data you provide is **very important** to the study.
- Every day, we will send you a reminder Email including the questionnaire link.
- By **Day 7 [date]**, we will send you an email asking you to share a set of images or/and videos that **show how you generated different new ideas in your project**.
- Again on **Day 14 [date]**, we will send you an email asking you to share a set of images or/and videos **that show you evaluate and select the new ideas that you generated in the project**.
- Also on Day 14 **[date]**, we will send you instructions about how to export your browser history and upload it to our server.
- Then, we will schedule your final interview for the study on [date]. This is when you will be paid.

THANK YOU

For your time and effort participating in this study, we will offer you a payment of $80 if you:

- Document work on your project for at least three days per week by completing the following subtasks:
  - Complete at least 1 helpful information form;
  - Complete at least 1 trouble information form;
  - Complete the diary review form.
- Share with us the two artifacts (images, videos, or documents) to illustrate your project;
- Upload your Firefox account browser history;
- Participate in the last interview.

All participants who complete these tasks and provide genuine and thoughtful responses will be paid an additional $40 "response quality bonus"

CONTACT DETAILS If you have any questions, please do not hesitate to contact me by sending me an Email (**yinglongz@unc.edu**) at any time before, during, or after the study.

APPENDIX H

Coding schemes

Three different coding schemes were developed to analyze **RQ.1**, **RQ.2**, **RQ.4**, and **RQ.5**. **Table H.1** shows the datasets used for developing these coding schemes. Each coding scheme includes one lower-level category (examples) and one or more higher-order categories (themes).

Coding schemes	**Datasets (Questions included in data analysis)**
Scheme 1: RQ.1 and RQ.2	Q.1 and Q.3 in Appendix D.1
Scheme 2: RQ.4	Q.4.2 and Q.4.3 in Appendix E
Scheme 3: RQ.5	Q.2 in Appendix D.2 Q.6.1 and Q.6.2 in Appendix E

Table H.1: Datasets used in developing the initial coding schemes

Categories	Examples	Notes
Domain Knowledge	Art Theory	Information about art theory
	Game design related thoery	Information about game design
	Historical knowledge	Information about history knowledge
	Plants	Information about plants
	Knowledge about carbon sequestration	Information about carbon sequestration
	Mythology	Information about mythology
	Psychology theory	Information about psychological theory
	Quotes	Information about quotes
Examples	Examples	Finsihed examples of a product or design
Information about a place or location	Background information about a place/location	Background information about a place/location
	Geographical information	e.g., the size (area) of chapel hill, the population of NC
Information about a product or service	Pricing	Price of a product or service
	Properties & Quality about a specific product or service	Information about the properties and quality of a product or service
Information about a specific business, association, society, civil establishment or organization	Information about a specific business, association, society, civil establishment or organization	Information about a specific business, association, society, civil establishment or organization
Informaton about a person	A specific person's background	The bio of a person
	A specific person's contact information	e.g., email, phone number, address of a person
	A specific person's work/research	e.g., reading some's papers, watching talk videos
Inspiring information	Inspiring information	The infomration motivates themselves to continue working on the project
laws	laws	Legal information
Time/date	Time/date	Information related to time or date (e.g., information on calendar, deadline, schedules)
Procedure knowledge	App user manual	Online software/app manuls, but adobe fonts should not be considered in this category.
	Demonstration - videos	Visual information (videos) about how to do something
	Steps - articles	Textual information (articles) about how to do something
Tips, opinions, or recommendations	Tips, opinions, or recommendations	Tips, opinions, recommendations about a specific topic
Tool websites	Tool websites	Wesbites of online tools (e.g., online tools for creating fonts)

Table H.2: Scheme 1: information needs

Categories	Examples	Notes
Idea evaluation and selection	Evaluate/Test their method/plan	Evaluate or test a method/plan and to make sure it could work in the project
	Narrow down project research scope	Eliminate some ideas or ideas in the project
	Select ideas	Eecide what to do or design in their project
Ideation	Generate own ideas	Create their own ideas
Learn/figure out how to do something	Figure out how to design something	e.g., like how to design a color, how to create a character in writing
	Improve design process/skill/technique	Figure out how to make the design process better or more efficiently
	Learn how to use a new technique, skill, or tool in a project	Figure out how to use a new technique,skill, or tool. Not including improving design process/skill/technique
	Use a tool or technique to put ideas into practice	e.g., using online tool to create a font
Keep motivated	Keep motivated	Find something that can motivate themselves continue working on the project
Plan a project	Get the project started	Figure out how or where to start the project
	Help plan a project	Doing research to plan a project
	Start a project research	Figure out where to start the research for the project
Purchase something	Purchase something	Purchase something needed in the project
Seek for inspiration	Seek for inspiration	Looking for someone's design or finished examples. This process does not include generating ideas

Table H.3: Scheme 1: intents

Categories	Examples	Notes
Blog	Blog	-
Search	Google	-
Images	Images_other	Unidentified image sites
	Instagram	-
	Pinterest	-
Q&A	Q&A	-
	Q&A Forums	-
	Quora	-
	Stack_overflow	-
	Stack_overflow	-
	Tool_QA	-
Shopping	Amazon	-
Social	Reddit	-
	Facebook	-
	Social_media_other	Unidentified social sites
Videos	Videos_other	Unidentified video sites
	YouTube	-

Table H.4: Scheme 2: Resources

Categories	sub-categories	Examples	Notes
Communication	Communication	show their work/projects	show their work or project to others
Look for specific information	Look for specific information about a tool	look for inforation about a tool	look for information about a tool that will be used in the project
	Look for specific information that is needed for design	look for information for design	look for specific information that is needed for designing a specific part of the project
	Look for specific information about a person	know about a person	look for information to check the background of a person (e.g., name, contact, address, work experience, roles)
		research other people's work	look for a person's work (talk videos, finished project demos)
	Look for specific information about a place	know about a place	look for background infromation about a place or location
		look for "on-the-ground" knowledge about a place	look for "on-the-ground" knowledge about a place or community in social media resources
		look for information about a product	look for informaiton about a product or service (e.g., pricing, quality, avaliablity)
	Look for specific information about a resoruce	find a specific resource	Look for a specific resource (e..g,)
	Look for specific visual information	look for visual information from images	look up specific information from images (e.g., owl face)
	Look for specific information about a question/topic	look for specific information for asnwering a question or knowing a topic	look for specific information to answer a question or knowing a topic in the project
	Look for specific information about a company/organization	know about a company or organization	look for general information about a company or organization. This category more focuses on organizations, not tools
	Look for summaries or reviews about a topic	look for summaries or reviews of a topic	look for synthesized information about a topic
Managing information	Organize information	save images that may inspire their work	use the tool to save images that may inspire their work
		save relevant articles for research	use the tool to save articles for research

Table H.5: Scheme 2: reasons for using a resource (part 1)

Categories	sub-categories	Examples	Notes
Motivation	Motivation	looking for information that can motivate me to work	looking for information that can motivate themself to work
Specifically support creative processes	Combine ideas	help combine ideas	use the resources to combine ideas.
	Create ideas	help generate ideas	use the resources to generate ideas.
		look for information for ideations	look for information to generate ideas.
	Evaluate ideas	find other people's suggestions/comments	find other people's comments or suggestions on a related topic.
		test or evaluate a design plan/idea	test or evaluate their design plan/idea with the help of the resource
		find comments/suggestions from other professionals	find professionals' comments or suggestions on a related topic.
		learn lessons from other's work	learn lessons by exmaining others' work (e.g., watching videos, looking at finished product, reading articles)
		get feedback from people they know	ask for feedback from friends, family, or colleagues
	Look for inspiration	browse images for inspiration	use image sites to browse finished work/design (images)
		look for examples	look for finished exmaples
		seek for inspiration	looking for informaiton for inspiration
	Select ideas	narrow down ideas	eliminate some ideas or plan that does not work
		help select ideas	make decisions to choose an idea with the help of a resource
		compare and select different design styles	compare and select different design styles that they had in their minds
		look for information that can help make a decision	look for specific information that supports the decision making process in their design
Support learning domain knowledge	Look for broad information about a topic	understand/learn broad topics that are related to a goal	learn or get an understanding a broad topic that is related to their goal
	Learn or look for domain knowledge	learn domain knowledge	learn domain-specific knowledge: art theory, game design related theory, historical knowledge, plants, carbon sequestration, mythology, psychology, quotes
		look up domain knowledge	look up specific domain knowledge: art theory, game design related theory, historical knowledge, plants, carbon sequestration, mythology, psychology, quotes
Support learning procedure knowledge	Learn or look for procedure knowledge	look for answers to technical questions	look for answers to a technical question that needs to be resolved in the project
		look for information about how to do something	look for information showing how to do something
		look for information to learn a skill/technique/tool	look for information to learn a skill/technique/tool/feature

Table H.6: Scheme 2: reasons for using a resource (part 2)

Categories	notes
Can not provide a personal touch af a human being	from the articles or textual information, it is difficult to get a deeply understanding of the persons who wrote them
Can't provide a bunch of information about products	The information about the products is limited to a specific perspective
Can't see something visually performed	Articles or textual information were not good at visually showing how something is performed
Do not need to search information	Don't need to search for more information right now
Do not want too much information	Search engines provide too much information
Don't know what questions to ask in search engines	Dont know what to search
Google images have less exmaples of work from experts	Some other resources provide more exmaples created by experts
Information provided by search engines are too general	Search results are too general
Just need a specific type of information resources	Have a specific resource to use in their mind
Search can not provide everything needed	Some information can't find using search engines
Want to get a different or new resource	Want to use a resource instead of search engines

Table H.7: Scheme 2: reasons for not using search engines

Categories	Examples	Notes
Address feedback	Address feedback	Address feedback from colleagues or clients
Communication and Feedback	Communications	Talk with other people in the project
	Distracted by other people	Distracted by other people while working on the project
	Get feedback from other people	Have trouble collecting feedback from other people (e.g., family, friends, colleagues)
Creative processes	Can't efficiently evaluate or test ideas	Can't find an efficient way to create a low lost "prototype" for testing and evaluating an idea/plan
	Have trouble generating ideas	Can't generate many ideas
	Have trouble making a decision	Have trouble making a design decision
	Have troubles combining some ideas	Have troubles combining some ideas
	Have troubles figuring out their design options	Have troubles figuring out their design options (e.g., what to design, how to design something, and what to design next)
	Research/design plan doesn't work	Intial plan did not work
Search	Distracted by the information from search engines	Distracted by the information from search results
	Can't find the exact information that is looked for	Can't find the exact information that they look for
	Difficult to track searching progress	Difficult to track what were searched
	Have trouble generating a right query	Have trouble coming up with a efficient query
	Can't direct to useful links	Resources direct to an unuseful webpages
	Search results are too similar	Redundant search results
Information seeking and organization	Don't know where to look for information	Don't know which resource to use to look for information
	Have troubles organizing and making sense of the information saved or notes	Have troubles organizing and making sense of the information that participants saved or the notes they took
	Have troubles tracking and organizing the saved images	Have troubles tracking and organizing the images that were saved
	Lack of domain knowledge	Don't have sufficient domain knowledge about a specific topic
Internet issue	Internet issue	lost internet connect
Lack of motivations	Lack of motivations	lack of motivations to continue working on the project
Negative emotion about the project	Negative emotion about the project	had negative emotion when working on the project (e.g., upset, annoyed, challenged, feeling silly)
Quality of resources	Bad website design	Bad usability of a website
	Broken Links	links broken
	Have troubles finding some professional resources online	Some professional resources are scarce and even not existing.
	Unreliable resources	Resources are not reliable
Time constraint/time pressure	Time constraint/time pressure	Feel time constraint or time pressure from different factors
Tools usages	Have troubles using a software or tool in a proper way	Have troubles using a tool or software in the project
	Lack of right tools	Don't have a tool needed
Workplace and settings	Workplace and settings	Issues related to workplace, settings, or environments where the project is conducted

Table H.8: Scheme 3: challenges

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