

The Persistence of Analogies in Design Decision-Making


Stephen Hassard
University College London

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Thesis Declaration

I, Stephen Hassard confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: 

Date: March 9th 2011

Abstract

Previous theories of design decision-making have discussed how designers use analogical reasoning to quickly scope the solution space down to one viable solution. This initial analogy forms the template of a possible action plan that is then modified to suit the unique properties of that particular problem. This use of analogical reasoning allows designers to quickly engage with the problem and generate a workable solution. Our findings indicate that this initial analogy actually persists across all stages of decision-making, and does not play a role solely during the first stage of scoping. This analogical persistence leads to poorer design decisions.

This thesis presents a series of studies that adopt a mixed method approach to investigating the influence of analogies on the decision-making of Interaction Designers. We employed qualitative methods such as the Critical Decision Method for Eliciting Knowledge (Klein, 1989), which aided in identifying analogical persistence as a problem that leads to poorer quality decisions. We also employed quantitative methods such as the Design Fixation paradigm (Jansson & Smith, 1991) to investigate how different types of analogies (self-generated & provided Priming Analogies) can influence the expression of analogical persistence.

Finally in an attempt to mitigate the potential pitfalls of analogical persistence, this thesis attempts to control it using principles from Design Rationale (Lee & Lai, 1991) and Reflection (Schon, 1983). Rather than seeing a decrease in analogical persistence, our manipulation actually increased fixation. A follow-up study identified that designers tend to poorly appraise the weaknesses in the initial analogy, which may have led to the aforementioned unexpected result. These findings challenge the notion that greater understanding of the design space will lead to higher quality design decisions.

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1. Introduction

Decision-making, though an important cognitive component of the act of design, is often overlooked (Zannier, 2007). Decision-making, regardless of design discipline, is concerned with the evaluation of the viability of a particular situation in light of the requirements of the design brief. A cornerstone of the decision-making process (Klein, 1999) is the use of analogical reasoning as way to scope the solution space and to quickly engage with the design problem. Designers are able to use analogies as a template for a possible solution by drawing upon similar situations that have worked in the past. Traditionally, this process of analogical reasoning has been viewed as an initial framing device, but this thesis discusses how this initial analogy can actually persist across all stages of decision-making (Klein, 1987a). This initial analogy is used in more than just the initial stage of idea generation, but is also utilized during the later stages of decision-making like mental simulation and solution evaluation. While analogies are an important cognitive component of design decision-making, this analogical persistence across all stages of decision-making can lead to overall poorer quality design decisions.

1.1. Research Aims

The aim of this research is to investigate how analogical persistence influences decision-making in Interaction Designers, with a particular focus on mitigating the inherent issues with analogical persistence. To answer this question, both quantitative and qualitative methods were employed. Qualitative methods such as Protocol Analysis (Ericsson & Simon, 1993) and the Critical Decision Method for Elicitation of Knowledge (Klein, Calderwood, & MacGregor, 1989) were employed as hypothesis generating techniques, while such quantitative methods as the Design Fixation paradigm (Jansson & S.M. Smith, 1991) allowed us to observe, manipulate, and validate the findings from the qualitative approaches. By using a range of different methodologies, we can gain an accurate idea of how analogical persistence in Interaction Designers manifests, the factors that influence it, and how to best mitigate the potential pitfalls while retaining the clear benefits of analogies during design decision-making.

The objectives of this thesis are:

- Extend current Naturalistic Decision-Making research into the field of design decision-making
- Address issues of validity in the Design Fixation paradigm, specifically generalisability, stimuli, and the confounding variable of familiarity
- Provide insight into how different analogies influence analogical persistence
- Mitigate analogical persistence by using ecologically valid methods, such as Reflection and Design Rationale

1.2. Chapter Summary

This thesis is composed of a total of ten chapters. Listed below is an overview of each chapter detailing its aims, goals and contribution towards the defined research question.

1.2.1. Chapter Two

There are many different perspectives on what constitutes design decision-making. Mechanical Engineers for example see decision-making as a linear evaluation of a set of possible solutions in which one solution is chosen for its achievement of the most design requirements with the minimal amount of resources. Researchers such as Klein & Brezovic (1986) postulate that this view on decision-making is idealistic and simply unrealistic in a real world setting. In contrast to the engineering view on design, the work done by Klein (1999) is primarily concerned with achieving an accurate description of how environmental stressors can impinge on how designers engage in the decision-making process. Chapter two presents a summary of both sides of this argument with a focus on which of the current models of decision-making are possibly the most realistic description of the design decision-making process adopted by Interaction Designers.

1.2.2. Chapter Three

Chapter three discusses an explorative study looking at the decision-making process of Interaction Designers in a real world setting. To frame our discussion, we examine how Interaction Designers make decisions in the context of the Recognition-Primed Decision-Making model (Klein, 1997). Three variations of this model, which account for different types of decisions, are examined as descriptors of the decision-making process exhibited by Interaction Designers. By pairing the Critical Decision Method for Eliciting Knowledge with screenshots of recently designed interfaces, we were able to probe the process of, as well as identify important factors that influence, design decision-making. The chief finding that emerged from our analysis was that the

analogical reasoning that Interaction Designers engage in at the outset of the decision-making process to frame the solution space is not simply an initial first stage of the decision-making process as postulated by Klein (1999), but rather, persists across all of the decision-making stages. The analogies that designers were employing allowed them to quickly frame the solution space but designers were also relying on those analogies to the point where they were no longer a help to the decision-making process.

1.2.3. Chapters Four Through Six

A concern with the results from chapter three was that the analogical persistence discussed by participants was not an accurate reflection of their decision-making processes, but simply a function of a post-hoc rationalization. To address this issue, we used a quantitative approach (i.e. the Design Fixation paradigm (Jansson & S.M. Smith, 1991)) to provide methodological triangulation for the study presented in chapter three. However, an issue with using the Design Fixation paradigm in this capacity is that there are various threats to validity that need to be addressed. Chapters four through six each address a different threat to the validity of the Design Fixation paradigm with an overarching goal of replicating analogical persistence. Chapter four examines the generalisability of Design Fixation; chapter five looks at the confounding variables of stimuli; and chapter six is concerned with the issue of familiarity and how it can impact the Design Fixation paradigm. By addressing each of these threats to the validity of the Design Fixation paradigm, we can be confident that the results we are observing are a true reflection of analogical persistence and not simply a function of a potentially problematic paradigm.

The biggest threat to the external validity of the Design Fixation paradigm is its generalisability. Traditionally, replication of Design Fixation outside of a population of Mechanical Engineers has been problematic (Purcell & Gero, 1991; Purcell, Williams, Gero, & Colbron, 1993). In chapter four, we discuss how the failure to replicate design fixation outside of Mechanical Engineers was due to the measures used to gauge the influence of the initial analogy. By employing a more sensitive measure, we were able to replicate Design Fixation among Interaction Designers. In addition, by replicating the findings of previous Design Fixation studies among Interaction Designers, we quantitatively illustrated how a flawed initial analogy can influence all stages of decision-making from idea generation to the proposed final solution.

Chapter five continues our discussion of the threats to the validity of the Design Fixation paradigm by addressing the problem of materials. Traditionally, many of the Design Fixation studies have used the same, or very similar, materials to the ones used

in the original Jansson & Smith (1991) study (e.g. Chrysikou & Weisberg, 2005; Purcell et al., 1993). Any new materials that were utilised were limited to the Mechanical Engineering domain of participants (Perttula & Sipila, 2007; Perttula & Liikkanen, 2006; Purcell & Gero, 1996; Tseng, Moss, Cagan, & Kotovsky, 2008). In this study, participants were presented with two different design briefs, both newly generated. One design problem was a newly generated Mechanical Engineering problem, for comparability to previous studies, and the other was a newly generated Interaction Design problem. Our results indicated that we were able to replicate our findings from the Design Fixation studies in the previous chapters using newly generated materials, thereby checking that the use of different test materials yielded the same results. Therefore the influence of the initial analogy on decision-making is actually a function of analogical persistence and not simply a function of the materials used.

Chapter six concludes our discussion regarding the individual threats to the validity of the Design Fixation paradigm by examining the role of familiarity. We addressed the issue of materials used in Design Fixation studies and found that a higher level of fixation was observed in the materials that were traditionally used when compared to newly generated stimuli. We hypothesised that this result was a function of participant's familiarity with the presented stimuli. Participants were shown two different design problems: one problem that they would be highly familiar with (a desktop calendar application), and another problem that they would not be familiar with at all (a communication device between aquatic mammals and marine biologists). Results indicated that one's familiarity with the common usage of an artefact actually has a limited impact on the types of solutions that participants generated. By demonstrating the limited effect that familiarity had on the types of solutions proposed, when we explicitly controlled for it, we were able to demonstrate how the influence of the analogy that we observe in the Design Fixation paradigm is a function of analogical persistence, rather than a confounding variable inherent to the paradigm.

Chapters four through six each address a different threat to the overall validity of the Design Fixation paradigm. Chapter four addressed the generalisability, chapter five attended to the materials, and chapter six was concerned with the confounding variable of familiarity. Underlying all of these chapters was the goal of replication. To provide methodological triangulation to the findings presented in chapter three we adopted a quantitative measure to observe the influence that an initial analogy can have across all stages of decision-making. Within each chapter we were able to replicate analogical persistence and illustrate in each case that it was not a function of some of the issues

regarding the Design Fixation paradigm.

1.2.4. Chapter Seven

After validating the Design Fixation paradigm in previous chapters, we used it to quantitatively investigate how analogies can persist across the entire decision-making process of Interaction Designers. Chapter seven extends the Design Fixation paradigm beyond its current limitations, by pairing it with a think-aloud which allows us to use it to observe how different types of analogies influence analogical persistence. In chapter three we found that Interaction Designers draw upon analogies from personal experiences and use existing artefacts to engage with the design brief (Visser, 2006). The Design Fixation paradigm in its current incarnation analyses how examples, or Priming Analogies, can influence the types of solutions proposed by participants. In chapter seven we look at how Interaction Designers use the provided Priming Analogies & Self-Generated Analogies in their decision-making process. By examining these different sources of inspiration, we can see how the usage of these different analogies overlap or differ and gain some insight into how best to mitigate the potential problems with analogical persistence.

Since the current Design Fixation paradigm is solely concerned with the provided Priming Analogies, and we were interested in how Self-Generated Analogies are used, it was necessary to pair a think-aloud protocol with the existing Design Fixation paradigm. Participants' verbalizations revealed that several behaviours, for each of the two sources of inspiration fostered analogical persistence. Our results demonstrated that there was a clear disconnect between what designers think and what they do. Self-Generated Analogies were observed to be prone to selective recall in that participants only discussed how the best bits of that analogy were remembered and the problematic elements were forgotten and consequently did not influence their solutions. Priming Analogies were seen to narrow the solutions space by causing participants to believe that the provided example was the single best solution to the design brief. Another important result that was common across both types of analogies was that participants were aware of how the presence of these analogies could unduly influence the decisions that they were making; despite this acknowledgment participants had no coping mechanisms in place to maintain the benefits of the initial analogies but mitigate the potential pitfalls of analogical persistence.

1.2.5. Chapter Eight

Chapter seven highlights the fact that participants were aware of the limitations of their chosen analogies but very few, if any, had any coping strategies in place. In the past,

little work has been able to mitigate the effects illustrated in the Design Fixation paradigm (e.g. Purcell & Gero, 1996). Chrysikou & Weisberg (2005) were one of the few researchers to successfully control for Design Fixation. This was accomplished by providing participants with a pre-generated list of the problematic features contained within the provided example solution. While successful, this technique has no applicability outside of a controlled lab setting. In chapter eight we aimed to control fixation by using an approach based on Chrysikou and Weisberg but in a more ecologically-appropriate manner. It was hypothesised that by encouraging participants to reflect on the types of analogies they were employing they would be able to generate their own list of problematic features which in turn would mitigate Design Fixation. It was thought that encouraging participants to reflect on the analogies that they employed in their decision-making would mitigate analogical persistence but actually our study yielded the inverse effect. Reflection increased the influence of the initial analogy on decisions that were exhibited in the types of solutions proposed by participants. Subsequently, a follow-up qualitative analysis of the design rationale templates used by participants to facilitate reflection on the analogies was conducted. This follow up study identified several behaviours that may have fostered the observed increase in analogical persistence.

1.2.6. Chapter Nine

In chapter nine we examined the validity of the behaviours identified in the qualitative follow-up presented in chapter eight using methodological triangulation and a think-aloud protocol. In this study a think-aloud protocol was paired with the experimental design employed in chapter eight. By examining the verbalisations produced by participants across the reflection portion of the study and the sketching component, we were able to examine the cognitive processes that may have contributed to the observed increase in analogical persistence. This study compares and contrasts the behaviours identified from participants' verbalisations against the behaviours identified in the follow-up examination of the design rationale templates in chapter eight. Employing a think-aloud protocol reproduced some of the previously identified behaviours, and provided additional insight into how some of those behaviours may have contributed to the increased influence of the initial analogy. This chapter closes with a discussion of the implication that these findings have on the field of Design Rationale.

1.2.7. Chapter Ten

Chapter ten closes this dissertation with a summary of the contributions towards knowledge, a discussion of the limitations of this dissertation, and possible research threads to emerge from this work that may be built upon in the future.

1.3. Summary of Main Findings

Below is a summary of the key findings broken down by the pertinent chapters.

- Identified the persistence of analogies across all stages of design decision-making (Chapter three)
- Addressed issues of validity in the Design Fixation paradigm, specifically generalisability (Chapter four), the issue of stimuli (Chapter five), and the confounding variable of familiarity (Chapter six)
- Extended the Design Fixation paradigm to observe not just Priming Analogies but Self-Generated Analogies as well (Chapter seven)
- Investigated how different types of analogies, namely Priming Analogies and Self-Generated Analogies, encourage different behaviours which foster this analogical persistence (Chapter seven)
- Raised concerns regarding the viability of using common design methodologies, such as Structured Reflection and Design Rationale, as an ecologically valid approach to mitigating analogical persistence (Chapter eight)
- Generated a list of behaviours that actually foster analogical persistence caused by the intersection of Design Rationale and Reflection (Chapters eight & nine)

2. Moving Past a General Framework of Design Decision-Making

2.1. Introduction

Design decision-making is an important area of research that, while an integral component of the cognitive toolset used by designers, has received little attention from the design cognition community (Zannier, Chiasson, & Maurer, 2007). To date, what work done in this area, has focused on establishing one unified framework that can be used to understand design decision-making. The issue with the current emphasis on establishing one particular framework is that the area of design is composed of many different sub-disciplines ranging from Mechanical Engineering (Olewnik & Lewis, 2005) to Fashion Design (Eckert & Stacey, 2001). These sub-disciplines, while sharing many commonalities, do differ significantly in how they approach, frame, and understand the design problem (Akin, 2001; Lawson, 2006). These individual differences exhibited by each design discipline, in conjunction with an emphasis on one single approach to understanding design decision-making, have led to a fractured field of competing research. While the existing work has led to an understanding of what types of information are used in these decisions, the factors, both internal and external, that can influence these decisions are less well understood. This chapter aims to move past the debate of a universal design decision-making model and focus on one specific design discipline, specifically Interaction Design, to understand which factors impact those design decisions. By focusing on the factors that influence the decisions that Interaction Designers make, we can hope to support behaviours that led to higher quality design decisions and suppress problematic behaviours that lead to faulty decision-making.

2.2. Why Decision-Making is Integral to our Understanding of Design Cognition

Interaction Designers employ a wide variety of skills when they engage in the design process such as: decision-making (Highsmith, 2004), mental simulation (Guindon, 1990), mental modelling (Adelson & Soloway, 1985), problem structuring (Guindon, 1990), idea generation (Perttula, 2006) and creativity (Finke, 1996). While all of these cognitive skills are important the amount of attention that is devoted to each is not

equal. Paradoxically, whilst decision-making has been identified as an important area of design cognition, in comparison to other areas like problem solving, research in this area has been lacking (Zannier et al., 2007).

A contributing factor to the neglect of design decision-making is that traditionally design has been seen as primarily a problem-solving activity (Bonnardel, 2000). This focus on problem solving is due to Simon in his (1996) work was one of the first to highlight the importance of understanding design cognition. Simon discusses that the act of design as a problem-solving activity, with a particular emphasis on viewing design cognition as the continual structuring and reframing of the problem to transform it from an ill-defined and difficult problem to a structured problem with a clear solution path. The issue with this perspective is that the design process is composed of so much more than solely structuring an ill-defined problem (Zannier et al., 2007). Problem structuring is but one component of the skills that designers employ. Viewing the design process as a problem-solving activity has influenced most of the work to date on design cognition, which consequently has led to other important areas of design cognition to be neglected (Bonnardel, 2000). As a reaction to the heavy influence of Simon's work some researchers have over-compensated and have characterised the design process primarily as a decision-making activity (Hazelrigg, 1998), which is also a highly problematic position to adopt as the act of design is composed of more than one cognitive component. Recent work (Bonnardel, 2000; Zannier, 2007) has highlighted that neither approach is entirely correct and that we need to adopt a more holistic approach in which several different cognitive skills are employed with decision-making being an important component.

Tang et al. (2008), highlight another important aspect that speaks to the importance of understanding design decision-making: the pervasiveness of design decisions. Each element of the design artefact is in some way influenced by a decision made by a designer or a design team. For example, a designer can be faced with such high-level decisions like which interaction modality to use (Wii vs. PS3), or a more finite decision like the spacing between elements of the interface. To quantitatively highlight the importance of design decisions on the final artefact, Tang et al. (2008) discuss the direct connection between the types of decisions being made and the quality of the artefact produced. In their study, the higher the quality of the design decision, the higher overall quality of their proposed design solutions were, and conversely Interaction Designers who engaged in a faulty decision-making process produced markedly poorer design solutions.

While an important component of the design process, design decision-making has received little attention from the broader design cognition community. Considering the pervasiveness of decision-making on the design process, coupled with a call from researchers highlighting the importance of decision-making, a greater emphasis on this area of design decision-making is needed.

2.3. Duelling Perspectives of Design Decision-Making

To date much of the work in the area of design decision-making has primarily focused on modelling the decision-making process. By focusing on the establishment of a framework that describes in detail how designers make their decisions, researchers have created a splintered field of research with different design disciplines viewing design decision-making differently. Akin (2001) and Lawson (2006) both highlight how different design disciplines approach and frame design problems using different strategies and heuristics.

The field of decision-making can broadly be broken down into two main perspectives: Rationalistic Decision-Making (RDM) and Naturalistic Decision-Making (NDM) (K. M. Piegorsch et al., 2006). The Rationalistic approach to design decision-making is exemplified by the field of Mechanical Engineering which views design decision-making as a tool to achieve the ‘best’ single solution (Hazelrigg, 1998; Olewnik & Lewis, 2005; Suh, 1995). Other design disciplines, such as Architecture and Agile System Developers, view decision-making as a descriptive tool to aid in structuring ill-defined design problems (Klein & Brezovic, 1986; A. Tang, 2007; Zannier & Maurer, 2005). These two inherently different perspectives on what design decision-making is, and is not, has led to a broken view of the applicability of each model to the field of design. This emphasis on the different theoretical underpinnings of design decision-making has taken attention away from other useful areas of design decision-making research, such as examining the factors that may influence the types of decisions that designers may make. To move past the establishment of one definitive model and begin to understand what different factors can contribute both positively and negatively to the design decision-making process, we have focused on one discipline, Interaction Design. As the myriad of design disciplines view design decision-making differently it is worth setting a context by discussing the two different decision-making perspectives and their suitability in describing the decision-making of Interaction Designers.

2.3.1. *Rationalistic Decision-Making*

The Rationalistic Decision-Making (RDM) paradigm takes a logical, or analytic, approach to decision-making by assuming that a set of alternative solutions can be generated and that the decision-maker can, within reason, judge the success of each outcome. This approach emphasises that each solution can be measured using clear and discernible criteria, and the “best” option to choose from the generated set is the one that maximises utility and minimises cost. While this perspective has been shown to adequately describe decision-making in certain contexts, applying this perspective to the design process is problematic. Before a discussion of the issues surrounding Rationalistic Decision-Making and design it is important to first define the meaning of the term.

Three key features define the RDM paradigm: decision alternatives, utility function, and probabilities (Orasanu & Connolly, 1995; Siddall, 1972; Simon, 1955). The first defining characteristic of the RDM approach is that for each decision there must be a set of possible alternatives to choose the optimal solution from. This solution set must be composed of alternatives that are known to the individual, as well as the probability of each particular outcome occurring. The second characteristic of RDM deals with choosing which option from that solution set is the best possible course of action. To choose which one particular course of action is the most appropriate, one must judge the success of that option in relation to the other alternatives. To judge the most suitable course of action, each possible option must be evaluated in relation to how much energy must go into making that particular option work and how successful that outcome will be. The ‘optimal’ solution will be the one course of action that has the highest level of success for the minimal amount of effort. This score, the amount of effort versus the success, is known as the utility. The third defining characteristic of the Rationalistic approach to decision-making is the probability of a particular solution occurring. For example, one particular solution may have a very high utility (i.e. it achieves the most of the requirements for the minimal amount of input), but the chance of it occurring may be extremely low. In conjunction with the utility value the probability scores determine which alternative from the solution set is the best choice.

Simon (1996) criticises the RDM paradigm by pointing out that this perspective is impractical in the context of design. The idea of a finite number of solutions to a given design problem that can be linearly evaluated and an optimal design solution selected is unrealistic. Design problems have been described as ‘wicked problems’ (Buchanan, 1992), meaning that there are an infinite number of satisfactory solutions to

any particular design problem (Rittel & Webber, 1973). This approach to viewing design decision-making is impractical in that designers do not have the cognitive resources to linearly evaluate a potentially endless number of solutions to find the optimal design. To reduce the number of possible solutions down to a manageable number of alternatives designers must employ cognitive short-cuts which the Rationalistic Decision-Making paradigm cannot account for.

While the RDM perspective on design decision-making has its faults, this theory is not without its supporters. The discipline of Mechanical Engineering has long supported the view that there are a finite number of options, to a particular design problem, and that an optimal design can be attained (e.g. Olewnik & Lewis, 2005). This focus on the documentation of all possible iterations and alternatives, while cumbersome, has been entrenched in the discipline as an essential part of the design process. Some engineers have even gone as far as to characterise design as purely a decision-making exercise (Hazelrigg, 1998). Two 'tried and true' decision-making methodologies, which exemplify this approach to design decision-making, are Axiomatic Design (Suh, 1995) and the House of Quality method (Hauser & Clausing, 1996). Proponents of these methodologies list the benefits as threefold. The first is to promote logical evaluation of all possible solutions to the design problem at hand. The second benefit is to promote the use of quantifiable facts and figures to support those decisions. Lastly, the third benefit is to remove the designer from any outside bias or influence on the types of solutions that will be produced. Recent work by Olewnik & Lewis (2005) describes how these industry standard methodologies are deeply flawed and do not even conform to the three key benefits of adopting a RDM approach. By simulating the relative weights that are assigned to each individual design element Olewnik & Lewis (2005) were able to illustrate a range of flaws: from designers imposing their own preferences on weightings to designers providing a false sense of reliability by providing arbitrary weights on unquantifiable elements of the design problem. The myriad of issues raised by Olewnik & Lewis (2005) are more than just specific issues with those particular formal methods, they also highlight some of the fundamental issues with adopting the rationalist approach to understanding design decision-making.

2.3.2. *Naturalistic Decision-Making*

In contrast, the Naturalistic paradigm emphasises the importance of situational pressures and how people deal with complex cognitive functions in realistic settings

(2005). Naturalistic Decision-Making (NDM) suggests that, due to the pressures and limitations of our environment, engaging in a linear evaluation of the available options is not realistic; rather, individuals use cognitive shortcuts to quickly reach a viable decision (Orasanu & Connolly, 1995).

The NDM perspective arose as a reaction to the disconnect between the laboratory based results of the RDM perspective and the difficulty that those models had in terms of explaining some of the real-world decision-making processes that were employed. Klein, Calderwood, and Clinton-Cirocco, (1988) first discussed this disconnect in the examination of how firefighters, when in-situ, engaged in the decision-making process. Rather than engaging in a linear evaluation of all possible options for an optimal solution firefighters actually used cues derived from their environment to elicit a pre-formulated action plan based on analogical reasoning. Firefighters would use cues from the situation at hand to select a similar situation from the past that has been successful. The similar situation, generated through analogical reasoning, provided a template for when actions in the past were appropriate for this type of situation. This action-plan template would then be modified based on any characteristics unique to their particular situation. This approach to decision-making was a vastly different approach to understanding decision-making in-situ than had been previously proposed by the RDM school of thought. Several models have been produced which aim to encapsulate the decision-making process that people participate in in-situ (see table 2.1 for a synopsis of the major models in this field). While each model differs, in terms of its focus and theoretical assumptions there are several characteristics common to all NDM models which are: diversity of form, situation assessment, use of mental imagery, context dependence, and dynamic processes (Lipshitz, 1995).

Decision Making as Argument Driven Action	Lipshitz (1988)	Postulates that while people may use different strategies to reach decision all of those strategies are underpinned by the same six attributes: framing (how the problem is defined), uncertainty (the noise that interferes with the selection of a course of action), logic (The rationale for the chosen course of action), handicaps (the constraints affecting the decision-making process), and therapies (techniques that can be used to address issues in the previous five attributes)
Decision Cycles	Connolly (1989)	While most models emphasise the selection of one alternative Connolly would argue that one alternative is never truly selected and there is a continual cycle between situation assessment, alternative evaluation, and course of action.
Dominance Structuring	Montgomery (1989)	Emphasis that an alternative is chosen when it is at least as attractive as the alternatives on all of the important characteristics and is superior to the alternatives on at least one characteristic.
Explanation Based Decision Making	Penning & Hastie (1986)	Originated as a model explaining the decision-making process of jurors. Decision-making under this model focuses on creating a narrative, from the situational evidence, that makes sense to the decision-maker. An alternative is then selected by how well that alternative matches the internal narrative.
Image Theory	Beach & Mitchell (1987)	Postulates that a decision is reached when one alternative from the solution set best matches three images: Value (the principles of the decision-maker), Trajectory (the goals that the decision-maker wishes to accomplish), and Strategic (how the decision will be actualised).
Participatory Decision Making	Kaner (2007)	Is defined by its emphasis on inclusion of all stakeholders, full understanding by all participants and shared responsibility for all decisions made by the group. Participatory decision making is characterised by three phases: divergence (stakeholders are separated on the issue at hand), groaning (stakeholders vocalise the issues that gave rise to the need for a decision), and convergence (the group comes together as a single unit to form a decision).
Recognition Primed Decision Making	Klein (1997)	People reach decisions using a combination of situational assessment, generating an action plan through analogical reasoning, and mental simulation
Requisite Decision Model	Phillips (1984)	This approach to decision-making emphasises coming to a decision by constructing and modelling the shared understanding of the problem space. A decision is reached when a consensus is reached regarding the model of the problem space
Situation Assessment	Noble (1986)	Emphasises the collection and interpretation of information from various sources (the environment, the context, and the background of the decision-maker) under intense time pressure.
Task Characteristics and Human Cognition	Hammond (1988)	Hammond's model examines how the information from various sources (the environment, the context, and the experience of the decision-maker) is collated to reach a decision. This model differs from other NDM models in that it discusses a continuum between RDM and NDM in terms of the strategies that are used to reach a decision.

Table 2-1 Popular models of Naturalistic Decision-Making.

The first defining characteristic of all Naturalistic Decision-Making models is diversity of form. From Table 2.1 we can see that there is a wide diversity of ways that decision-makers come to a particular decision. For example the Recognition Primed Decision-Making model uses recognition and analogical reasoning, while the Explanation based model of decision-making focuses on reaching a decision through the construction of a narrative. This diversity underscores the futility of trying to encapsulate how decisions are reached through a single concept such as maximising utility like in the RDM perspective. The second characteristic common to all NDM models is situation assessment. All NDM models have some element of constructing a mental model of the problem space through environmental cues. The third characteristic of NDM models is mental imagery. While the basis of the RDM perspective was choosing the solution based on quantifiable cognitive processes, such as the utility value, NDM models use cognitive processes that involve creating mental representations of the situation. The fourth defining characteristic of NDM models is context dependence. As described earlier the fundamental basis of the NDM approach to understanding how decisions are formulated in the real world is by understanding the context of the situation. The fifth characteristic of the NDM perspective is dynamic processes. A basic assumption of Naturalistic Decision-Making is that the decision-making approach is not composed of discrete stages which are completed in a linear fashion to arrive at a successful course of action. Naturalistic Decision-Making emphasises the dynamic nature of how people make decisions in-situ. It is worth noting though that while some models subscribe whole-heartedly to this constant iterative approach to decision-making, such as the Decision Cycle model (Lawson, 2006), other such as the Recognition Primed Decision-Making model do adhere to some level of linear progression through the various stages of decision-making.

Based on the issues inherent to a RDM approach to design decision-making, as well as the strengths of the NDM approach, it seems that NDM is a better theoretical perspective through which to examine design decision-making. While the strengths inherent to NDM are promising, its suitability for describing the decision-making process of Interaction Designers is still unclear.

2.3.3. *Recognition-Primed Decision-Making*

Of the various models discussed within Table 2-1, academics regard the Recognition-Primed Decision-Making (RPD) model as the most prototypical representative of the field of Naturalistic Decision-Making (Lipshitz, Klein, Orasanu, & Salas, 2001). Due to

RPD's prominence within the field of NDM, we have chosen to use this model to frame our discussion of the decision-making process employed by Interaction Designers within chapter three. What follows is a brief discussion regarding the origins of the RPD model, its evolution, as well as some of the fundamental issues that surround this model.

The central tenet of Recognition-Primed Decision Making model is to provide a description of how people can use their experience to arrive at decisions without having to engage in an arduous mental search for the optimal solution (Klein et al., 1988). Klein, Calderwood, and Clinton-Cirocco (1988) describe people as leveraging their experience to reach decisions by using a combination of situational assessment, generating an action plan through analogical reasoning, and mental simulation. This model stands in stark contrast to the Rationalist Paradigm which emphasises the generation of multiple options for selection of an optimal solution.

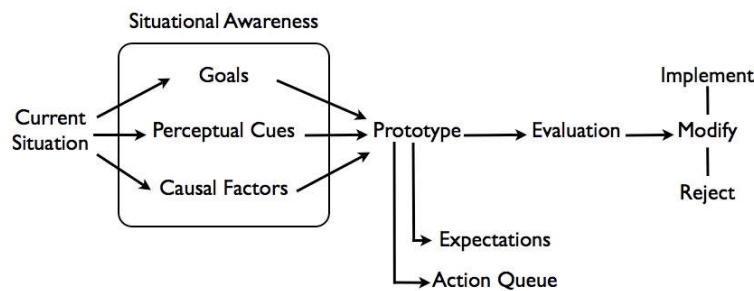


Figure 2-1 The original Recognition-Primed Decision Making model (Klein, 1988)

When developing the RPD model Klein et al. found that when experienced decision-makers were faced with a situation in which a quick and decisive course of action was necessary the first thing they did was to assess the decision point they were faced with and, on the basis of the outcome of this assessment, select a 'best course of action'. This series of actions in the RPD model is characterised by three distinct phases: situation recognition, serial action option evaluation, and mental simulation (McLennan & Omodei, 1996).

The initial stage of the RPD model, situation recognition, involves the decision-maker classifying the situation at hand as either unique or common based on previous knowledge. A common event is characterised as a successful match between the present situation and a familiar analogy or prototype in memory. Based on this initial matching stage, a series of goals that will satisfy the decision point are identified and potentially achievable goals are set.

The second stage of RPD, the serial option evaluation stage, involves compiling a potential plan of action to address the goals that are required of the situation. If there

is more than one potential plan of action then each plan is evaluated, one after the other, until a satisfactory one is decided upon. This plan of action does not necessarily produce the most optimal solution, but rather yields the first proposed solution to satisfy the goals of the decision point.

In the final stage, mental simulation, the decision-maker mentally walks through the proposed action plan to evaluate the potential outcomes and the potential problems. Based on this analysis the proposed action plan will be executed if no problems are identified, or modified to address any identified issues.

These three stages formed the basis of the original model (as depicted in figure 2-1). While these three stages were an accurate description of the decision-making of the interviewed fire-fighters it became apparent that when this model was applied to other fields it fell somewhat short in its descriptive power. From this shortcoming the RPD model was further refined to three distinct variations (Klein, 1999). Each of three variations represent the three most common types of situations that one could face: A familiar situation which has an accompanying familiar set of actions, a situation in which the decision-point is unclear and ill-defined but yet once it has been refined has a clear course of action, and a situation which we recognise as familiar but has an ever-changing course of required actions.

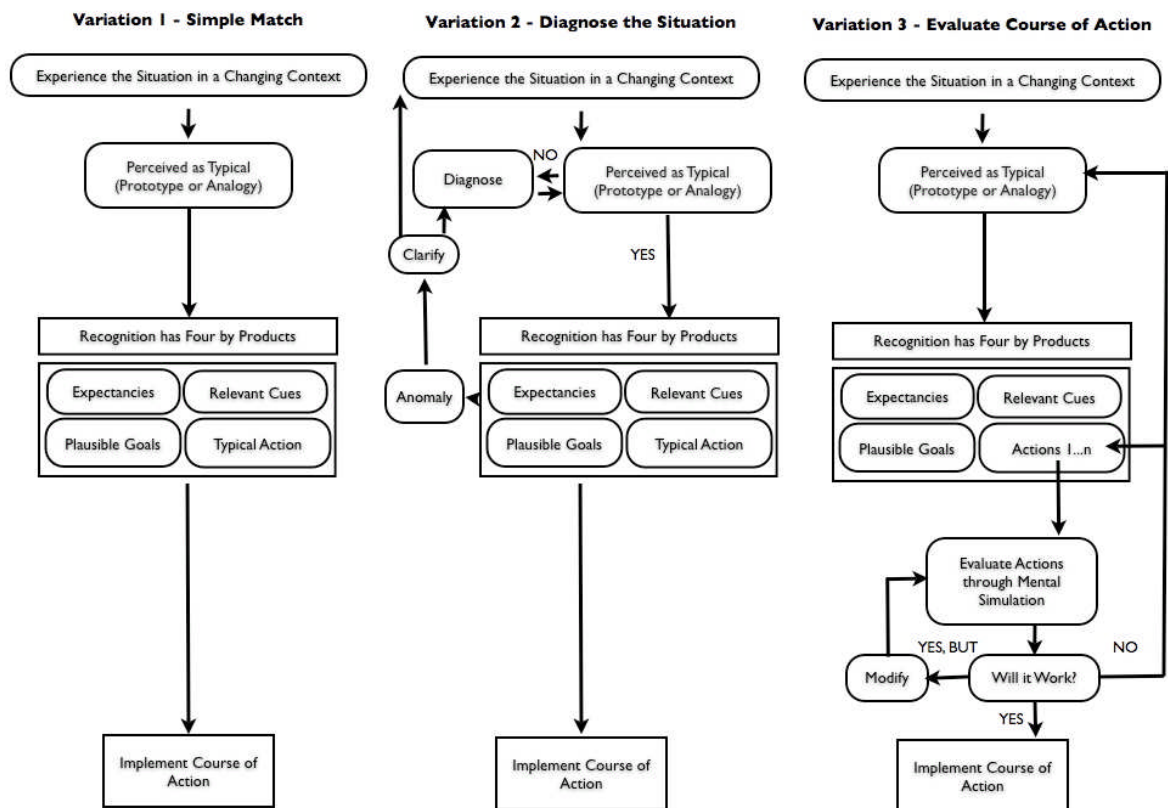


Figure 2-2 The three variations of the Recognition Primed Decision-making Model (Klein, 1999)

The focus of the first variation is the situation in which a 'simple match' is made between the familiar situation and a familiar course of action. This match is based on identifying the situation as either typical, which has a clear solution, or as familiar, in which they have encountered a similar situation in the past. Since the situation is identified as typical/familiar, the decision-maker will recognise a course of action which has successfully accomplished this task in the past. This identified course of action is reached by understanding the priorities of the situation, the information that needs to be taken into account, the expected outcome, and the typical actions which have solved the situation in the past. The proposed solution, under the first variation, is a single and familiar analogy coupled with a clear and familiar set of actions to make the initial decision.

Not all problems that people encounter are typical or familiar. The second variation entails assessing a situation where no typical scenario exists. Since either no familiar analogy is known, or various analogies are identified, a greater attention to the diagnosis stage of the model is required. When no typical case is evident, more information must be gathered to refine the range of possible analogies down to a manageable level of one or two. This evidence-gathering stage is further complicated by the fact that the individual may have misinterpreted the problem and chosen an ill-suited match from which to build a potential solution. It is possible that the decision-maker will not realise this until a point is reached at which it is clear that the proposed solution to this problem will not, in fact, be a viable answer.

While the second variation of the RPD model deals with an ambiguous problem coupled with a simple solution, the third solution focuses on the other end of the decision process: a simple analogy coupled with an ever-changing set of solution-focused actions. Under these conditions the individual must engage in a continual process of mental simulation in order to continually adjust the proposed solution as difficulties in the proposed solution arise. Mental simulation allows the decision-maker to cope with this ever changing action plan in an efficient and economical fashion.

To date any use of the RPD model in the area of design decision-making has been the original unitary model (Klein, 1987). While the newer variations have been applied and validated across several different fields of research (Klein, 1999), they have not been examined in the context of their descriptive power of the decision-making of Interaction Designers.

2.4. Differences in Design Cognition Based on Subject Discipline

As discussed earlier, different design disciplines have different perspectives on what design decision-making is composed of. The field of Mechanical Engineering viewed design decision-making as a logical assessment of all available options to find the optimal solution. This view was characterised by the Rationalistic perspective on decision-making. On the other hand, design disciplines such as System Design and Ergonomics view design decision-making as understanding how complex environmental factors, specifically time pressure, can impact the decisions that they make (Klein, 1993). These two fundamentally different perspectives have coloured our views on what design decision-making is and is not. While each model of design decision-making is an accurate reflection of its representing design disciplines it is problematic to generalise these principles across design disciplines.

Both Akin (2001) and Lawson (2006) discuss how difficult it is to generalise, which cognitive processes are involved in design, across design disciplines. Akin (2001) highlights the fundamental differences between the cognitive processes that Architects and Engineers employ. Architects were characterised by behaviours such as using an analogy as a basis for discourse as well as use a greater variety of representations than their engineering counterparts do. Lawson (2006) echoes these fundamental differences by discussing the overlapping and disparate cognitive skills that uniquely identify each design discipline.

2.5. Rationalistic vs. Naturalistic Decision-Making among Interaction Designers

Yates et al. (2001) highlight an important issue in regards to these two differing perspectives on design decision-making: context. Each of the two perspectives of decision-making discussed earlier highlight how people make decisions in the particular context that surrounds them at that time. In some cases a rationalist view on decision-making is a better indicator of what actually occurs while in other cases Naturalistic Decision-Making may be a more accurate reflection. This then begs the question if both views have been applied to understanding design decision-making which of the two is a more accurate depiction of the process that Interaction Designers engage with?

Considering the issues with the rationalistic perspective as well as the applicability of Naturalistic Decision-Making to the related fields of system design (Miller & Woods, 1997; Mitchell, Morris, Ockerman, & Potter, 1997) it would seem that the Naturalistic Decision-Making perspective may be a more appropriate match to understanding the decision-making process of Interaction Designers. Both Klein (Klein,

1999) and Orasanu & Connolly (1995) have compiled several factors which define a decision-making situation which is best described by NDM: namely a situation which is characterised by time pressure, high-stakes, ill-defined goals, dynamic environments and input from multiple team members. Both groups of researchers state that, while not every situation will be defined by all of these characteristics, an NDM-appropriate decision making situation will conform to the majority of them. In a similar vein, design, while not defined by all of those characteristics, does conform to the vast majority of the NDM identifiers. Characteristics of time-pressure and high-stakes have been discussed by Lawson (2006), while the ambiguous nature of design goals has been discussed by Buchanan (1992).

Klein was one of the first researchers to apply the NDM framework to understanding design decision-making. While Klein's work has provided the basis for much of the NDM work on design decision-making (Miller & Woods, 1997; C. M. Mitchell et al., 1997) it is not without its issues, specifically, the issue of validity.

Klein first examined design decision-making in the context of Naturalistic Decision-Making, in a study he conducted with Brezovic (1986), which examined the design strategies that were employed by system designers. Fifty system designers were interviewed using a combination of semi-structured interviews as well as the Critical Decision Method of Knowledge Elicitation. What emerged from this data were that designers used an informal decision-making process which relied heavily on their personal background. This personal decision-making utilised several techniques, or information sources, such as matching the problem to an analogue, drawing on personal experience, as well as using informal mock-ups and experiments. Klein described the decision-making process that designers employed as one in which the designer, when faced with a decision, will search for an analogy that best matches the problem at hand. The appropriateness of this starting analogy is next tested using mental simulation and then modified to better suit the original decision point. Designers were primarily concerned, not with evaluating all the options at hand and selecting the optimal one; but rather, taking a starting analogy and modifying it to suit the design goal.

While evidence was found in Klein & Brezovic (1986) to support the inappropriateness of a rationalist perspective on decision-making, no framework to model or analyse these results from a Naturalistic Decision-Making perspective was proposed. The data that were identified in this study was important in that it highlighted important NDM characteristics, such as the use of analogies to narrow down the problem space, and the usefulness of mental simulation in the decision making process.

The issue though is that while this study was explorative in nature the findings were taken as validation of the Recognition-Primed Decision-Making model as a framework to understand design cognition (Klein, 1987a).

The assertion of the unqualified usefulness of the Recognition Primed Decision-Making framework as a model to understand design decision-making has, despite these issues, remained unchallenged and unexamined, with researchers tending to simply build on this assertion (Kaempf, Klein, & Thordsen, 1991; C. M. Mitchell et al., 1997). Some of the more recent work in the area (e.g. Zannier & Maurer, 2005) has started to widen the theoretical base from that used by previous work. While the application of the NDM perspective to the sister area of system design is not without its issues, it does provide evidence to indicate that this theoretical perspective, over the rationalistic approach to decision-making, may be a more appropriate lens through which to examine decision-making among Interaction Designers.

2.6. Design Decision-Making: Conclusion

Recently researchers have begun to acknowledge decision-making as an important component of the cognitive tool set employed by designers. While this increased body of work is welcome it has led to a field of research, which has become divided and stagnant. This academic stand off is partly related to the difficulties of generalising across design disciplines. Researchers such as Lawson & Akin (Akin, 2001; Lawson, 2006) have discussed how different design disciplines employ different strategies and heuristics when they engage with the design process. These inherent differences between design disciplines have led to two competing views on design decision-making; the Rationalist decision-making perspective, as embodied by the Mechanical Engineering Discipline, and the Naturalistic Decision-Making perspective as discussed in the context of System Design. Each perspective championing its own model as an accurate reflection of how designers in general engage with the decision-making process. While modelling the decision-making process of designers is an important component of decision-making research this debate has led to other areas of decision-making being ignored. To broaden our approach to design decision-making research we need to move past focusing on the establishment of a universal framework and embrace the notion of context. Each decision-making model, be it rationalistic or naturalistic, may be an accurate reflection of each particular design discipline. By focusing on one particular design discipline, in this case Interaction Design, we can move past the framework and begin to examine others area of interest within the field of design

decision-making such as how different factors, both internal and external, can fundamentally influence how designers come to the decisions that they do.

2.7. Design Fixation

In chapter three we present an explorative study that discusses the influence that an initial analogy can have across all stages of the decision-making process. As discussed under the review of the decision-making literature, an analogy is used as an initial step in the scoping of the solution space and nothing more. Chapter three highlights the issues regarding this assumption. To address the issue of construct validity, through the process of methodological triangulation (Morse, 1991), we have employed a quantitative approach to examining the influence of analogies on the decision-making process by using the Design Fixation paradigm (Jansson & Smith, 1991). Chapters four through nine employ the Design Fixation paradigm as a way to observe and manipulate the influence that the initial analogy can have on a designer's decision-making.

The Design Fixation paradigm was originally proposed by Jansson & Smith (1991). Jansson & Smith illustrated how the mere presence of an example can fundamentally change the design process by causing designers to incorporate inappropriate elements of the example into their own designs. Jansson & Smith devised a paradigm that allowed them to quantitatively assess the degree to which the design process can be influenced by the inclusion of an example. The basic methodology of the Design Fixation paradigm, as outlined by Jansson & Smith, is as follows. At the outset of the study participants were randomly assigned to one of two groups. The first group was given a design brief and asked to sketch out as many ideas as possible, within the allotted time frame, in response to that design brief. The second group was given the same design brief but in addition were given an example of a possible solution to that design problem. The included example was fundamentally flawed in several important ways: the example either directly contradicted requirements stated in the design brief, or contained solutions which were illogical considering the purpose of the design brief.

Brief: Design a car-mounted bicycle rack. Your proposed solution must satisfy the following issues: 1) easy mounting of at least three bicycles; 2) easy mounting of the rack; 3) the proposed bicycle rack cannot harm the bike or the car; 4) the rack must be versatile for all makes of both bikes and cars.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example of a present day bike rack. The bicycle is set in the rails and the vinyl coated hook is attached to the seat tube of the bike, and then the hook is tightened down by hand with a wing nut. One should note the difficulty in mounting the middle bikes on the rack.

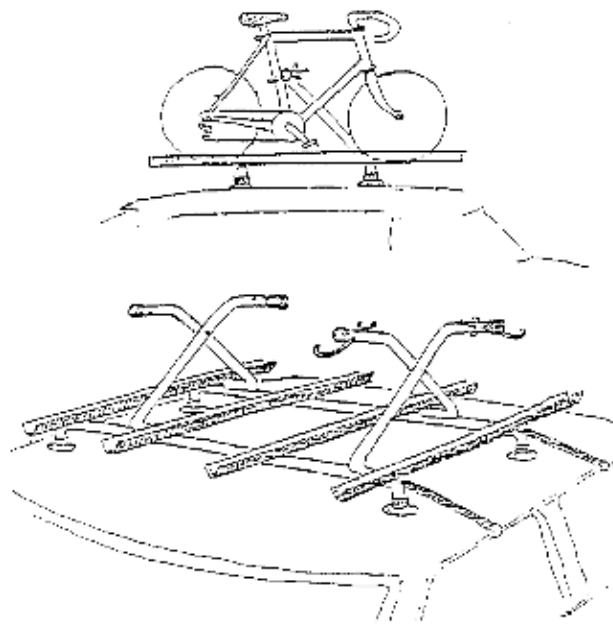


Figure 2-3 The design brief and the accompanying flawed example from Jansson & Smith (1991)

To assess the influence that the flawed pictorial example had on the types of solutions generated the produced sketches were analysed to see how many of the flaws that were placed by the experimenters were present in the proposed solutions. Participants who were primed by the included example produced solutions far more similar to that initial example when compared to the control group which received solely the brief. The only study to drastically change the basic experimental paradigm was Chrysikou and Weisberg (2005).

Chrysikou and Weisberg (2005) retained the same basic methodology but the real difference between this work and all of the previous studies was how the sketches were analysed. Previous Design Fixation studies measured the influence of the flawed

priming example by the presence or absence of the flaws placed in the example solution by the experimenters. The more flaws included in the design the higher the level of fixation. In comparison, under the scoring procedure used by Chrysikou and Weisberg (2005), each design was scored along three separate dimensions of fixation: 1) A measure of similarity, which was composed of direct physical similarities, reproductive similarities, and analogical similarities; 2) reproduction of intentional flaws; and 3) reproduction of unintentional flaws (which were identified retrospectively). A direct physical similarity occurred when the design generated was a direct copy of the pictorial example provided. Reproductive similarities were characterised by specific elements of the pictorial example being incorporated into the final design. Analogical similarities occurred when the same principles as the pictorial example were used without copying the physical characteristics of the example. Intentional flaws are characterised by incorporating specific flaws from the pictorial example that were placed there by the experimenter, which previous to this work was the sole measure of fixation in the Design Fixation paradigm. Unintentional flaws are characterised by the incorporation of flaws in the provided examples that were not specifically placed by the experimenter.

While Design Fixation measures the influence of an initial example on the types of solutions generated can we actually use this paradigm to evaluate the persistence of analogies across the decision-making process? The concern is that by using the Design Fixation paradigm we are not observing the influence of analogies, but rather, the influence of pictorial examples on the decision-making process.

2.8. Design Fixation and Analogical Persistence

As discussed earlier, analogies are used in the design process to aid in quickly identifying a viable solution from a large pool of adequate resolutions (Bonnardel, 1999; Klein, 1997). To aid in narrowing the pool of viable solutions designers must structure the design space. This structuring of the design space is achieved through analogical reasoning, in which designers draw upon previous experiences to look for solutions that have worked in similar situations. These analogies can take many forms; from anecdotal experiences (Bonnardel, 1999) to examples of previous work (Eckert, Stacey, & Earl, 2005; Herring, Chang, Krantzler, & Bailey, 2009). While the modality may differ the purpose is still the same: to quickly structure the design space to one or two workable proposals based on work that has been done in the past. Eckert et al. (2005) discuss how designers use examples of previous work as a way to access the inherent knowledge surrounding that design problem. Previous examples of other work

were used to prime knowledge pertinent to that particular design problem. Eckert discusses how the use of previous examples and design knowledge are inherently intertwined where one cannot exist without the other.

Purcell & Gero (1991) were able to illustrate the influence of previous examples without the inclusion of physical examples. Rather than provide a graphical solution to the design brief, they provided a verbal description of a possible flawed solution. What was found was that these verbal descriptions were just as influential in producing Design Fixation. This illustrates that there is more to the Design Fixation phenomenon than the influence of graphical examples. While Purcell & Gero (1991) describe the effect that these verbal solutions have on the overall design process, they do not discuss the possible mechanisms that may cause the exhibited multi-modal fixation.

Analogies can take many different forms, from memories of past experiences to physical examples. The only difference between the different modalities is the source of the analogical reasoning. By presenting participants with a faulty primed example we are priming them with an analogy versus asking them to generate their own. This distinction between these two analogical sources is discussed in more depth in chapter seven of this thesis. By using a primed analogy, i.e. a flawed pictorial example, we can quantitatively assess the influence of the initial analogy on the entire design decision-making process.

2.9. Design Fixation: Conclusion

The Design Fixation paradigm allows us examine and manipulate the influence that an initial analogy can have over all stages of the decision-making employed by Interaction Designers. Chapters four through nine of this dissertation employ the Design Fixation paradigm, or variations of, to validate and manipulate analogical persistence. This quantitative approach provides an appropriate compliment to the qualitative methods used to understand the decision-making process of Interaction Designers (chapter 3, chapters 7 – 9).

3. Understanding Design Decision-Making

3.1. Introduction

The study reported in this chapter is an exploratory study focusing on how Interaction Designers engage in decision-making. As briefly discussed in the previous chapter, little work has been done at the intersection of decision-making and Interaction Design. The three main bodies of research that have engaged with this particular area of research (N. Hammond, Jørgensen, MacLean, Barnard, & Long, 1983; Klein & Brezovic, 1986; Zannier, 2007) have not been without their issues. Each of these bodies of work was limited in relation to the conclusions that we could draw in regards to how Interaction Designers make decisions. The aim of this study was to build upon the limited work that had been done in this field, and to provide a slightly more detailed, while theoretically grounded exploration of how Interaction Designers engage in the decision-making process.

To date research that has examined the decision-making process of usability experts has been limited. Hammond et al. (1983) provided the foundation of decision-making among usability practitioners with an explorative study looking at the process by which these designers reached their decisions. Five designers, who had all worked on the development of the same system, were interviewed about the types of decisions that they made as well as how they reached those particular decisions. While the exact analysis method that was used was unclear, it did seem to contain elements of an open-coding strategy, like the strategy found in a grounded theory approach to data analysis (Strauss & Corbin, 1998). From the analysis, the authors propose a descriptive model of the decision-making process exhibited across the five designers; however, this study does not engage with the wider decision-making literature in any meaningful fashion. Due to its theoretical isolation Hammond et al. (1983) study lacks the common nomenclature used across different models of decision-making that would allow researchers to draw comparisons between this work and different strands of decision-making research. For example, a large portion of the study discusses different ways in which the designers consider the user in their decision-making. While the authors never use the term, they are referring to a process of mental simulation that designers use to test the usability of their proposed artifact. While this work was important in that it set the stage and context for research in this area, it is limited in its theoretical application.

The next study to investigate the intersection of usability practitioners and decision-making was Klein and Brezovic (1986). Adopting a similar methodological and theoretical, approach to Hammond et al. (1983), Klein and Brezovic (1986) interviewed several usability practitioners about how they engage with the decision-making process with a focus on a descriptive account of this process. What set Klein & Brezovic (1986) apart was that, although no direct connections were made between this work and the wider field of decision-making research, there was some engagement with some of the psychological processes that may be involved. For example, one of the key findings of their work was how the interviewed designers relied heavily on analogical reasoning in their decision-making. In an ironic twist, despite its theoretical isolation, this early work would later inform the Recognition-Primed Decision Making model (Klein et al., 1988).

After Klien and Brezovic (1986), the examination of how usability practitioners made decisions was largely ignored. Work in other fields of decision-making continued to mature, but the refinements and implications that were being discovered in other areas were rarely applied back to the field of design decision-making. Zannier (2007) began to bring some of the theoretical developments from other domains of decision-making, and examine how those models worked in the context of design decision-making. This work was an important development in our understanding of design decision-making as it began to bring together disparate threads from differing fields of decision-making research and examined how these threads applied, or possibly were irrelevant to the area of design decision-making. While Zannier (2007) was a large step forward in the area of decision-making and HCI, it was not without its faults. Zannier (2007) presented a series of qualitative studies which aimed at identifying the processes used in decision-making. While each study used a different methodology to probe at the decision-making process, such as interviews in one study and the completion of templates in another, this methodological triangulation was confounded by the ever-changing conditions that the participants were being examined under. In one study the decision-making process of lone designers was being examined, while in another, which was claimed to provide methodological triangulation, decision-making was being examined at an organisational level. While each of these conditions does provide valuable information about how design decision-making can change depending on the level of engagement, these studies are too different to provide any type of comparability let alone validation.

Research at the intersection of decision-making and the area of Interaction Design has been rare. Early work by Klein & Brezovic (1986) and Hammond et al. (1983) were instrumental in providing a basis for this field of research. Though both of the aforementioned studies lack theoretical underpinnings, they do have some applicability outside of these isolated studies. By not tying the results from Klein & Brezovic (1986) in to larger models of decision-making it is difficult to identify components that are common to all Interaction Designers rather than just those particular instances. However, Zannier (2007) has begun to integrate the decision-making of Interaction Designers with recent models of decision-making. The issue though with Zannier (2007) this work was that the scope of the research was too wide and the validity of those findings came at a cost.

The goal of this thesis is to adopt a more moderate position that takes into account all of these studies. Our examination of the decision-making processes employed by Interaction Designers had to be grounded in the wider decision-making literature, yet remain focused enough in our investigation so as to provide a clear picture as to the exact processes that were being used by participants. To provide a theoretical grounding for our study, which will allow us to make comparisons between our findings and existing research in the area, we chose to structure our study around the Recognition-Primed Decision-Making (RPD) model, specifically the three variations (Kaempf et al., 1991; Klein, 1997; C. M. Mitchell et al., 1997) as discussed in the previous chapter. To date any use of the RPD model in the area of design decision-making has been the original RPD model (Klein, 1987a). While these newer variations have been applied and validated across several different fields of research (Klein, 1999), these variations have not been examined in the context of the decision-making of Interaction Designers. The aim of this study was to use these variations to frame our examination of the decision-making process that Interaction Designers use.

3.2. Method

3.2.1. Participants

To ensure the greatest level of generalisability from this study of interaction designers, two sub-populations were examined: academic (n=3) and professional (n=3). The academic population was defined as designers whose experience in interface design was primarily from the context of academic work while the professional population was made up of designers whose experience was primarily from an industry context.

Participant	Job	Background	Experience (Years)
1	PhD Student: Develops news web-sites for small businesses	Academic	5
2	Research Fellow: Develops digital libraries prototypes	Academic	5
3	PhD Student: Develops Bio-medical software	Academic	2
4	Interface Design: Develops mobile phone applications	Industry	4
5	Interface Designer: Managing a paperless office	Industry	2
6	Interface Designer: Develops financial advisory software	Industry	2

Table 3-1 Demographic of Participants

Table 3-1 presents a series of short profiles of the individuals that participated in this study. Participants were recruited through departmental communication channels using snowball sampling with the exception of participant 6 who was recruited through personal connections. All participants recruited through the departmental channel either worked for, or had been affiliated with, the University College London Interaction Centre at one point.

3.2.2. Design

To probe the decision making process employed by Interaction Designers, an adaptation of the Critical Decision Method for Eliciting Knowledge (CDM) was employed (Klein et al., 1989). Traditionally CDM commences with the subject being asked to recollect an important decision that they recently had to engage in. Once a premise for the conversation has been established, the interviewer then asks a series of probing questions based on the information provided by the participant. To greater reflect the graphic nature of Interaction Design, the CDM methodology was modified for this study. As opposed to commencing with the recollection of a recent decision, each participant was instructed to bring with them a screenshot of an interface they had recently worked on. Each interview commenced with the participant being asked to describe the design decisions that were involved in the provided screenshot, as well as the rationale behind each of those decisions. The screenshot was used in order to provide focus, direction, and greater control of the interviewing process, as well as to act as a referent to the topic of discussion. In keeping with CDM, a series of probing questions were used throughout the interview. These questions were further

supplemented with several pre-written questions depending on which topics had already naturally arisen through the course of the interview. Table 3-2 presents the probing questions used in the interview, as well as examples of how those questions were used in the interview. In accordance with a data-driven approach to analysing the data, these pre-written questions were modified after each interview so as to refine the emergent categories.

Decision (initial starting point)	What was the biggest decision you had to make when putting together this interface?
Analogies	How did you come up with the initial idea for your design?
Constraints	What factors were taken into consideration when planning the design of your website?
Experience	How much do you think your experience designing web pages played a factor in your design process?
Environment	What external influences, if any, played an important part in the decision-making process?
Problem Solving	When you start to think about breaking down the overall design goal into something more tangible, how did you go about that?
User	Did you, at any point, imagine yourself in the role of the user?
Time Pressure	How much did deadlines and other forms of time pressure impact your design?

Table 3-2 Example of Interview Questions.

3.2.3. Procedure

In order to explore the design decision-making process of Interaction designers, a series of semi-structured interviews were employed. These interviews ranged from 35 to 50 minutes with an average duration of 40 minutes. The interviews were then analysed using a Theoretical Thematic Analysis coding strategy (Braun & Clarke, 2006). The results of this analysis were then contrasted against the RPD Model (Klein, 1999) to ascertain the appropriateness of the RPD model in explaining the process underlying Interaction Designers' design decisions. Five of the interviews were recorded and transcribed. Due to technical difficulties, the only record of the sixth interview were the notes taken during the interview, as well as a recording of the interviewer's portion of the conversation.

3.2.4. Analysis

There are several approaches to analysing qualitative data. One can adopt a data-driven approach, in which a rich-description of what occurred is obtained and themes emerge from the data. Alternatively, one can also adopt a theoretical perspective, which investigates in detail one particular aspect of the data which is identified by the research question. As a specific research question was being investigated, in this case the relation between the RPD variations and design decision-making, a Theoretical Thematic Analysis (TTA) was conducted. A TTA is a multi-stage coding process which looks for themes in a data set in the context of a particular research question (Braun & Clarke, 2006).

The first stage of the qualitative analysis was to gather data to examine how Interaction Designers make design decisions. These recorded interviews were then transcribed verbatim. To obtain a realistic reflection of the manner in which the conversation took place many idiosyncrasies of the interviewees were written into the transcripts, such as pauses, “urm”s & “ah”s. As the data were being transcribed, any ideas or insights that emerged were noted. These notes were used in the later stage of semantic analysis.

The preliminary phase of the analysis used an open-coding strategy. At this stage codes are generated by identifying significant sentences or quotations and associating a label which aimed to encapsulate a relevant theme or idea (Braun & Clarke, 2006). Each code that was generated could appear multiple times throughout the interview under various quotations and sentences that reflect that particular theme, but the code may also have been used in conjunction with other codes to more accurately describe the data. This deconstruction was then repeated in an iterative fashion until the entire interview was coded.

There are several levels of granularity that can be used to break down the transcript into discrete codes. At one extreme, a word-by-word analysis can be conducted to establish a set of codes while, at the other extreme, a paragraph-by-paragraph analysis can be utilised. The concern with adopting a word-by-word approach is that an unwieldy number of codes may be generated and the meaning behind the data lost. A paragraph-by-paragraph approach was not adopted, since the codes that would result from this level of analysis would be so few and high-level as to reveal little meaning. In the context of this study, the most appropriate approach was a sentence-by-sentence level of analysis. Braun & Clarke (2006) recommended this approach to open

coding as a line-by-line analysis is less likely to result in the researcher ‘seeing’ what they want in the data.

Once the surface level meanings had been encapsulated in the code list, the analysis then progressed to examine the data for latent themes, i.e. the underlying ideas, by examining the relationships between the codes generated at the semantic level of the analysis. The goal of this secondary analysis was to establish and examine relationships between the codes identified in the preliminary stage of the analysis in order to obtain an initial understanding of the themes that emerge from the data. By creating relationships between individual codes, these relationships began to cluster together to form broader themes. The aim of this clustering is to give shape to the data by organising the codes under broader theoretical concepts. From the axial coding stage of the analysis many micro-level codes started to cluster into cohesive themes. These inter-related micro-level codes formed several meso-level codes which encapsulated common themes that ran throughout the common micro-codes. If these higher level abstracted codes started to relate to each other, then the process was continued in an iterative fashion until a singular macro-code was available to encapsulate all of the related themes. From these relationships, and broader macro-categories, a model of design decision making emerged.

3.3. Results & Discussion

From this analysis three themes were identified that encapsulated the decision-making of Interaction Designers. The thematic map in Figure 3-1 summarises the clustering of individual codes into the broader latent themes that will be further discussed. What follows is a detailed discussion of the relationships between the identified themes and the RPD variations. To illustrate the relationship between the identified themes and the data, a summary of Participant 2's decision-making process is used as a consistent example as he/she was the most articulate in terms of verbalising their thoughts.

What emerged from the Theoretical Thematic Analysis were three stages that encapsulated how the participating Interaction Designers reached their design decisions: using an initial analogy as the starting point, modifying the initial analogy based on various constraints, and evaluating the proposed design through mental simulation. These three stages support the Recognition Primed Decision-Making model of design decision-making, as discussed by Klein (1999). Analogy use and mental simulation appear as important stages in the DDM process and also play key roles in the RPD model. Discrepancies between the data and the traditional view of RPD also emerged,

with the persistence of the initial analogy across all stages of the DDM process being the largest difference.

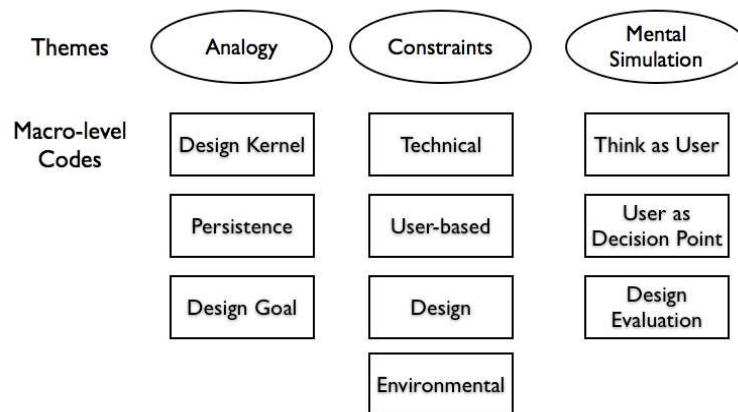


Figure 3-1 A thematic map illustrating the clustering of semantic codes to identify latent themes

3.3.1. Analogical Persistence in the Decision-Making Process

The initial stage in the Recognition Primed Decision-Making model is to quickly narrow down the possible solution space by identifying a single analogy or prototype that most closely matches the observed situation. This initial analogy is used to provide a framework from which to narrow the solution space to a more manageable level. This is an important characteristic of not only the RPD model, but many Naturalistic Decision-Making models (Lipshitz, 1995). This stage was uniformly identified as the commencement point for all design decisions that were discussed. All participants discussed how the design they created was based, either intentionally or unintentionally, on an analogous within domain example. All participants mentioned this concept when engaging in the decision-making process with no participants citing the concept of their design coming from an original/inspirational source. To better illustrate the usage of an initial example to scale down the problem space, a summarised account of participant two's decision-making process is presented below.

Example 1 - Digital Library Search Interface - Stage 1

Participant 2 was faced with designing a new search function for a digital library. The primary design goal for this project was to reduce the complexity of searching an elaborate academic catalogue. From the beginning of the decision-making process the interface used by Google seemed to be the solution to emulate, in that it produced potentially complicated results but yet retained a simple and non-threatening

interface. As a way to build on this simplicity and retain some of the power of complex searching of the original digital library, the initial search would take place on the simple Google-like search bar but refinements would be suggested based on the syntax of the search terms as a way to obtain a simple query but maintain the leverage of an advanced search.

When Participant 2 was faced with a complex situation that was fraught with ill-defined goals and time-pressures, he/she streamlined the problem space by identifying an analogy that matched the requirements of the situation, in this case the Google search interface.

“Ah yeah, I also think I was trying to copy Google as well. Trying to be evocative of a plain, long plain box and one single button” - Participant 2

This initial example let the designer begin the decision-making process without having to engage in a rational linear evaluation strategy. While this Google example was not the optimal option at the time, it was deemed satisfactory in terms of the design requirements. This initial Google example functioned as a way that allowed the decision maker to quickly attain a starting point from which to engage with the decision-making process. The use of examples were more than just starting points in the decision-making process. These examples persisted throughout the entire design process, with characteristics of the initial analogy being apparent in the final design solutions:

“There are a few bits and pieces that have been kind of borrowed from systems ... this IVR thing – the reason why I thought of the visual thing was because I had found some instructions for something that had it mapped out in a kind of hierarchical way and so that gave me inspiration for visualising it that way” - Participant 4

From the above quotation we can see that the example of an old Interactive Voice Recognition (IVR) manual provided the starting point for the decision, but was characterised throughout the design process as well. This persistence of a key base concept seems to have strongly influenced the final outcome of the design decision-making process. In conjunction with this persistence of the original design analogy, at no point in the interviews did any of the designers discuss comparing several design examples to find the most appropriate. No evidence for a linear assessment to obtain an optimal solution was exhibited. This finding of a lack of alternative generation among designers has been reflected in the work of Ball et al. (1998), where it was found that engineers generated very few, if any, alternative solutions. This persistence of an initial

idea overriding the evaluation of plausible alternatives is also echoed in Darke's idea of a Primary Generator (1979). Darke (1979) states that a Primary Generator is the situation in which a designer commences the design process with a simple idea, and latches onto this idea for the remainder of the design process, at the cost of evaluating alternative solutions to the problem. It is worth noting that in the latter stages of design decision-making the persistence of the Google analogy became a hindrance to the overall decision-making process. The example below illustrates the problems of the Google analogy in the latter stages of the decision-making process.

When Participant 2 engaged in a mental simulation of his/her proposed solution he/she found that the simplicity of the Google interface was not feasible to replicate under the conditions of his/her design problem. The amount of information that needed to be conveyed in the digital library search was inherently too complex for the Google-like interface. Rather than begin the DDM process anew and select a more appropriate analogy, Participant 2 struggled with adapting the Google analogy to suit the needs of the digital library problem. In the end a revision of the design was proposed with modifiable drop down boxes to supply the added complexity needed for the query.

The above example illustrates that the influence of the initial analogy was felt throughout the entire design decision-making process rather than as an initial starting point. Participant 2 was reluctant to discard this initial example and its inherent flaws for a new and more appropriate analogy, which would have potentially saved Participant 2 much time and wasted effort. The analysis of the interviews indicates that interaction designers rely heavily on the use of analogies as a way to commence the DDM process. In all the discussions with the interaction designers, it seemed that the resulting end decision was a modified variant of this original analogy.

3.3.2. Constraints and the Changing Action Plan

After the initial analogy has been identified in the first stage, the second stage is the modification of this analogy to not only better suit the initial design goal but, as well, to accommodate various 'constraints'. The term 'constraints' in this context refers to any influence which fundamentally changes the initial course of the decision. The impact of constraints on the decision-making process of designers has been discussed by previous researchers. Hammond et al. (1983) identified constraints as one of the major influences on the formation of a design decision. Even outside the domain of DDM, the importance of constraints on the design process has been widely discussed with all parties agreeing on the powerful impact that different constraints have on shaping the

design process (Lawson, 2006). The issue, though, is that, while the importance of constraints has been identified by the design research community the impact of constraints on RPD is far from clear.

To illustrate the impact that constraints can have in the DDM process, a continuation of the previous example is provided. While the first stage of Participant 2's DDM process was to choose the Google search interface analogy as a way to streamline the viable solution space, this second example illustrates how various constraints influenced the development of the digital library interface.

Example 2 - Digital Library Search Interface - Stage 2

After the initial Google-like analogy had been selected, Participant 2 was then confronted by the immediate practicalities of trying to execute this Google-like interface. The most immediate problem with executing this design analogy was working within the constraints of the programming language specific to the digital library. The ranking of the results that Google returns was not possible to accomplish based on the existing structure of the programme. Programming in that particular language was also affected by various time crunches, such as upcoming deadlines as well as certain family situations. There were other issues that led to several major modifications, such as the task itself, which was too complex to handle ambiguous entries into the search box. In the end, Participant 2 determined that to avoid the complexity of the search results and ambiguity of the search queries, a partially filled search bar would guide the user and narrow the potential ambiguous terms that the user might enter.

From the passage above we can see that the initial idea of a Google-like search interface was not able to meet the demands of the various constraints imposed on the design process. The constraints of the existing system, in conjunction with time constraints and the fallibility of the user, led to a modification of the initial analogy. From these we can see that the limitations that influenced the DDM process ranged from technical constraints to, environmental constraints, to user based constraints. These represent just some of the constraints that emerged from the data.

“So we were really constrained by what we could do as in how drastic we could be with the redesign because it's not like you've got these nice little plugs you can just plug new bits into” - Participant 4

The first, or second variations, of RPD is supported by the data, since the common element between the two is that a simple course of action, which when executed, will achieve the original goal. In contrast, the third variation of the RPD mode emphasises the evaluation of an ever-changing decision process, as does our data. The discussed constraints emphasised the difficulty of generating a design solution as the flux created by these constraints led to an ever-changing environment.

3.3.3. Mental Simulation

The third stage identified was the evaluation of the proposed design using the act of mental simulation. After the initial analogy has been selected and modified based on different types of constraints, the designer evaluates the proposed solution by walking themselves through the use of the proposed solution and examining how well that solution addresses the design goal that was set out at the onset of the process.

Example 3 - Digital Library Search Interface - Stage 3

Once a solution was proposed Participant 2 engaged in evaluating the feasibility of the solution. As discussed in Example 2, Participant 2 created a possible solution by having a partially filled in search bar. As Participant 2 imagined himself/herself in the role of the user he/she realised that, if the user was going to have to move around or even retype some of the predefined search terms to customise their query, this solution was not feasible or realistic. As this evaluation returned a negative match between the solution and the design goal this led to a revision of the proposed design. In the end the final design was a combination of the initial Google-like search bar in conjunction with a series of drop-down boxes that aimed to refine the search after the initial query had been run. This solution proved to be a modification of the original Google analogy to accomplish the design goal, while controlling for all of the influencing constraints.

The majority of statements within the design evaluation theme reflected the act of mental simulation, with the designer imagining him/herself as the user and participating in a mental walkthrough of how the user could, or could not, accomplish their goals, given the current course of action in the decision process. In the latter portion of the analysis a linkage between the codes 'design evaluation', 'thinks as user', and 'user task completion' became evident. Throughout the narrative of the interviews these three codes were constantly being mentioned in the context of the evaluation of their proposed solutions. This linkage further illustrates the process that Interaction

Designers used to evaluate their proposed solutions by conducting a process of mental simulation in which they placed themselves in the role of the user. This linkage among the codes further reaffirms the presence and evaluative use of mental simulation as an important component in a cyclical process of adopting a starting analogy, refining that analogy based on constraints, and evaluating the potential success of the proposed solution. This iterative approach strongly echoes the Recognition Primed Decision-Making framework, in which the act of mental simulation is used to evaluate a potential course of action and based on that mental simulation either a refinement of the course of action may occur or a completely new cycle maybe proposed.

The notion of mental simulation as a way to refine the ambiguous course of action is a defining characteristic of the third RPD variation. As discussed earlier the previous two models place an emphasis on being able to identify a clear and concise course of action that will successfully achieve the initial decision point.

3.3.4. Decision-Making in Designers and the Three variations of RPD

The three stages of design decision-making that have been identified thus far, while not a perfect match, do have much in common with Klein's Recognition Primed Decision-Making model (1999); namely, the reliance on the use of analogies to narrow down the problem space and the use of mental simulation as a technique to ascertain the success of the proposed solution. With the exception of the influence of constraints in moulding the decision making process, the stages that emerged in this analysis confirm the appropriateness of using the RPD model to describe Design Decision Making. An issue that needs to be addressed outside of the validity of the RPD model in the context of design, is the issue of DDM and the developments of RPD that have occurred since Klein's original work on DDM (Klein, 1987a; Klein & Brezovic, 1986). At the outset of the RPD model (Klein et al., 1988) it was a single unified model to facilitate the understanding of Naturalistic Decision-Making, as opposed to the current context in which the RPD model is composed of three distinct variations. As discussed earlier in this chapter, these three variations aim to describe in detail the different type of situations decision makers would have to face in real world settings. While the stages of DDM discussed thus far confirm the general appropriateness of the RPD model, what do the results of this study indicate about the specific relevance of each of the three RPD variations?

The first stage that was discussed was the role of analogies in design decision-making. One of the points made was that designers used a single analogy to narrow down the problem space, with no alternative analogies being considered as appropriate

starting points. In all of the interviews, the use of alternative analogies was never discussed nor mentioned. A simple match between the situation at hand and the one single analogy was mentioned in all interviews. Based on this use of a single design analogy, we can discard the second variation of the Recognition Primed Decision-Making model. The focus of the second variation is that the decision maker is faced with an ambiguous situation in which there are multiple matching analogies. This use of a single design analogy lends support for both the first and third variation of the RPD model. What differentiates the first and third variations of RPD is how the decision is reached. If a typical response is available, then the first model is most applicable but, if the course of action must be modified, then the third of the variations is a better fit.

The first Recognition Primed Decision-Making variation is not supported by the data, since the first model revolves around the concept that there is a typical situation, as well as a simple course of action, to complete the goal. Therefore, the first model is unable to account for the ever-changing decision-path exhibited in our data. The third variation of the RPD model, on the other hand, places as much emphasis on evaluation of an ever-changing decision process as our data does. The focus of the third variation is on a simple solution coupled with an ill-defined and ever-changing decision path. In the RPD model this is accounted for by the use of evaluative mental simulations of the proposed solution and reformulation of the decision-path to a more suitable course of action. This evaluation of the present state of the decision using mental simulations, as mentioned before, was a strong theme to emerge from the data, with multiple references to evaluating the state of the design by placing oneself as the user and creating a mental simulation of how well this proposed solution would satisfy the original design goal.

The themes that have emerged from our data driven analysis provide evidence that the third variation of the Recognition Primed Decision-Making model, in which a simple analogical solution is proposed and is subjected to an ever-changing solution (constraints), and an evaluative mental simulation on the ill-defined course of actions (design evaluation) is the most representative of the design-decision making process used by interaction designers.

3.3.5. *Limitations*

The main issue with our finding of the persistence of the initial analogy is one of post-hoc rationalisation. The discussion of a single analogy through the design decision-making process may simply be a function of only remembering the one analogy that participants ended up using throughout the design decision-making process, with other analogies being used and discarded along the way. To address this issue the study

presented in chapter 4 takes a quantitative approach, by using the Design Fixation paradigm (Jansson & S.M. Smith, 1991) to validate the persistence of the initial analogy across all stages of the design decision-making process. By using a quantitative approach to our follow-up study we can then provide theoretical triangulation to bolster the validity of the results from this study.

3.4. Conclusion

By examining the relation between the Recognition Primed Decision-Making model and design decision-making the impact of analogies emerged as an important element to the decision-making process of Interaction Designers. This over-reliance on an initial analogy, while echoed across all participants interviewed, could not be accounted for by the current RPD models. Several themes emerged from the Theoretical Thematic Analysis that reinforced the RPD model with the persistence of the initial analogy across all phases of the decision-making process being the largest divergence between our results and the model (Klein, 1997). As briefly described in the above limitations section an alternative explanation to the finding of analogical persistence is one where multiple analogies are considered but only one is taken to the completion of the decision-making, and that is the only analogy that is remembered. This alternative hypothesis is another plausible explanation to the results highlighted in this chapter. To address this alternative hypothesis and replicate our findings, we decided to employ methodological triangulation by using the Design Fixation paradigm (Jansson & S.M. Smith, 1991). The Design Fixation paradigm provides a quantitative approach to measuring and understanding how influential an initial idea or analogy can be on the entire design process. As discussed in chapter two, the Design Fixation paradigm allows us to prime participants with a flawed initial analogy. As this initial analogy contains carefully manipulated errors we can examine the solutions proposed by participants for the presence or absence of those errors. The greater the number of errors present in the proposed solution, the greater the influence of that initial Priming Analogy. By using this quantitative measure we can gauge the level of influence that one analogy can have over the entire decision-making process; from analogical selection to mental simulation. If our initial hypothesis as to the influence of analogical persistence were to hold we would expect the initial Priming Analogy to heavily influence the final solution(s) as solely one analogy is used across all stages of decision-making. In the context of the alternative hypothesis, that multiple analogies are considered and used but just not remembered, we would expect there to be little influence of the initial flawed Priming Analogy as multiple analogies will be considered and employed in formulating a viable

action plan that satisfies the requirements of the design problem. The study presented in the following chapter addresses the plausibility of this alternative explanation to the results presented in this chapter using the quantitative approach of the Design Fixation paradigm.

4. Validation of Analogical Persistence in Design Decision-Making

4.1. Introduction

The previous chapter discussed how analogies negatively and positively influence the entire design decision-making process. The main issue with the results discussed in the previous chapter is one of validity; specifically internal validity. From what we have observed, it is difficult to ascertain how much our findings are truly representative of analogical persistence or are merely a function of the methodology employed. While measures were taken to be as stringent as possible in our qualitative analysis, there are still alternative explanations that overshadow our findings. A plausible explanation for the persistence of the initial analogy is simply a matter of the fallibility of post-hoc rationalization. It is possible that the participants interviewed only remembered the one analogy, from a multitude of analogies used, that was taken to completion in the decision-making process. To address concerns like this, we need to establish methodological triangulation, i.e. use several different methodologies to complement, and validate, the findings of analogical persistence. The aim of this study was to adopt a quantitative perspective on the examination of analogical persistence on design decision-making to address the issue of internal validity raised in the previous chapter.

We have chosen to employ the Design Fixation (DF) paradigm (Jansson & S.M. Smith, 1991) to observe and manipulate the possible influence of an initial analogy on the entire design decision-making process. By comparing the types of solutions generated from a design brief against the same design brief with a flawed pictorial example, we can observe how and under what conditions the priming analogy (the flawed example) are the most influential on the decision-making process of interaction designers. The primary focus of this study is to use a different methodological perspective to observe the issue of analogical persistence within the design decision-making process of Interaction Designers. While the Design Fixation paradigm does allow us to leverage a quantitative perspective on the issue of analogical persistence, it is not without its own validity problems. The Design Fixation paradigm has several threats to its external validity that need to be addressed before one can be confident in its use to provide sound methodological triangulation. Before we discuss the specific

validity issues of the Design Fixation paradigm it is worth defining the term external validity. External validity is concerned with how representative the findings, of a particular study, are of the true phenomenon, or the amount which these findings generalise past the specifics of the experimental paradigm. In the case of the Design Fixation paradigm there are several threats to validity that need to be addressed. Design Fixation has been replicated numerous times using Mechanical Engineers but attempts to produce similar results among differing design populations has been problematic. This study directly examines this issue of generalisability.

4.1.1. Issues with Design Fixation

While Design Fixation has been identified and replicated numerous times among Mechanical Engineers, the application to other design domains has been neither successful nor conclusive. Purcell and colleagues (Purcell & Gero, 1991, 1996; Purcell et al., 1993) extended the original work of Jansson & Smith (1991) by examining the impact of Design Fixation across several different design populations (Industrial Designers & Architects). Purcell and his colleagues found that while DF was replicated among Mechanical Engineers, fixation among Industrial and Interior Designers, was only marginal. A potential explanation for these conflicting findings is that DF occurs when there is match between the domain of expertise of the designer and the domain of the problem presented, so DF may be less robust when there is a mismatch between these two variables. Failure to replicate in previous studies was due to non-engineering designers being given engineering based problems; by giving designers domain-relevant problems, DF should be exhibited. By addressing these issues of generalisability we hope to test whether Interaction Designers are just as susceptible to DF, ultimately in order to provide quantitative evidence of the persistence of analogies across all phases of the design decision-making process.

4.2. Method

4.2.1. Participants

Thirty-two Interaction Design students participated in this experiment. Participants were recruited from two postgraduate programs in the Greater London area. Sixteen students were recruited from the MSc in Human-Computer Interaction with Ergonomics from University College London and sixteen participants were recruited from the MSc in Interaction Design from Middlesex University. All participants had on average 8 months of experience as Interaction Designers.

4.2.2. Materials

Four different design problems were used: two differing domain problems focusing on Mechanical Engineering principles (the bike rack problem and the spill-proof coffee cup problem from the original Jansson & Smith (1991) as illustrated in Appendix A) and two within-domain problems focusing on Interaction Design principles (a digital music player problem and a medicine dispenser problem designed specifically for this study as detailed in Appendix A). Each problem was comprised of a short description of the design problem, and a list of criteria that each solution must conform to. As familiarity has been raised a possible issue in regards to the expression of Design Fixation (Purcell et al., 1993), the design problems were accompanied by a brief questionnaire to ascertain the familiarity of the participant with the devices in each design problem. Familiarity was scored on a Likert scale ranging from 1 ('Have never used the device') to 5 ('Frequently use the device').

4.2.3. Experimental Procedure & Design

The experiment employed a 2 x 2 mixed design, with the between subject manipulation being the Presentation (Brief Only vs. Brief & Flawed Example) and Problem Discipline (Mechanical Engineering and Interaction Design) manipulated within-subjects.

Participants were run in two separate groups broken down by university. Participants were randomly assigned to either the Brief Only condition or the Brief & Flawed Example condition. The Brief Only group (n=16) were given just the design brief, while the Brief & Flawed Example group (n=16) were given the same design problems but with an inherently flawed pictorial example solution that violated at least two of the constraints identified in the design brief.

Each participant was presented with a booklet containing two different design problems: one Mechanical Engineering problem and one Interaction Design problem. These presentations were counterbalanced for presentation order as well as all combinations of the problem domain. Participants were instructed to: construct as many solutions as possible in the allotted time for each design problem, write comments with every design, and number each individual design. Participants were allotted 25 minutes for each design problem.

Problem 1	Problem 2
Music Player	Bike Rack
Music Player	Coffee Cup
Medicine Dispenser	Bike Rack
Medicine Dispenser	Coffee Cup

Table 4-1 Order of Problem Presentation

4.2.4. Analysis

To quantify the generated designs, the scoring procedure used in Chrysikou & Weisberg (2005) was used. This scoring procedure provides greater detail in terms of the characteristics of fixation than the scoring procedure used by Jansson and Smith (1991), which solely looked at the presence or absence of certain flaws that were placed in the Fixation condition by the experimenter. In Chryiskou & Weisberg (2005), each design was scored along three separate dimensions of fixation: 1) A measure of similarity, which is composed of: direct physical similarities, reproductive similarities, and analogical similarities; 2) reproduction of intentional flaws, and 3) reproduction of unintentional flaws. A direct physical similarity occurred when the design generated was a direct copy of the pictorial example provided. Reproductive similarities were characterised by specific elements of the pictorial example being incorporated into the final design. Analogical similarities occurred when the same principles as the pictorial example were used without copying the physical characteristics of the example. Intentional flaws are characterised by incorporating specific flaws from the pictorial example that were placed there by the experimenter. Unintentional flaws are characterised by the incorporation of flaws in the provided examples that were not specifically placed by the experimenter. Table 4-2 contains an example of the specific scoring criteria used in the analysis (the full scoring criteria is contained in Appendix A). On each generated design a percentage score was created for a specific fixation measure by dividing the design score on that measure by the maximum possible score for the measure, then these were averaged over all the generated designs to produce a single summary score for that fixation measure. This process was repeated for each of the fixation measures producing summary scores with potential limits of 0 (complete absence of fixation) to 1 (maximum fixation).

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout and features as an example	0-1
Reproductive Similarity	1) use of album, 2) vertical volume bar, 3) use of excessive controls, 4) use of arrows for linear navigation, 5) use of cover flow, 6) placement of add/remove buttons	0-6
Analogical Similarity	1) Alternative ways to display playing music , 2) alternative ways to navigate music collection	0-2
Intentional Flaws	1) Excessive controls, 2) excessive visual embellishments, 3) counterintuitive volume	0-3
Unintentional Flaws	1) not able to search, 2) no display for current track	0-2

Table 4-2 An example of the scoring criteria used for the music player problem

4.3. Results

To investigate whether the solutions generated under the Brief & Flawed example condition were markedly more similar to the provided examples than the solutions generated under the Brief only condition, a mixed series Multivariate Analyses of Variance (MANOVA) was used to analyse the four dependent variables (Reproduced Similarities, Analogical Similarities, Intentional Flaws and Unintentional Flaws). As in the earlier studies that used these five fixation measures, all participants scored zero on the Direct Physical Similarities (Chrysikou & Weisberg, 2005). Consequently, since this result was constant across all groups, the Direct Physical Similarities measure was removed from the analysis.

4.3.1. Design Fixation in Interaction Designers

Figure 4.1 clearly illustrates that the designs generated under the Brief & Flawed Example condition were significantly more similar to the provided examples (Reproduced Similarities (RS) $M = 0.413$, $SD = 0.183$; Analogical Similarities (AS) $M = 0.432$, $SD = 0.268$; Intentional Flaws (IF) $M = 0.403$, $SD = 0.214$; Unintentional Flaws (UF) $M = 0.332$, $SD = 0.277$) when compared to the brief only condition (RS $M = 0.144$, $SD = 0.189$; AS $M = 0.185$, $SD = 0.150$; IF $M = 0.276$, $SD = 0.190$; UF $M = 0.085$, $SD = 0.110$). This behaviour was exhibited across all three measures of fixation (RS $F(1,30) = 16.88$, $p < .01$; AS $F(1,30) = 10.29$, $p < .01$; UF $F(1,30) = 10.91$, $p < .01$).

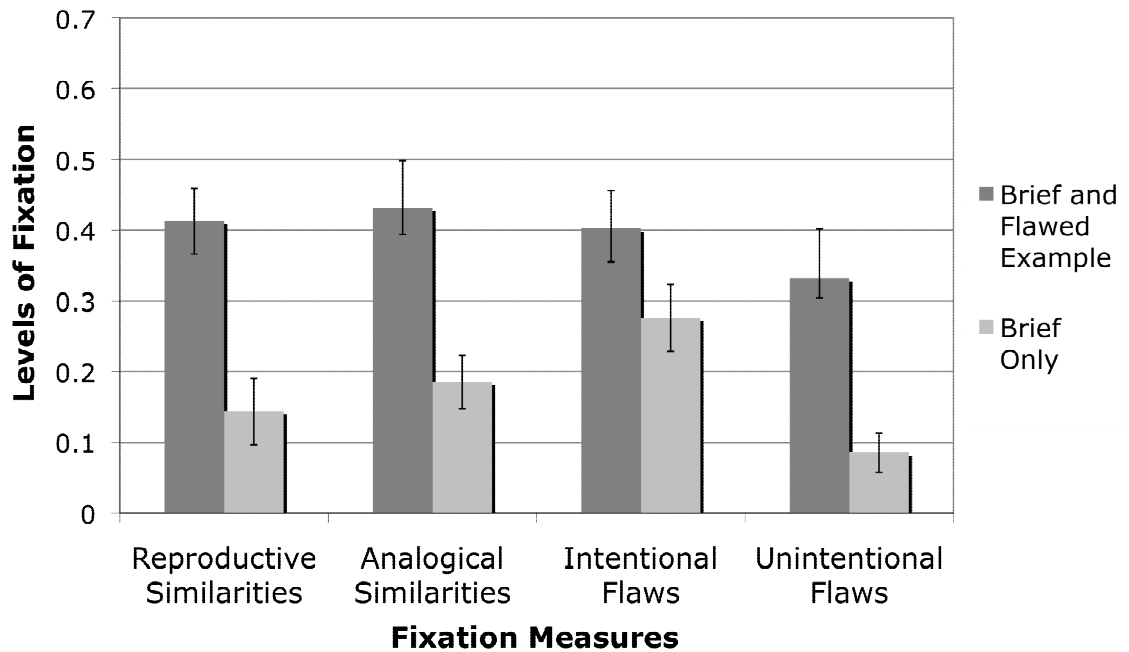


Figure 4-1 Levels of fixation between the presentation conditions for each fixation measure. Error bars indicate standard error of the mean.

The notion of two types of flaws as discussed by Chrysikou and Weisberg (2005) is an arbitrary distinction if the perspective of the participant is considered. The distinction between Intentional and Unintentional flaws is simply an artefact of the experimenter but from the point of the view participants, they are unaware of which flaws were placed by the experimenter and which are flaws that were inherent to the example. By combining the two measures of fixation into a unified measure examining the flawed elements of the example, regardless of the source, we can gain a more accurate picture of how participants fixate. While the distinction between Intentional and Unintentional flaws is arbitrary both of these measures of fixation were kept in the previous analysis so as to allow for comparability back to previous Design Fixation studies. Previous to the work of Chrysikou & Weisberg (2005), all Design Fixation studies calculate fixation scores by the presence of flawed characteristics from the original example in the proposed solutions. In this study this is exemplified by the Intentional Flaws measure of fixation.

When fixation is examined with the unified measure of Reproduced Flaws, the results remain consistent with the results discussed in the preceding paragraphs. The Reproduced Flaws measure of fixation demonstrated that there was a significant difference between the two presentation conditions $F(1,30) = 10.24, p < 0.01$ with the Brief + Flawed Example condition exhibiting higher levels of fixation ($M = 0.367, SD = 0.198$) as compared to the Brief Only condition ($M = 0.181, SD = 0.124$).

4.3.2. Design Fixation and the Effect of Differing Problem Disciplines

While the main effect of Presentation (whether the participants were given a flawed Priming Analogy or not) was generally robust across measures, the same cannot be said about the main effect of Problem Discipline. There was a main effect of Problem Discipline, $F(4,27) = 3.558, p < .05$, but as illustrated by Figure 4.2, the observed effect can be attributed to the Reproduced Flaws measure of fixation. Participants incorporated significantly more of the Reproduced Flaws of the original examples into their solutions to the Mechanical Engineering problems ($M = 0.355, SD = 0.248$) than they did in the Interaction Design problem solutions ($M = 0.193, SD = 0.233$), $F(1,30) = 9.07, p < .01$. No significant differences were observed between any of the other measures of fixation.

The main effect of exposure to a flawed graphical example; therefore, produces a fairly robust impact on a range of fixation measures. However, the main effect of problem discipline results in a fixation effect that was restricted to the Reproduced Flaws fixation measure.

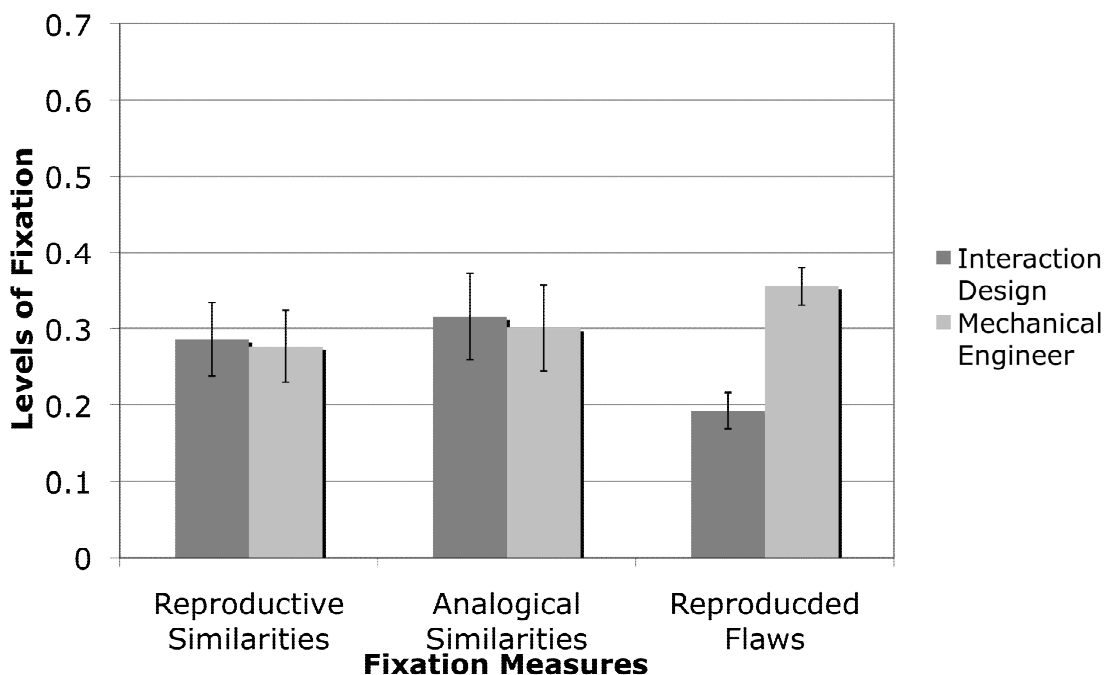


Figure 4-2 Differing levels of fixation within each fixation measure across problem disciplines. Error bars indicate standard error of the mean.

4.3.3. The Effect of Exposure Within Each Problem Discipline

While there was no significant interaction observed between Problem Discipline and Presentation ($F(3,28) = 0.957, p > .05$), Figure 4-3 does illustrate that there were several notable differences between the Brief and Flawed Example condition and the Brief Only condition. To investigate these differences a series of independent sample t-tests

were conducted within each problem discipline in order to examine the discipline-specific differences between the experimental groups on each fixation measure.

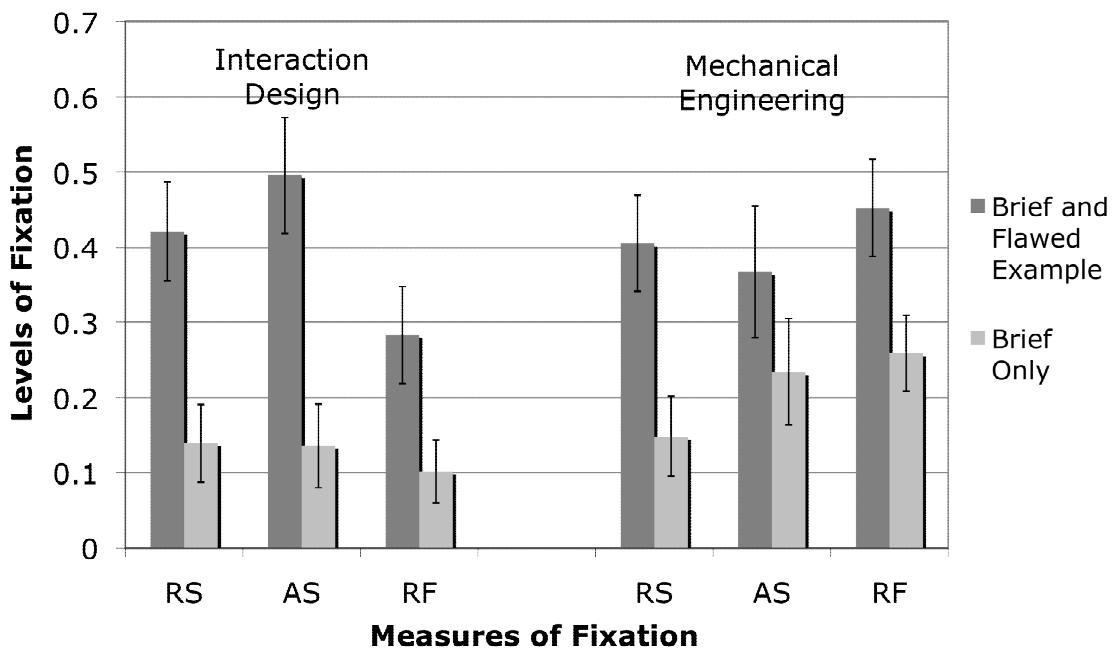


Figure 4-3 Levels of fixation in each fixation measure separated by experimental condition and problem discipline. RS = Reproductive Similarities, AS = Analogical Similarities, RF = Reproduced Flaws. Error bars indicate standard error of the mean.

Figure 4.3 illustrates differing patterns of fixation between the two problem disciplines. When participants were working on a problem from their own design discipline they tended to fixate across all measures of fixation (Reproductive Similarities $t(30) = 3.36$, $p < .01$; Analogical Similarities $t(30) = 3.77$, $p < .01$; Reproduced Flaws $t(30) = 2.34$, $p < .05$). In comparison, when participants were working on a design problem with which they were not familiar, they focused on the physical characteristics of the provided example namely the Reproductive Similarities ($t(30) = 3.09$, $p < .01$) and Reproduced Flaws ($t(30) = 2.348$, $p < .05$). Figure 4.3 illustrates quite clearly that the inclusion of a within domain problem causes fixation across all measures of fixation, while the presence of an example in a domain that they are not familiar with increases fixation on only the physical properties (RS & RF) of that flawed graphical example.

In summation, we can see that by showing a participant a graphic example, the designs they create will be markedly closer to the initial example. When examining the differences between the experimental conditions, we see that the introduction of a pictorial example increases levels of Reproductive Similarity and incorporation of Reproduced Flaws from that example, independent of problem discipline. Outside of this common thread, which spans the two design domains, we found that analogical similarities were limited to within-domain problems.

4.4. Discussion

The primary focus of this study was to address issues of external validity, within the Design Fixation paradigm, by replicating Design Fixation in a non-Engineering population, namely Interaction Designers. By replicating Design Fixation among Interaction Designers we are able to in turn validate the analogical persistence identified in the previous study. Examining how the domain of the problem as well as the domain of expertise of the participant allowed us to address one threat to the external validity of the Design Fixation as well as provide theoretical triangulation to the previous study.

As previously mentioned, replication of Design Fixation outside of the Mechanical Engineering discipline has been problematic (Purcell & Gero, 1996; Purcell et al., 1993). When the discipline of the designer was controlled for, DF was observed to be present among different design disciplines but was only marginally significant. Purcell et al. (1993) hypothesized that the marginally significant results of their study were due to a mismatch between the discipline of the designer and the discipline of the problem, e.g. fixation among Interaction Designers would be significantly higher when working on an Interaction Design problem than when working on an engineering problem (which they have no expertise in).

Results from this study indicate that Design Fixation is present in Interaction Designers. Purcell et al. (1993) hypothesised that a match between the problem domain and the domain of expertise would yield fixation; however, the results from this study do not support this hypothesis. The results from this study suggest that DF was in fact present among the solutions generated in Purcell et al, (1993) Therefore, the marginal significance obtained by Purcell et al., (1993) was most likely not a result of a mismatch between problem discipline and domain of expertise, but a function of the outcome measure used.

The increased levels of fixation that were observed in this study may be attributed to the usage of a more sensitive outcome measure. In both Purcell & Gero (1991) and Purcell et al. (1993), the measure of fixation employed were lists of the particular flaws placed in each example by the experimenters. Fixation was then coded based on the appearance of these particular characteristics. Under the more sensitive measure created by Chrysikou and Weisberg (2005), these characteristics would only be accounted for by the Intentional Flaws measure of fixation. If only the Intentional Flaws measure of fixation had been utilized in this study, we would have drawn the same conclusion as Purcell et al. (1993), as illustrated in Figure 4.1. By widening the scope of fixation

measures to include such characteristics as analogical similarities and reproductive similarities, we can see that DF is in fact fairly robust across design disciplines.

When we took a more focused approach to analysing the individual measures of fixation we began to see evidence for Purcell's hypothesis. A significant difference in fixation was recorded between the types of designs generated across all measures of fixation when Interaction Designers were faced with a problem domain they were familiar with (as illustrated by Figure 4.2). When engaging in the design decision-making process with a problem domain familiar to them, participants focused on superficial elements of the flawed examples (i.e. Reproductive Similarities and Reproduced Flaws).

The validity of analogical persistence was confirmed by employing the Design Fixation paradigm to quantitatively assess whether or not these initial results were an artefact of a post-hoc rationalisation of the design decision-making process. Results indicated that when Interaction Designers were given a flawed example at the outset of the decision-making process that the solutions generated were markedly closer to the experimental analogies when compared to the control group.

This persistence of an initial idea overriding the evaluation of plausible alternatives is echoed in Darke's idea of a Primary Generator (1979). Much like the persistence of the initial analogy the Primary Generator is best described as an idea that a designer begins the design process with, then latches onto for the remainder of the design process, at the cost of evaluating alternative solutions to the problem. This phenomenon is well documented in the area of design research, but its presence is taken as simply inevitable with little work being done on understanding its effects in a more holistic manner to the design process. Other areas outside design research have commented on similar phenomena such as Gestalt psychology and the differing types of fixation (e.g. Functional Fixedness Duncker, 1945, Mental Ruts (S. M. Smith, 1995)), as well as the Anchoring Effect in the decision-making literature (Tversky & Kahneman, 1974). The Gestalt idea of fixation discusses how the problem solving process can become disrupted by differing elements (such as recency, repetitions, familiarity) which prevent the individual from successfully completing the problem and 'fixating' on particular characteristics of the problem in question. For example, Duncker (1945) described the phenomenon of Functional Fixedness in which the traditional use of an artefact prevented the participant from imagining other, more innovative, ways to use these objects to solve the problem at hand. Participants were given a matchbox,

containing one match, a candle and a thumbtack and were instructed to light the candle and attach it to the wall. Participants were unable to solve the problem as they were fixated on the traditional use of a matchbox and were not able to imagine the box as a candle holder that could be attached to the wall with the thumbtack. The Anchoring Effect is similar in that it documents the disruption of a normal cognitive system, in this case decision-making, by the inclusion of an initial example. Tversky and Kahneman (1974) discussed the inclusion of an example before a participant engages in the decision-making process will provide an answer that is markedly closer to the given example than if they hadn't been given an example solution. This 'anchoring' to the initial example, as well as the related phenomenon of the primary generator, and fixation build a picture in which the presence of an initial idea, analogy, or example can profoundly influence the outcome of the process in question. These phenomena further underline the relevance of the findings from the first study from a theoretical standpoint.

The results of this study demonstrate how the inclusion of a flawed example can lead to a faulty framework in which certain suppressed elements of the analogy were carried through to the conclusion of the decision-making process. The flawed graphical example created a framework in which certain elements of the design problem were highlighted and other elements were suppressed. The presence of these faulty elements in the final solutions were indicative of this faulty framework. This persistent and faulty framework created by a faulty analogy demonstrates the over-reliance on a single analogy rather than a series of analogies which would support the issue of the results from the first study being a function of post-hoc rationalization.

4.5. Conclusion

The primary aim of this study was to replicate analogical persistence using a quantitative method. By replicating Design Fixation in Interaction Designers we have addressed both the issue of internal validity from the previous study as well as the threat to external validity of the Design Fixation paradigm. By adopting a more sensitive measure than the one used in previous studies (Jansson & S.M. Smith, 1991; Marsh, Landau, & Hicks, 1996; Perttula & Sipila, 2007; Perttula & Liikkanen, 2005, 2006; Purcell & Gero, 1991, 1996; Purcell et al., 1993; Tseng et al., 2008) we were able to replicate Design Fixation in a non-engineering population. This replication provides methodological triangulation to the previous study by demonstrating how a Priming Analogy can influence the entire design decision-making process from the initial stages of idea generation through to the final stage of offering a solution to the design problem. By illustrating quantitatively how an initial analogy can persist across all stages of the

decision-making process we are more confident in the representativeness of the findings from the previous qualitative study.

At the outset of this chapter we discussed an alternative explanation to the results from the previous study, which posed a threat to the construct validity of analogical persistence. By using the Design Fixation paradigm we can see how a singular analogy, at the outset of the design process, can impact the entire design decision-making process. By providing methodological triangulation we also addressed this threat to the construct validity of analogical persistence. While we have addressed the issue of internal construct there are still other threats to the both the internal and external validity of the Design Fixation paradigm. The next two chapters each deal with a possible threat to the validity of the Design Fixation paradigm.

5. Design Fixation and Internal Validity – The Stimuli

5.1. Introduction

While the Design Fixation paradigm allows us to examine and manipulate the influence of analogies, it is not without its issues. The previous chapter raised the issue of external validity, specifically the generalisability of Design Fixation across different design domains. This chapter continues with our examination of validity by examining the threats to internal validity by addressing the issue of the materials. To date many of the Design Fixation studies have used similar stimuli to those created by Jansson & Smith (1991). While consistent stimuli increases sensitivity and comparability across studies, it also raises a concern to the internal validity of the Design Fixation phenomenon. To use the Design Fixation paradigm with any confidence to provide methodological triangulation, we need to address this threat to internal validity by replicating the previous study with new stimuli.

5.1.1. *Replication of Design Fixation and the Materials used*

Since the first Design Fixation study (Jansson & Smith, 1991), work that has aimed to replicate these findings has primarily relied on the original stimuli. While there are clear benefits to using the same materials as Jansson & Smith (1991), particularly allowing for direct comparison across different studies, this consistent use of the same problem set does raise the concern that the results exhibited in the previous chapter were not a function of the experimental manipulations of the DF paradigm but rather were a function of the problems used.

Researchers such as Purcell & Gero (1991) have used the same, as well as similar, stimuli to the ones created by Jansson & Smith in their investigations of the Design Fixation phenomenon. While their use of Jansson & Smith's stimuli were appropriate, considering the goals of the study, it does bring in to question the validity of their reported findings. For example, Purcell & Gero (1991) were investigating the generalisability of Design Fixation across several different design disciplines, in particular Architecture, Industrial Design, and Mechanical Engineers. Purcell & Gero (1991) used the same structure, and stimuli, as the original DF study. Fixation was reproduced in the engineering population but the replication of fixation failed to exhibit among the non-engineering populations. While this failure to replicate was addressed in the previous chapter the constant use of the Jansson & Smith (1991) stimuli in that

study as well as the previous chapter does threaten the internal validity of the Design Fixation paradigm. This issue of materials is not just related to the work done by Purcell & Gero (1991) but has been observed in several other studies which have investigated different aspects of Design Fixation (e.g. Chrysikou & Weisberg, 2005; Purcell et al., 1993).

Recently several studies have begun to use different problems to elicit Design Fixation (Perttula & Liikkanen, 2006; Purcell & Gero, 1996; Purcell et al., 1993) and have had success in recreating the results of Jansson & Smith (1991), but with one crucial caveat: the design discipline of the tested population. All studies to date that have employed different design problems, to elicit fixation, have been solely in the context of Mechanical Engineering students. As discussed in the previous chapter the Design Fixation paradigm does manifest differently within different design disciplines. So while the replication of DF using different stimuli is promising the confounding variable of design discipline needs to be addressed.

To quantitatively investigate the influence of analogies on the decision-making process of Interaction Designers, we need to be confident that the results that we are observing in the Design Fixation paradigm are attributable to our experimental manipulations and are not a function of fundamental flaws with the paradigm itself. To address issues of internal validity, specifically the problem of stimuli, we replicated the design of the study discussed in the previous chapter with the use of entirely new stimuli to separate the observed phenomenon from flaws within the paradigm.

5.2. Method

5.2.1. Participants

Twenty-two Interaction Design students from the MSc in Human Computer Interactions with Ergonomics from University College London participated in this experiment. Participants had on average 8 months of experience as Interaction Designers.

5.2.2. Design

As the focus of this study was to examine the confounding issue of the materials used in the previous study, a similar experimental design to the previous chapter was employed. A 2 x 2 mixed design was used with Presentation condition (Brief Only vs. Brief & Flawed Example) being the between-subjects variable, and the Problem Domain (Interaction Design vs. Mechanical Engineering) being the within- subjects variable.

The Brief Only and the Brief & Flawed Example conditions were the same format as the study in the previous chapter. The difference between the two presentation

conditions is the amount of information that is provided with each problem. The Problem Domain condition manipulates the design characteristics that the participants would be familiar with. The Interaction Design condition is a within-domain problem, i.e. a successful solution would be based upon leveraging design principles that the participants would have an understanding of. The second problem domain condition is the Mechanical Engineering problem, which is based on a design area in which the participants would not have an understanding of the design principles necessary to generate a successful solution to the design brief.

5.2.3. Materials

Participants, at the outset of the study, were given a booklet containing two design problems. One design problem was a within-domain problem that participants would be familiar with (Interaction Design) with the other problem being a design problem from a differing domain (Mechanical Engineering). Each design problem contained a brief outlining the overall goals of the problem as well as the criteria necessary for a successful solution. Unlike the study in the previous chapter, this study used completely new design problems to address the issue of stimuli on the internal validity of the Design Fixation paradigm. New design problems were generated so as to avoid any overlap with subject areas that were already covered in Jansson & Smith (1991) to avoid any potential confounding variables. The Brief Only condition contained a verbal description of the design problem while the Brief & Flawed Example condition contained the same verbal description with the addition of an inherently flawed graphic example. The flawed pictorial examples contained at least two flaws that violated several of the design constraints identified in the verbal description of the design problem. The new design problems are included in Appendix B.

5.2.4. Experimental Procedure

Participants were randomly assigned to one of the two presentation conditions. Participants were instructed that they would be presented with two different design problems, one being an Interaction Design problem and the other being a Mechanical Engineering problem. Prior to commencement participants were instructed that they had 25 minutes for each design problem and during that time they should generate as many solutions as possible in response to each design brief. In addition they were instructed to annotate each design, as they felt necessary and to number each individual design. Each participant was paid six pounds for their involvement in the study as per University College London regulations.

5.2.5. Analysis

As in the previous study the same scoring procedure created by Chrysikou & Weisberg (2005) was employed. Each design that participants generated was analysed along two dimensions of fixation: 1) Similarity, which is operationised by the three measures of Direct Physical Similarity (DP), Reproductive Similarities (RS), and Analogical Similarities (AS) and 2) Reproduction of Flaws from the presented example which was originally composed of Intentional (IF) and Unintentional Flaws (UF).

As discussed in the preceding chapter, these four measures of fixation are different ways in which fixation can be exhibited. Direct Physical similarity is a binary measure to account for when the design generated is a direct copy of the provided example. Reproduced Similarities accounts for specific features of the provided pictorial example being present in the generated designs. Analogical Similarities are similar to Reproduced Similarities in that a feature of the provided example is inappropriately incorporated into the final design but rather than focus on the physical aspects of the feature the fixation is on the principles behind that feature. Intentional Flaws are characterised by incorporating specific flaws from the pictorial example that were placed there by the experimenter. Unintentional Flaws, on the other hand, are the incorporation of flaws from the example, which were not initially identified by the experimenter.

In this study Unintentional Flaws and Intentional Flaws have been combined from two separate measures into one unified measure of fixation, referred to as Reproduced Flaws (RF). In previous studies, such as Chrysikou & Weisberg (2005), UF and IF were studied in isolation of each other. The division of flaws between intentional and unintentional was an artefact of the experimenter and not truly reflective of the phenomena being studied. As the participant is not aware of what flaws have been specifically included to measure fixation (IF) and which flaws were fixated upon per chance (UF), to the participant a flaw is simply a flaw. Figure 5.1 below illustrates the various measures of fixation and how they relate.

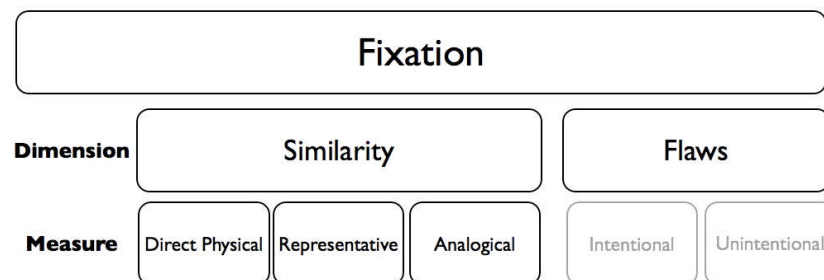


Figure 5-1 Fixation and its component phenomena

Each design generated was given a percentage score, on the four above measures of fixation, which indicated the level of fixation exhibited in the design. Below is an example of the scoring criteria employed in this analysis, the complete set of scoring criteria is contained in Appendix B. A score of zero was indicative of a complete absence of fixation and a score of 1 was maximum fixation. The score for each measure was obtained by dividing the design score for each individual measure by the maximum total that could be obtained for that measure.

Direct Physical Similarities	Same shapes, patterns, controls, layout, and features as example
Reproductive Similarities	1) Cube like rotation 2) Simple grid system 3) Drop down menu for multiple calendars 4) Two drawings for calendar navigation
Analogical Similarities	1) use of 3D view 2) Floating calendar sections 3) Non-linear navigation between months
Reproduced Flaws	1) Static weeks will not work 2) Ambiguous navigations between months 3) No current display for month/year

Table 5-1 Scoring criteria for the calendar problem presented

5.3. Results

To investigate the experimental manipulations of our two independent variables (Presentation and Problem Domain) a similar type of analysis, as used in the previous study, was conducted. As we have one within-subject independent variable, one between-subject independent variable, and four dependent variables, a mixed-design Multivariate Analysis of Variance (MANOVA) was conducted. A MANOVA was employed to provide an understanding of each of the main effects of each independent variable as well as minimize our risk of over-testing our four dependent variables (Direct Physical, Reproduced Similarities, Analogical Similarities, and Reproduced Flaws). Of the four measures of fixation discussed in the above Methods section three were analysed as per previous studies (e.g. chapter four and Chrysikou & Weisberg, 2005). The Direct Physical measure of fixation, which takes into account the situation in which participants copy the provided pictorial example, was removed from the analysis. None of the participants proposed any simple facsimiles in their final design solutions: each design generated was a novel solution.

5.3.1. Presentation

The Design Fixation paradigm employed in this study postulates that designers who are shown a flawed example will produce designs that are more similar to the given example when compared to control participants in the Brief Only condition who had not

been exposed to the example at all. As is evident from Figure 5-2, we can see that this hypothesis holds with a replication of the findings from the previous study (main effect of Presentation $F(3,18) = 3.413, p < .05$). Participants who were given the flawed example in conjunction with the design brief had higher levels of fixation (RS $M = 0.222, SD = 0.204$; AS $M = 0.372, SD = 0.342$; RF $M = 0.345, SD = 0.267$) when compared to the Brief Only condition (RS $M = 0.043, SD = 0.072$; AS $M = 0.058, SD = 0.077$; RF $M = 0.100, SD = 0.088$). These higher levels of fixation are indicative of participants who were exposed to the flawed pictorial examples incorporating more elements of that example into their design than the control condition.

Significant differences between the Brief & Flawed Example condition and the Brief Only condition were observed over all three dependent variables (RS $F(1,20) = 7.525, p < 0.05$; AS $F(1,20) = 8.793, p < 0.01$; RF $F(1,20) = 8.315, p < 0.01$).

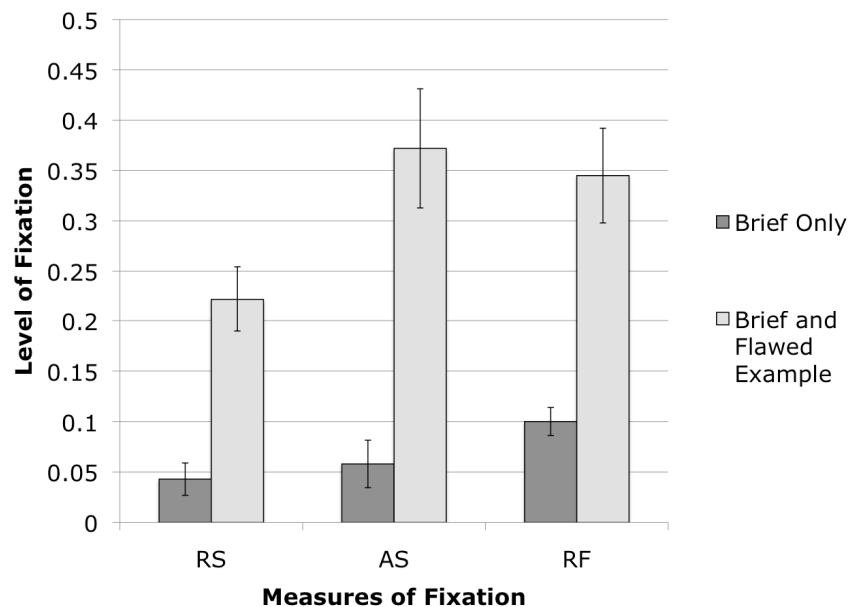


Figure 5-2 Levels of fixation between presentation conditions across all measures of fixation. RS = Reproduced Similarities, AS = Analogical Similarities, RF = Reproduced Flaws. Error bars indicate standard error of the mean.

5.3.2. Problem Domain

In the previous study it was observed that the domain of the problem that participants were given did have some influence on the types of solutions that were generated. In the previous study it was shown that types of problems that participants were given only impacted the number of specific problematic characteristics of the flawed example being incorporated into the final solutions, as indicated by the significant effect of Problem Discipline on the Reproduced Flaws measure of fixation. In the previous study, using the potentially problematic stimuli, the domain of the problem had no impact on

the other two measures of fixation (Reproduced Similarities and Analogical Similarities).

The introduction of new stimuli did offer slightly different results than the ones observed in the previous study. Figure 5.3 illustrates that there was no effect of Problem Domain on any of the measures of fixation ($F(3,18) = 1.00, p >.05$). The previous study showed that more specific problematic characteristics from the flawed example were present in the final solutions when dealing with a problem from a domain that they were not familiar with (i.e. Mechanical Engineering); however, this finding was not replicated when new stimuli were presented. When new stimuli were used the mean level of fixation observed on the ME problems dropped from 0.355 (chapter four) to 0.176 which is more inline with the levels of fixation observed in the Interaction Design condition across both studies (chapter four $M = 0.193$, chapter five $M = 0.256$). While the replication of two measures of fixation does indicate a certain level of internal validity for those measures of fixation we can observe the impact that differing stimuli can have an expression of how many flaws from the priming example are incorporated into the final solutions.

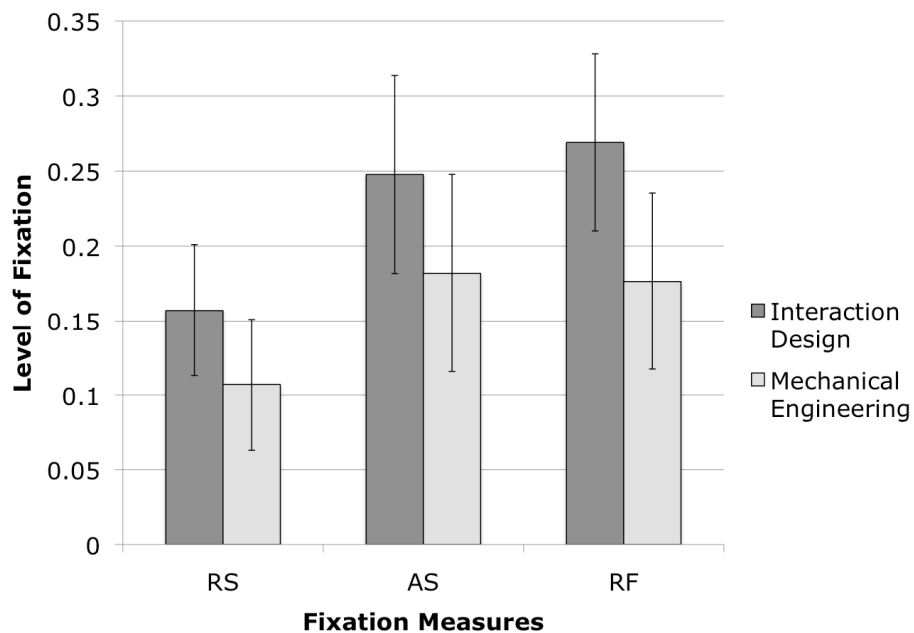


Figure 5-3 Levels of fixation for each problem discipline across all three measures of fixation. RS = Reproduced Similarities, AS = Analogical Similarities, RF = Reproduced Flaws. Error bars indicate standard error of the mean.

5.3.3. Fixation Patterns

In the previous study differing patterns of fixation were noted when comparing the various measures of fixation across the two differing problem domains. What was noted in the previous study was that when participants engaged with a within domain problem (i.e. an Interaction Design problem) they were far more likely to be influenced by the

flawed Priming Analogy, as illustrated by the significant differences between Presentation conditions across all measures of fixation. When participants engaged with a problem domain they were not familiar with they tended to fixate on the physical aspects of the flawed example i.e. the Reproduced Similarities and Reproduced Flaws measures of fixation. Considering the issue of stimuli on the internal validity of the Design Fixation paradigm it does beg the question: are the fixation patterns reflective of the differences between engaging with a problem participants are familiar with or not, or is it a function of the stimuli used?

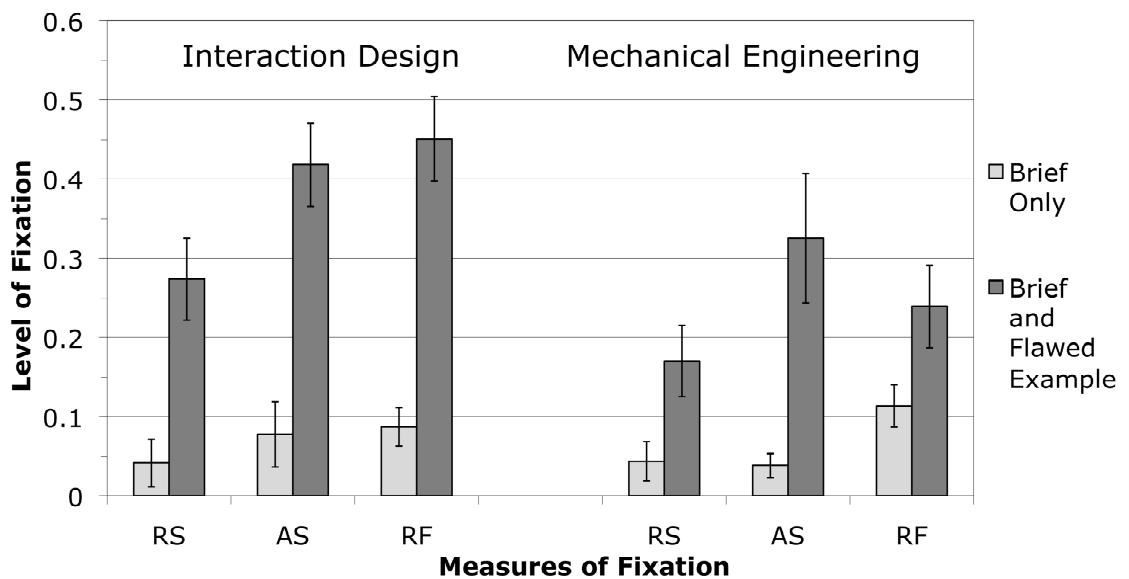


Figure 5-4 Levels of fixation for each measure of fixation across both problem disciplines. Error bars indicate standard error of the mean.

Problem Domain	Measure of			
	Fixation	<i>t</i>	<i>df</i>	<i>p</i>
Interaction Design	RS	3.342	20	0.003
	AS	3.533	20	0.002
	RF	3.509	20	0.002
Mechanical Engineering	RS	1.425	20	0.169
	AS	2.179	20	0.041
	RF	1.169	20	0.256

Table 5-2 Follow up independent sample *t*-tests for each component of figure 5.4

Figure 5.4 illustrates the level of fixation for all three fixation measures across both problem disciplines. What emerged was that the fixation patterns were not replicated. While the within-domain levels of fixation were consistent in both studies, the differing domain levels of fixation were not significant. From Table 5-2 we can see that there was a significant difference between the two Presentation conditions on the

Analogical Similarities measure in the Engineering problems ($t = 2.179, p < 0.05$).

When we correct for the possibility of over-testing using a Bonferroni correction by using a corrected alpha of 0.008 ($\alpha = 0.05 / 6$) this difference is no longer significant. From this analysis we can conclude that the patterns exhibited were not a function of within versus differing problem domains, but rather were a function of the problems presented to the participants.

5.4. Discussion

In the previous study it was demonstrated that by extending our conceptual measurement of fixation from a predefined list of counter-intuitive features to a more holistic approach to measuring fixation, we could in fact replicate Design Fixation in a non-engineering population. By replicating the Design Fixation among a non-engineering population of designers we were able to address a main threat to the external validity of this paradigm: the representativeness. The aim of this particular study was to address another important threat to internal validity: stimuli. While many Design Fixation studies have used the same stimuli so as to allow for comparison across multiple studies it has overshadowed some of the results as a possible confounding variable (e.g. Purcell & Gero, 1991). To address the confounding issue of stimuli we replicated the previous study with an entirely new problem set. The introduction of new stimuli produced consistent results on some of the experimental manipulations, such as Presentation, and produced mixed results on other manipulations such as Problem Domain.

5.4.1. Presentation

The replication of the results, with newly generated stimuli, exhibited in the previous chapter attests to the robustness of the Design Fixation paradigm. Under both studies it was observed that by priming people with a flawed analogy at the outset of the design problem that participants will rely on that analogy to the point of producing solutions that are markedly closer to the provided example in comparison to the participants who were given only the design brief. Previous to the study in chapter four, studies that attempted to reproduce Design Fixation in a non-engineering population were met with mixed results. With the replication of fixation in both chapter four and this study we can see that using a more sensitive measure can reveal Design Fixation among Interaction Designers. By producing the same results in both studies, using completely different stimuli, we can feel more confident that the issue of does not influence the internal validity of the Design Fixation paradigm.

5.4.2. Problem Domain

While the effect of Presentation (Brief Only versus Brief & Flawed Example) replicated despite the use of different stimuli, the same cannot be said for the effect of the Problem domain manipulation (within-domain versus differing-domain problems). In the previous study it was observed that the types of problems that participants were given had no effect on the influence of the Priming Analogy on two of the three measures of fixation. The only measure of fixation to show any effect of Problem Domain was the Reproduced Flaws measure. Results from the previous study showed that when participants were engaging with a problem that they were not familiar with (i.e. the Engineering based problems) they were more likely to incorporate problematic characteristics of the priming example into their final solutions. This result makes sense as one would expect a participant who is familiar with the domain of the problem to have an easier time identifying problematic elements of the flawed example and remove those from the proposed solution.

In this study, we did not replicate the difference in the influence of the priming example between the Interaction Design problem and the Mechanical Engineering problem. All three measure of fixation (Reproduced Similarities, Analogical Similarities, and Reproduced Flaws) showed no difference in terms of how much the Priming Analogies influenced the design decision-making process. When we specifically compared how the Reproduced Flaws measure of fixation expressed itself across the two different stimuli sets (Jansson & Smith (1991) problems and the new problems used in this study) we can see that the level of fixation from the previous study drops to a consistent level exhibited by the Interaction Design problems used in both studies. The higher levels of fixation exhibited using the older stimuli do provide evidence to indicate that the types of examples used by previous Design Fixation studies (e.g. Jansson & Smith, 1991; Purcell & Gero, 1991; Purcell et al., 1993) fosters higher levels of fixation. The observed higher levels of fixation indicate that using the types of stimuli proposed by Jansson & Smith (1991) to produce Design Fixation may be a relevant issue.

5.4.3. Fixation Patterns

In the previous study, it was hypothesized that the differences in the expressions of fixation between the two problem domains was a potentially descriptive pattern. It was hypothesised that these fixation patterns could describe whether a participant was dealing with a within-domain problem or a problem from a differing domain, depending on the relative values of the different fixation measures. The results in chapter four

illustrated that when participants were engaged with a within-domain problem, when provided with a flawed priming example, they were far more likely to produce solutions that were markedly closer to that initial flawed example in comparison to the solutions generated by participants who were only given the design brief. This was true across all of the fixation measures. Chapter four also discussed the fact that when participants were engaging with a design problem from a domain they were not familiar with, they also tended to fixate not on the analogical elements of the priming example but also on the physical aspects of that initial provided Priming Analogy.

However, results from this study did not support our hypothesis that these fixation patterns were descriptive of the participant's level of familiarity with a given design problem. While the behaviour exhibited by the within-domain problems remained consistent, the levels of fixation observed among the engineering problems were not replicated. In this study there was no difference between the types of solutions generated between the participants who received the flawed example, and the group of participants only given the brief. The results of this fixation pattern analysis underscores that there are possible issues with the original stimuli.

While Design Fixation was replicated, regardless of the stimuli used, the fact that the expression of fixation across the two different design domains does raise some questions. A possible explanation of the differing results between studies may be due to the participant's level of familiarity with these examples. Previous studies have highlighted how familiarity may impact Design Fixation. Purcell & Gero (1996) discussed how attempting to control for the familiarity of the stimuli may interfere with fixation. The next chapter examines why using unfamiliar stimuli causes Design Fixation to manifest differently.

5.5. Conclusion

The primary goal of this study was to address a threat to the internal validity of the Design Fixation paradigm: the stimuli used. While the effect of Presentation was replicated, the influence of Problem Domain was not, implying that the expression of fixation across design domains may be affected by the stimuli. Despite the issues regarding the problem domain, the fact that we were able to consistently measure fixation when Interaction Designers engaged with Interaction Design problems highlighted the robustness of the Design Fixation paradigm when a more sensitive measure is used. By addressing these threats to internal validity, generalisability and stimuli, we can be more confident in the internal validity of the Design Fixation paradigm itself. While the previous two chapters have dealt with the issue of

generalisability and the issue of materials we still have not dealt with all of the potential threats to validity. Earlier we discussed how the confounding variable of familiarity may account for the observed increase in analogical persistence. The next chapter addresses the last threat to validity: the confounding variable of familiarity.

6. Design Fixation and Internal Validity – the Issue of Familiarity

6.1. Introduction

In the previous two chapters we have discussed several threats to the validity of the Design Fixation paradigm. This study continues this exploration of possible threats to the internal validity of the Design Fixation paradigm by examining the influence of familiarity on how analogies influence the types of decisions Interaction Designers make when producing design solutions. In the previous chapter, it was noted that the stimuli created by Jansson & Smith (1991) actually produced higher levels of fixation when compared to newly generated stimuli. While the influence of the flawed examples was consistent across both studies when participants were engaging with a within-domain problem, fixation did not persist when participants were working with problems in an unfamiliar design domain. Consequently, it was hypothesised that our failure to replicate fixation with the newly generated stimuli may be a function of the participant's level of familiarity.

6.1.1. *Familiarity and Design Fixation*

The first study to replicate the findings of the original Design Fixation study identified familiarity as having an important effect on the levels of fixation exhibited by the participants (Purcell & Gero, 1991). When Purcell and Gero (1991) attempted to replicate Jansson & Smith (1991) with different design disciplines fixation was only replicated in the original engineering population and fixation in the non-engineering population was hypothesized to be a function of familiarity. Familiarity was operationalised as one's knowledge of the device as a function of extended exposure or use.

The role of familiarity plays an important part in Naturalistic Decision-Making. In the first stage of decision-making, as described by Klein and Calderwood (1991), the decision-making process begins by using analogical reasoning to find a previous example that is similar enough to the decision to be made that it can be used as a template to create a proposed action plan. The analogy that is chosen by the decision-maker as the decision template is a situation that the decision-maker is highly familiar with (Klein, 1987b). Ward et al. (2002) discuss how, in open-ended design tasks, a

familiar situation or artefact forms the basis for which all of the participant's proposed solutions are derived. However, this notion of a familiar example forming the basis of all generated solutions is not a new idea to the domain of design research (e.g. Eckert & Stacey, 2001; Eckert et al., 2005; Jansson, Condoor, & Brock, 1993).

In the context of the Design Fixation paradigm the flawed pictorial example acts as a Priming Analogy that participants use to construct their proposed action plan, which produces solutions that are visibly influenced by the flawed example. The intersection of familiarity and Design Fixation is a matter of expression. If we are to look at how the Design Fixation paradigm functions in the context of Priming Analogies we would expect that participants would be more heavily influenced by the flawed pictorial example when it is an artefact that they are unfamiliar with since there would be no competing analogies for the singular decision template. Alternatively, when participants are engaged with a problem in which the artefact in question is highly familiar, we would expect less interference from the Priming Analogy since there would be competition between the provided Priming Analogy and a Self-Generated Analogy.

To investigate the impact that familiarity has on the Design Fixation paradigm, using the Prucell and Gero (1991) definition, we should explicitly control for familiarity. By explicitly controlling for familiarity as an independent variable we can begin to unravel and understand how one's familiarity with an artefact can influence levels of fixation.

6.2. Method

6.2.1. Participants

Twenty-two Interaction Design students from the MSc in Human-Computer Interaction with Ergonomics from the University College London participated in this study. Participants had on average 8 months of experience as Interaction Designers.

6.2.2. Design

Like the two previous Design Fixation studies presented in this thesis a 2 x 2 mixed design was used. The between-subjects variable was Presentation (Brief Only vs. Brief & Flawed Example) and the within-subjects variable was Familiarity (High vs. Low). As per the previous studies, the Presentation condition manipulates how much information the participant is provided with at the outset of the study. In the Brief Only condition, participants received a design brief which outlined the overall goals of the problem as well as the requirements necessary for a successful solution. In the Brief & Flawed Example condition, participants received the same design brief, but in addition

were given a flawed pictorial example of a possible solution to that particular problem. This flawed example acted as a Priming Analogy for the design decision-making process. Within the provided example there are several problematic characteristics implanted by the experimenter. These problematic features were either in direct contradiction to the accompanying design brief, or were in themselves counter-intuitive. As briefly discussed earlier, Familiarity is defined as ones understanding of the functionality device through prolonged frequent exposure.

6.2.3. *Materials*

As the level of familiarity was explicitly controlled for in this study a pilot study was conducted to ensure that the problems presented were truly reflective of their relative familiarity conditions. Six problems were used: the Interaction Design problem from the previous study and five newly generated problems. Three problems were generated to be low in familiarity and three were generated to be high in familiarity. Appendix C contains the six design problems used in the pilot study. A group of 5 post-graduate students, from the University College London Interaction Centre, were asked to rate their familiarity with each of the six problems on a Likert scale ranging from 1 to 5 where 1 was indicative of 'Have never used the device' and 5 was representative of 'Frequently use the device'. From the six design problems generated two were selected which were the highest and lowest rated. The highest rated design problem (the calendar problem) was categorised as the high familiarity problem and the lowest rated (the marine mammal communicator problem) was used as the representative of the low familiarity condition.

In the main study, each participant was given a booklet containing two design problems; one for each level of familiarity. To eliminate any type of order effect all possible combinations were presented across all participants. At the end of each booklet a questionnaire was given which asked participants to report how familiar they were with the two design problems contained in the booklet. For each of the two problems participants were asked to rate their familiarity using the same Likert scale that was used in the pilot study. This self-rating of familiarity was used to corroborate the familiarity classification of the pre-study.

Calendar

Brief: Simple home based computers are able to handle complex graphics but yet not all applications take advantage of this fact. Design a new calendar system that keeps track of appointments as well as display the current date. Proposed designs must meet several requirements: 1) able to add/remove appointments, 2) be able to navigate between all twelve months 3) display current date as well as appointments for that day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

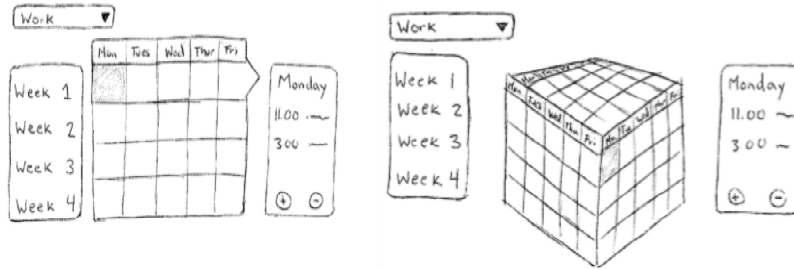


Figure 6-1 The high familiarity design brief with accompanying flawed example.

Marine Mammal communication system

Brief: Although the surface of the earth is mostly covered by oceans little is known of what happens beneath the waves. Marine Biologists are interested in developing a system to communicate with intelligent marine mammals in hope of learning more about the ecology of the oceans. The following issues must be taken in to considerations in any and all proposed solutions: 1) be able to send and receive messages, 2) Be able to deal with a range of questions ranging form simple yes/no questions to more complex questions such as 'how many are in your pod?', 3) Be able to communicate at various depths

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

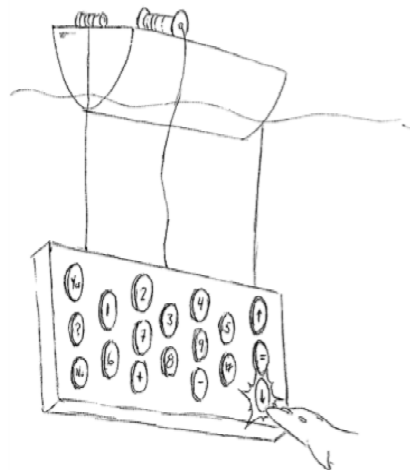


Figure 6-2 The low familiarity design brief and accompanying flawed example.

6.2.4. Experimental Procedure

Participants were randomly assigned to one of either the Brief Only condition or the Brief & Flawed Example condition. Participants were instructed at the outset of the study that they would have 25 minutes for each design problem, and were asked to

generate as many solutions as possible in response to the design briefs. In addition participants were asked to annotate each proposed solution as they felt necessary to communicate their design ideas, as well as number each proposed solution. Each participant was paid six pounds for their participation.

6.2.5. *Analysis*

The analysis, originally proposed by Chrysikou & Weisberg (2005) that was used in the previous chapters was also employed to measure the influence of the flawed priming example. Each solution that was generated in response to each design brief was coded along four different measures of fixation: Direct Physical Similarity (DP), Reproductive Similarity (RS), Analogical Similarity (AS), and Reproduced Flaws (RF).

As explained previously, each fixation measure accounts for different ways in which the flawed priming example can influence the produced solutions. Direct Physical Similarity is a binary measure, which accounts for whether or not the participant copied the proposed solution for his or her own solutions. Reproductive Similarities measures how many of the physical elements of the flawed solution were incorporated into their final solutions. For example, a Reproductive Similarity would be if the proposed solution used the same angle of presentation as the example or if they used the same physical objects in their sketches. The Analogical Similarities measure of fixation accounts for the inappropriate incorporation of characteristics from the flawed example, that while not physically similar, are influenced by the underlying ideas present in the Priming Analogy. An example of an analogical similarity would be incorporating a suction cup into a final design when the provided example used a magnet. While the magnet and suction cup differ physically they both use the same underlying principles and function within the design problem. The last measure of fixation is Reproduced Flaws. RF accounts for the inclusion of specific problematic elements from the flawed example that were either placed by the experimenter or were counter-intuitive characteristics of the design that were inadvertently discovered by the participant.

Each generated solution was given a percentage score on each of the above measures of fixation. Each score indicated the level of fixation. A score of 1 was indicative of maximum fixation and a score of zero indicated no fixation was present. The scoring criteria used in this study are contained within Appendix D.

6.3. Results

As with the previous studies a mixed-measures MANOVA was used to analyse the main effects of the experimental manipulations (Presentation and Familiarity), any

possible interactions between the two independent variables, as well as take into account possible over-testing with several dependent variables. As per previous studies the Direct Physical Similarity measure of fixation was removed from the analysis. None of the 22 students who participated in this study copied any of the provided flawed solutions. While several of the solutions exhibited high levels of fixation each solution was novel, to some degree.

6.3.1. Presentation

The reliability of the Design Fixation paradigm continues as we again replicated the main effect of Presentation, $F(3,18) = 28.596, p < .01$. Figure 6-3 illustrates the significant differences between Presentation conditions across all three measures of Fixation. (Reproductive Similarities, $F(1,20) = 14.32, p < 0.01$; Analogical Similarities, $F(1,20) = 17.502, p < 0.01$; Reproduced Flaws, $F(1,20) = 89.008, p < 0.01$) As discussed in previous chapters, the exposure to the flawed Priming Analogy caused participants to produce solutions that were markedly closer to the problematic solution (RS, $M = 0.296, SD = 0.107$; AS, $M = 0.410, SD = 0.196$; RF, $M = 0.623, SD = 0.156$) when compared to the participants who were only given the design brief and left to generate their own analogies based upon experience (RS, $M = 0.070, SD = 0.053$; AS, $M = 0.125, SD = 0.078$; RF, $M = 0.066, SD = 0.046$).

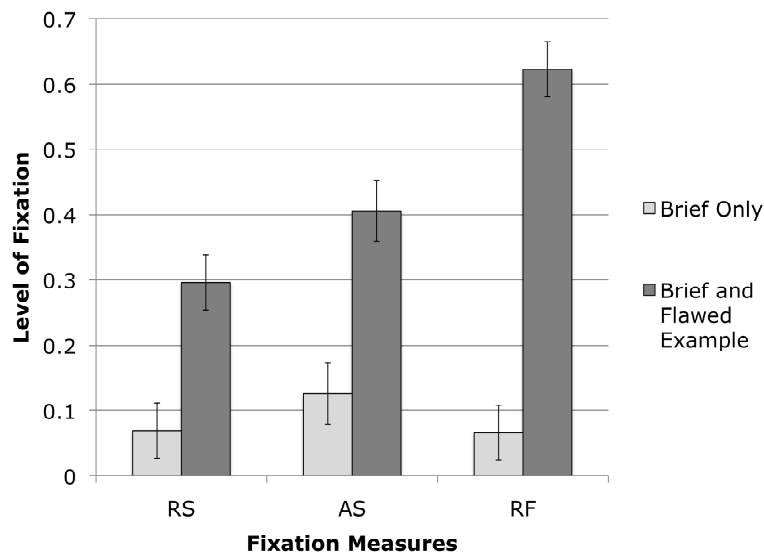


Figure 6-3 Presentation conditions across the different measures of fixation. RS = Reproductive Similarities, AS = Analogical Similarities, RF = Reproduced Flaws. Error bars indicate standard error of the mean.

As we are investigating the influence of familiarity on the Design Fixation paradigm it is worth noting how the Presentation effect differed between the two different familiarity conditions. Of the three measures of fixation only Reproduced Flaws

displayed a significant interaction between Presentation and the level of familiarity ($F(1,20) = 5.995, p < 0.05$).

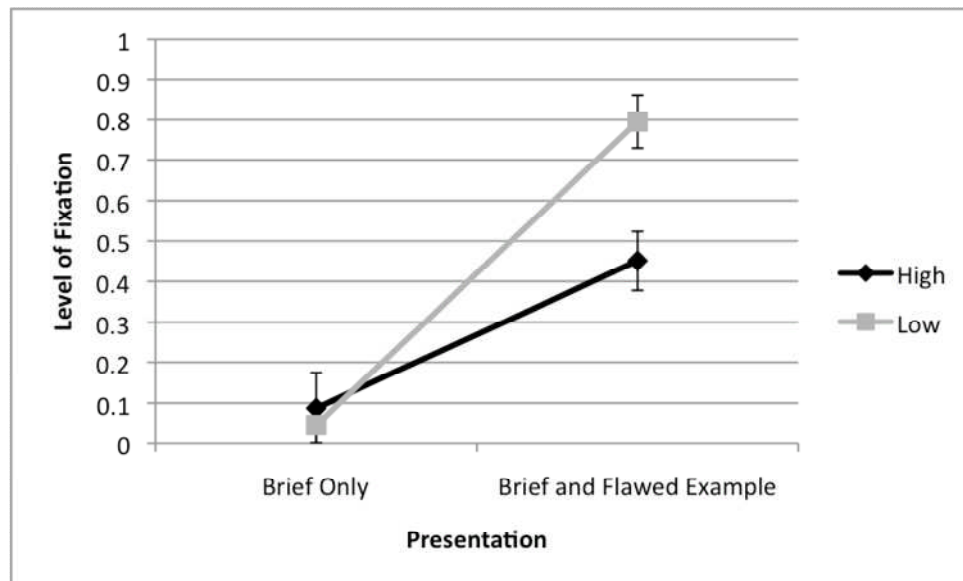


Figure 6-4 Interaction between familiarity and presentation. Error bars indicate standard error of the mean.

From Figure 6-4 we can see that Familiarity had no effect in the Brief Only condition (High Familiarity, $M = 0.087, SD = 0.113$; Low Familiarity, $M = 0.046, SD = 0.151$). This result is not surprising as the Design Fixation paradigm itself is constructed in such a way to measure the influence of the provided example. If no example was provided, as was the case in the Brief Only condition, then our coding scheme would register little fixation since we have no way of measuring the influence of participants' own Self-Generated Analogies. The Presentation and Familiarity interaction, occurs in the Brief & Flawed Example condition. Participants showed higher levels of fixation, i.e. produce solutions that were more influenced by the initial Priming Analogy, when they engaged with a problem that they were unfamiliar with (Low Familiarity, $M = 0.796, SD = 0.270$) compared to the solutions produced from the problem in which the participants were highly familiar with the type of design problem (High Familiarity, $M = 0.451, SD = 0.325$).

6.3.2. Familiarity

No main effect of familiarity was observed, $F(3,18) = 1.207, p > .05$. From the results of the previous study, we hypothesised that familiarity might have accounted for higher levels of fixation. To investigate this hypothesis, a series of focused post-hoc tests were used to investigate to see if any of the measures of fixation were significantly different from each other despite the lack of an overall main effect. Based on the results from the previous study, we would expect the inclusion of flawed example to have a greater

impact on a participant's level of fixation when engaging with a design problem in which they have little knowledge of the artefact from the design brief. From Figure 6-5 we can see that the only measure of fixation to show any significant difference between the familiarity conditions was Reproduced Flaws. The same pattern discussed in relation to the Presentation X Familiarity interaction was exhibited. Participants were far more likely to incorporate specific characteristics of the flawed example into their proposed solutions when engaging with a design problem when they had little knowledge of the artefact in question ($M = 0.420$, $SD = 0.439$) when compared to the solutions generated from the design problem that participants would be highly familiar with ($M = 0.269$, $SD = 0.301$).

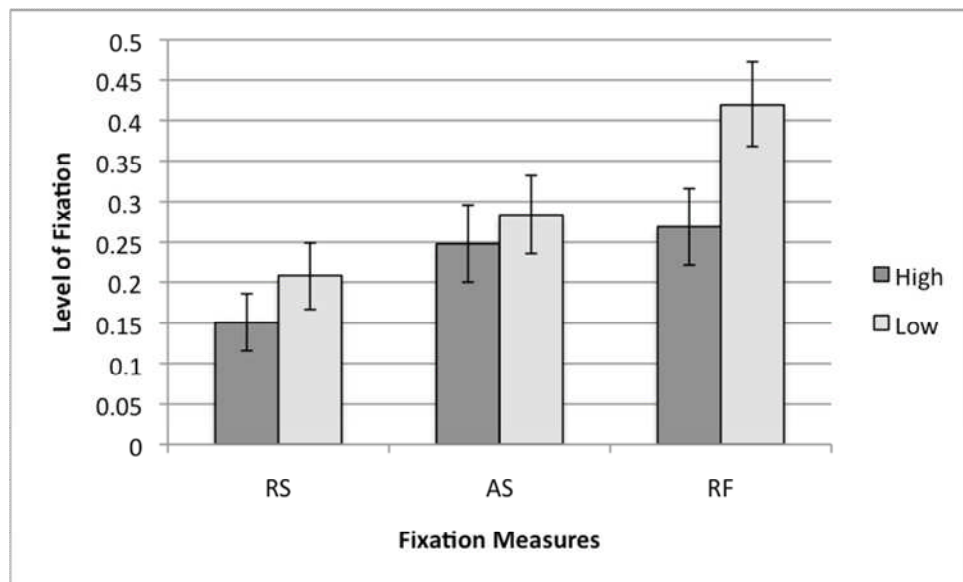


Figure 6-5 Levels of fixation for each level of familiarity across all three measures of fixation. RS = Reproductive Similarities, AS = Analogical Similarities, RF = Reproduced Flaws. Error bars indicate standard error of the mean.

6.4. Discussion

The primary goal of this study was to investigate how a participant's level of familiarity with an artefact can dictate how influential a Priming Analogy is in the decision-making process. It was hypothesised that priming examples that were highly familiar would have less impact on the types of solutions generated by participants due to competition from participant's own highly familiar Self-Generated Analogies. On the other hand, design problems that participants had little knowledge of would be more likely to be influenced by the provided primed analogy since participants would be less likely to have their own Self-Generated Analogy that would compete to form the decision template.

Of the three measures of fixation analysed Reproduced Flaws was the sole metric that displayed results consistent with our hypothesis. A higher number of the flawed characteristics from the original example were exhibited in the Low Familiarity condition when compared to the types of solutions produced in the High Familiarity condition. In contrast, the other two measures of fixation (Reproduced Similarities and Analogical Similarities) showed the same level of fixation across both measures of familiarity, i.e. that familiarity made no difference on how many analogical or physical characteristics of the flawed pictorial example were incorporated into the final solutions. These results, in conjunction with the results from the main effect of Presentation, demonstrate that while the presence of an example does increase participant's level of fixation among Reproduced Flaws this effect does not generalise to whether participants fixate on physical or analogical elements of the primed example.

As Reproduced Flaws was the only measure of fixation to display behaviour consistent with our hypothesis why did we not observe the same results on the other two measures of fixation? Our results indicate participants fixated on problems regardless of the familiarity with the problem. Based on our results, we could hypothesise that the provided Priming Analogy has a stronger influence than the self-generated one in relation to the Reproduced Similarities and Analogical Similarities measures of fixation. Familiarity with the design problem only dictates how much the Self-Generated Analogy is over-ridden when it comes to the specific problematic characteristics of the flawed example.

6.5. Conclusion

The goal of this study was to examine a potential confounding influence on the Design Fixation paradigm: the level of familiarity of the design problems. Researchers such as Purcell and Gero (1991) have discussed the problem with familiarity and the expression of Design Fixation. From our results in this study we can see that the familiarity of the design problem does impact the Reproduced Flaws measure of fixation. As discussed in chapter three, the traditional measure of Design Fixation was the presence or absence of specific flawed characteristics of the provided example among the final proposed solutions, as measured by the Reproduced Flaws measure of fixation. By again taking this narrow view of Design Fixation we can see the confounding nature of familiarity on the final solutions, as discussed by Purcell and Gero (1991). By manipulating levels of familiarity and examining them in the context of a more sensitive measure of fixation (Chrysikou & Weisberg, 2005), we began to understand in which conditions differing levels of familiarity with the design problem became an issue.

By replicating Design Fixation across each of the three previous studies (chapters 4 – 6) we can see the robustness of the phenomenon of analogical persistence. The key difference between the two approaches, though, is the types of analogies being examined. In the first study (chapter three) we examined the influence of Self-Generated Analogies. The Design Fixation paradigm on the other hand, lets us manipulate and observe the conditions where analogies are most influential, but the paradigm is constrained by the fact that we are only examining provided Priming Analogies. To bring these, quantitative and qualitative approaches together, we need to expand the Design Fixation paradigm beyond its current format. The next chapter discusses the limitations of the Design Fixation paradigm as it currently stands, and how we can adapt it to use different types of analogies, not just provided Priming Analogies.

7. Design Fixation and Self-Generated Analogies

7.1. Introduction

In its current format the Design Fixation (DF) paradigm lets us measure the level of influence of a Priming Analogy by examining the presence and absence of particular problematic characteristics from the flawed example in the produced solutions. While the Design Fixation paradigm lets us observe how influential a Priming Analogy can be, it does not let us observe directly how a participant's Self-Generated Analogies influence decision-making. The aim of this study is to investigate how Self-Generated Analogies express themselves under the Design Fixation paradigm. By pairing a think-aloud protocol with the Design Fixation paradigm we investigated how Self-Generated Analogies compared to the Priming Analogies were used in the Design Fixation paradigm.

7.1.1. *Limitations of the Design Fixation paradigm*

From the study presented in chapter 3 we know that Self-Generated Analogies can be just as influential on the design decision-making process, as the provided primed analogies used over the last three chapters. Currently, the Design Fixation paradigm considers the 'Brief Only' condition to be a control condition, i.e. that fixation does not occur in the absence of a flawed pictorial example. To a certain degree this is true, in that when no flawed example is given to participants (in the Brief Only condition) there are no observable flawed characteristics that can be incorporated into their proposed solutions. From chapter 3 we know that Self-Generated Analogies can have a similar effect on the provided Priming Analogies, since participants incorporated problematic elements of their own self-generated examples into their final solutions.

The main flaw with the Design Fixation (DF) paradigm, in its current state, is that it is difficult to elicit specific information of how fixation may occur with these Self-Generated Analogies. There is no experimental control over the 'Brief Only' condition; and consequently, there is no ability to conduct any type of quantitative analysis to examine how fixation manifests. To quantitatively analyse the design solutions generated, using the DF paradigm, there needs to be the ability to compare the produced designs to a predetermined flawed example in order to ascertain which faulty features the designer has fixated upon. While a quantitative analysis of the 'Brief Only'

condition in this study is impossible, a qualitative analysis of the design solutions could provide some additional information as to how Self-Generated Analogies fit into the Design Fixation paradigm.

To understand how analogies influence the decision-making process we need to investigate how these Self-Generated Analogies are used and what causes them to persist throughout the entire decision-making process. By pairing a think-aloud requirement with the Design Fixation paradigm we can qualitatively examine how similar, or dissimilar, Self-Generated Analogies are used as compared to Provided Priming Analogies (e.g. the flawed pictorial examples given to participants). The goal of this study was to understand the specific strategies that Interaction Designers utilize when using different types of analogies (Self-Generated Analogies vs. provided Priming Analogies) and how those strategies help or hinder analogical persistence.

7.1.2. Design Fixation and Different Types of Analogies

As discussed in chapter two, when individuals are faced with a decision they use analogical reasoning to recall similar situations that they have encountered in the past. This Self-Generated Analogy forms a template from which the decision-maker can formulate a possible successful solution to the problem (Klein, 1999). In the case of Interaction Designers faced with a novel design problem, they use analogical reasoning to look for similar design problems they have encountered in the past for a possible viable solution (Klein & Brezovic, 1986, Chapter 3). Bereciatura et al. (2008) highlights another source of inspiration that designers draw upon outside of their own personal experiences: examples of similar work. Techniques such as mood boards and product libraries (Buxton, 2007) allow designers to draw upon a range of artefacts for inspiration that they may not have been aware of. These examples, from an analogical perspective, can be seen as Provided Priming Analogies (PPA) in that they prime an analogy within the designer that can then be used, like Self-Generated Analogies, to frame and understand the problem space. While at first glance the Design Fixation paradigm may seem artificial it does build upon this idea that is commonly used in the field of design. Designers can use artefacts outside of their own personal experience to initiate decision-making much like participants who have been provided with an example solution to initiate the decision-making process.

While we can observe the end-product of analogical persistence in Design Fixation, we have very little understanding of the behaviours that foster this behaviour. By pairing a think-aloud protocol with the Design Fixation paradigm, we investigated how different analogies are used in decision-making, and if these analogies help or

hinder analogical persistence. Ericsson and Simon (1980) hypothesised that encouraging participants to verbalize their thoughts continually, i.e. think-aloud, while they are engaged with the task, provides insight into the cognitive processes that are involved in the current task. Chrysikou and Weisberg (2005) were the first to conduct a think-aloud protocol paired with the DF paradigm. While the results were helpful in understanding how the provided examples were being used, the aforementioned analysis focused exclusively on analysing the usage of the provided examples. Chrysikou and Weisberg (2005) provided no data to indicate how Self-Generated Analogies were used by designers.

7.2. Method

As discussed earlier, the Design Fixation paradigm only lets us examine the influence that the provided primed-analogies have on the final sketches. To overcome this limitation, a think-aloud protocol was included (Ericsson & Simon, 1998) with the traditional DF paradigm (Jansson & Smith, 1991). This allowed us to understand not only the strategies used in the primed-analogy condition but also how Self-Generated Analogies factor into analogical persistence.

7.2.1. Participants

Twelve participants from a mixture of backgrounds took part in this study. Five participants were from an academic background, all with a specialization in Human-Computer Interaction, and averaged 1.5 years of experience with HCI practices. The seven other participants were from an industry background with an average of 3.5 years of employment as Interaction Designers. Participants were run individually in a small lab to avoid distractions and to facilitate the focusing on the task at hand. The average length of each session was 45 minutes.

7.2.2. Design

A traditional Design Fixation paradigm was employed in this study to investigate the influence of different types of analogies. More specifically the amount of information presented was manipulated between-subjects with the addition of a think-aloud requirement. The main experimental manipulation, as per the Design Fixation studies presented earlier in this thesis, was the amount of information that was presented to the participants. In the Brief Only condition, participants were provided with a design brief outlining the overall goals and constraints of the problem. During fixation, or the Brief & Flawed Example condition, participants were provided with the same design brief with a pictorial example of a possible solution to that design problem. The provided

example contained several problematic elements that ran either in direct contradiction to the requirements laid out in the design brief or were counterintuitive methods of addressing those requirements. These two Presentation conditions allowed us to observe the influence of different types of analogies on the decision-making process of Interaction Designers. Since the Brief Only condition contained only the design brief, participants were generating their own analogies to structure and frame the design space. In the Brief & Flawed Example condition, participants were provided with a flawed example. The impact of this provided primed analogy can then be directly observed.

To allow us to observe the influence of the Provided Primed Analogy and to investigate how the use of Self-Generated Analogies compares to using Priming Analogies used in the DF paradigm, all participants were encouraged to verbalise their thoughts throughout the duration of the study. Asking participants to verbalise their thoughts enabled us to understand the cognitive processes involved in the use of not only the primed analogy, but also, the Self-Generated Analogy (Ericsson & Simon, 1998).

7.2.3. Materials

To reduce the chance that our findings would be the result of one particular design problem participants were given two different Interaction Design problems (see Appendix D). The first problem asked participants to propose a device that marine mammals could use to communicate with marine biologists. The second presented problem asked participants to redesign a calendar program with a heavy emphasis on 3D animations. Both design problems contained a design brief outlining the goal and the constraints of each particular design problem. In keeping with the Design Fixation paradigm, one of the two problems, in addition to the brief, contained an inherently flawed example of a potential solution. The example contained several flaws placed by the experimenter, which directly contradict the brief. Problem presentation was randomized and counterbalanced to ensure that the order of presentation did not unduly influence the results. With the addition of a think-aloud to the Design Fixation paradigm each participant's verbalisations were recorded for analysis using an MP3 recorder.

7.2.4. Procedure

Participants were randomly assigned to one of the two Presentation conditions. Participants were given 25 minutes to sketch as many solutions as possible for each design problem and to number each individual sketch produced. As discussed above,

all participants were asked to verbalise their thought processes as they generated solutions to the given design problems. To avoid some of the issues discussed by Ericsson and Simon (1998) (i.e. capturing a participant's meta-cognitive processes rather than their current thought processes), in regards to verbalising one's thoughts participants were instructed that they were not explaining their thoughts to the experimenter but were asked to verbalise their own internal thoughts to the best of their ability. These verbalisations were recorded with supplementary notes generated throughout the study. Participants were paid six pounds for their participation.

7.2.5. Analysis

The verbalisations generated from the think-alouds were transcribed verbatim. To obtain a realistic representation of the participant's verbalisations pauses as well as idiosyncrasies such as "urm"s & "ah"s were noted. The transcriptions from each participant were analysed according to the tenets of Protocol Analysis (Gilhooly & Green, 1996). The transcripts generated by the first three participants were used to generate a coding scheme. The creation of the initial coding list was driven by our desire to understand the different behaviours surrounding the use of different analogies on the Design Fixation paradigm. The creation of the codes was done in an iterative fashion to describe in the greatest detail possible the verbalisations generated by the participants. From this initial coding scheme the remaining transcripts were segmented and coded as described by Green & Gilhooly (1996). As a precaution a fellow academic was asked to code two randomly selected transcripts using the coding list provided. The codes generated from this analysis were compared to the codes generated from the previous analysis for a sense of how similar or dissimilar the coding of the selected transcripts was. An inter-rater reliability of 87% was achieved meeting the threshold requirement of 85% necessary for a valid coding scheme (Green & Gilhooly, 1996).

7.3. Results & Discussion

From the protocol analysis we were able to observe how participants used different types of analogies to aid in their decision-making process. While there was some commonality between how the two differing analogies were used, namely to frame the solution space, they did differ in a number of important ways. Detailed below are several behaviours that were observed in the participants, which highlight the different uses of the two analogies.

7.3.1. Self-Generated Analogies

In most instances, when faced with a design problem, Interaction Designers use analogical reasoning to generate a potential action path that has worked in the past based on the cues provided by the design brief (Klein, 1999; Klein & Brezovic, 1986). We observed from the recorded verbalisations that Self-Generated Analogies were used in two unique ways within the Design Fixation paradigm. Of the two identified behaviours ‘using SGA as a counterexample’ was aimed at understanding the problem space while the ‘Selective Recall’ behaviour was observed to actively contribute to analogical persistence.

7.3.1.1. Selective Recall

Participants interviewed indicated that they viewed their Self-Generated Analogies as superior in comparison to examples provided by others. This was due to the perception that the key benefit of Self-Generated Analogies was that only the extreme characteristics of the analogy were recalled. These SGAs were seen as superior to the provided primed analogies in that the positive aspects of the analogy would be incorporated into the proposed solution while the influence of the negative characteristics could be forgotten over time and hence removed from any type of influence.

[I'm] trying not to go to it [the provided example] straight away ... I might copy it. I'm trying to think back to things I'd already seen [self-generated analogy]... the things I remember are the things that were the most positive parts about it or the most negative parts about it. Obviously I don't have a photographic memory of my outlook calendar or anything like that but I think the things that stand out for me are really good or really bad. And I'm trying to think of the really good ones and try and get those across in this [sketch].... (Participant 6)

However, experimental evidence indicates that, while designers think that they are consciously ignoring negative elements of an analogy, these negative characteristics still influence the decision-making process (S. M. Smith, Ward, & Schumacher, 1993; Tversky & Kahneman, 1974).

7.3.1.2. Using Self-Generated Analogies as a Counter Example

The other usage of the Self-Generated Analogy was to act as a counterpoint, which enabled the participants in the Brief & Flawed Example condition, to explore the possible fallibilities of the provided example. At several points throughout the study many participants discussed the influence that the provided Priming Analogy was having

on their ability to create novel solutions that addressed the needs and goals of the design brief.

okay I'm trying to work [out] what this is [the brief] and this [the provided example] is restricting me at the moment (Participant 8)

Since the provided example was an external artefact, the participant could use the remembered characteristics of their SGA as a method of testing the suitability of the provided primed analogy in matching those particular characteristics.

How do Zoo-Keepers communicate with dolphins? ... There could be something hanging here ... it would look natural so it doesn't look digital like that [the provided example]... but it looks like something out of their own environment. Then you can kind of teach them how to communicate with that. There could be something like they get a treat [if they do it correctly]. Otherwise I think it would be really hard to communicate with the animals if they don't get a treat. I'm thinking instead of this [the example] where you see digits and all that maybe you would see something like all rocks and things that are familiar to the animals. (Participant 5)

Participant 5 describes several helpful features in their Self-Generated Analogy of a zoo enclosure, such as the faux-natural settings as well as the Pavlovian condition that zoo-keepers employ, to act as a counterpoint to highlight important features that are absent from the Provided Primed Analogy. In addition to those helpful characteristics being absent from the provided Priming Analogy they also highlight an important issue with the flawed example namely one of acceptance. By increasing the similarity of the communication device to be more in line with things dolphins would find in their natural surroundings the higher the likelihood that the marine mammals would accept and consequently use the communication device.

While the Self-Generated Analogy was a counterpoint to elucidate some of the problematic characteristics of the provided flawed example, the inverse behaviour was not observed. Participants did not use the characteristics of the flawed Priming Analogy to probe the possible issues with their Self-Generated Analogy. In the light of the selective recall behaviour, participants' use of the flawed example to highlight potential problems in their Self-Generated Analogies would seem like a valuable coping strategy. This behaviour would actually be more beneficial, as compared to the counter-

example behaviour described above, because there is no physical artefact in the SGA to help identify the negative or positive characteristics. Using the provided example as a counterpoint it would make it easier to form critical evaluation of a solution's strengths. Despite the use of this behaviour to evaluate the Priming Analogy, participants did not scrutinise their Self-Generated Analogies to the same degree.

The use of comparing individual characteristics of one artefact to that of another is by no means novel; in that this cross-comparison between the artefact and the analogy is a hallmark of analogical reasoning (Hesse, 1963). Hesse (1963) describes analogical reasoning as a series of small hypothesis testing exercises where each characteristic of the generated analogy is tested against the situation at hand to determine which aspects of the generated analogy are helpful in that particular situation, and which are not applicable or problematic. When participants were given a Priming Analogy the majority of them used characteristics of their Self-Generated Analogy to test the appropriateness of the characteristics of the Priming Analogy. However, this behaviour though does not generalise a flawed priming example; when provided with a flawed priming example a participant did not use this analogy as a counterpoint to evaluate the appropriateness of their Self-Generated Analogy. A Priming Analogy seems to override any of the participant's Self-Generated Analogies to form the template from which an action path is created. The fact that a flawed example still overrides a more effective Self-Generated Analogy was discussed in the previous chapter. What remains unclear is why the provided Priming Analogy is able to trump Self-Generated Analogies, especially when participants discussed the superiority of their own analogies when this display this 'selective recall' behaviour.

7.3.2. Provided Primed Analogies

As discussed earlier, Interaction Designers use Self-Generated Analogies to scope and understand the problem space. In addition to generating their own analogies to engage in the design decision-making process they also use examples of previous work that have been done in similar areas to inspire their designs (Bereciartua et al., 2008; Herring et al., 2009). These previous examples serve the same function that Self-Generated Analogies do, namely to structure the solution space by providing a template from which a viable action plan can be generated. In our earlier discussion regarding Self-Generated Analogies, participants discussed the benefits of using their own analogies (as evidenced by the selective recall behaviour), but despite this perceived strength the presence of a flawed Priming Analogy seemed to always form the basis of the proposed action-plan. Below are several observed behaviours that provide some

context to this over-riding behaviour.

7.3.2.1. Primed Analogies as the 'best' solution

In the presence of the primed analogy, participants produced sketches that were clearly based on the flawed pictorial example as opposed to any of their own self-generated analogies. This can be explained by the fact that participants discussed the included flawed pictorial example as the optimal solution to that particular design problem. The primed-analogy is seen as the 'best' solution, so this establishes the dangerous notion that a successful solution must either evolve from, or emulate, this analogy.

...well they've already taken the good keyboard idea maybe I could come up with some type of marine mouse.... I think they already have a better idea [referring to the example]. I would have designed that.. [upon reflection] Later on I thought I based my .. I guess my designs were variations of that example really. So I looked at that and thought 'the looks like a good solution' anything else wouldn't be as good (Participant 7)

... I like the idea of displaying the information this way (referring to the enclosed example of a digital calendar) ... this struck me as the best way to do it I tried my best to stay away... although I don't think it helped much... (Participant 2)

This perception of a 'best' solution demarcates the solution space by providing a framework of what is and is not part of the design brief. By viewing the provided example as the 'optimal' solution, participants were influenced to create designs that were based on that solution. This assumption fundamentally coloured the individual characteristics of the flawed Priming Analogy, which caused participants to skip the evaluation process, as described in the counterpoint behaviour, participants assumed that the characteristics of the experimenter's flawed analogy were in fact the best way to address the criteria set out in the design brief. In the context of the marine mammal communication system, it was observed that all of the solutions generated under the Brief & Flawed Example condition were devices to be used primarily by the marine mammal. In contrast, participants given the same design problem in the Brief Only condition primarily produced solutions that would be used by the marine biologists to communicate (see Figure 7-1 and 7-2).

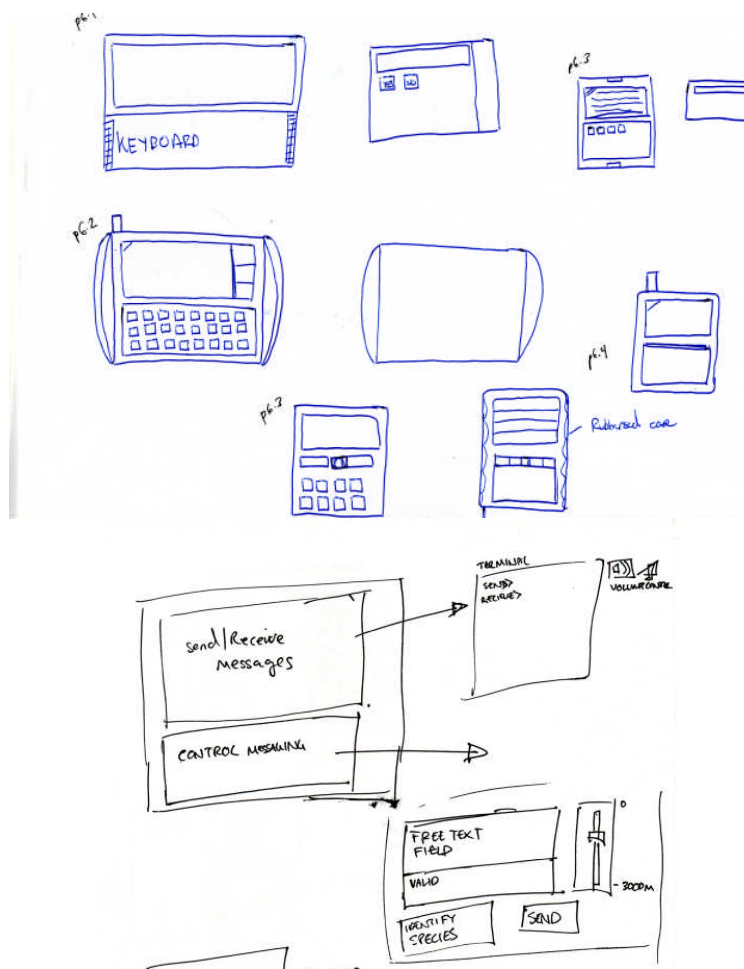


Figure 7-1 Sketches produced by participants who were not exposed to the flawed example in the marine mammal communication system problem.



Figure 7-2 Sketches produced by participants who were exposed to the flawed priming example in the marine mammal communication system problem.

The perception that the flawed example was the ‘best’ solution to the design brief does provide evidence as to why the provided Priming Analogy is so influential across all

stages of the decision-making process. Perttula and Liikkanen (2006) discussed two theories that may potentially underpin the fixation observed in the Design Fixation paradigm: Unconscious Conformity and Memory Blocking. In Unconscious Conformity, designers unconsciously incorporate high-level elements of previous examples into their design solutions. The opposing explanation of Design Fixation is Memory Blocking, which states that exposure to possible solutions pre-emptively exhausts the pool of possible solutions before the design process even commences. To assess which theory was a more accurate representation of the cognitive processes involved in Design Fixation, Perttula and Liikkanen (2006) coupled a think-aloud approach with an analysis of several behavioural methods, such as the number of solutions produced and the categories of the solutions. The study drew attention to the lack of theoretical work in this area and delineated these two possible explanations regarding the underlying mechanics of the phenomenon but Perttula and Liikkanen (2006) was inconclusive as to which theory was more suitable to describing how Design Fixation occurs. The identified behaviour from our study provides evidence that the Memory Blocking approach may be the most apt description of Design Fixation, since the pool of solutions was exhausted due to the fact that the provided solution was perceived to be the best solution. Based on this, one could hypothesise that since the provided solution is perceived as optimal the exploration of the solution space is pre-emptively terminated, which leaves the participant with a limited list of possible solutions to the design brief.

7.3.3. Evaluation of Produced Sketches and the Influence of the Priming Analogy

The perception that the provided primed-analogy was the optimal solution to the design brief was carried over to the last stage of decision-making; when generated sketches are supposed to provide the best solution to the design brief. Figure 7-3 contains a sketch chosen by Participant 3 as the best solution to the marine mammal communication device design problem, of the three they had generated. That sketch was chosen despite evidence to indicate the inappropriateness of using a keyboard approach (dolphins primarily communicate through sound not through touch). This disconnect between what participants perceived as the best solution and the actual appropriateness of their own preferred solution highlights the problems with reflecting on our own meta cognition (Nisbett & Wilson, 1977).

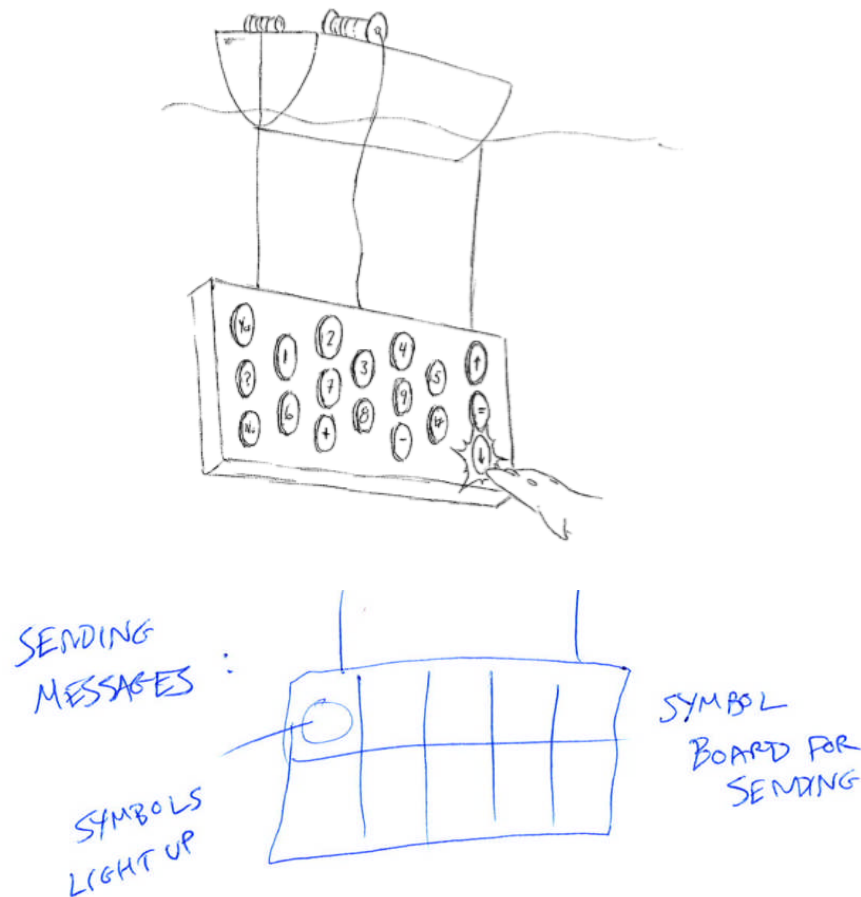


Figure 7-3 Original example and the preferred generated solution by Participant 3

This identified behaviour does have some consequence for the viability of the commonly discussed design process of generating several designs then choosing the best one as a way to overcome some of the problems of fixation which in turn avoids deeply flawed design solutions (Tohidi, Buxton, Baecker, & Sellen, 2006). Figure 7-3 illustrates how the persistence of an initial analogy can influence even the final stage of the decision-making process. This behaviour is worrying, because participants may believe they are being objective in their selection criteria when they are actually still unduly influenced by the primed analogy.

7.4. Conclusion

The goal of this study was to look past solely the Provided Priming Analogies traditionally used in the Design Fixation paradigm, and to look at how different types of analogies may foster analogical persistence. In its current state the Design Fixation paradigm only provides information as to how influential a provided example can be on the decision-making process of Interaction Designers. From the results in chapter three we know that the analogies that participants generate themselves, not just provided Priming Analogies, can persist across all phases of the design decision-making process and cause problematic solutions. By pairing a think-aloud technique

with the Design Fixation paradigm we investigated how these Self-Generated Analogies are used in the Design Fixation paradigm, and consequently how Self-Generated Analogies function in relation to when the Priming Analogies are provided. From the verbal reports produced by the participants we were able to identify several behaviours that were unique to the different types of analogies being used. It was observed, much like in the previous chapter, that the provided Priming Analogies seemed to over-ride the use of a Self-Generated Analogy in forming a decision template. This behaviour seemed to be in part due to the belief exhibited by most participants that the provided analogy was perceived as the best solution to the design brief. The most concerning finding was that of the best generated solution, from all of the alternatives created by that participant, was the one most like the provided primed analogy. This finding does bring into question the value of different techniques which encourage designers to rationally evaluate all of their produced solutions and choose the best one.

Design theorists have discussed several ways in which to overcome the mental block that can occur in design, be it from an analogy or another source of inspiration (e.g. Buxton, 2008; Cross, 1994). Cross (1994) discusses several commonly used techniques that designers employ to enlarge their solution space and overcome issues of fixation such as: Transformation, Random Input, Why?Why?Why?, and Counter-Planning (pp 53-54). The Counter-Planning behaviour, i.e. pitting an idea (the thesis) against its counterpart (the antithesis) to highlight the strengths and weaknesses of the idea, observed in this study displayed how while helpful that behaviour is only used in specific instances, i.e. in the critique of the provided artefact. The counter-planning technique was absent from critiquing Self-Generated Analogies, which considering some of participants' assumptions regarding Self-Generated Analogies, would actually be more helpful in the overall quality of the design decisions proposed by participants. Also our finding that the Priming Analogy was viewed as the optimal solution brings into question the viability of techniques like the Why?Why?Why? technique. In the Why?Why?Why? technique, designers are encouraged to ask themselves a series of why questions until a dead-end is achieved in their rationalisation. As illustrated in Figure 7-3 the assumption that the Priming Analogy is the optimal solution carries over into the participant's evaluations of which generated solutions are the most effective at addressing the design brief. The solution that was most similar to the Priming Analogy was chosen as the most effective solution. Participants who exhibited this behaviour were aware of the similarities between their solution and the

provided example but this was seen as a key strength to its success. There was a clear disconnect between the perceived strengths of their own generated solutions and the actual strengths and weaknesses. This highlights a fundamental problem with these types of design techniques; namely how poor we are as cognitive beings at metacognition (Nisbett & Wilson, 1977). All of the techniques discussed by Cross (1994) are based on the belief that one can accurately reflect on their own designs and step outside of their own biases to provide an unbiased evaluation. The results above illustrated that this is a difficult task. While some of these techniques were observed in this study, such as Counter-Planning, the desired behaviour of mitigating fixation was not observed i.e. coping strategies.

While the value of such techniques as Why?Why?Why? is called into question by the results of this study it is important to reiterate the benefit of mitigating analogical persistence. Analogical reasoning is an important and central component of the act of design (Lawson, 2006); because analogies provide a heuristic which allows designers to scope a potentially vast solution space down to a workable number of solutions (Klein, 1987b). While there are clear benefits to using analogies to structure the solution space, this can lead to framework in which designers rely on the analogy to the point of incorporating inappropriate elements of that analogy into their final solutions or to even cause reluctance to remove a clearly problematic characteristic from their solutions. While techniques such as the ones described by Cross (1994) may not be as valuable as originally thought, other techniques are available which may be more suitable to reducing fixation in Interaction Designers such as Design Rationale (Lee, 1997).

8. Mitigating Analogical Persistence

8.1. Introduction

The previous study highlighted some of the ways that different types of analogies can foster analogical persistence. Self-Generated Analogies were prone to analogical persistence, because participants believed they were only using the particular strengths of that analogy to structure their decision action-path despite experimental evidence to indicate otherwise. Previous examples were also problematic, because participants saw them as the optimal solution to the design brief. This belief that the provided Priming Analogy being the best solution even influenced the perception that the best solution they created was the one most similar to the flawed pictorial example. This raises some concerns to the viability of various design techniques aimed at reducing fixation (e.g. Cross, 1994). Despite the difficulty in mitigating fixation (e.g. Purcell & Gero, 1991; Smith et al., 1993) it is an important issue that needs to be addressed. Chrysikou and Weisberg (2005) were able to successfully mitigate fixation within the Design Fixation paradigm, by providing participants with a listing of all the flawed characteristics of the provided pictorial example. However, this manipulation, lacks ecological validity. This study aims to build upon the work of Chrysikou and Weisberg (2005) by taking a qualitative approach to mitigating analogical persistence. More specifically, by adopting a more ecological valid approach to encouraging designers to generate their own lists of problematic features. This quantitative study produced some surprising results. Attempting to mitigate analogical persistence actually increased the influence of the initial analogy. To address this surprising result the second portion of this study was a follow-up qualitative analysis to examine the behaviours exhibited by the participants that may have contributed to this observed increase in analogical persistence.

8.1.1. *Mitigating Fixation*

To date, most work aimed at lessening the impact of primed examples has been unsuccessful (e.g. Purcell & Gero, 1991; Smith et al., 1993). Purcell and Gero (1991) attempted to retain the benefits of using examples to frame the solution space, but reduce the influence of problematic elements by using verbal descriptions of the solution, as opposed to a pictorial example. While there did seem to be some reduction in several of the measurements taken, the presence of fixation was still detected. Most studies have aimed to reduce fixation by instructing participants to ignore the examples

that they have been provided with (Marsh et al., 1996; S. M. Smith et al., 1993; Ward & Sifonis, 1997). In each of these studies participants were instructed that the included example was problematic, and that it should be explicitly avoided in relation to the types of solutions they should propose. Despite these explicit instructions, fixation was still exhibited with participants incorporating inappropriate elements of that initial primed examples into their solutions. The only study which has achieved any level of success in terms of lessening the influence of the provided examples was the aforementioned Chrysikou and Weisberg (2005). In addition to the two conditions traditionally associated with the Design Fixation paradigm, a control group with just a verbal design brief and a fixation condition which is the design brief plus a flawed example solution, Chrysikou and Weisberg (2005) also introduced a third condition called the ‘defixation’ condition. In the defixation condition participants received the design brief, the flawed pictorial example, and a set of instructions detailing each of the problematic features of the included example. Results indicated that the types of solutions generated in the defixation condition were significantly closer to the sketches from the control group than the fixation condition. This technique, while effective, would not replicate in a ‘real-world’ setting.

An ecologically valid approach to reducing the influence of the negative aspects of the initial analogy must fit within the design process. The design process is difficult to characterize (Lawson, 2006) However, Wolf et al. (2006) discussed a fairly abstracted design process used in Interaction Design that will be adopted to frame our discussion. The design process discussed by Wolf et al. (2006) is composed of four stages.

1. The exploration of the design space with a focus on possible solutions to the particular design problem.
2. Design judgements – which are self-generated heuristics, based on their experience, knowledge, and existing design guidelines, which help designers make fully informed design decisions.
3. The construction of the artefact
4. Design ‘crit’ - which focuses on the future of use/development of the artefact and how it could be improved in light of this.

To lessen the effect of analogies on the decision-making process, a methodology which highlights the inherent problems of the primed analogy must naturally fit somewhere within these four stages of the design praxis.

Considering these four stages of the design process, which interval would be the

most useful and least intrusive in highlighting the fundamental issues with the problematic analogy, in a more ecologically appropriate manner? The focus of our study is to highlight the possible issues with the analogies that are used in the design decision-making process; therefore it is natural to look at a way to leverage the Design ‘crit’ portion of the design process. The chief focus of the ‘crit’ is to critically evaluate the strengths and weaknesses of the design solution. The issue with this approach is that the critique focuses on the artefact, as it stands, as opposed to the initial analogy. While this may highlight particular issues with the current state of the artefact, it does not probe the issues with the underlying analogy which, as discussed in the first study, influences the decision-making process very early on in the design process. As analogical reasoning allows designers to narrow and frame the solution space (Klein, 1999) we would need to probe the potential problems with the initial analogy as early as possible in the design process. Even the first stage of the design process, as outlined by Wolf et al. (2006), is in some sense too late for this type of intervention since exploration of the solution space, as framed by the analogy, has begun. This study proposes a structured intervention before the design process commences. By encouraging Interaction Designers to reflect on the types of analogies they use, as well as the inherent strengths and weaknesses of those analogies, at the outset of the design process we hope to decrease the impact of the negative characteristics of the analogy.

8.1.2. Reflection as a Tool to Mitigate Fixation

To obtain a more ecologically valid approach to reaching a list of the problematic features of the analogies used in the design decision-making process we have provided an intervention at the outset of the study that would encourage participants to reflect on the types of analogies they use. Before we discuss the use of reflection to aid in the decision-making process of Interaction Designers, it is important to define what is meant by the term reflection. While the term reflection is used fairly broadly there are in fact two types of reflection that are commonly used interchangeably: reflection-in-action and reflection-on-action (Schon, 1983). Reflection-in-action is a process that involves continually reshaping the problem as we are engaged with it. Reflection-in-action is composed of four discrete stages. The first stage is to define and understand the design problem. The second stage is to frame the solution space. The third stage is then testing this frame against the design problem and the last stage is to then reevaluate the design problem based on the results of stage three. These four stages are cyclically repeated until a solution is reached. Each cycle of the four stages allows the designer to reflect (a conscious activity) on what is working and what is not working of the

proposed solution. Reflection-on-action is not a continual reflection while engaged in the design process, but rather a post-hoc examination on the design process as a whole. Reflection-on-action deals with examining what we did in order to solve the problem and aims to understand how our reflection-in-action contributed to the proposed solution.

The use of reflection in the area of decision-making among Interaction Designers is not new. Cockton et al. (2004) used reflection to increase the validity of Heuristic Evaluation (Nielsen & Molich, 1990). By asking participants to use a structured report to reflect on the discovery and analysis phases of the Heuristic Evaluation. This reflection-on-action (as the reports were used to facilitate post-hoc reflections on the process) allowed participants to make better quality design decisions in terms of identifying valid usability problems. While Cockton et al. (2004) demonstrated the usefulness of reflection-on-action in relation to design decisions, can we utilise reflection-in-action as a structured method with the same level of success?

By encouraging participants to engage in reflection in action near the outset of the study, we hypothesise that participants will be able to identify the problematic characteristics of their chosen analogy when the level of commitment is still low. To encourage this behaviour, we have chosen to use principles from Design Rationale to best facilitate the desired behaviour.

8.1.3. Design Rationale

While it is important to look at how our study fits within the context of the design process; it is also important to choose a methodology that highlights the strengths and weaknesses of the initial analogy grounded in existing design practices. Design Rationale is an established methodology used to structure the design decision-making process to promote higher quality and better-informed decisions (Lee & Lai, 1991). Adopting this approach would allow our participants the ability to make higher quality decisions by using the organization afforded by Design Rationale to deconstruct and understand how and why analogies are used. This deconstruction will hopefully yield the same results, but in a more ecologically appropriate fashion, as those of Chrysikou and Weisberg (2005).

The end goal of Design Rationale is to promote higher quality decision-making in the design process, and this can be achieved in a multitude of ways which all fall under the Design Rationale banner. We require a way in which to achieve better decisions through understanding and highlighting the analogies that are used in design decision-making. Traditionally, Design Rationale has been used to create a historical record of

the information and the analyses that went into the choice of a particular feature or the way an artefact was constructed (Klein, 1993). In addition to the historical aspect of Design Rationale, the term is also used in relation to two other aspects of the design decision-making process: a tool to detail the psychological benefits of a particular artefact, and as a description of the design space (Lee & Lai, 1991). As a repository of decisions, Design Rationale can also be used to postulate the benefits of the artefact, and to describe the design space as it currently stands in the design process. This description of the design space allows designers to come to higher quality design decisions, by helping them to categorise the strengths and weaknesses in the design space and to form possible alternatives that may build upon the identified strengths or address the highlighted weaknesses. We chose to leverage this use of Design Rationale as a way to understand the design space as a more ecologically appropriate tool to identify the faulty characteristics of the initial analogy.

Within the different goals of Design Rationale there are also different levels to which Design Rationale principles can be employed. Tang (2007) describes a continuum of ways in which Design Rationale principles can be operationalised ranging from the least informal to the most formal methods.

- *No Explicit Rationale*: Where designers rely mostly on intuition as opposed to employing any systematic methods. As designers are relying mostly on intuition no information is captured at all during the design process. Any design decisions that are justified are either reconstructed or deduced based on the state of the artefact and the overall goals of the design problem.
- *Informal Rationale*: The rationale for the design decisions is captured in a largely unstructured fashion relying mostly on notes written during the design process.
- *Template Based Rationale*: The rationale is captured during the design process using pre-defined templates as a way to chronicle the required information with a minimum amount of additional cognitive effort on the part of the designer.
- *Argumentation-Based Rationale*: Each design decision is captured in the context of how that particular design decision relates to other alternative options. This relationship is captured using a syntax that focuses on how ideas and relationships between those entities are represented.

- *Quantitative Rationale*: Collects not only the decisions in terms of how they relate to alternatives but also quantifies those choices in such measures as cost and benefits.

Considering the range of ways that Design Rationale can be operationalised in the design process, we wanted a technique which would allow designers to understand the design space, while critiquing the analogy, with a minimum amount of interruption to the design process. The informal portion (i.e. no Explicit Rationale or Informal Rationale) of the Design Rationale continuum would be unsuccessful, as it would not allow the designer a deep enough understanding of the design space. The more structured portion of the continuum (i.e. Argumentation Based Rationale or Quantitative Rationale) would be too onerous at such an early phase in the design process. The Template Based rationale was chosen because it allowed the greatest amount of descriptive information to be collected with a minimum interruption to the design process. The Template Based approach to Design Rationale will allow participants to formally demarcate the design space by examining not only the types of analogies they are using, but also, the inherent strengths and weaknesses of those analogies.

It was expected using the Template Based approach would allow Interaction Designers to be able to recognise the faulty elements of the analogies they use, and address those potential problems in their design decisions.

8.2. Method

8.2.1. Participants

Participants were forty students studying for an MSc in Human-Computer Interaction (19 males and 21 females). Participants had on average 8 months of experience as Interaction Designers.

8.2.2. Design

This study employed a two-by-two between-subjects design with two independent variables: Presentation (Brief Only vs. Brief & Flawed Example) and Reflection (Reflection vs. No Reflection). Participants were randomly assigned to one of the four experimental groupings (see Figure 8-1 for graphical representation of the experimental design).

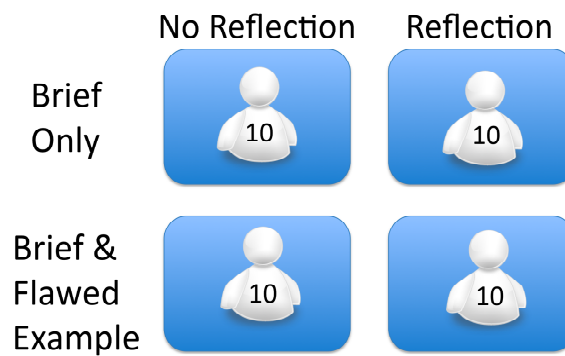


Figure 8-1 Graphical representation of the experimental design.

As in all Design Fixation experiments the presence or absence of a flawed Priming Analogy was manipulated. In the Brief & Flawed Example condition, participants were given a picture of a possible solution to the design brief in addition to the verbal design brief. This flawed example is meant to prime the participants to engage with the flawed analogy as opposed to generating a different analogy based on their personal experiences. The provided solution contained several features that were not only counter-intuitive, but are also, in direct contradiction to the information contained within the design brief. Those in the Brief Only condition received solely the verbal design brief.

To test our hypothesis that reflection on the initial primed analogy will mitigate the fixation effect, participants were randomly assigned to either the Reflection condition or the No Reflection condition. In the Reflection condition, participants were asked to spend ten minutes actively critiquing the analogies that they were using, be it the provided flawed analogy in the fixation condition or their own Self-Generated Analogies in the Brief Only condition, by using the provided template to structure their reflection. In the no reflection condition participants were simply given ten additional minutes in the idea generation portion of the study.

8.2.3. *Materials*

All participants were asked to design a calendar system that would take advantage of the powerful computing abilities of modern computers. In response to this design brief participants were asked to generate as many solutions as possible within the allotted time frame. The design problem contained a brief verbal description outlining the goal of the design brief and the requirements necessary for an acceptable solution. Contained below in Figure 8-2 is the design brief given to participants.

As is traditional in the Design Fixation paradigm, participants were given variations of this design brief depending on which of the presentation conditions they

were assigned to. Participants in the control condition were given only the verbal portion of the design brief. Participants assigned to the Fixation condition were, in addition to the design brief, given a possible solution to the design brief, as illustrated by the two sketches in figure 8.2.

Simple home based computers are able to handle complex graphics but yet not all applications take advantage of this fact. Design a new calendar system that keeps track of appointments as well as display the current date. Proposed designs must meet several requirements: 1) able to add/remove appointments, 2) be able to navigate between all twelve months 3) display current date as well as appointments for that day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

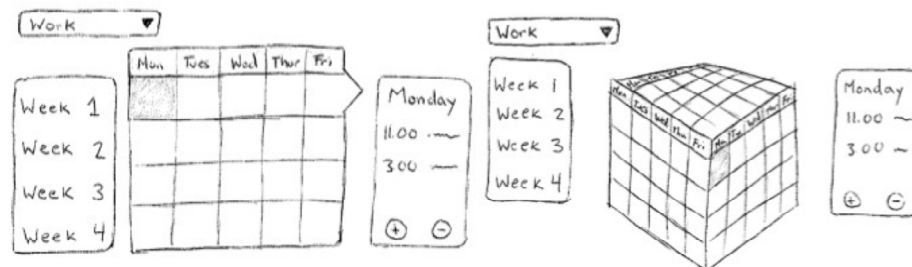


Fig 1. Calendar View

Fig 2. Navigation View

Figure 8-2 The design brief, with accompanying flawed example, given to participants.

To facilitate reflecting on the design analogies that were being used in the design decision-making process, some participants were provided with a template to fill-out at the outset of the study. Participants in the No Reflection condition were only given the design problem as per the instructions detailed above. Depicted in Figure 8-3 are the instructions and template given to participants who were asked to reflect on the flawed example that accompanied the design brief. Since the participants were given a primed analogy, they were also asked to judge the inherent strengths and weaknesses of that particular analogy. For participants that were only given the design brief there was an extra component of the reflection template that asked them to list what analogies the design brief elicited (Figure 8-4). Once participants identified the analogies that they would be using in their decision-making, they were instructed to judge the inherent strengths and weaknesses of their Self-Generated Analogy.

Instructions

Please spend the next ten minutes reflecting on the above example included with the design brief. In consideration of the overall design goal of the brief, as well as any of the listed requirements, what would you say are the particular strengths and weaknesses of this example? In what ways does the provided example fail to meet the requirements of the design brief and conversely in what ways does the included example address the requirements detailed in the design brief. Please list as many strengths and weaknesses of this example you can in the space provided on the next page.

Strengths	Weaknesses

Figure 8-3 Reflection instructions for the brief & picture condition.

Instructions

Please spend the next ten minutes reflecting on the above design brief. Considering the overall goal of the design brief as well as the listed requirements does this design brief remind you of any similar programs that you have used in the past? What example or examples come to mind when you reflect on this design brief? Of the example(s) that come to mind what are the relative strengths and weaknesses in the context of the design brief?

In consideration of the overall design goal of the brief as well as any of the listed requirements please write down one or two examples that this design brief reminds you of in the section labelled Similar Examples. In what ways does the one or two examples fail to meet the requirements of the design brief and conversely in what ways does that example or examples address the requirements detailed in the design brief. Please list as many strengths and weaknesses of that particular example you can in the space provided below.

Similar Examples	
Strengths	Weaknesses

Figure 8-4 Critiquing instructions for the brief only condition.

8.2.4. Procedure

Participants were tested in two separate groups split along the two Reflection conditions. All participants were given a booklet that contained the design brief and the appropriate accompaniments depending on which of the four experimental conditions they had been randomly assigned. Participants were instructed to generate as many solutions as possible, within the time limits. To delineate multiple sketches for one idea

from separate ideas, participants were asked to number each idea before they moved on to the next idea. Each session lasted a total of 35 minutes. In the Reflection condition, the first ten minutes of the session was composed of critiquing of the primed analogies with the remainder of the session devoted to the idea generation task. In the No Reflection condition the entire 35 minutes was devoted to the idea generation task.

8.2.5. Analysis

As in the previous studies, the scoring procedure created by Chrysikou and Weisberg (2005) was employed. Each design that participants generated was analysed along three measures of fixation: Reproductive Similarities (RS), Analogical Similarities (AS) and Reproduced Flaws (RF). These three measures of fixation analyse the different ways in which fixation can be exhibited. RS accounts for specific features of the provided pictorial example being present in the generated designs. From the example in Figure 8-2 an example of a Reproductive Similarity would be if a proposed solution contained the same four-week grid-like system used in the flawed pictorial example. AS are similar to RS in that a feature of the provided example is inappropriately incorporated into the final design, but rather than focus on the physical aspects of the feature the fixation in AS is on the principles behind that feature. Again in reference to the included example in Figure 8-2, an Analogical Similarity would be the use of multiple floating calendar sections to denote different sections of the calendar. RF are characterised by incorporating specific flaws from the pictorial example that were either placed there by the experimenter or were inherent to the pictorial example. An example of a Reproduced Flaw from the flawed example given to participants was that there was no way to display the current date despite it being a requirement of all successful solutions. The specific scoring criteria used are located in Appendix B.

Each design that was generated was given a percentage score, on the three above measures of fixation, which indicated the level of fixation that the design in question exhibited. A percentage score of zero was indicative of a complete absence of fixation while a score of 1 was indicative of maximum fixation. The score for each measure was obtained by dividing the design score for each individual measure by the maximum total that could be obtained for that measure.

8.3. Results & Discussion

8.3.1. Quantitative results

Results were analysed using two-factorial multivariate analysis of variance (MANOVA). The three dependent variables were: the level of fixation for Reproductive

Similarities, the fixation levels of Analogical Similarities, and the levels of fixation on Reproduced Flaws. As discussed earlier, our hypothesis was that encouraging Interaction Designers to understand the design space through reflection on the analogies that they use to make decisions, would lessen the persistence of these analogies. It was expected that fixation levels across all three dependent variable (Reproductive Similarities, Analogical Similarities, and Reproduced Flaws) would be lower in the Brief Only condition when compared to the Brief & Flawed Example group which was not given the Design Rationale template.

8.3.1.1. Reproductive Similarities

The Reproductive Similarities measure of fixation gauges how many of the superficial elements of the primed analogy are incorporated into any of the solutions proposed by the participants. For example, using the same format and details from the primed example would be considered Reproductive Similarities. The more similar the proposed solution is to the example the higher the level of fixation. The Brief Only condition is included as a control to account for the number of features included in the scoring criteria (see Appendix B) that would occur simply by chance. There was a main effect of Reproductive Similarities, $F(3,36) = 4.064$, $p < 0.05$. While this overall difference indicates that 4 participant groups are significantly different in terms of how many surface features were incorporated into their solutions, this overall result does not indicate how the two independent variables accounted for this variance.

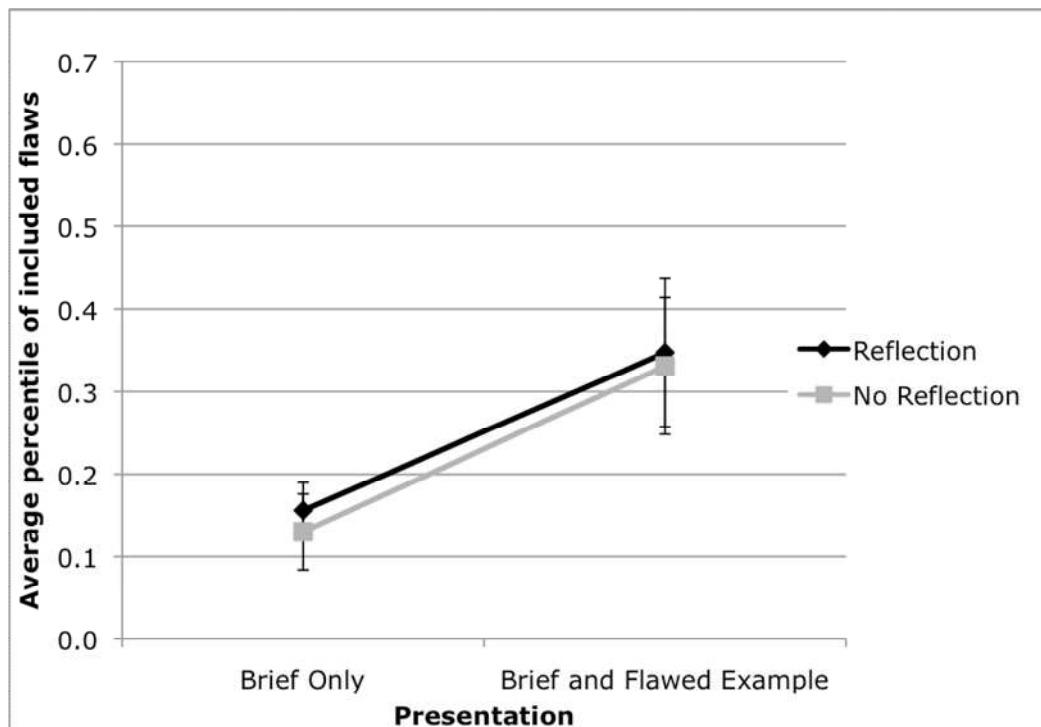


Figure 8-5 Fixation levels for Reproduced Similarities across experimental conditions. Error bars indicate standard error of the mean.

Figure 8-5 illustrates the levels of fixation across the four experimental groupings. We can see that the significant difference that was observed in the overall multivariate test can mostly be attributed to the Presentation condition (Brief Only $M = 0.130$, $SD = 0.1445$ vs. Brief & Flawed Example $M = 0.339$, $SD = 0.265$; $F(1,36) = 11.392$, $p < 0.01$) since the scores for the Reflection manipulation are approximately the same (Reflection $M = 0.252$, $SD = 0.246$ vs. No Reflection $M = 0.231$, $SD = 0.232$; $F(1,36) = 0.635$, $p > 0.05$). In terms of our hypothesis we can see from these results that encouraging participants to understand the design space through reflection had no impact on the levels of fixation exhibited. From these results we can conclude that 1) designers are more likely to propose solutions that are similar to the primed analogy; and 2) that encouraging designers to understand the design space through structured critiquing does not mitigate this fixation.

8.3.1.2. Analogical Similarities

Reproductive similarities focus on the influence of surface level features on the produced solutions, while analogical similarities ascertain the influence of the underlying structure of the initial analogy on the solution space. Our original hypothesis was that the act of reflecting on the initial analogy would lead to lower levels of fixation, i.e. analogical persistence would be mitigated. Figure 8-6 illustrates how encouraging participants to understand the design space through reflection affects the influence of the analogies that were used. Unfortunately, encouraging participants to reflect on the initial analogy had the inverse of the expected effect and there was actually an increase in the reliance on the initial analogy.

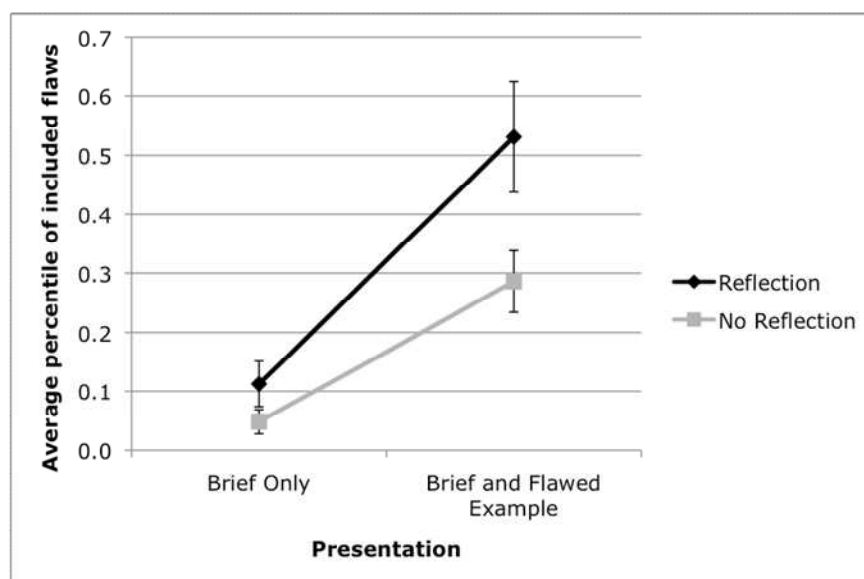


Figure 8-6 Fixation levels for Analogical Similarities across all experimental groups. Error bars indicate standard error of the mean.

As illustrated by Figure 8-6 presentation did have a profound effect on the types of solutions that were generated. Participants who were given a primed analogy produced solutions that were far closer to that analogy when compared to the participants who generated their own analogies (Brief Only $M = 0.081$, $SD = 0.102$ vs. Brief & Flawed Example $M = 0.409$, $SD = 0.264$; $F(1,36) = 32.234$, $p < 0.01$).

Encouraging participants to understand the design space through reflection actually caused participants to incorporate more elements of the primed analogy into their proposed solutions (Reflection $M = 0.322$, $SD = 0.308$ vs. No Reflection $M = 0.167$, $SD = 0.172$; $F(1,36) = 7.143$, $p < 0.05$). The significant effect of Reflection indicates that there were differences in the levels of fixation exhibited by the different experimental groups. This main effect though does not provide us with detailed information in how the act of reflection affects each of the experimental groups.

The first follow-up independent sample t-test examined the difference between the Reflection vs. No Reflection groupings within the Brief Only condition. There was no observable difference between the two Reflection conditions (Reflection $M = 0.113$, $SD = 0.124$ vs. No Reflection $M = 0.048$, $SD = 0.064$; $t = -1.466$, $p > 0.05$). This result is expected, as stated earlier, because when measuring fixation we are measuring the presence/absence of specific defining features of the primed analogy. As both groups in the Brief Only condition were not exposed to the flawed pictorial example we would expect them to have comparable levels of fixation. The second follow-up t-test examined the difference between the two Reflection conditions within the Brief & Flawed Example manipulation. The independent sample t-test indicated that there was a significant difference between the two groups with the highest level of fixation being exhibited by the participants instructed to reflect on the Provided Primed Analogy (Reflection $M = 0.531$, $SD = 0.296$ vs. No Reflection $M = 0.286$, $SD = 0.164$; $t = -2.286$, $p < 0.05$). It is clear from this result that the overall multivariate effect for Analogical Similarities is primarily accounted for by the large difference in fixation exhibited between the Reflection and No Reflection groups in the Brief & Flawed Example condition.

8.3.1.3. Reproduced Flaws

The Reproduced Flaws measure of fixation gauges the number of faulty elements from the initial analogy that are present in the solutions proposed by the participants. While the previous two measures of fixation are neither inherently positive nor negative, the Reproduced Flaws measure deals solely with problematic elements of analogies on the design decision-making process. There was a main effect of Presentation (Brief Only

$M = 0.171$, $SD = 0.125$ vs. Brief & Flawed Example $M = 0.459$, $SD = 0.258$; $F(1,36) = 11.392$, $p < 0.01$), but no main effect of Reflection (Reflection $M = 0.374$, $SD = 0.271$ vs. No Reflection $M = 0.256$, $SD = 0.211$; $F(1,36) = 3.554$, $p > 0.05$). While providing participants with a primed analogy caused them to incorporate problematic elements of the analogy into their solutions, critiquing that analogy had no impact on mitigating fixation as we had hoped.

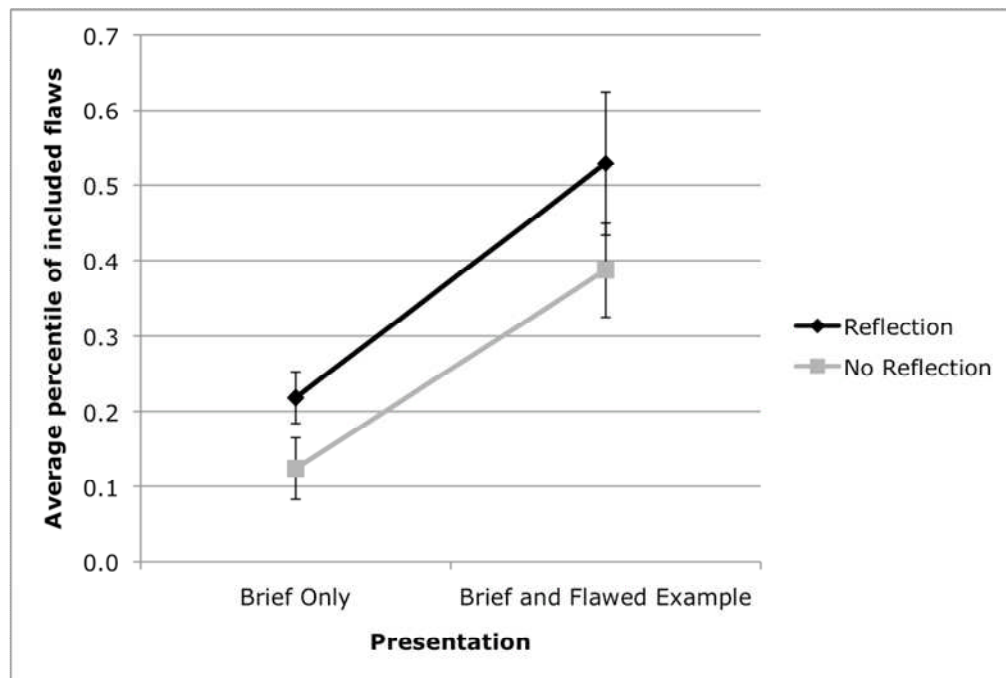


Figure 8-7 Fixation levels for Reproduced Flaws across all experimental groups. Error bars indicate standard error of the mean.

8.3.2. Quantitative analysis – Discussion

Based on the results from Chryskou and Weisberg (2005) we had hypothesised that asking participants to reflect on the types of analogies they were using, as well as the strengths and weaknesses inherent to that analogy, would reduce the influence of the faulty primed analogy. What we found was that the independent variable of Reflection only seemed to influence the number of structural elements (i.e. Analogical Similarities) of the flawed analogy that appeared in the produced sketches. By encouraging participants to reflect on the analogies that they were using we actually increased the influence of the initial analogy.

We hoped that encouraging designers to understand the design space through reflecting on the analogies that they use, we would help designers make higher quality decisions (i.e. avoid the problematic elements of the analogies that they use and not incorporate them into their proposed solutions). However, this structured reflection had no effect on the incorporation of surface features into the solution sketches or the

inclusion of problematic features of the flawed example. In the case of the Analogical Similarities measure of fixation, encouraging reflection actually led to more reliance on the Provided Primed Analogy.

8.3.3. *Follow up Qualitative Analysis*

The goal of this study was to enable Interaction Designers to make better quality design decisions by mitigating the influence of the analogies that they use. By encouraging participants to reflect on the strengths and weaknesses of the analogies they were using we hoped to retain the benefits of using analogies in design decision-making while eliminating the pitfalls of analogical persistence. Results indicated that not only was our manipulation unsuccessful, but that it also increased the influence of the initial analogy. To identify possible behaviours that may have contributed to observed increase in analogical persistence a follow up qualitative analysis of the rationale templates was performed.

To provide structure to this analysis the Theoretical Thematic Analysis framework (Braun & Clarke, 2006) was employed. Theoretical Thematic Analysis is a coding framework which focuses on an explorative open-coding approach to data segmentation within the context of a focused research question. As we were interested in patterns of behaviour across all participants, i.e. how participants constructed their understanding of the design space and which behaviours may have led to an increase in fixation, the Theoretical Thematic Analysis approach to data analysis was appropriate.

We were primarily interested in a description of how participants had mentally constructed, and consequently explored the design space, so the data were analysed at a semantic level, i.e. themes were identified from the explicit meaning of the data not from an interpretive stance in which meaning to the statements may be inferred. Each statement that was made, regardless of strength or weakness, was broken down into discrete descriptive units. This open-coding approach emphasises taking each statement and breaking it down into several codes. Each code aims to encapsulate a relevant idea or theme which describes the meaning of each statement from the critiquing template. The theoretical thematic analysis of the rationale templates identified certain behaviours that were consistent across participants. To provide an idea of consistency within the codes generated, Table 8-1 illustrates the code distribution across all of the participants.

The behaviours that were identified are discussed across two sections: the behaviours were used to understand the design space and the behaviours may have contributed to increased analogical persistence. The first section examines the

behaviours that were used to elicit the strengths and weaknesses from the problematic analogy. The second portion of the results section specifically looks at behaviours that may have led to the increased levels of fixation exhibited in the study presented in the first half of this chapter.

Participant	Identify Strengths & Weaknesses	Contrast Against SGA	Contrast Against Requirements	Contrast		
				Against Usability Guidelines	Misattributing Weaknesses as Strengths	Reluctance to Classify Weaknesses
4	X					X
6	X	X	X		X	
25			X		X	X
26	X	X	X			X
27	X		X			X
28	X		X		X	X
29	X	X	X	X	X	X
30			X	X	X	X
31	X			X	X	X
32	X	X	X	X		X

Table 8-1 Distribution of observed behaviours across all participants.

8.3.4. Identifying Strengths and Weaknesses

Participants constructed their own understanding of the solution space by eliciting the strengths and weaknesses of the Provided Priming Analogy. Participants were able to identify the inherent strengths and weaknesses of the provided analogy through several different contrasting behaviours:

- the provided analogy against their Self-Generated Analogies
- the provided solution against the requirements from the design brief
- the flawed example against their self-generated requirements of what features they believed were important to that particular product
- the flawed pictorial solution against established usability guidelines.

8.3.4.1. Contrast against Self-Generated Analogies

As was discussed in chapter seven, participants used their Self-Generated Analogies as a source to contrast against the Provided Primed Analogy. This behaviour allowed the participants to highlight certain features of the flawed solution that worked well, and other features which were problematic based on how well one analogy achieved that task when compared to the other. The excerpt below, from Participant Six's rationale template, illustrates how they used their Self-Generated Analogy of iCal to understand and highlight some of the problematic features of the provided example.

“The Button for the detailed day overview is missing – like the day view in iCal” Participant 6

One of the requirements of the design brief given to all participants was that any proposed solution needed to display the appointments for the current day. The provided flawed solution accomplishes this through the use of a floating window to the side of the calendar. Participant 6 believed that, rather than having isolated sections, that different views would be a better method of addressing the issue of how information was displayed to the user.

8.3.4.2. Contrast against Requirements from the Design Brief

A second method that participants adopted to elicit strengths and weaknesses of the provided primed analogy was contrasting the example against the requirements of the design brief. The design brief that participants were given contained several requirements that all solutions must adhere to. This behaviour was mostly used in the identification of strengths as opposed to the elicitation of weaknesses of the pictorial example.

“Main view - easy to understand the system & how to use it (i.e. add/remove appointments)” Participant 30

The above quotation illustrates how Participant 30 used the requirements from the design brief (a successful solution must be able to add/remove appointments) as a way to gauge how well the provided example accomplished this feature. In this specific case, the provided Priming Analogy was successful because the method used to add/remove appointments (two buttons marked + and -) was simple, to implement to accomplish this requirement of the design brief.

8.3.4.3. Contrast against Usability Guidelines

The third method that participants used in the elicitation process was to contrast the primed analogy with established usability guidelines and techniques. The quotation below illustrates how Participant 31 was able to identify one of the fundamental flaws of the proposed solution, namely the ambiguity of navigating between the twelve months of the calendar using the 3D cube interface.

“Can’t test design eg. Cubed month navigation. Bizarre navigation” Participant 31

The issue of ambiguous navigation in the flawed pictorial example was highlighted, in the case of Participant 31, by the problem of testing the 3D cube navigation with this level of fidelity. This issue of user-testing highlighted the fact that the 3D cube interface was ambiguous and potentially problematic to a successful design.

8.3.5. *Awareness of Weaknesses*

The three behaviours we have just discussed have illustrated that participants were aware of some of the problematic characteristics inherent to the flawed pictorial example. Participants displayed different strategies of how to begin to analyse the inherent strengths and weaknesses of the provided primed analogy. The identification of these behaviours does raise a question: if participants are aware of the weaknesses and are able to identify them then why was there evidence of increased fixation? Why were more problematic elements incorporated into their proposed solutions when they were able to identify the problem? The following section discusses some of the behaviours exhibited by participants in their rationale templates that may have led to an increase in analogical persistence.

8.3.5.1. *Misattributing weaknesses as strengths*

Participants were able to identify weaknesses in the flawed pictorial example that were included with the design brief. Despite being able to identify problematic characteristics of the flawed pictorial example this awareness was not sufficient to decrease fixation. One of the behaviours exhibited by participants, which in part explains the observed increased levels of fixation, was identifying design features as strengths when in fact they were weaknesses. In these instances, the participants were able to identify the problematic features as important but these features were mislabelled as strong points of that design.

“Navigation view is attractive for users to use, and clearly shows appointments on different months.” P27

The above quotation illustrates how this behaviour manifested in the rationale templates. Participant 27 identifies one of the flaws of the primed example, i.e. the cube like navigation, but rather than it being seen as a problem or a potential oversight of the design it is seen as a strength. The cube like navigation is an issue as it only has six sides and consequently is incapable of adequately navigating across twelve months as is a stated requirement in the design brief. In the case of Participant 27 this problematic feature was actually seen as a strength in that it would appeal to a technologically savvy audience.

Keane (1988) discusses the idea that people use analogies as a way to generate hypotheses where each element of an analogy is a testable hypothesis to see if it is beneficial to the problem at hand. When engaging in analogical reasoning, according to Keane (1988), individuals will try to map individual properties of their chosen analogy on the problem they are engaged with. At the outset of the comparison, all of the

features of the analogy start as neutral characteristics. These neutral characteristics are tested against the problem to see if they are helpful in solving the problem or bear no relevance to the problem. If the neutral characteristic is deemed to be helpful it is considered a positive characteristic, but if it is completely unrelated to that particular problem it is categorised as a negative characteristic. The example that Keane (1998) used is of using billiard balls as an analogy to help understand molecules. A positive element of the source analogy (the billiard balls) is the movement, which directly maps on to how molecules move. A negative element though would be the colour of the billiard balls, as this bears no relation to our understanding of molecules.

Considering this use of analogies to generate hypotheses and label them as either helpful or a hindrance, we can see that it is possible that characteristics of the initial analogy could be mislabelled as positive when in fact they would be negative. Rather than reject an inappropriate element of the initial analogy (i.e. designated as negative) participants inadvertently labelled it as a positive characteristic and accepted it into the final generated solution. While this type of analogical error seems to foster the inclusion of problematic design features into design solutions this was not the only observed behaviour that may have contributed to the higher levels of fixation.

8.3.5.2. *Reluctance to classify weaknesses*

Participants were also reluctant to label features as weaknesses. While participants were able to identify problematic features most of the time, these features were actually identified as potential problems to be investigated as opposed to weaknesses that should, be avoided in their own solutions. The quotation below illustrates participants' reluctance to classify problematic features of the design as a weakness.

“Unsure how you would know what month you are looking at - where is it labelled?” Participant 30

Participant 30 highlights that the included design has no display for current day or month, which is in direct contradiction to the requirements of the design brief, but yet the participant did not classify this element as a problem. Rather the weakness was framed as a question, which implies that this is an issue to investigate, rather than as a problem to be avoided in his own designs.

“Where is Saturday & Sunday? Is it not there because it's a work calendar? What if I work weekends?” Participant 26

Another example of this reluctance is taken from Participant 26. One of the problematic characteristics placed in the flawed pictorial example was the lack of Saturday and Sunday on the calendar. Despite this being a significant flaw in the solution, Participant

26 phrased all of their statements as questions as opposed to simply labelling them as problems. This reluctance to identify a problematic design feature as a weakness may promote higher levels of fixation by encouraging participants to spend greater amounts of time sketching out the problematic features in hopes of understanding these problematic features.

8.4. General Discussion

The aim of this study was to eliminate analogical persistence using ecologically appropriate methods like Design Rationale and Reflection-in-action. Results from our study indicate that not only was our hypothesis incorrect, but the methods we proposed actually increased analogical persistence. Participants who were asked to use the provided reflection templates, to gain a better understanding of the design space, actually incorporated more problematic elements of the initial analogy as compared to the No Reflection condition. When we performed a secondary qualitative analysis on the reflection templates used, we found that the structured reflection encouraged by the experimenters did aid participants in identifying problematic elements of the analogy. However, this awareness of weaknesses actually increased the likelihood the problematic analogy would be incorporated into the decision-making action plan, rather than be discarded as dictated by our hypothesis. These findings beg the question why would bringing one's attention to the possible weaknesses of the initial analogy increase analogical persistence?

As discussed in the previous chapter, participants referred to the provided Priming Analogy as the 'best' solution to the design brief. This behaviour provided evidence to indicate that the fixation observed was due to pre-emptive exhaustion of the solution space. Perttula & Liikanen (2006) hypothesised that the fixation effects that are observed under the Design Fixation paradigm are a function of one of two phenomena: a pre-emptive exhaustion of the solution space or that designers unconsciously conform to the provided example. While Perttula & Liikanen was inconclusive as to which phenomenon was responsible for the effects observed in the Design Fixation paradigm, the study presented in this chapter provides evidence to support the pre-emptive exhaustion of the solution space understanding of Design Fixation. Participants were actively engaging in understanding the strengths and limitations of the initial analogy. Therefore an observed increase in fixation cannot be accounted for by participants' unconscious desire to conform, since they were consciously disseminating the artefact. If the unconscious conformity argument was valid, conscious reflection on the artefact should have no effect. However, in this study reflection actually increased the observed

level of fixation. This in conjunction with the findings from previous study, that although participants are aware of the problems that an example can pose they view the provided solution as the 'best' solution to the problem, indicates that participants are consciously aware of the problems of the initial analogy but as the solution space has been pre-emptively exhausted there is not a better option than the one provided to them. This exhaustion of the solution space also leads the designer to view the provided example as the best solution, because it is the least flawed solution available from the limited solution space.

The primary aim of this study was to use principles from Design Rationale, in conjunction with reflecting on the analogies that form the basis of the decision-making process, to help participants gain a better understanding of the solution space and consequently overcome the narrowing influence of their initial analogy. By encouraging participants to reflect on the analogies that they use, it is possible that we inadvertently caused participants to narrow the solution space even further. The observed increase in fixation may be a function of the solution space narrowing to such a degree that participants had few sources of material to draw upon, which caused them to rely more heavily upon the initial analogy since it was the only option available.

8.5. Conclusion

To investigate how the act of gaining a better understanding of the design space through reflection actually increases the influence of the analogy, we need to gain a better understanding of how participants were constructing their understanding of the solution space. A follow-up qualitative study was conducted examining the content of the templates that participants completed at the outset of the study. The hypothesis of this study was that by encouraging participants to generate their own lists of problematic features of the analogies, this manipulation would mitigate fixation in an ecologically valid manner. Contrary to our hypothesis, it was found that encouraging participants to reflect on the useful characteristics of their initial analogy, actually caused participants to incorporate more of those problematic elements into their final solutions. By examining the reflection templates of those participants, we were able to identify such behaviours as 'reluctance to classify problematic characteristics as weaknesses' and 'misattributing weaknesses as strengths'.

While these behaviours highlight some of the problematic ways in which participants use analogies, there is a lot of information that is missing by employing this type of analysis. By examining these behaviours from a post-hoc perspective we are only engaging with a limited portion of the behaviours that actually contribute to

increased analogical persistence. To overcome this limitation of a post-hoc analysis we need to replicate the study presented in this chapter with the addition of a think-aloud protocol. Employing a think-aloud protocol overcomes the limitations of a post-hoc analysis by providing us with concurrent verbalisations of the decision-making process utilised by Interaction Designers. By pairing a think-aloud protocol with the experimental design detailed in the next chapter we not only gain a more detailed understanding of the behaviours and cognitive processes that led to increased fixation; but also provide validation to the behaviours identified in this study through methodological triangulation.

9. A Validation of the Behaviours Contributing to Increased Fixation

9.1. Introduction

The study presented in chapter eight illustrated the effect of using Design Rationale techniques to encourage reflection in Interaction Designers and consequently how this affected the influence of analogies on the decision-making of Interaction Designers. The increased levels of fixation observed indicated that encouraging participants to actively reflect on the analogies that form the foundation of their decision-making actually increased the influence of that analogy. A follow-up qualitative study highlighted particular behaviours that may have been responsible for the increased influence of the initial analogy. The goal of this final study was to validate the behaviours identified in the previous chapter by pairing a think-aloud requirement with the reflection manipulation from the studies represented in chapter 8.

In the previous study, we were able to identify certain behaviours that may have fostered the increased influence of the initial analogy from an analysis of the Design Rationale templates. Behaviours such as ‘misattributing weaknesses as strengths’, and ‘a reluctance to classify problems as weaknesses’ provided some insight into what was causing participants to incorporate more problematic elements of the priming example into their final solutions. The issue with this type of examination is that the data that were analysed post-hoc, which provides us with a limited view of the types of behaviours that increase analogical persistence. In this final study, we have supplemented the data from the previous study with a think-aloud protocol so as to provide a richer picture of the types of behaviours and cognitive processes involved in increased analogical persistence. Pairing a think-aloud requirement with the reflection manipulation in this chapter allowed us to investigate the validity of the relationship between behaviours identified in the previous chapter and the observed increase in analogical persistence. Verbal data generated from the think-aloud requirement allowed us to supplement the data from the previous study by looking at which cognitive processes were involved in increasing fixation that would otherwise remain undetected if only the reflection templates were analysed.

9.2. Method

By employing a think-aloud protocol (Ericsson & Simon, 1993) in conjunction with the reflection manipulation from the previous chapter we were able to provide validation to

our findings through a different methodological approach. As per the studies in the previous chapter, this final study focused on the experimental intersection of the presence of a problematic Priming Analogy and the instructions to reflect on said analogy. The results from this study investigated the validity of the behaviours fostering fixation that were identified in the previous chapter.

9.2.1. Design

In this study, we were primarily interested in the observed increase in fixation observed in participants who were instructed to reflect on the strengths and weaknesses of the flawed Priming Analogy so we replicated this condition (Reflection and Brief & Flawed Example) with the addition of a think-aloud protocol. A think-aloud protocol allowed us to examine the cognitive processes involved in the decision-making task at hand. These verbalisations were recorded and also transcribed. As participants' verbalisations were recorded each participant was interviewed and tested individually in a lab with minimal distractions. To supplement the data generated by participants' verbalisations, notes were also taken during the interviews. These two sources of information were collated and analysed for behaviours that may have led to increased analogical persistence. The presence or absence of the identified behaviours from chapter eight provided us with a measure of validity.

9.2.2. Participants

The study was conducted with six participants who were experienced in Human-Computer Interaction methods. Table 9-1 contains descriptive profiles of the six participants. All participants were recruited through personal channels from both University College London and the University of Manitoba. All participants, with the exception of Participants 1 and 3, were recruited through the Masters course in Human Computer-Interaction in the above mentioned institutions. Participant 1 was recruited through personal channels at University College London.

Participant	Education	Years of Experience
1	PhD from the University of Sussex– Experience in the design of Air Traffic Control interfaces	5
2	MSc from the University College London Interaction Centre. Currently working in industry as a information architect.	2
3	PhD from City University– Experience in designing commercial websites	6
4	MSc from the University of Manitoba. First year student.	1
5	MSc from the University of Manitoba. In the final year of a MSc in HCI with a focus on 3D interactions on an Interactive Table	3
6	MSc from the University of Manitoba. In the final year of a MSc in HCI with a focus on collaborative musical displays.	3

Table 9-1 Participant Profiles.

9.2.3. *Materials*

Participants were given the design brief for the calendar problem used in the previous chapters. This design brief was a short problem statement which outlined the goals and requirements of the design exercise. In addition to the design brief, all participants were provided with the same additional materials as were used in the previous chapter: a flawed example solution as well as a template to encourage reflection. The flawed example given to participants contained several problematic elements, which either directly contradicted the requirements stated in the design brief, or were generally counter-intuitive to the purpose of the design brief. This flawed example primed a faulty analogy in the mind of the designer which can then be quantitatively analysed to ascertain its influence on the overall design decision-making process. In addition to the flawed Priming Analogy, all participants were also provided with a template that encouraged them to reflect on the inherent strengths and weaknesses of the provided problematic analogy.

9.2.4. *Procedure*

Participants were provided with instructions at the outset of the study that they would be given a design brief and that the purpose of this study was to generate as many solutions

as possible in response. Participants were instructed to read over the provided material, to acquaint themselves with the requirements of the study, and were given an opportunity to clarify any problems before the commencement of the study. In addition, participants were instructed to verbalise their thoughts throughout the entirety of the study. To avoid issues regarding extended periods of silence, probing instructions were employed if needed. If participants spent longer than one minute in silence they were asked “what are you working on now?” This particular probing statement was used so as to avoid causing participants to reflect on their own thoughts, rather than verbalise their thoughts (Ericsson & Simon, 1993).

This study, like the experiment presented in chapter eight, was composed of two sections. The first portion, which was ten minutes in duration, was concerned with allowing the participants to reflect on the strengths and weaknesses of the provided flawed example and to complete the Design Rationale template given to them at the outset of the study. At the end of ten minutes, participants were instructed to move on to the sketching portion of the study. Participants were given twenty minutes to sketch as many solutions as possible in response to the design brief.

9.2.5. Analysis

All audio files that were generated by the study were transcribed verbatim. To ensure that a realistic reflection of the subject matter was obtained such verbal idiosyncrasies such as pauses, 'umms', and 'ahhs' were transcribed. In addition to the verbalisations generated by the participants, supplementary information was generated in the form of notes taken during the study by the experimenter as well as notes taken during the transcription of the verbalisations.

The analysis was conducted over multiple stages. The first portion of the analysis was to segment the transcript into discrete concepts. Each concept was a self-contained unit of information (H. H. Tang & Gero, 2000). Each of the discrete segments identified in the first portion of the analysis was labelled with a code that aimed to encapsulate the idea of that particular segment. Multiple codes could be assigned to the same segment. These codes were then clustered based on inter-code relationships. The clustering of these codes led to the creation of meta-codes i.e., codes which captured the relationship between several related segment codes. These meta-codes provided us with an overview of the dominant themes and behaviours inherent to the data set. These meta-codes themes also allowed us to examine the behaviours responsible for increased analogical persistence within the verbal protocols. These identified behaviours were then

contrasted against the findings from the previous study to provide us with an indication to the validity of the behaviours from chapter eight.

9.3. Results & Discussion

From the verbal data generated from the think-alouds, several of the same behaviours from the previous study were identified. The think-aloud data not only provided methodological triangulation, but also provided more information as to the cognitive processes involved in the manifestation of the behaviours identified. The results and discussion section is composed of two sub-sections. The first sub-section discusses the results from this chapter in the context of the behaviours identified in the previous chapter. Specifically, the replicability of those identified behaviours as well as how the verbalisations extend our understanding of those behaviours. The second sub-section discusses several cognitive processes that were identified through the collected verbalisations that would not have been identifiable if not for the think-alouds.

Table 9-2 illustrates the behaviours discussed in the previous study that were exhibited in the think-aloud protocols. All of the observed behaviours in this study showed a similar distribution to the previous study, in terms of frequency, across all participants. By pairing a think-aloud with the experimental paradigm employed in the previous study we were able to gain additional insight into not only how those previously identified behaviours manifested; but also, how several cognitive processes interplayed with those behaviours to yield higher levels of fixation.

Participant	Number of Sketches	Identify Strengths & Weaknesses	Contrast Against Self-Generated Analogies	Contrast Against Requirements	Contrast				One to One Strength and Weakness	Depth strategy	Explicitly Improve Flawed Solution
					Against Usability Guidelines	Mis-attributing Weaknesses as Strengths	Reluctance to Classify Weaknesses	Against Usability Guidelines			
1	3	X		X	X	X	X	X	X	X	
2	3	X	X	X			X	X	X	X	X
3	5	X	X		X		X	X	X		X
4	10	X		X		X	X	X	X		
5	2	X	X	X		X	X	X	X	X	X
6	1		X	X	X	X	X		X		X

Table 9-2 Distribution of codes all participants.

9.3.1. Validation of Behaviours from Study 9.1

Table 9-2 illustrates the behaviours that were identified in the previous study and their presence, or absence, across the participating designers in this study. All of the behaviours identified in the previous study were replicated, with the majority of all participants exhibiting the fixation fostering behaviours. All behaviours were exhibited by at least 67% of the participants. The only exception to these results was the ‘contrast against usability guidelines’ behaviour, which was exhibited by only 50% of the participants.

While the think-aloud verbalisations validated the presence of many of the behaviours, it also provided further insight into how these behaviours manifested. The following two sections discuss several aspects of the ‘reluctance to clarify weakness’ behaviour. The gathered verbalisations provided us with more details into how this behaviour manifests that we were not able to assess using the limited post-hoc analysis of the rationale templates.

9.3.1.1. Reluctance to classify weaknesses - Narratives

In the previous study, reluctance to classify weakness was identified in all but one of the participants. This behaviour was characterised by a participant’s reluctance to classify any potential problems with the flawed analogy as an outright weaknesses. Participants were more likely to discuss the problems with the proposed solution as potential issues that should be further explored. The data generated from the think-alouds added a further dimension to this behaviour which was the construction of a narrative to explain away that problematic feature.

“Ummm... so where is Saturday & Sunday? It must not be [there] because it's a work schedule. That's a good idea to simplify the design.”

Participant 4

The above quotation illustrates how Participant 4 was able to identify a main weakness of the provided primed solution, namely that it doesn't have any weekends. This is a major flaw, since it compromises the basic functionality of the calendar. Rather than this being labelled as a weakness, Participant 4 composed a narrative to explain away the problem, i.e. that the exclusion of the weekend is a conscious choice to streamline the design.

The use of narratives is not foreign to the decision-making literature. Many of the Naturalistic Decision-Making models discuss the use of narratives (e.g. Penning & Hastie, 1986). Traditionally, narratives have been used to test out the potential strengths and weaknesses of the proposed course of action. While the nomenclature differs across

different models of Naturalistic Decision-Making the idea of narratives as an important component of the decision-making process remains consistent (Lipshitz, 1995). In the Recognition Primed Decision-Making model (Klein, 1998), the term used to denote this behaviour is mental simulation. Under the Explanation-Based model of decision-making this type of behaviour is referred to as ‘constructing the narrative’ (Pennington & Hastie, 1986). While the use of narratives is discussed in many different models of decision-making, it is worth noting that narratives have never been discussed in the case of rationalising away existing flaws as seemed to be the case in this study but rather as a tool to structure and understand the problem space. This focus on using a narrative to explain away the flaws of the original example, rather than testing it, could in part explain the increased levels of fixation observed in the previous chapter.

9.3.1.2. Reluctance to classify weaknesses – Dissonance between intentions and actions

In addition to the use of narratives, participants were observed discussing particular characteristics as weaknesses, but failed to commit those weaknesses to paper. While the problematic characteristics were verbally identified as a weakness, this categorisation was not reflected in the rationale template. Rather, those identified weaknesses were committed to paper as potential problems requiring further exploration.

Participant 6 Verbalisation – Thinking about a calendar there are typically Saturdays and Sundays. It doesn’t have those and I don’t see a way to turn those on or off, nor an easy way to access some of the more complicated functionalities. So I think it might fail on virtue of its calendar’ness.

Entry on template – Where is Sat and Sun? Not particularly obvious

This discrepancy between identifying the issue verbally and failing to commit that judgement to paper does indicate that the act of committing a judgement to paper may increase this reluctance (Pennington & Hastie, 1986). By encouraging participants to reflect on the inherent strengths and weaknesses, perhaps we are placing too much emphasis on de-constructing the characteristics of the flawed solution as either positive or negative. From the verbal data it is clear that participants can identify problematic elements of the design, but the act of committing those opinions to paper seems to cause participants to waver in their opinions. While the study presented is somewhat artificial in design, i.e. more elements of defining and exploring the design space are under the designers’ direct control and not as strictly detailed by the design brief and flawed

solution. This study highlights some important issues that may have some important implications for the field of Design Rationale. The central claim to Design Rationale is that by cataloguing the decisions inherent to the construction of an artefact, as well as the process behind them, future designers can use that information to aid them in making better design decisions. The worrying fact is that the information that is recorded may not be an accurate reflection of what the designer is thinking. This disconnect between what the designer is thinking, and the record of that thought process questions some of the basic benefits of using Design Rationale.

9.3.2. Cognitive Processes Contributing to Fixation

The first section discussed some of the behaviours identified in the previous chapter that were replicated from the verbalisation generated by participants. This section discusses some of the cognitive processes that emerged from the think-aloud data which may, in addition to the aforementioned behaviours, contribute to the increase in analogical persistence observed earlier. The concurrent verbalisations were able to shed light onto the thought process and timing of the observed behaviours from the first study. In addition to the behaviours identified in the previous study the verbal data indicated several cognitive strategies that in and of themselves may have led to increased analogical persistence.

9.3.2.1. Depth versus Breadth Approach to Understanding the Solution Space

One of the primary goals of using Design Rationale principles is to foster higher quality design decisions by widening the solution space through understanding the limits of the existing solution space using careful and focused analyses (A. Tang et al., 2008). Participants in this study tackled the task of defining and understanding the solution space in very different ways. Most participants adopted a depth approach, in which they focused on exploring as many facets as possible of one or two designs, where some others adopted a breadth approach, in which participants generated as many different ideas as possible to explore the various different types of solutions available to them.

A significant portion of the participants (see Table 9-2 for a distribution of this behaviour across participants), after completing the reflection portion of the study, spent the remainder of the study working on one or two design ideas in detail. Participants who adopted this 'depth' strategy spent the majority of the sketching portion of the study working on one drawing. This one proposed solution was continually refined to ensure that each necessary feature outlined in the design brief was present and devoid of any problems. Two brief case studies are presented below which contrast the depth strategy, observed in most of the participants, against the breadth strategy used by two

participants. This breadth/depth approach has been noted by various researchers as a way to demarcate the solution space by transforming a wicked problem into a structured problem (Akin, 2001; Ball & Ormerod, 1995; Ball, Onarheim, & Christensen, 2010). It is worth noting that the two examples in Figures 9-1 and 9-2 represent either extreme of this behaviour. From the small sample, these approaches to understanding the solution space did not seem to be bimodal but rather on a continuum (Ball & Ormerod, 1995; Ball et al., 2010). Although the examples presented in Figures 9-1 and 9-2 are not quite typical of the other participants they do illustrate the differences in behaviours between these two approaches. The presence of these behaviours as a way to engage with understanding the solution space, among our participants is not surprising, considering the goal of our structured reflection templates was to encourage participants to understand in greater detail the design space. What is not as well understood is the influence these behaviours have on the Design Fixation paradigm.

P6 – Depth strategy

Participant six, throughout the entire sketching portion of the study produced one possible solution to the design brief. While only one solution was proposed each function of the calendar was described in detail. In addition to a detailed description of what the proposed calendar would, and would not do, the participant also discussed several different views (day, week, month) and what the benefits and weaknesses of each of those views would be. The features that were in the proposed solution were far more rigorous in relation to the solutions produced by other participants in that each feature was tested against the requirements of the design brief. In total the one solution spanned three pages, which was composed of three different views, and eight different features that were all discussed in detail.

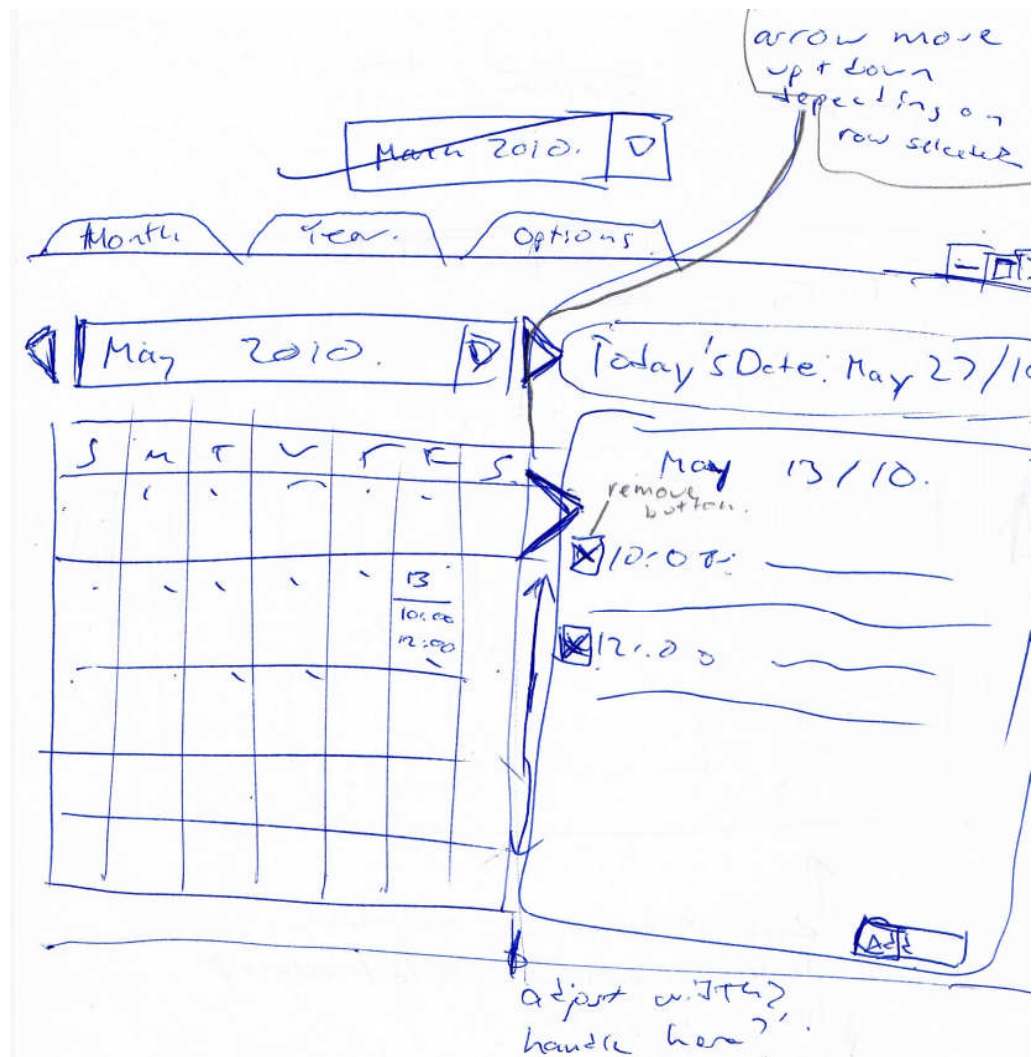


Figure 9-1 Sketch produced by participant 6 using the depth strategy.

P4 – Breadth approach

Participant four proposed a total of ten different solutions in response to the provided design brief. Each of the ten proposed solutions contained enough detail to communicate the basic premise of the idea but contained little to no detail of the actual functionality. Each solution contained minimal detail in terms of how it satisfied the requirements listed in the design brief. Of the ten solutions, the most detailed solution was a ‘time-tunnel’ idea which described how one would navigate through a circular tunnel interface with the more recent appointments closer to the user while the farther away the appointment was chronologically the farther it would be on the interface. In contrast, the least detailed solution used solely icons to provide the details that a traditional calendar would. The solution contained nothing more than few icons and area pointing towards an empty box which represented a traditional grid like interface to a calendar. Both of these solutions are contained in the figure below.

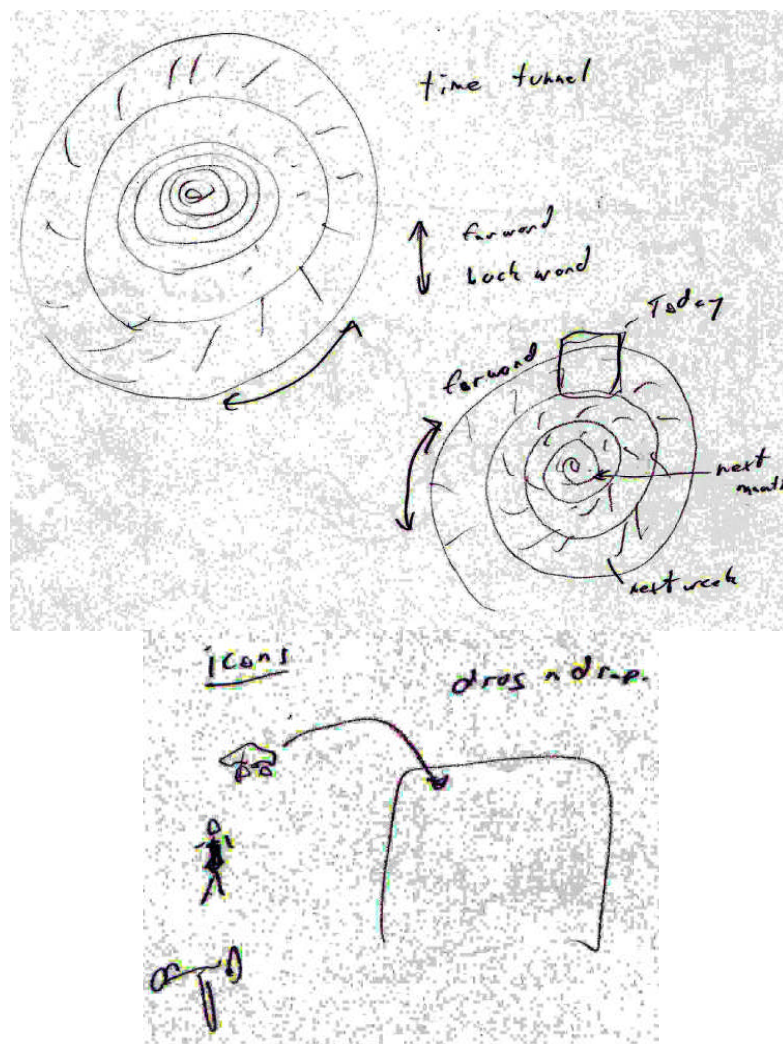


Figure 9-2 Two sketches produced by participant 4 using the breadth strategy.

From the two examples described above, the differences are quite apparent. The depth approach was characterised by one or two drawings, on average, which contained far more detail. The breadth approach is concerned with generating a multitude of ideas at a superficial level with little to no functionality, and/or incorporation of the basic requirements as outlined by the design brief.

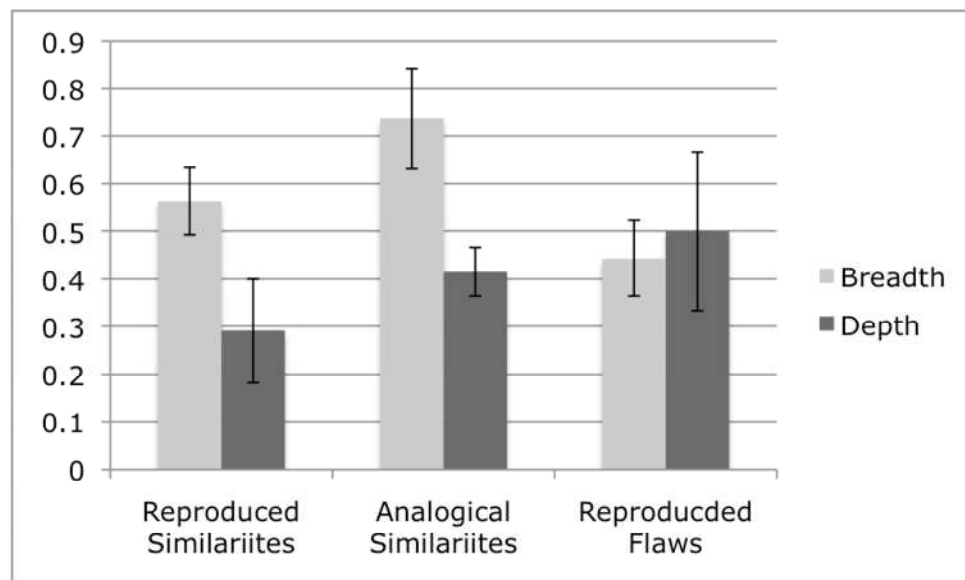


Figure 9-3 Fixation scores across all participants with standard error bars indicative of the standard error of the mean.

Of the six participating Interaction Designers all but two demonstrated the depth strategy (average number of designs: Depth = 2.4; Breadth = 8). The two participants who did not use this approach adopted a breadth approach, in which more design ideas were proposed at the cost of the level of detail. Participants using this strategy did not engage with each solution past the sketching of the general concept. Little detail was provided in terms of what functions their solution would accomplish and how it would accomplish those functions. The two participants who adopted a breadth approach produced markedly more design ideas in comparison to the depth grouping at the cost of any level of engagement with the design problem. Figure 9.3 illustrates the average fixation scores across all six participants. These fixation scores were calculated using the same scoring criteria used in the previous study. Appendix D contains the scoring criteria used to measure the level of fixation exhibited in the solutions generated by the participants Interaction Designers. Due to the small samples size in both conditions, any quantitative analyses would be low power, however from examining the raw data does show a trend for lower fixation scores on the Reproduced Similarities and Analogical Similarities measures of fixation in participants who adopted the depth

approach. A larger sample size would be required to examine the implications that these two strategies have on analogical persistence.

9.3.2.2. Explicitly improve flawed solution.

Many of the codes generated by the verbal protocols were from direct references to the flawed solution, specifically how the solution could be improved. By encouraging participants to try and identify the strengths and the weaknesses of the provided analogy, they became markedly more inclined to spend the sketching portion of the experiment focusing on improving the flawed example. While it would be reasonable to assume that participants would want to incorporate the identified strengths and remove the weaknesses from their proposed solutions, this was not how the introduction of the Design Rationale templates manifested. As opposed to generating new ideas based on the results of the first portion of the study, several participants explicitly referred to improving some of the identified problems.

“So with this redesign we are going to look at the strengths that I listed before, and the weaknesses and we are going to try and redesign it so we keep the strengths but try to minimise the weaknesses. With any design there are always tradeoffs. “ Participant 2

By focusing on ‘improving’ the provided flawed example it seems that participants were inadvertently incorporating more problematic characteristics of the Priming Analogy then addressing the identified weaknesses. This behaviour illustrates how focusing on the rationale of a design decision can narrow the solution space even further, and enforce a ‘patch-up’ mentality through relying more heavily on the Priming Analogy. By encouraging participants to understand the design space, in hopes of making better quality design decisions, the reflection actually reinforces the problematic analogy.

9.4. Conclusion

The goal of this study was to investigate the validity of the behaviours identified in the previous chapter that may have increased analogical persistence. By pairing a think-aloud protocol with the existing experimental design we were able to use methodological triangulation to address the validity of the results from chapter eight. In addition to providing methodological triangulation, the think-alouds allowed us to gain additional information about the cognitive processes involved in fixation that were not apparent from previous analyses. These behaviours, in conjunction with some of the identified cognitive processes, provide insight into why encouraging participants to understand the design space through reflection increases the problematic behaviour it is

trying to eliminate. Cross (1994) discusses how a narrow view of the design space can lead to problematic solutions, and the different design methodologies that can be used to broaden designers' understanding of the design space and to prevent problems like analogical persistence. Methodologies such as Reflection (Cockton, 2004) and Design Rationale (Tang et al., 2008) have been used in the past as tools to improve the quality of design decisions. Behaviours such as 'the depth strategy' as well as 'misattributing weaknesses as strengths' identified in both this study and the previous chapter highlight some of problems surrounding the intersection of these two methodologies.

The biggest issue raised by this study is the disconnect between the thoughts that were verbalised by participants and the resulting behaviours. Participants would discuss their thoughts in one fashion but when it came to acting upon those thoughts and beliefs a dissonance occurred. Behaviours such as 'the use of narratives' and 'reluctance to classify weaknesses' highlight the struggle that participants had with this disconnect. These findings reinforce how difficult it is to accurately reflect on one's own thought process (Nisbett & Wilson, 1977). This finding is of particular importance since understanding one's own cognition to make better-informed decisions is a fundamental cornerstone of the Design Rationale process. This inconsistency between one's thoughts and their resulting actions calls into the question the value of such design principles as Design Rationale.

Both Design Rationale (Lee & Lai, 1991) and Reflection (Schon, 1983) are important pillars of leveraging our understanding of design cognition to help designers make better quality design decisions. However, the intersection of the two seems to foster problematic behaviours in Interaction Designers. The next chapter concludes this thesis with a discussion of these issues.

10. Conclusions

The purpose of this research is to understand the cause of analogical persistence, the factors that affect its expression, and how we can mitigate its potential pitfalls while retaining its benefits. It was observed early in this thesis that while analogies formed the basis from which all solutions were derived, Interaction Designers could rely on these analogies to such a degree that the overall quality of their decisions was influenced. This final chapter will summarise the contributions to knowledge, provide a brief discussion of the limitations of this research, and close with potential avenues of research that may build upon this work.

10.1. Contributions Towards Knowledge

10.1.1. Analogies Persist Across all Stages of Decision-Making

As stated by many researchers, analogical reasoning is a cornerstone of the design process (Bonnardel, 2000; Eckert et al., 2005; Klein & Brezovic, 1986; Schraefel, Hughes, Mills, G. Smith, & Frey, 2004). Researchers, such as Klein, take this statement one step further and state that analogical reasoning forms the foundations from which we make decisions (e.g. Klein, 1999). Analogical reasoning is an important component of design decision-making as it allows designers to quickly scope the solution space to a pre-formulated template solution based on a similar situation that the designer has encountered previously. Discussion of how analogies form the foundations of our decision-making usually define these analogies as first stages that set up a possible solution which is refined over several iterative stages (Klein, 1987; Klein & Calderwood, 1988). As illustrated in every study discussed in this dissertation, these seed analogies can persist across all stages of the decision-making process. However, problematic characteristics of the initial analogy are still present in the final proposed solutions, despite a participant's engagement in the later stages of decision-making (such as mental simulation), which is primarily concerned with eliminating these problematic elements from the proposed solution.

The initial study, presented in chapter three was an explorative examination of how Interaction Designers engage in the decision-making process in a 'real-world' setting. To frame our discussion of how Interaction Designers come to their decisions, we analysed our results in terms of three variations of the Recognition-Primed Decision-Making (RPD) model (Klein, 1999). It became evident that the analogies

participants used at the outset were not an initial stage from which later stages were built upon, but rather these ‘seed’ analogies persisted across all stages of decision-making.

The primary goal of employing analogical reasoning in the initial stage of decision-making is to quickly and effectively generate a possible course of action despite the heavy cognitive load that designers can be under (Buchanan, 1992; Lawson, 2006). The stages of decision-making that follow from the initial point of analogical reasoning are in place to ensure that any problematic elements of the decision-making process are removed or mediated (Klein, 1999; Klein & Calderwood, 1991; Lipshitz, 1995). Chapter three presented evidence of the initial analogy actually undermining these goals by promoting problematic behaviours, such as designers’ reluctance to search for a more appropriate analogy when faced with evidence to indicate the inappropriateness of their initial analogy. Such problematic behaviours prolong the decision-making process, with the end-product being a lower quality design solution.

While our findings supported the idea of analogical persistence, other equally viable hypotheses may explain the results from this first study. While only one analogy was reported which in turn led us to believe, it is possible that if we were to examine the decision-making employed during the design process there may be many other influences that play a part in problematic decision-making. To address this issue, a quantitative study using the Design Fixation paradigm was included as a way to validate analogical persistence using methodological triangulation. The Design Fixation paradigm examines how many problematic characteristics of an initial flawed example are present in the produced sketches, which allows us to observe the degree to which an initial analogy influences all stages of decision-making from idea generation until the proposed final solution. Over several studies (chapters 4-6) we were able to demonstrate how issues with an initial Priming Analogy are not removed from the proposed action plan through the later stages of decision-making, as postulated by Klein (Klein, 1987a, 1989; Klein et al., 1988; Klein, Whitaker, & King, 1988), but rather can be observed even in the final proposed action plan (i.e. the artifact).

These findings highlight how an initial analogy, which forms the basis of the solution path proposed by designers, can impact the entire decision-making process. The idea of an initial idea disrupting the creative process is not new to the domain of design with prominent researchers such as Darke (1979), Cross (1994), and Buxton (2008) commenting on this issue, specifically with a focus on practical applications to addressing this disruption to idea generation. While the aforementioned work has

focused on addressing the issue of why previous experiences can limit the solution space it has been taken for granted and assumed to be an incontrovertible fact. What separates the work in this thesis from this previous research is our focus on the theoretical underpinnings of the limiting nature of a seed idea, in this case an initial analogy, and how it influences all stages of the design process. By examining the role of the initial analogy, we hope to understand why analogical persistence occurs in the first place. By understanding the context of this sort of fixation and how it manifests, we can begin to build specific hypotheses to target different approaches to eliminating the issue of analogical persistence.

In contrast to the practical focus of the above-mentioned researchers, the work of Smith et al. (1993) serves as a theoretical counterpoint. Smith et al. (1993) presented three experiments that examined how previous experience constrains the solution space, with all generated solutions being a variation of an initial exemplar. Participants were presented with sketches of aliens and were asked to generate as many solutions as possible in response to the design brief (create an alien that would live on a far away planet). It was found that the presence of these initial examples constrained the solution space, and that the solutions generated were heavily based on these initial examples. The work presented in chapters three and four of this thesis extends Smith et al. (1993) theoretical approach to understanding the constraining effects of experience on the design process by providing a bridge with the practical emphasis put forth by Darke (1979), Cross (1994) and Buxton (2008). The work presented takes a real-world application and develops a theoretical understanding of the decision-making process used by Interaction Designers in-situ.

10.1.2. Addressing Threats to the Validity of the Design Fixation Paradigm

Our first study highlighted how analogical persistence can lead to lower quality decisions, which in turn led to problematic designs. By taking a qualitative approach, we were able to gain insight into how Interaction Designers come to the decisions that they do in-situ. An alternative explanation to our conclusion that one initial analogy chosen at the outset influences the decision-making process, is that several analogies were considered, but only one analogy was taken to completion and that analogy was the only one remembered. An axiom of the scientific method is ruling out alternative hypotheses. A secondary study was conducted to test the validity of the issue of analogical persistence. Since the study presented in chapter 3 adopted a qualitative approach to examining design decision-making in Interaction Designers, the Design Fixation paradigm (Jansson & Smith, 1991) was employed as a quantitative

methodology in the subsequent study to allow us to manipulate the initial analogy and observe how that problematic analogy impacted the types of solutions generated. By using a different methodological approach we can employ methodological triangulation to replicate and validate analogical persistence (Morse, 1991). While the Design Fixation paradigm allowed us a level of control over the influence of the initial analogy, there were several threats to the external and internal validity of the paradigm that needed to be addressed before we could be confident that we were eliciting analogical persistence using Design Fixation.

10.1.2.1. External Validity

The largest issue with the Design Fixation paradigm has been its generalisability. In the past, using the Design Fixation paradigm with different design disciplines has led to inconsistent results when using a sample of Mechanical Engineering students results from the Design Fixation paradigm remain consistent. However, issues arise when attempting to apply the Design Fixation paradigm to a non-engineering based design discipline. Researchers such as Purcell and Gero (Purcell & Gero, 1991; Gero & Purcell, 1993; Purcell & Gero, 1996) have demonstrated that when using the Design Fixation paradigm with a non-engineering sample, in their case Architects & Interior Designers, there was a failure to replicate. These studies attributed their failure to replicate to a mismatch between the domain of the presented problem and the domain of the designer. Our work illustrated that their failure to replicate exhibited was not due to a domain mismatch, but rather the measure that they were employing was not sensitive enough to detect the influence of the flawed priming example. By using a more holistic approach to measuring fixation, such as the measures used by Chrysikou and Weisberg (2005), we were able to measure how much the Priming Analogy influenced the solutions that they generated.

10.1.2.2. Internal Validity

By employing the Design Fixation (Jansson & Smith, 1991) paradigm, we were able to manipulate the type of analogies that would serve as the foundation of the design decision-making process. This quantitative approach, while not as rich in data as the initial qualitative study, did allow us to tease apart the influence that various confounding variables have on the observed analogical persistence. In addition to the concerns regarding the generalisability of the Design Fixation paradigm there were also several threats to the internal validity. Chapter five addressed the issue of materials employed in the Design Fixation paradigm while chapter six addresses the confounding variable of familiarity.

The study presented in chapter five addressed the confounding issue of the

stimuli used in Design Fixation paradigm. Work by Purcell and Gero (Purcell & Gero, 1991; Purcell et al., 1993) highlighted that some of the results derived from the Design Fixation paradigm were specific to the stimuli presented.

To address this issue we generated new stimuli to present in our studies. Two sets of problems were generated because one set of new stimuli had been successfully used among Mechanical Engineers and differing design domains were the issue. One problem was based on the principles emphasised in Mechanical Engineering, while the other set of stimuli were based on Interaction Design principles. This allowed comparability between our study and previous studies on the topic of stimuli and the Design Fixation paradigm. By presenting participants with newly generated problems and accompanying flawed pictorial examples, we were able to illustrate that the results originally presented in chapter four were not a function of the stimuli used but rather were a function of analogical persistence. Chapter five illustrates, in the context of Interaction Designers, that the results using the Design Fixation paradigm validating our earlier qualitative findings were not a function of the stimuli used in chapter four.

While chapter five addressed the issue of materials as a confounding variable to the expression of analogical persistence, the stimuli were not the only threat to the internal validity of the Design Fixation paradigm. Another issue raised by researchers was the confounding variable of familiarity. Researchers such as Purcell & Gero (1993) have argued that the effect of the initial analogy measures by the Design Fixation paradigm is heavily influenced by one's familiarity with that particular problem. More specifically, the fixation measurements that are gathered can not be solely attributed to the presence of the provided Priming Analogy, but rather the fixation measures are an expression of both the problematic example and one's familiarity with the type of problem encountered. To be confident that the results generated in the Design Fixation paradigm were reflective of our manipulation we needed to address the confounding issue of familiarity.

To reject the hypothesis that the analogical persistence exhibited by the Design Fixation paradigm is a function of one's familiarity with the presented design problems, we presented each participant with two design problems of differing levels of familiarity. By presenting two differing problems we were able to compare the application and uses of unfamiliar and highly familiar problems. When the two problems were compared, it was found that familiarity was not a confounding variable to the Design Fixation paradigm.

While the Design Fixation is a useful paradigm which allows us to observe and

manipulate the analogies used in decision-making, it is not without its flaws. Issues with generalisability, stimuli, and confounding variables have been raised to undermine the validity of this paradigm. In chapters four through six we have taken each of these concerns and addressed each one individually. By tackling each threat to the validity of the DF paradigm we can confidently use this paradigm as tool for validation of analogical persistence and to investigate different types of analogies.

10.1.3. How Different Analogies can Influence Analogical Persistence

By using the Design Fixation paradigm, we can manipulate and directly observe the influence of the initial analogy on the overall decision-making process by examining the types of solutions Interaction Designers generate under different conditions. The issue though with the Design Fixation paradigm in its current state is that it can only account for one particular type of Priming Analogy: examples of previous work. Researchers such as Herring et al., (2009), Linsey (2008), and VanLehn (1998) discuss different sources of inspiration that designers draw upon when engaging with the design process. While drawing on previous examples is a valid method to engage with the design process, Interaction Designers also draw upon their own experiences of previous design problems (as discussed in chapter three). While participants in the fixation condition in the Design Fixation paradigm are relying upon the provided Priming Analogy, participants in the control condition are using Self-Generated Analogies to begin the decision-making process. By comparing and contrasting the solutions generated between these two different types of analogies, we were able to see that Interaction Designers engage with each type of analogy using different behaviours.

The current state of the Design Fixation paradigm allows us to observe how a provided Priming Analogy influences the decision-making process by comparing how similar the final solutions, generated by participants, are to the initial provided analogy. In the Brief Only condition, there is no provided Priming Analogy, so we have no idea to what level the initial analogy participants have generated has influenced their decision-making process. To address this issue, we paired a think-aloud protocol with the Design Fixation paradigm. By capturing the verbalisations of participants in both the Brief & Flawed Example condition and the Brief Only condition, we were able to compare and contrast the different ways in which participants used the different types of analogies in their decision-making. Results indicated several behaviours that Interaction Designers employed during the Design Fixation study. When using Self-Generated Analogies, Interaction Designers perceived the analogies as useful and remembered only the best characteristics of the analogy.

When examining how participants employed the provided primed example, it was found that the participants perceived the flawed pictorial examples as the ‘best’ solution to the design brief. This problematic behaviour continued throughout the evaluation phase of the decision-making process, where the ‘best’ solution from the generated solutions was the sketch most similar to the provided Priming Analogy. Both of these behaviours, among others discussed in chapter 7, are problematic because they underline the disconnect between how analogical persistence occurs and current ways to address those issues. Cross (1994) discussed several techniques that are commonly used in design practice that address the constraining effect of a particular idea. Techniques such as the ‘Why,Why,Why’ method, in which designers ask themselves a series of probing questions aimed at uncovering problematic thought processes that led to problematic designs, do not accomplish what they set out to do if the designer’s metacognition is completely disconnected from the issues surrounding the design problem at hand.

While Chrysikou and Weisberg (2005) conducted a similar study the work presented in chapter 7, differentiates itself by the scope of the analysis undertaken. Chrysikou and Weisberg (2005) only captured and analysed verbal protocols in the fixation condition. We know from previous studies (e.g. chapter three, VanLehn, 1998) that designers can draw upon other sources of inspiration to engage with the design process. By extending the capturing of participants verbalisations to include the Self-Generated Analogies that participants were using in the Brief Only condition, we gained more understanding of how different analogies can impact the expression of analogical persistence.

10.1.4. Particular Design Methods can Increase Analogical Persistence by Fostering Maladaptive Behaviours

The goal of this thesis was to use our findings about analogical persistence to mitigate the potential pitfalls and foster higher quality decision-making in Interaction Designers. Principles from both the areas of Reflection (Schon, 1983) and Design Rationale (Lee & Lai, 1991) were employed in the hopes of retaining the benefits of using analogies in design decision-making without the limitations. Chapter 8 demonstrated that when participants were encouraged to better understand the solution space by reflecting on the analogies they were using, they produced solutions which were far more like the Priming Analogy. Therefore, attempting to mitigate analogical persistence actually made it worse.

Previous work has attempted to eliminate the effect of a primed example, using

the Design Fixation paradigm, but few have been successful in these endeavors. Chrysikou and Weisberg (2005) were able to mitigate the inclusion of problematic elements of the priming example by providing participants with a list containing all of the issues contained within the flawed pictorial example. While this manipulation was successful in this setting, the applicability of this method outside of a laboratory is fairly limited. By building on this idea, we hypothesised that using principles from the literature on Reflection and Design Rationale would replicate Chrysikou & Weisberg (2005) in a more ecologically valid fashion.

Results from this study illustrated that encouraging participants to reflect on the strengths and weaknesses of their initial analogies increased analogical persistence. Participants who were encouraged to reflect and dissect their initial analogies produced solutions that included far more problematic elements when compared to participants who were only allowed to sketch. Follow-up studies highlighted, and validated, several behaviours, that the experimental paradigm encouraged which resulted in increased analogical persistence.

Chapters 8 & 9 highlight an important assumption regarding the implied usefulness of some of the methods used by Interaction Designers in-situ to overcome the limiting nature of previous experiences. The area of Design Rationale has long been seen as a way to provide a framework from which designers can make more informed and higher quality design decisions (Karsenty, 1996; Zannier & Maurer, 2005). The use of Reflection (both in-action & on-action) has also been seen as a way to understand the solution space, and through that structured understanding identify and remove problematic features from the construction of the artefact (Louridas & Loucopoulos, 2000). The studies presented over chapters 8 & 9 have brought some of these assumptions into question by highlighting how the use of these methods can increase fixation.

While both Reflection and Design Rationale are commonly used in the design community as methods to make higher quality design decisions (Karsenty, 1996; Zannier & Maurer, 2005), the intersection of Reflection and Design Rationale is not an area that has garnered much attention from the design community. Both of these methods are concerned with encouraging the designer to understand, in greater detail, what are the strengths of weaknesses of their solution/design/artefact. Through these methods, designers can identify the particular issues inherent to the artifact and consequently address them. Where these two methods differ is in the continuation of the process of refinement. In the case of Reflection, this is an immediate cycle of reflection,

reworking, and reflection again. The locus of the Reflection approach to improving the design solution is on an individual level (Louridas & Loucopoulos, 2000). Alternatively, the Design Rationale approach is focused on the wider design system, not just that of the individual designer. By understanding and documenting the design space, the goal is for knowledge to be reused by other individuals to aid them in their decision-making when confronted with a similar situation (Ramesh & Dhar, 1992). While the locus of the two methods is different (individual refinement vs. systems approach) the primary goal is the same: to produce a higher quality artefact by improving understanding of the current state of the solution space. It is possible that these two differing loci have kept the research investigating this intersection to a minimum.

The intersection of these two design methods may be a cause of increased analogical persistence. While the initial goal of the two methods is similar; their application differs. Each of these design methods has been discussed with their own unique end-user in mind. It is possible that while the primary goals are similar the different approaches are too disparate to combine in an ecologically valid, meaningful approach to mitigating analogical persistence. By using these two methods in conjunction it is possible that we are undermining each methods ability to fully understand the solution space, which primes the initial analogy to an even greater extent than before. To understand how the overlapping goals and the disparate loci of these methods interact, a more focused study investigating this particular research question needs to be conducted.

While the two methods that were employed in these studies to help Interaction Designers make higher quality design decisions are commonplace they are not the only methods used in industry that may help to eliminate the effects of analogical persistence. Tools such as Design Consequences (Reichelt, 2007) or Parallel Design (Myles, 2010) are promising techniques that may be better suited at eliminating the problematic elements of the initial analogy.

10.2. Limitations & Future Directions

The aim of this thesis was to investigate the issue of analogical persistence, its causes, influences, and possible methods to mitigate it. Different methodologies, both quantitative and qualitative, were used to investigate analogical persistence. While these differing methods were used to provide methodological triangulation some limiting factors regarding those methods need to be addressed.

10.2.1. Limitations

To probe and manipulate analogical persistence we have employed the Design Fixation paradigm. This paradigm provided us with a quantitative approach that allowed us to directly measure the level of influence that the initial analogy had on the overall design decision-making process. While this suited the needs of our study, there are limitations inherent to this approach.

The largest issue with using the Design Fixation paradigm, as it currently stands, is one of ecological validity. While the early portion of this dissertation addressed a range of threats to the validity to the Design Fixation paradigm a fundamental drawback is one of generalising our findings from the Design Fixation paradigm to how designers approach decision-making in a 'real-world setting'. Factors such as extreme time constraints and the artificial nature of some of the design problems do raise some questions as to how we can draw conclusions in terms of how designers use analogies in a meaningful way. We have tried to address some of these issues by complementing this research with a qualitative study, as described in chapter three, in which participants described how they engaged in the decision-making process for a recent design problem they had encountered in their work, be it academic or industry-based.

Many researchers have discussed how the design process is experimental and exploratory in nature and that adopting the Design Fixation paradigm allows only a snapshot of the design process (Buxton, 2008; Cross, 1994). This work does not assume that there is a right or wrong solution; but rather, provides some insight into the behaviours that participants engage with that may contribute to the observed analogical persistence. The logic being that the time constraints imposed by the Design Fixation paradigm do not provide a true representation of the design decision-making process employed by Interaction Designers so if we extend the time that participants have to engage with the problem, then issues of analogical persistence would be addressed as designers explored the solution space and attempted different solutions. If we were to look at our results only in the context of the Design Fixation paradigm, then this may be a valid concern. However, when our quantitative results are taken in the context of qualitative findings presented in chapter three, we see that the issue of analogical persistence is not simply a function of the Design Fixation paradigm. It is an issue that plagues designers with a more realistic time frame to engage with, and explore the total solution space.

Another issue with the validity of generalising our results from the Design Fixation studies is the number of designers involved. Under the Design Fixation

paradigm participating designers work individually on the provided design brief. The isolated nature of the design process is being emphasised by virtue of the construction of the Design Fixation paradigm. It may be argued that many of the issues inherent to analogical persistence would be addressed when examined in a group setting. While the idea of the lone designer is seen as an unrealistic representation of what occurs in industry, it is worth noting that the participants from the study presented in chapter three were all design practitioners and that the aspects of the design that they worked on were in isolation of the rest of the design system. While uncommon the practice of the 'lone designer' is still active in industry. Prominent researchers such as Donald Norman have discussed the topic of 'design by committee' and championing the return to the idea of 'design dictator' (Norman, 2005). Norman describes how sometimes when design decisions are made by one individual, rather than by a consortium, the usability can improve, and 'design by committee' can in some instances be harmful to the overall design process. The isolated aspect of the participations in this research is a valid concern, but the idea of design decision-making from an individual perspective is not without precedent. The interaction between analogical persistence and groups of designers is an important area that should be addressed in future research. While Chapter 8 & 9 highlighted the problem with using individual focused design methods to overcome analogical persistence, the use of group focused design methods such as Design Consequences (Reichelt, 2007) or Parallel Design (Myles, 2010) may be a promising next step in examining ecologically valid design methods to overcome analogical persistence.

10.2.2. Future Directions

This dissertation closes with an examination of a possible way to mitigate some of the problematic elements of analogical persistence. The primary goal of the last portion of the thesis was to examine ecologically appropriate tools that Interaction Designers could use in-situ to aid in reducing the problematic elements of analogical persistence. By looking at tools such as Structured Reflection (encouraged reflection using principles from Design Rationale) we were hoping to find a design method that suited our needs. Instead, the intersection of Reflection and Design Rationale actually created more problems than it solved by actually fostering analogical persistence. As briefly discussed in the limitations section, by shifting our focus away from the individual designer to design tools with a collaborative component, we may be more likely to mitigate analogical persistence. Both Design Consequences (Reichelt, 2007) and Parallel Design (Myles, 2010) share the same goal of eliminating problematic elements

from the artefact by encouraging a greater understanding of the design space, but rather than encourage reflection on a personal level, a secondary designer is used to prompt and encourage the designer to engage with the problematic elements of the design. Both of these tools could be modified so that the reflection on the artefact could be shifted to the analogies that are being used in the decision-making process.

Design Consequences is a collaborative design tool devised by Reichelt (2007) which focuses on an iterative design refinement process between several members of the design team. The Design Consequences exercise begins with the team, of no more than eight individuals, being briefed on the design problem as well as provided with several examples of the type of output that the designers are expecting to get out of the exercise. After this initial introduction and brief, each designer sketches for seven minutes a possible solution to the provided design brief. Next each designer passes their solution to the designer directly to their right. The next designer then further refines/builds upon that design for another seven minutes, with the opportunity to ask the previous designer for any clarification regarding their design. At the end of that design interval, each designer must present the sketch they are currently working on to the group of designers to receive group feedback. The strength of the Design Consequences tool is that it hinges on the secondary designer continuing the design process as a way to refine the proposed solution by building on the strengths of the idea and eliminating the problematic characteristics. At first glance this particular design tool seems to fall prey to some of the issues raised by this dissertation, i.e. the priming effect of example solutions; however, this particular tool aims to address issues like that through the different understanding of the solution space that your fellow designer has. The locus of this technique is not grounded in understanding the design space in greater detail, but rather using the secondary designer's different understanding of the solution space to highlight information that may have been suppressed by the original designers understanding of the solution space.

Parallel Design (Meyles, 2010) is another design tool that leverages different perspectives on the design space to eliminate problematic elements from the proposed artefact and make better informed design decisions. Under the Parallel Design method designers are assigned to one of several small design teams (the goal is to have groups of roughly equivalent skill sets and levels). All of the design teams are then briefed on the design problem as well as the goals of the design session. Each of the small design teams will work on their ideas in parallel. No communication is allowed between the different design teams. After a pre-determined time limit, each design team comes

together and presents their team's idea to the larger grouping of designers. Feedback is given on each design with the goal of one particular idea being selected to be continued to the next stage of development. This iterative design process combined with the efficiency of parallel design groups provides a foundation from a method in which problematic characteristics of the proposed solution are removed from the artefact.

Both Parallel Design and Design Consequences leverage the different understandings of the same solution provided by different designers. It is hoped that this feedback from fellow designers can be used as a source to make better design decisions, which could mitigate the potential pitfalls of analogical persistence on the decision-making process of Interaction Designers.

10.3. Final Conclusions

This thesis challenges two important views that are currently held about design decision-making. Firstly, from a theoretical perspective the work presented over the previous nine chapters has tested the current view that the analogies are simply used in the first stage of decision-making to scope the problem space and quickly engage with the problem. Researchers, such as Klein (1999), have postulated that the issues inherent to these analogies are refined and removed over later stages of decision-making. Our work highlights the fact that problematic characteristics can persist across the entire decision-making process from idea generation through to solution selection. Secondly, from a practical perspective, we have drawn attention to the fact that some of the design methods currently employed to aid in improving design decisions can actually increase analogical persistence.

This thesis provides a strong body of evidence to challenge some of the theoretical and practical assumptions we have of the decision-making processes employed by Interaction Designers and provide a basis for future design tools aimed at helping Interaction Designers come to higher quality decisions.

11. References

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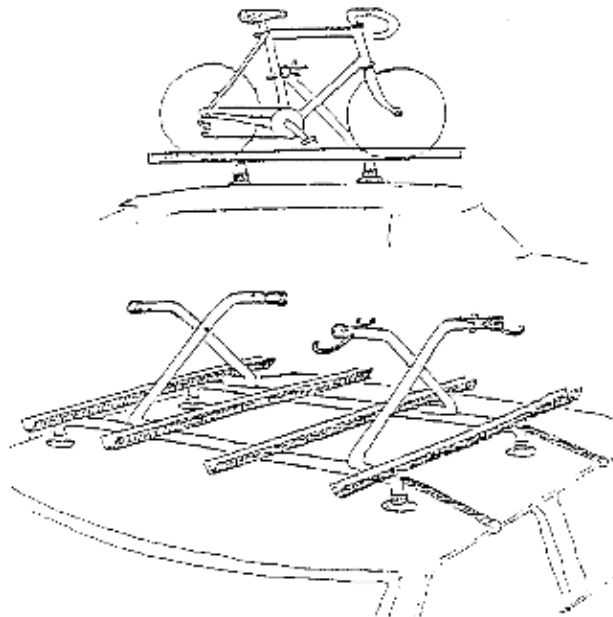
12. Appendix A: Materials for Chapter 4

The Bicycle Rack Problem

Brief: Design a car-mounted bicycle rack. Your proposed solution must satisfy the following issues: 1) easy mounting of at least three bicycles; 2) easy mounting of the rack; 3) the proposed bicycle rack cannot harm the bike or the car; 4) the rack must be versatile for all makes of both bikes and cars.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example of a present day bike rack. The bicycle is set in the rails and the vinyl coated hook is attached to the seat tube of the bike, and then the hook is tightened down by hand with a wing nut. One should note the difficult in mounting the middle bikes on the rack.

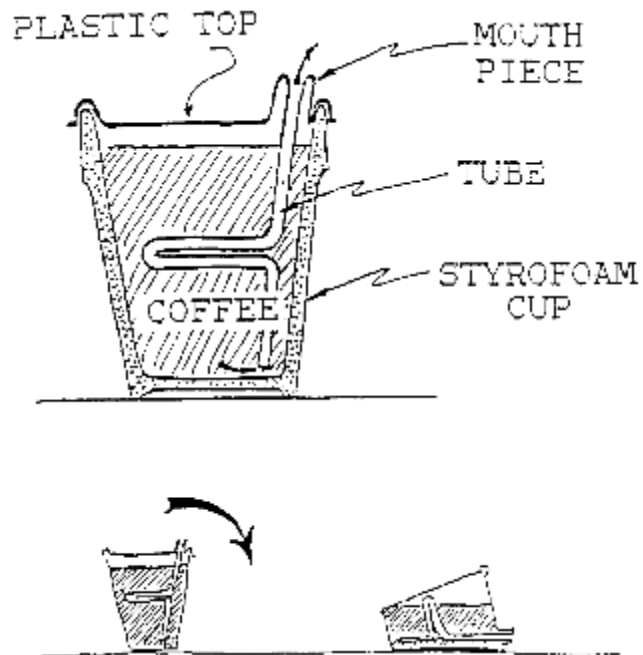


The Spill Proof Coffee Cup

Brief: The goal of this problem is to design an inexpensive, disposable, spill-proof coffee cup. The proposed solutions must satisfy the following issues: 1) The proposed solution must be operable by one hand; 2) must be durable; 3) there must be no straws or mouthpieces included in the proposed solution.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

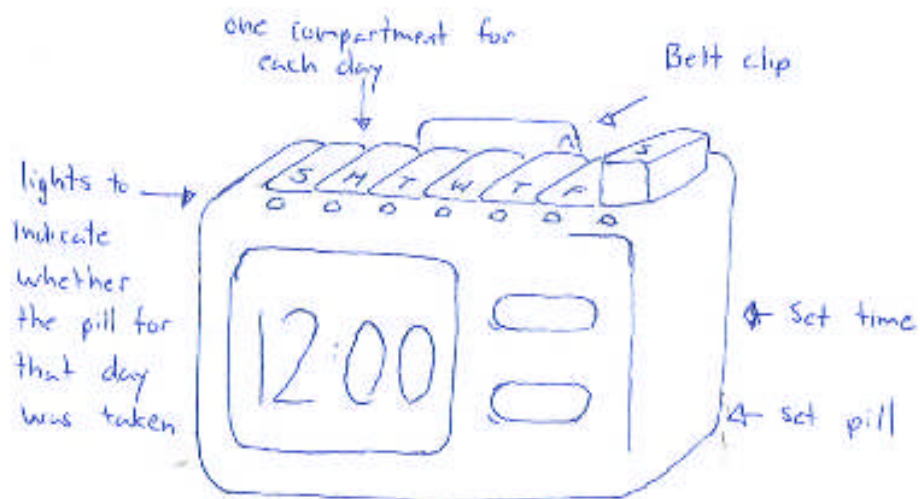


Medicine Dispenser/ Reminder for Elderly Individuals

Brief: Design an apparatus that will dispense as well as remind a patient when to take their medications. The following issues must be addressed in the proposed solutions: 1) Remind the individual which medication to take, 2) Keep track of medication taken, 3) Device must be able to alert elderly individuals who suffer from a range of sensory impairments such as Hearing difficulties and being short-sighted, 4) Must be able to handle medication at least two different time periods in one day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

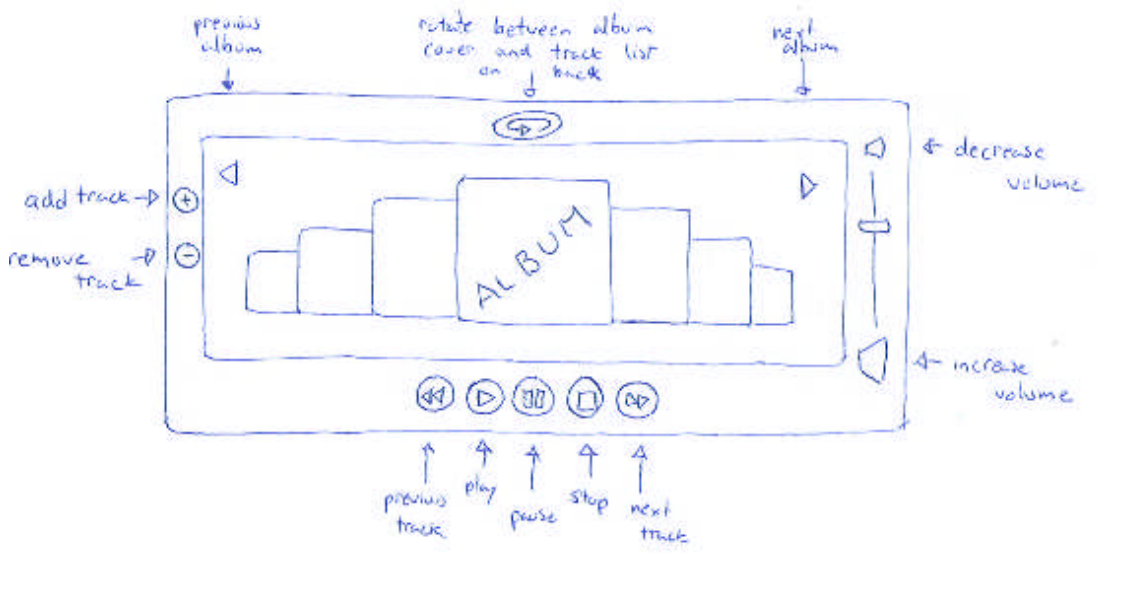


Digital music library manager

Brief: Design a programme, which will organize and play digital music on an old computer which has limited resources. This programme is targeted at older computers so a minimal interface is necessary. The following issues must be addressed in the proposed solutions: 1) Unnecessary graphics should be avoided 2) Buttons be kept to minimum 3) Be able to add and delete tracks 4) Display the current playing song 5) Manage the volume 6) Be able to navigate to other tracks in the collection 7) Be able to Stop, Pause, and Play tracks.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.



Bike Rack Problem

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, type of car, tire railings, suction cups, and attachment mechanisms as example	0-1
Reproductive Similarity	1) Use of top of the car, 2) use of suction cups, 3) use of tire railings, 4) use of the same type of sketch angle, 5) use of same type of car roof as example	0-5
Analogical Similarity	1) Alternative ways to attach car, instead of suction cups, 2) Alternative ways to secure bike on the rack	0-2
Intentional flaws	The generation of a top-mount design	0-1
Unintentional flaws	1) The use of suction cups to hold rack on car, 2) placing rack in vertical position	0-2

Spill-proof coffee cup

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, and angle as example design, as well as styrofoam cup with a mouthpiece and straw	0-1
Reproductive Similarity	1) Use of straw, 2) use of mouthpiece (extension of cup lid), 3) use of overflow device inside of cup (bent straw), 4) use of the same type of sketch angle, 5) use of same type of sketch pattern (double layer cup)	0-5
Analogical Similarity	1) Alternative ways to prevent overflowing instead of bent straw 2) alternative ways to insulate cup	0-2
Intentional flaws	1) use of straw that would leak, 2) styrofoam, squeezable cup, 3) hot liquid coming uncooled from the straw	0-3
Unintentional flaws	1) base of the cup is narrower than the top 2) a straw that is permanently attached to the lid, making it not flexible during use	0-2

Medicine Dispenser

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) Top mounted compartments, 2) same sketch angle, 3) one compartment for each day, 4) Large clock display 5) same placement of controls	0-5
Analogical Similarity	1) Alternative ways to provide reminder in single unit (eg. vibration), 2) alternative ways to dispense medicine (isolated compartments)	0-2
Intentional flaws	1)one compartment for each day, 2) visual reminders for visually impaired population	0-2
Unintentional flaws	1) ambiguous controls (simply copy set time and set pill buttons) 2) no notification for people with visual impairments (fixate on light for hearing impaired)	0-2

Music Player

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) use of album 2) vertical volume bar 3) use of excessive controls, 4) use of cover flow 5) use of arrows to navigate albums in linear fashion 6) placement of track control (add/remove buttons)	0-6
Analogical Similarity	1) Alternative ways to display playing music (different method but still with controls under track information), 2) alternative ways to navigate music collection (tracks separate and grouped by album)	0-2
Intentional flaws	1) Excessive controls, 2) excessive visual embellishments, 3) counterintuitive volume	0-3
Unintentional flaws	1) not able to search, 2) no display for current track	0-2

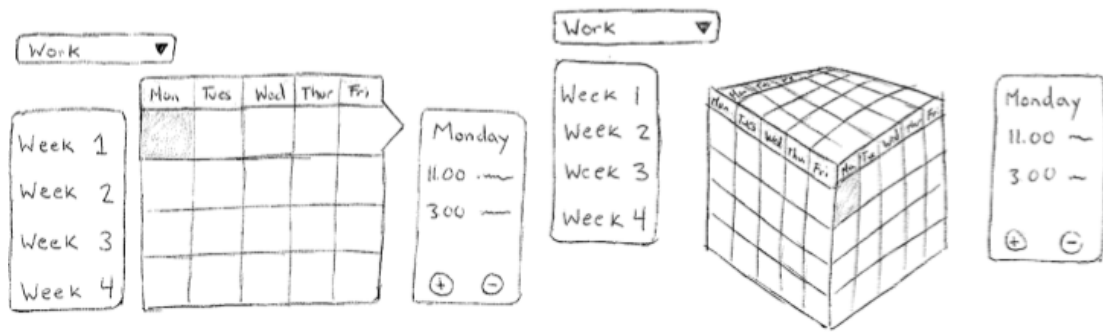
13. Appendix B: Materials used in Chapter 5

Calendar

Brief: Simple home based computers are able to handle complex graphics but yet not all applications take advantage of this fact. Design a new calendar system that keeps track of appointments as well as display the current date. Proposed designs must meet several requirements: 1) able to add/remove appointments, 2) be able to navigate between all twelve months 3) display current date as well as appointments for that day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

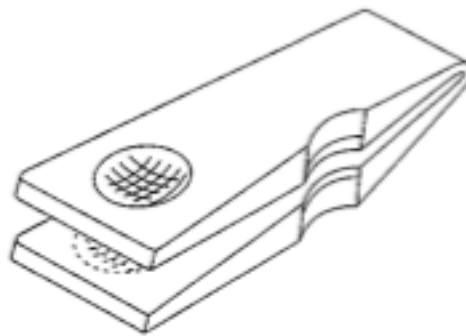


Nail Clipper

Cutting and cleaning our nails is a necessary and common activity, but despite of it's commonality people can still use upwards of three different devices to cut their fingernails, cut their toenails, and clean their nails.. Design a single device which is able to accomplish these three activities. Each proposed design must conforms to the following requirements: 1) the use of minimal components, 2) is able to finger as well as toe nails, 3) is able to clean underneath the nails.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.



Cube-like Calendar Problem Scoring Criteria

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) Cube like rotation 2) Simple grid system 3) Drop down menu for multiple calendars 4) Two drawings to illustrated calendar navigation	0-4
Analogical Similarity	1) Use of 3D view 2) Floating calendar sections 3) Non-linear navigation of calendar months	0-3
Reproduced Flaws	1) Static weeks will not work, 2) Ambiguous navigation between months, 3) No current display for month/year, 4) Secondary information to display detailed information	0-4

Nail Clipper Problem Scoring Criteria

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) Use of nail clipper on side 2) Use of grip 3) Same sketch angle	0-3
Analogical Similarity	1) Use of single lever system 2) Separation of pressure and cutting features (i.e. clipper on side but pressure applied on top)	0-2
Reproduced Flaws	1) Single Cantilever, 2) No cleaning	0-2

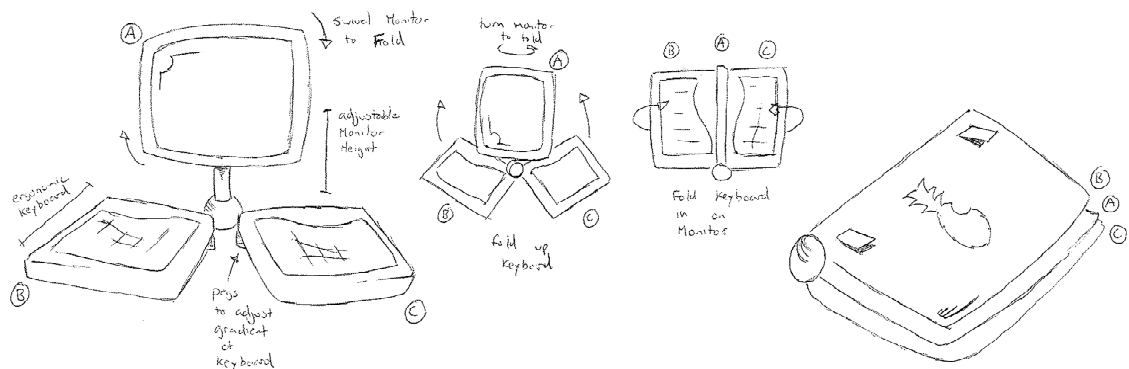
14. Appendix C: Materials From the Pilot Study in Chapter 6

Ergonomic Laptop – Based on US patent (US5278779)

Brief: The occurrence of Repetitive Strain Injury (RSI) is on the increase as the use of poorly designed input devices are used, with laptops being particularly bad. Redesign a laptop that is more in keeping with ergonomic considerations. The primary goal of this redesign is to reduce the strain on users and reduce ergonomic related injuries. Each proposed redesign must take into account the following criteria: 1) Reduce strain on the user, 2) durable build, 3) easily portable.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

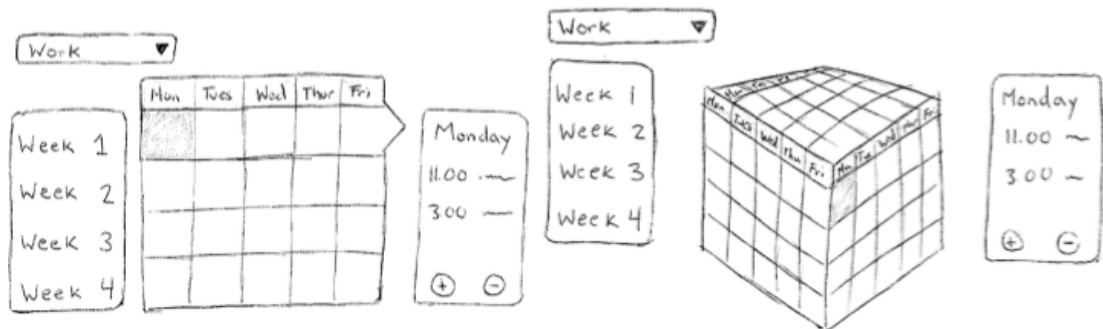


Calendar

Brief: Simple home-based computers are able to handle complex graphics but yet not all applications take advantage of this fact. Design a new calendar system that keeps track of appointments as well as display the current date. Proposed designs must meet several requirements: 1) able to add/remove appointments, 2) be able to navigate between all twelve months 3) display current date as well as appointments for that day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example solution to show how each design should be presented.

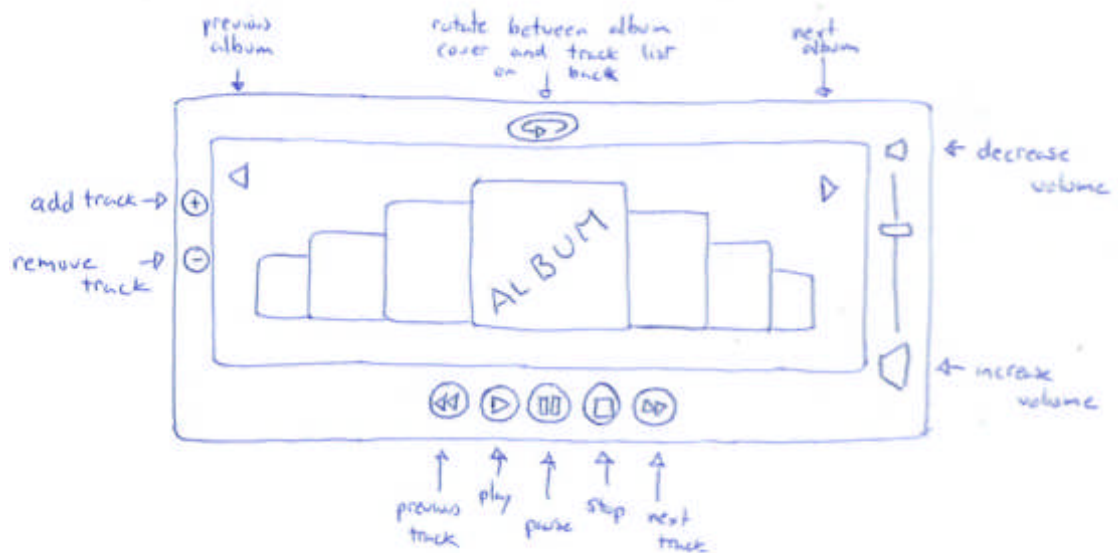


Music Player

Brief: Design a programme, which will organize and play digital music on an old computer which has limited resources. This programme is targeted at older computers so a minimal interface is necessary. The following issues must be addressed in the proposed solutions: 1) Unnecessary graphics should be avoided 2) Buttons be kept to minimum 3) Be able to add and delete tracks 4) Display the current playing song 5) Manage the volume 6) Be able to navigate to other tracks in the collection 7) Be able to Stop, Pause, and Play tracks.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

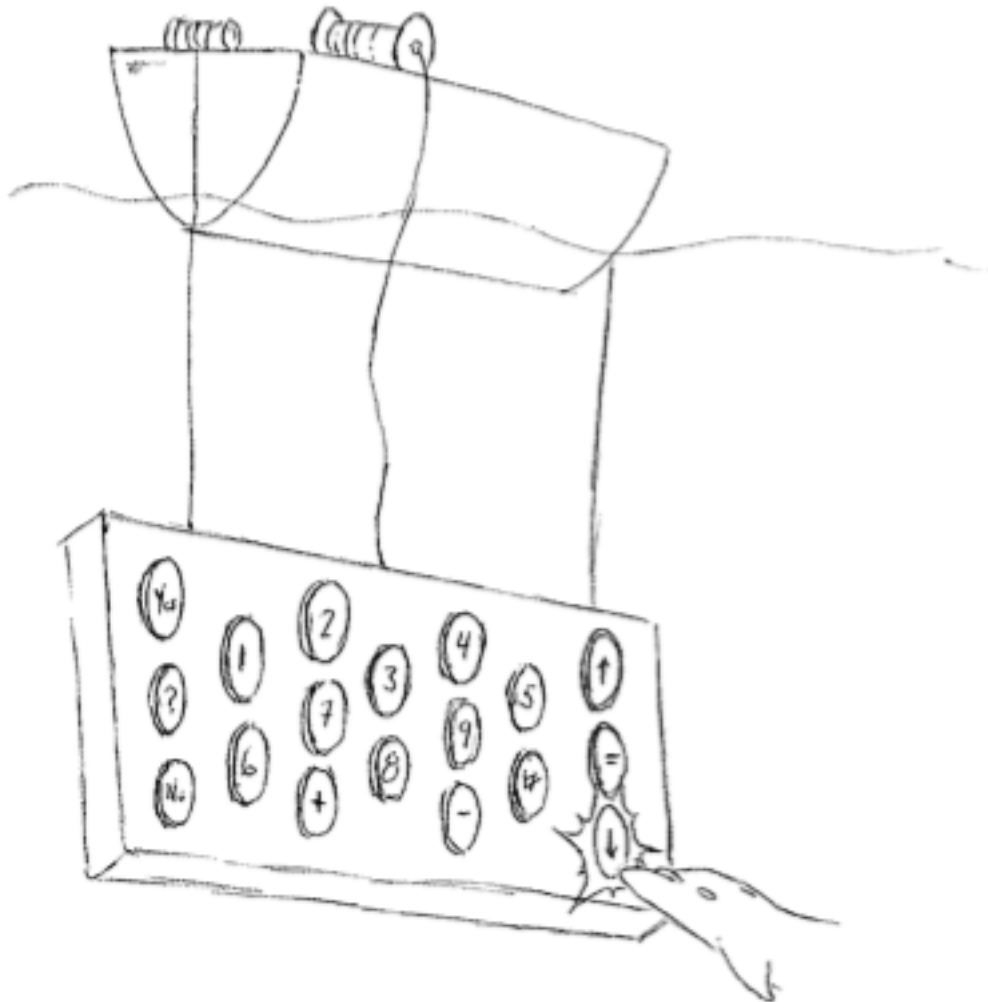


Marine Mammal communication system (based on US patent US5392735)

Brief: Although the surface of the earth is mostly covered by oceans little is known of what happens beneath the waves. Marine Biologists are interested in developing a system to communicate with intelligent marine mammals in hope of learning more about the ecology of the oceans. The following issues must be taken in to considerations in any and all proposed solutions: 1) be able to send and receive messages, 2) Be able to deal with a range of questions ranging form simple yes/no questions to more complex questions such as 'how many are in your pod?', 3) Be able to communicate at various depths

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example solution to show how each design should be presented.

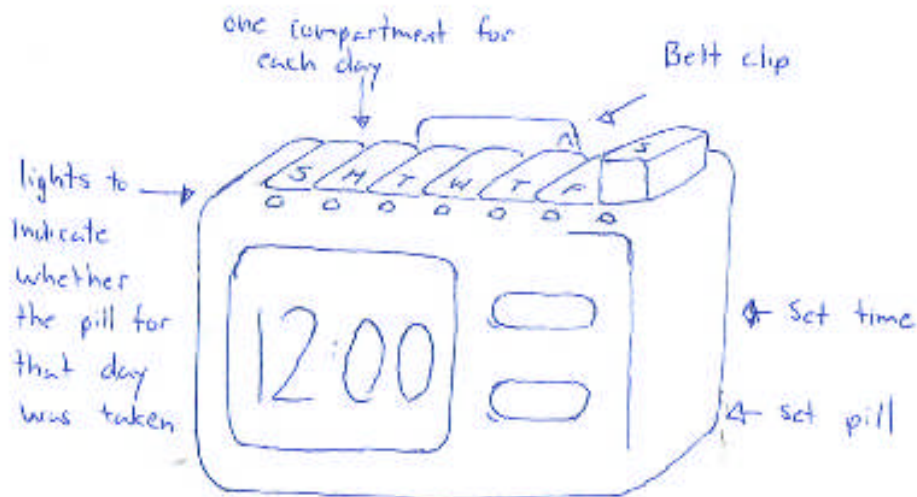


Medicine Dispenser

Brief: Design an apparatus that will dispense as well as remind a patient when to take their medications. The following issues must be addressed in the proposed solutions: 1) Remind the individual which medication to take, 2) Keep track of medication taken, 3) Device must be able to alert elderly individuals who suffer from a range of sensory impairments such as Hearing difficulties and being short-sighted, 4) Must be able to handle medication at least two different time periods in one day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like

Example: Below is an example solution to show how each design should be presented.

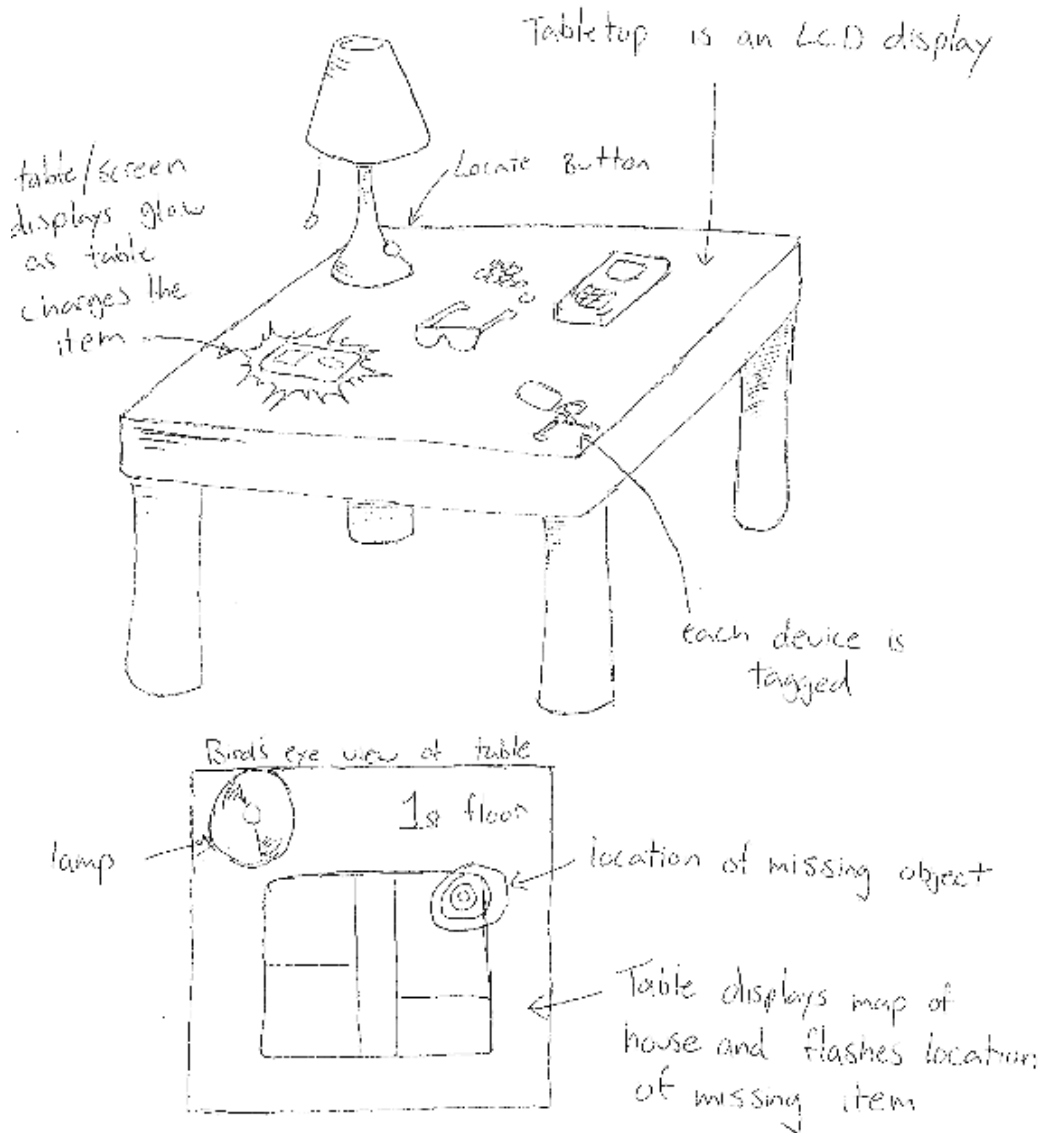


Lost Key Locater

With an ever growing number of items that people can carry on their person at one time it is no surprise that many of these items are misplaced and can be difficult at times to locate. Design a system that organizes and can help locate items when they are misplaced in the household. Proposed designs must conform to the following criteria: 1) Must be able to help organise common items that people carry on their person such as mobile phones, MP3 player, glasses and keys. 2) Be able to locate any of those items if misplace.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have twenty-five minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example solution to show how each design should be presented.



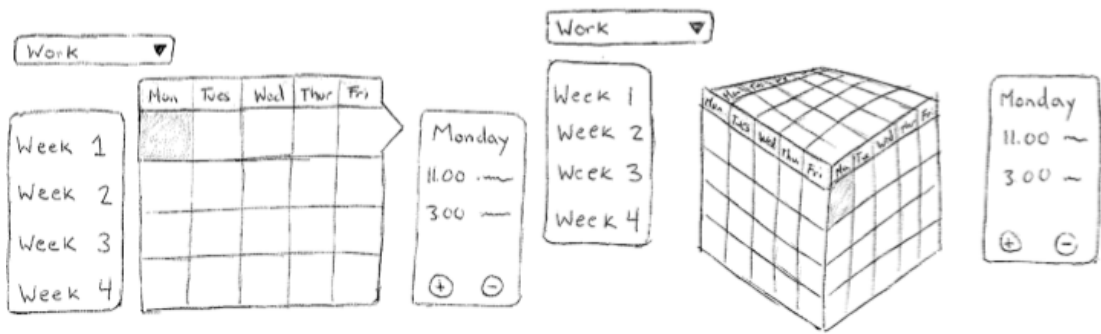
15. Appendix D: Materials used in Chapter 6 & 7

Calendar

Brief: Simple home-based computers are able to handle complex graphics but yet not all applications take advantage of this fact. Design a new calendar system that keeps track of appointments as well as display the current date. Proposed designs must meet several requirements: 1) able to add/remove appointments, 2) be able to navigate between all twelve months 3) display current date as well as appointments for that day.

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example solution to show how each design should be presented.



Cube-like Calendar Problem Scoring Criteria

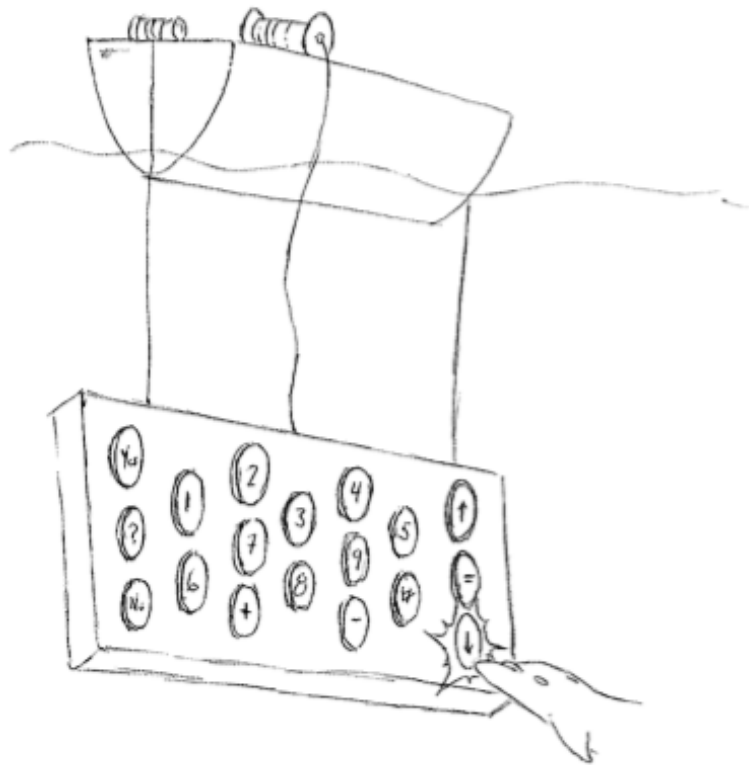
Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) Cube like rotation 2) Simple grid system 3) Drop down menu for multiple calendars 4) Two drawings to illustrated calendar navigation	0-4
Analogical Similarity	1) Use of 3D view 2) Floating calendar sections 3) Non-linear navigation of calendar months	0-3
Reproduced Flaws	1) Static weeks will not work, 2) Ambiguous navigation between months, 3) No current display for month/year, 4) Secondary information to display detailed information	0-4

Marine Mammal communication system (based on US patent US5392735)

Brief: Although the surface of the earth is mostly covered by oceans little is known of what happens beneath the waves. Marine Biologists are interested in developing a system to communicate with intelligent marine mammals in hope of learning more about the ecology of the oceans. The following issues must be taken in to considerations in any and all proposed solutions: 1) be able to send and receive messages, 2) Be able to deal with a range of questions ranging form simple yes/no questions to more complex questions such as 'how many are in your pod?', 3) Be able to communicate at various depths

Proposed solutions need not be detailed or complete. A simple sketch complete with annotations is all that is required. You have fifteen minutes to complete this exercise. You are not limited to one solution. You may propose as many solutions as you would like.

Example: Below is an example solution to show how each design should be presented.



Marine Mammal Communication System problem scoring criteria

Measure	Definition	Score
Direct Physical Similarity	Same shapes, patterns, controls, layout, and features as example	0-1
Reproductive Similarity	1) Same sketch angle, 2) Use of board and boat, 3) Illuminated Circular buttons, 4) Inclusion of Dolphin	0-4
Analogical Similarity	1) Use of touch sensitive buttons to communicate, 2) Two separate units, 3) Inclusion of animal to illustrate use	0-3
Reproduced Flaws	1) Lack of proper communication buttons, 2) Inappropriate feedback for mammals (sound would be more appropriate)	0-2