

Analogies in Design Decision-Making

Stephen T. Hassard
UCL Interaction Centre
UCL, Gower Street
London, WC1E 6BT
+44 (0)20 7679 0683

s.hassard@ucl.ac.uk

Ann Blandford
UCL Interaction Centre
UCL, Gower Street
London, WC1E 6BT
+44 (0)20 7679 0688

a.blandford@ucl.ac.uk

Anna L. Cox
UCL Interaction Centre
UCL, Gower Street
London, WC1E 6BT
+44 (0)20 7679 0687

anna.cox@ucl.ac.uk

ABSTRACT

Design is becoming the decisive factor in whether a product is a commercial success, like Windows XP, or a critical failure, like Microsoft Bob. To leverage this factor we need to have a greater understanding of the cognitive processes behind Interaction Design. While there are a wide array of disciplines that fall under the umbrella of design, there are several cognitive processes that are common to all strata of design. Decision Making has been identified as an important factor in the design process but remains woefully under-explored. This paper aims to understand Design Decision-making (DDM) in the light of more recent developments in the wider decision-making field. Two studies were conducted, consisting of an initial theoretical thematic analysis to update the outdated models of design decision-making, and a follow-up quantitative study to validate the findings of the first study. Results indicate that while the current models of DDM do well to explain elements of the decision-making process they do not account for such things as the persistence of analogies across all stages of the decision-making process.

Categories and Subject Descriptors

D.2.2 [Design Tools and Techniques]: User Interfaces

General Terms

Design

Keywords

Design Decision Making, Naturalistic Decision Making, Recognition-Primed Decision Making, Interaction Design

1. INTRODUCTION

There is a wide set of cognitive processes involved in the process of design [35]. These cognitive skills range from problem structuring to decision-making. While many of these have been studied in great detail, our understanding of Design Decision-Making (DDM) is still quite naive and poorly understood in comparison to other cognitive skills involved in the design process [35]. The increased prevalence of viewing design as a complex decision-making process has caused many researchers to realise that each design iteration reflects the designer's choice in a path to satisfy the design goals [22]. A

designer can be faced with a high-level decision like which interaction modality to use (Wii vs. PS3) or a more detailed decision like the spacing between elements of the interface.

A recent study by Tang et al. [32] illustrates the need for a greater understanding of the DDM process by highlighting how the fallibility of faulty design decision-making can lead to markedly poorer quality designs. While research into the role of decision-making in Interaction Design has been an area of interest for some time (e.g. [7]), the models used are outdated and incomplete. This paper aims to update some of the current thinking on Design Decision-Making with a particular focus on the failure of these models to address such important phenomena as the impact that analogies have on the entire DDM process.

The focus of the first study was gaining a better understanding of DDM by examining it in the light of more recent models of decision-making. The most recent iteration of the Recognition Primed Decision-Making model (RPD) [11] was used to provide a framework for investigating Design Decision-Making, as it is the most typical model within its domain [19]. A key finding from this first study was that interaction designers rely on an initial analogy even in the face of overwhelming evidence of the inappropriateness of that particular analogy. This over-reliance had a knock on effect to all stages of the decision-making process, which the RPD model could not account for. A follow up study was conducted to provide quantitative evidence for this type of behaviour. The Design Fixation (DF) paradigm [8] was employed to probe the analogical over-reliance exhibited. A key concern that needed to be addressed with the use of the DF paradigm is its generalisability. Previously Design Fixation could only be replicated among an engineering population [27]. By replicating Design Fixation among Interaction Designers we aim to address the issues of the generalisability of DF as well as using quantitative methods to validate the analogical over-reliance exhibited in study 1.

1.1 Decision Making & Interaction Design

To date the research which intersects between Design Decision-Making and the area of Interaction Design is fairly limited. One of the earliest papers to investigate the importance of decision-making in interface design was Hammond et al. [7] which focused not so much on the processes involved but rather the context of the user in the decision-making process. The work that Klein et al. ([10] & [9]) was conducting served as a theoretical counterpoint to the focus centric work of Hammond by focusing less on the outputs and more on the processes involved in the decision-making of interface design. The work of Klein has formed much of the basis of DDM in interaction design with work such as Miller & Woods [20] and Mitchell et al., [21] building on Klein's initial work. Some of the more

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recent work in the area (e.g. [34]) has started to widen the theoretical base from that used by previous work. This work to date has focused on establishing a theoretical framework from which decision-making in interaction designers can be understood. At this stage in the maturity of the research area we need to branch out from establishing a framework and start to examine the implications we can draw from our understanding so far.

1.2 Naturalistic Decision Making

When examining the area of design decision-making there have been, traditionally, two main theoretical perspectives that could be adopted: the Rationalist and the Naturalistic perspectives [24]. The fundamental basis of Rationalistic Decision-Making (RDM) is that one can generate a series of alternatives and use clear and discernible criteria to evaluate which of the solutions maximises the utility and minimises the cost. In contrast, the Naturalistic paradigm emphasises the importance of situational pressures and how people deal with complex cognitive functions in realistic settings [11]. 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 and rather that individuals use cognitive shortcuts, such as satisficing, to quickly reach a decision [23].

Considering the emphasis that NDM places on understanding how people come to decisions in the context of their natural environment it would seem like a more appropriate lens through which to view Design Decision-Making. Both Klein [12] and Orasanu & Connolly [23] 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 [17], while the ambiguous nature of design goals has been discussed by Rittel & Webber [28].

Understanding Design Decision-Making is more than just applying a particular theoretical lens to the design process. To fully understand DDM we need to be able to describe and model the decision-making process that designers engage with. Within the umbrella of Naturalistic Decision-Making there are several proposed models [18]. Of all the differing models within the NDM framework the Recognition Primed Decision-making (RPD) is most associated with the NDM framework with RPD being seen as the 'prototypical NDM model' [19]. Due to its prominence within the Naturalistic Decision-Making framework RPD is a viable model to begin to understand the decision-making process that Interaction Designers engage in.

1.3 Recognition Primed-Decision Making

The central goal of RPD [11] is the 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 found when talking to experienced decision-makers that, when faced with a situation in which a quick and decisive course of action was necessary, the first thing people did was to assess the situation and, on the basis of that 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 [21].

Situation recognition involves classifying the situation as either unique or common based on previous knowledge. Based on this initial matching, a series of goals that will satisfy the decision point are identified. Serial option evaluation involves compiling a potential plan of action to address the goals that are required. 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. Mental simulation involves mentally walking 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 foundation of the original RPD model [15]. As the RPD model matured it became evident that not all situations share the same defining characteristics. In his later work Klein discussed three variations of the RPD model which aimed to capture some of the differing frameworks that we use under differing situations. Three variations were proposed which represented 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.

In all three variations of the RPD model the use of an analogy is central to the first stage in the decision-making process. In each of the variations when the decision-maker is assessing the situation to determine if it is typical or familiar the comparison to an existing analogy is employed. These analogies are recalled to memory and examined in the context of the current situation to extrapolate any useful information in possible ways to solve this particular decision point. This use of analogical reasoning forms the basis of the first stage in the RPD model.

2. STUDY ONE – RPD & DDM

To date any use of the Recognition Primed Decision-making model in the area of design has been the original singular RPD model [15]. In the broader decision-making literature the RPD model has evolved from a singular system into a more refined model composed of three variations. [12] These variations are needed to provide a finer level of granularity in terms of accommodating for the wide range of decisions that could be faced. These newer variations have been applied and validated across several different fields of research [12], these variations have not been examined in the context of DDM. The aim of this first study is to examine the use of these variations in the context of the Design Decision-Making processes of Interaction Designers.

2.1 Methods

There are several approaches to analysing qualitative data. On one hand, one can adopt a data-driven approach in which a rich-description of what occurred is obtained and themes emerge from the data. On the other hand is 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 DDM, a Theoretical Thematic Analysis was conducted. A Theoretical Thematic Analysis is a multi-stage coding process which looks for themes in a data set in the context of a particular research question [2].

2.1.1 Participants

Six Interaction Designers with various backgrounds and levels of experience (see table 1) were interviewed. These semi-structured interviews ranged in time from 35 to 50 minutes with an average duration of 40 minutes. These recorded interviews were then transcribed verbatim.

Table 1. Demographics of Participants

Participant	Job	Background	Experience (years)
1	PhD Student: Develops news websites for small businesses	Academic	5
2	Research Fellow: Developing digital library prototypes	Academic	5
3	PhD student: Development of Bio-Medical Software	Academic	2
4	Interface Designer: Development of mobile phone applications	Industry	4
5	Interface Designer: Managing a Paperless office	Industry	2
6	Interface Designer: Develops financial advisory software	Industry	2

2.1.2 Procedure & Design

To probe the decision-making process employed by Interaction Designers, an adaptation of the Critical Decision Method for Eliciting Knowledge (CDM) was employed [13]. CDM commences with the subject being asked to recollect an important decision that they recently had to make. The interviewer asks a series of probing questions based on the information provided by the participant. To reflect the graphic nature of Interaction Design, the CDM methodology was modified so the starting decision point was a recent interface they had worked on. Each interview commenced with the participant being asked to describe the design decisions that were involved in a provided screenshot, as well as the rationale behind each of those decisions. In keeping with CDM, a series of themes were covered to provide both breadth and depth to the interview (see table 2).

Table 2. Example interview themes.

Theme	Example Questions
Initial Decision	What was the biggest decision you had to make when putting together this interface?
Origin of Idea	How did you come up with the initial idea for this design?
Experience	How much do you think your level of experience played a factor in the design process?
Environment	Did any external factors play an important part in the decision-making process?
User	How did you consider the user in your design?

2.1.3 Analysis

The preliminary phase of the analysis was to examine the data at a semantic level. At this stage the explicit meaning of the transcripts is analysed to generate an initial coding list. The codes are generated by identifying significant quotations and associating a label which aimed to encapsulate a relevant theme or idea [2]. Each code that is generated can appear multiple times throughout the interview under various quotations and sentences that that particular theme. There are several levels of granularity that can be used to break down the transcript into discrete codes. As per Braun & Clarke's recommendations [2] a sentence-by-sentence analysis was conducted.

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. By creating relationships between individual codes, these relationships 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 these relationships a model of Design Decision-Making emerged.

2.2 Results and Discussion

What emerged from the Theoretical Thematic Analysis were three stages that encapsulated how the participating Interaction Designers reached the design decisions that they did: using an initial analogy as the starting point, modifying the initial analogy based on various constraints, and evaluating the proposed design through mental simulation (see figure 1).

These three stages support the RPD model of Design Decision-Making, as discussed by Klein [12]. Analogy use and mental simulation appear as important stages in the DDM process and also play key roles in the RPD model. Results indicate that the biggest discrepancy between the data and the traditional view of RPD was the persistence of the initial analogy across all stages of the DDM process being the largest difference. RPD considers the use of an analogy as a starting point in the decision-making process; as is discussed in more detail in the next section, participants described the analogy at all stages of the decision-making process due to an over-reliance on this initial analogy.

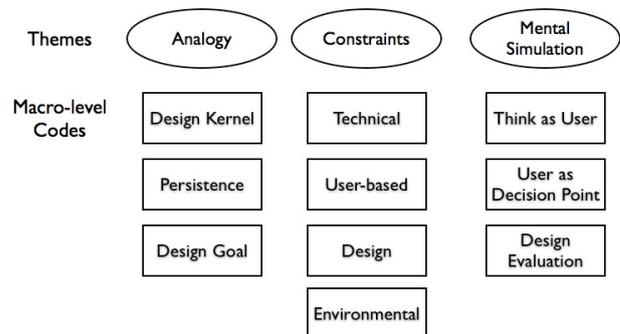


Figure 1. A Thematic Map illustrating the clustering of semantic codes to identify latent themes

2.3 Persistence of analogies

The initial stage in RPD 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 more manageable level. This is an important characteristic of not only the RPD model but many Naturalistic Decision-Making models [18]. 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. 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. These use of examples though were more than just starting points. These starting 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 quote we can see that the example of an old 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. [1], 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 Drake's idea of a Primary Generator [5]. Drake states that a primary generator is the situation in which a designer commences the design process with a simple idea, and latches on to 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 DDM the persistence of the Google analogy became a hindrance to the overall DDM 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 they found that the simplicity of the Google interface was simply not feasible to replicate under the conditions of their design problem. The sheer amount of information that needed to be conveyed in the digital library search was inherently too complex for the simplistic 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 which would 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.

2.4 Discussion

By examining the relation between the RPD 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 model. While several themes emerged from the Theoretical Thematic Analysis that reinforced the RPD model this analogical fixation was the largest divergence between the our results and the model. An alternative, and plausible, explanation for this result is that these discrepancies may have been a reflection of the post-hoc nature of the interviews with Interaction Designers. The discussion of a single analogy through the DDM process may simply be a function of only remembering the one analogy that participants ended up using through to completion, with other analogies being used and discarded along the way. A follow up study was conducted to investigate the validity of this claim by taking a qualitative approach using the Design Fixation paradigm [8].

3. STUDY 2 – VALIDATION OF THE IMPACT OF ANALOGIES IN DDM

The main concern with this finding from study 1 is the issue of validity. 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 simply only remembered the analogy that was taken to completion in the decision-making process. This second study

aims to further test this finding through using quantitative measures such as Design Fixation to probe the persistence of initial analogies on the entire Design Decision-Making process.

As discussed earlier, a key issue that needs to be considered in the application of the Design Fixation paradigm is the generalisability. While the phenomenon of DF has been identified and replicated numerous times among Mechanical Engineers the application to other design domains has been neither successful nor conclusive. Purcell et al. [25,26,27] have published several papers that have applied the DF paradigm to different design disciplines with mixed results. Purcell et al. [27] extended the original work of Jansson & Smith [8] by examining the impact of DF across several different design populations. What was found was that while DF was replicated among Mechanical Engineers fixation among the other design disciplines, in this case Industrial and Interior Designers, was only marginally significant. A potential explanation for these previous findings is that DF occurs when there is match between the domain of expertise of the designer and the domain of the problem presented and that DF is 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 will be exhibited. By addressing these issues of generalisability we hope to test whether Interaction Designers are just as susceptible to DF.

3.1 Methods

3.1.1 Participants

A total of 32 Interaction Design students participated in this experiment. Participants were recruited from two universities in the Greater London area.

3.1.2 Materials

Four different design problems were used; two problems focusing on mechanical engineering principles (the bike rack problem and the spill-proof coffee cup problem from the original Jansson & Smith study) and two problems focusing on interaction design principles (a digital music player problem and a medicine dispenser problem designed specifically for this study). Each problem had a short description of the design problem, as well as a list of criteria that each solution that the participant generated must conform to. The design problems were accompanied by a brief questionnaire that ascertained the familiarity of the participant with the devices in each design problem, as well as certain demographic information. Familiarity was scored on a Likert scale ranging from 1 ('Have never used the device') to 5 ('Frequently use the device').

3.1.3 Experimental Procedure & Design

The experiment employs a 2 x 2 mixed design, with the between subject variable being the Presentation (Design Brief and Brief + Visual example) and the within subject variable being the Problem Discipline (Mechanical Engineering and Interaction Design).

Participants were run in two separate groups broken down by university. Participants were randomly assigned to either the control or the experimental condition. The control group (n=16) were given simply the design brief, while the experimental, or fixation, group (n=16) were given the same design problems with an inherently flawed pictorial example solution which 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.

3.1.4 Analysis

To quantify the generated designs, a scoring procedure employed by Chrysikou & Weisberg [3] was used. This scoring procedure provides greater detail in terms of the characteristics of fixation than the scoring procedure used by Jansson and Smith [8] which simply looked at the presence or absence of certain flaws that were placed in the Fixation condition by the experimenter. Under the scoring procedure used by Chryiskou & Weisberg, 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 simply 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 3 contains an example of the specific scoring criteria used in the analysis. As there was a wide range of generated designs the scoring needed to accommodate this. 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. These were then 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 (maximal fixation).

Table 3. An example of the scoring criteria used for the Music Player problem

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) eye candy, 3) counterintuitive volume	0-3
Unintentional Flaws	1) not able to search, 2) no display for current track	0-2

3.2 Results

To investigate whether the solutions generated under the fixation condition were markedly more similar to the provided examples than the solutions generated under the control condition, a series of repeated measures analyses of variance (ANOVA) were run for four of the five fixation measures. As in the earlier studies that used these five fixation measures, all participants scored zero on the Direct Physical Similarities [3]. As this result was constant across all groups, this measure was removed from the analysis.) Repeated measures ANOVA was utilised for two reasons: firstly, to account for the fact that the dependent variable, the generated solution scores, were measured twice under paired conditions (each participating subject generated a solution to both an Interaction Design problem and an Mechanical Engineering problem) and secondly, to investigate whether there were any potential interactions between the within-subject effect of problem discipline (Interaction Design problem or Mechanical Engineering problem) and the between subject effect of exposure (whether the subjects were given a pictorial example or not).

3.2.1 Design Fixation in Interaction Designers

Figure 2 clearly illustrates that the designs generated under the fixation condition were significantly more similar to the provided examples (i.e. participants exhibited high levels of fixation) than the designs created by the control group across three of the four fixation measures (Reproductive Similarities $F(1,30) = 16.88, p < .01$; Analogical Similarities $F(1,30) = 10.29, p < .01$; Unintentional Flaws $F(1,30) = 10.96, p < .01$).

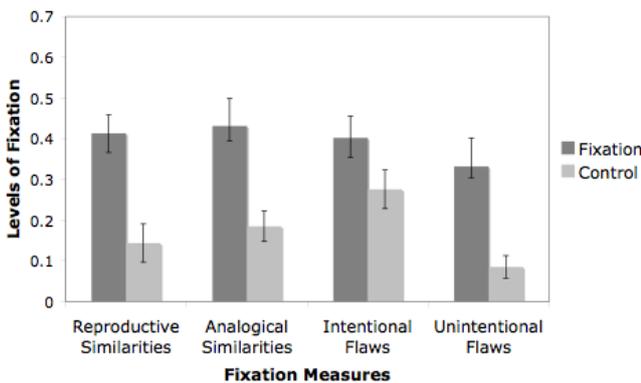


Figure 2. Levels of fixation between the presentation conditions for each fixation measure

The notion of two types of flaws as discussed by Chrysikou and Weisberg is an arbitrary distinction if the perspective of the participant is considered. From the point of the view of the participant they are unaware of which flaws were placed by the experimenter and which are flaws that were inherent to the example. The distinction between Intentional and Unintentional flaws is simply an artefact of the experimenter. By combining the two measures of fixation in to unified measure examining the flawed elements of the example regardless of the source we can gain a more accurate picture of how participants fixate. When fixation is examined as unified measure of Flawed Properties there is a significant difference between the two presentation conditions $F(1,30) = 10.24, p < 0.01$.

3.2.2 Design Fixation and the effect of differing problem disciplines

While the main effect of exposure (whether the participants were given a flawed graphic example or not) is generally robust across measures, the same cannot be said about the main effect

of problem discipline. Figure 3 illustrates the difference in fixation scores between the two given problem disciplines (Engineering problems versus Interaction Design problems). The unified Flawed Properties measure of fixation differs markedly between the two problem disciplines. Participants incorporated significantly more of the Flawed Properties of the original examples into their solutions to the Mechanical engineering problems than they did in the Interaction Design problem solutions, $F(1,30) = 9.07, p < .01$. No significant differences were observed on 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 which is restricted to one specific fixation measure.

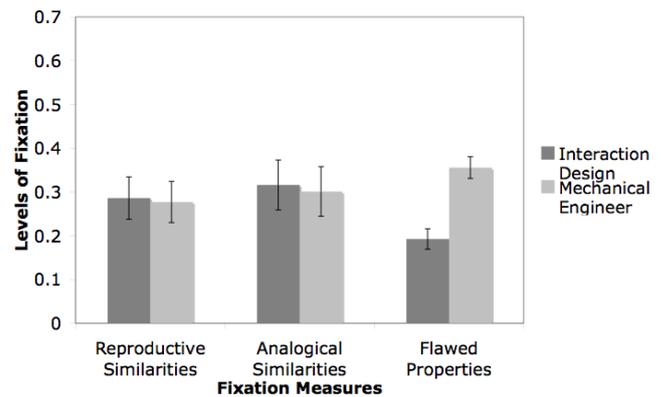


Figure 3. Differing levels of fixation within each fixation measure across problem disciplines.

3.2.3 The effect of exposure within each problem discipline

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.

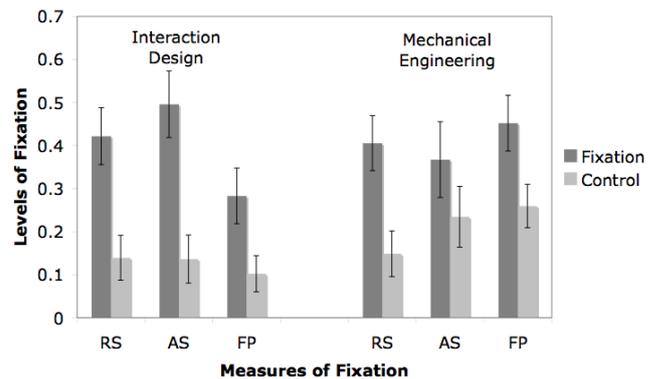


Figure 4. Levels of fixation in each fixation measure broken down by experimental condition and problem discipline. RS = Reproductive Similarities, AS = Analogical Similarities, FP = Flawed Properties

Figure 4 illustrates differing patterns of fixation between the two problem disciplines. When participants were working on a problem with which they had some level of expertise, they tended to fixate across all measures of fixation (reproductive similarities $t(30) = 3.36, p < .01$; analogical similarities $t(30) = 3.77, p < 0.01$; Flawed Properties $t(30) = 2.34, p < 0.05$). 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 ($t(30) = 3.09, p < 0.01$) and flawed properties ($t(30) = 2.348, p < 0.05$). Figure 4 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 of that flawed graphical example.

In summation, we can see that, by simply 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 flawed properties from that example, independent of problem discipline. Outside of this common thread which spans the two design domains, we see that analogical similarities are limited to within-domain problems.

3.3 Discussion

The main aim of this study was to replicate Design Fixation in Interaction Designers; which in turn provides evidence to reinforce the results of the first study. By controlling for the domain of the problem and the domain of the participant we aimed to address issues of the generalisability of DF and post-hoc rationalization in the first study.

In the past, replication of Design Fixation outside of the mechanical engineering discipline has been problematic [26,27]. 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. [26] 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.

The results of the second study indicate that Design Fixation is present in Interaction Designers. It is interesting to note that DF was not due to the mismatch between problem discipline and the participants' particular design discipline, as hypothesized by Purcell et al. [26]. The results from this study suggest that DF was in fact present among the solutions generated in Purcell et al. [26] and that its marginal significance was 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 can be potentially attributed to the usage of a more sensitive outcome measure. In both of Purcell's studies, 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 [3], 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 draw the same conclusion as Purcell et al. [27], as illustrated in Figure 2. By widening the scope of fixation measures by including such characteristics as analogical similarities and reproductive similarities, we can see that DF is in fact fairly robust across design disciplines.

When we take a more focused approach to analysing the individual measures of fixation we begin to see evidence for Purcell's hypothesis. A significant difference was recorded between the types of designs generated across all measures of fixation Interaction Designers were faced with a problem domain they were familiar with (as illustrated by Figure 4). When engaging in the Design Decision-Making process with a problem domain they were familiar with participants focused on superficial elements of the flawed examples (i.e. reproductive similarities and flawed properties).

The results of study two 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, given to the experimental condition, 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 supported the issue of the results from study one being a function of post-hoc rationalization.

4. GENERAL DISCUSSION

As demonstrated by the first study, the current models for understanding Design Decision-Making are not entirely satisfactory; namely in their ability to describe the persistence of initial analogies across all stages of the decision-making process. The issue though with the type of methodology employed in this initial study, namely a post-hoc reflection, does bring to the forefront issues of validity. For example, an alternative explanation to the persistence of this initial analogy could simply be that the decision makers only remember the one analogy that was taken through to the conclusion of the decision-making process.

The validity of analogical persistence was confirmed by employing the Design Fixation paradigm to quantitatively assess whether or not these initial results were simply an artefact of a post-hoc rationalisation of the DDM 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 Drake's idea of a Primary Generator [5]. Much like the persistence of the initial analogy the Primary Generator is best described as an idea that a designer commences the design process with and latches on to 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 yet 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, mental ruts), as well as the anchoring effect in the decision-making literature [33]. The gestalt idea of fixation discusses how the problem solving process can become disrupted by differing elements (such as recency, repetitions, familiarity) that prevent the individual from successfully completing the problem and 'fixating' on particular characteristics of the problem in question. For example, Duncker [6] described the phenomenon of functional fixedness in which the traditional use of an

artefact prevented the participant from imagining other, and 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 'think outside the box' and 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 & Kahneman [33] discussed that 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.

By taking into account the quantitative findings of the second study as well as the use of theoretical triangulation from related research domains, we can begin to draw some conclusions in regards to how Interaction Designers can leverage the power of analogies in DDM but at the same time be aware of their limitations and potential caveats. These findings raise particular theoretical issues that need to be addressed as well as applicable lessons we as Interaction Designers can draw from.

4.1 Theoretical

The primary benefit of Naturalistic Decision-Making, as a realistic and valuable perspective through which to understand Design Decision-Making, is undermined by its current inability to model or account for some of the issues we have raised. The core foundation of the NDM perspective is that it takes into account how people make decisions in the 'real-world' which take into account such important elements as: environmental influences and cognitive shortcuts. These myriad of environmental influences constrain the decision-maker who in turn utilize 'cognitive shortcuts' to quickly reach a decision in the face of these additional cognitive pressures. To gain an understanding of DDM we need to be able to model and understand these 'cognitive shortcuts' that Interaction Designers employ. From the evidence presented the current position of analogies is that they are a tool which can aid the initial stages of the decision-making process such as providing a framework to understanding the situation. As discussed earlier this framework has both positive and negative implications that need to be accounted for. If Naturalistic Decision-Making does not accurately reflect the actual decision-making process that is employed then its benefits of ecological validity over the Rationalistic Decision-Making paradigm may well be called into question.

4.2 Practical

The key implication for Interaction Designers, in terms of extrapolating these findings in to the realm of the practical, is that one must be aware of the potential problems that may occur from the initial analogy. Interaction Designers must be cognizant that there are limitations inherent to the framework they have chosen. Participants' refusal to move on to a more appropriate analogy that is better suited for the design problem is a prime example of the types of issues that Interaction Designers need to be aware of. While some might argue that

collaborative techniques like design critiques mitigate such problems, because they highlight potential flaws of the initial analogy, we must remain cautious in our reliance on external feedback to control potential problems. Explicit instructions to ignore harmful analogies are often not effective, since designers are unaware of their tendency to fixate [31].

4.3 Conclusion

The key finding of these two studies was the potential problems with over-relying on an initial analogy. The results from the second study, taken along with the problems illustrated by participant 2 in the first study, illustrate the problems that can occur in DDM. To avoid issues like these a balance needs to be achieved in terms of leveraging the benefits of analogies and lessening the impact of these negative constraints. To do this we need to gain a better understanding of how analogies interact with the entire decision-making process as opposed to seeing the use of analogies as an isolated first step in the DDM process. Future research in this area needs to be done with an inevitable final goal being to mitigate the potential pitfalls of analogical persistence in design decision-making.

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