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The Effect of Design Expertise on Solving Different Problems: An Exploratory Study

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Abstract

This paper presents empirical evidence of designers' cognitive activities while solving different problems. The hypothesis is that learning design problem solving also affects the way students tackle non-design problems. Eight senior industrial design students and eight senior students from other — or non-design— majors were recruited. 16 protocols were recorded and analyzed in total with each protocol involving two participants working as a team. Each group was asked to solve two problems: a design problem and a non-design problem. The design problem was chosen in order to fully correspond to the characteristics of a classic design problem and the non-design problem was chosen to miss a few aspects of design and, hence, become less designerly. The Protocols were, then, processed using FBS-based coding scheme. The cumulative distribution of the FBS codes across the protocols along with the Problem-Solution (P/S) index was used to analyze and compare the groups. The results of this study indicated that protocols from solving a design problem have a higher variation of the P/S index. Furthermore, the study found similarities in the strategies used by designers to solve design and non-design problems.

Keywords

Design Problem, Problem Solving, Problem-Solution Index, Design Cognition.

Introduction

The world nowadays is more complex than our minds and brains are able to process. Our limited cognitive equipment forces us to only deal with bounded aspects of that complex world at a time. Design recognizes these limitations (Lissack & Meagher, 2021).

Experienced designers frequently work with special methods depending on the situation and the problem (Gero & Kannengiesser, 2004). Lissack asserts that design tools and practices can make it possible for a listener to better grasp the intended meaning of a speaker. He believes that the problems associated with the transmission, cognition and understanding of the meaning could be eased if a designer were involved in the process. A designer would be able to set the stage so that the very actions one hopes to enable by a given exchange of meaning might have a better chance of occurrence. He reckons that designers are able to classify and arrange cognitive perception in confronting different situations (Lissack, 2019).

Designers' approach in focusing on a problem is to deal with mental and cognitive resources (Lawson, 2004). The method of dealing with important problems is to think designerly and solve problems in different fields of endeavor. Designers often try to define the issue so that they can manage to cope with the ill-defined problem in ways that include specific set of activities (Dorst, 2011). According to the literature on cognitive science, those are described as human problem-solving tasks performed in the analysis stage of the process. Solutions to a design problem are rational activities within the scope of the issue. As stated by Newell and Simon (1972), designing activities need enough information about the problem and the solution. Considering the specific characteristics of the design problem, there is limited information on the purpose, process and structure of the problem. The process of formulating the design problem is meant to gather information and make a framework for the issue at hand to compensate for incomplete information. Schön (1983) believes that designers are able to determine the scope of the problem and identify the critical issues. Formulating the design problem is mainly carried out in the early stages and continues intermittently during the session (Christiaans & Restrepo, 2001). Designers interpret the conundrum at the beginning of the session and make a subjective clarification of the problem and the solution. The initial viewpoint of the elucidated question occurs after the first discussion among the designers and results in creatingan overall structure of the designer's position. The conceptual framework is based on the goals, priorities and experiences of a designer (Restrepo & Christiaans, 2003). In this study, design and non-design students were observed while solving design and non-design problems in order to test whether the practice of design problem-solving has affected their general problem-solving behaviors in any way.

Design Problem

Specific strategies of designers are depicted in formulation and solving design problems. There are many creative ways to solve problems which are mostly known as design actions. In terms of design, questions are defined only in connection with the solutions (Cross, 1997; 2004).

The ability to modify a design problem is affected by increasing experience and skill which comes as a result of designers' thinking process. Design problems always contain many layers of intricacies within their principle; for example, determining the time needed to start and finish a process is not an easy task. A designer's primary task is to detect the scope of the problem. In fact, there are many solutions to an open problem and a designer cannot be sure that all the solutions to the issue are correct. There is neither an optimal or special method to a design problem nor is there a shortcut to reach to identify the best solution. The effectiveness of a solution is only achieved with time and practice.Designers move back and forth between the scope of the problem and the solution since the design problem is indefinable (Lawson, 2005; Jiang et al., 2014). Many studies have been conducted on designerly problems. Nature and features of the design problem, branch of design and designer's experience affect the method of formulating design problems and subsequently problem-solving strategies (Restrepo & Christiaans, 2004).

An optimal method to study design thinking is investigation of the problem's scope rather than solution. According to Jiang et al. (2014) industrial designers tend to focus more on the problem than designers in other fields.

According to Goel and Pirolli (1992) there are 12 special attributes that can be considered for a design problem. The extent to which a problem is designerly can be investigated based on these parameters; for example, a cooking problem lacks some of these characteristics and thus cannot be considered designerly in many ways. the impossibility of predicting the outcome of the design process is an important feature of the design problem. Each solution can be a subject for other designers and eventually lead to new hypothesis. The outcome of the design process is recognized using experience and judgment (Lawson, 2005). According to the general definition of design problem, problems in relation to mathematics, law, medicine and pharmaceutical science are not design problems (Restrepo & Christiaans, 2004). Generally, designerly characteristics of the problems are not determined because a design feature is available in every problem that is subject to change. For instance, a math question that is not basically a designerly problem generally has the ability to have designerly solutions. In this study, designerly characteristics of the problem-solving activities while solving design and non-design problems are examined through protocol study. An ontological coding scheme has been used to enable comparison of different protocols from a design process point of view.

Methodology and Tools

In this study, the FBS coding scheme was used to process and analyze the collected protocols. The FBS coding scheme is based on the Function-Behavior-Structure ontology of design conducted by Gero et al. (2012). The method has been used as a universal coding scheme for studying different protocols from a wide variety of domains and settings. The ontological definition of the codes in this scheme enables the comparison between different protocols and also the generalization of the findings. For the purpose of this study, the FBS coding scheme was preferred as the two groups of the design and non-design problems needed to be comparable. Specifically, the non-design problem was defined in a way to miss a few characteristics of design problems as per Goel and Pirolli's (1992) definition and hence become less designerly. The FBS coding scheme allows for tracking the designerly issues and processes discussed by the designers while solving the non-design problem and compare the cognitive strategies used by the design and non-design students while solving different problems.

Function-Behavior-Structure (FBS) Ontology of Design

According to Gero (1990), the FBS coding scheme relies on the design issues — as defined by the FBS ontology of design— to be used as the set of codes for tagging each design activity or verbalization in the protocol. (FBS) Ontological is defined based on three primary variables being function, behavior and structure. The final goal is to achieve ultimate ideas that form the Document (D). Function (F) is the key part of design . The designed subject's set of behaviors is used to achieve function and divided into two groups including Expected Behaviors (Be) and Structural Behavior (Bs). The structure of design issue, Structure (S), and Requirements (R) are addressed as well.

The amount of structure issues that are synthesized during a design session is usually much more than what is needed as the designers come up with multiple solutions for each problem and tend to maintain multiple tracks of thought while designing. The designers usually analyze the ideated structures in order to compare the designed subject's behaviors — i.e., characteristics— to the expected ones. Such behavior is known as Structural Behavior (Bs). This study benefits from the ontological foundation of the FBS coding scheme in the way that it can track any designerly cognitive activities even in protocols that do not necessarily fit inside the definition of design problems.

The LiNKODER software was used to measure and analyze the results of this study (Pourmohamadi & Gero, 2011; Saunders & Pourmohamadi, 2009). Specifically, the Problem-Solution index and the cumulative incidence of the FBS codes were used to analyze and compare the results from the different groups.

Problem-Solution Index

The design issues defined in FBS ontology are dividable to two categories including the ones related to the problem and the ones related to the solutions. For example, the Function issues are part of the problem and the Structure issues are part of the solution. Jiang et al. (2014) suggest the ratio between these two groups of design issues to be an indicator of the designer's state of affairs and the variations of this ratio to be a sign of the designer's cognitive strategies during a design session. Calculating the P/S index of different segments of the protocol captures the dynamic nature of the design activities and designers' focus. Studies indicate that designers focus simultaneously on the scope of the problem and solution. Choosing to focus on the problem or solution issues depends on different variables such as expertise, type of the problem and the methodology that designer uses (Yu et al., 2013). In FBS coding scheme, the P/S index is thus calculated as follows:

$$\text{P-S Index (Design Issue)}=\frac{\sum_0^0 \text{Problem Related Issues}}{\sum_0^0 \text{Solution Related Issues}}=\frac{\sum_0^0(\text{ R,F,Be})}{\sum_{k=0}^0(\text{Bs,S})}$$

In this study, the general features of the design activities are evaluated and compared through calculating the variations of the P/S index along different sections of design and non-design protocols.

Cumulative Incidence of Design Issues

Cumulative incidence is used for evaluating the properties of design protocols through the rate of generation of different design issues along the design session. Different features of the cumulative incidence graph are studied:

1. The first instance of a design issue along the design session, i.e., the root of the cumulative graph line

2. The trend of generation, i.e., the linearity and slope of the cumulative graph line.

Since the inspected features of the cumulative incidence graph are independent of the length of the protocol, it is possible to compare multiple design protocols with different lengths using these indices. For instance, Gero et al. (2012), used the cumulative incidence analysis to compare the results of multiple independent protocol studies and extract the commonalities across them.

Experiment Settings

Two cohorts of designers and non-designers were needed for this study to take on two design and non-design problems. The participants were chosen from senior undergraduate students with design and non-design majors studying at one of the biggest Iranian universities. A total of 16 participants were recruited to take on both given problems in teams of two — a total of eight teams.

The design problem was chosen from previous protocol studies and modified to cover for some cultural and language differences of the Iranian participants — for example turkish, kurdish and persian. For the non-design problem, a cooking question was devised by the authors through brainstorming and discussion with design experts. The aim was to maintain the complexity and size of the problem's solution space while differentiating it from the common sense on a design problem. The given problems presented to the participants are shown in the frames bellow.

1. *Design Question*

Tehran Subway Company intends to launch a new interior design for its wagons. The train has a completely different design with 5 (3+2) seats in every row in order to respond to the growing number of urban travellers.

In addition, the company wants to build a new waste collection and disposal system within passenger wagons. Current supplier of trash bins offered a series of new projects to the subway company but they weren't accepted. As a result, they began to undertake research in the field of waste managementand how to collect them in subways as well as conducting interviews with passengers and workers. You are invited as a designer to give one or more ideas about this. The concepts will be decided upon in tomorrow's meeting. Please consider the following details for your concept:

1. General Solution
2. Overall Form of the Product
3. Reason for the Selected Form
4. Multiple Views of the Product
5. Estimated Cost

Please think aloud while problem-solving and discuss the problem as a group. Avoid writing and sketching on paper; instead try to write everything on the board.

2. *Non-Design Question*

Tabriz Department of Education intends to offer a perfect snack for elementary school students. You are invited to provide a suitable food. The question is to cook a combination meal using eggs. Use the following ingredients as recommended. Onions, Potatoes, Carrots, Tomatoes, Bell pepers, Mushrooms, Peas, Chicken and Red meat. The amount of ingredients and the cooking method depend on your group descision. Conditions and criteria are as follows:

1. Creativity in Composition
2. Maintaining the Quality of Raw Ingredients, Hygiene and Safety
3. Least Amount of Waste Among Raw Ingredients
4. How to Serve and Provide Food in Proper Time

Please speak aloud while problem-solving, discuss the problem as a group and explain the work stages as well as your reasons for each choice.

Figure 1: *The process of answering the non-design problem.*

Eight senior students from industrial design major and eight senior students from other (non-design) majors were recruited. 16 protocols were recorded, coded and analyzed in total with each protocol involving two participants working as a team. The teams were formed to encourage natural verbal interactions during sessions. Each group was asked to solve two problems: a design problem and a non-design problem.

All sessions were recorded using both video and audio recorders and also the participants were asked to think aloud in addition to their natural discussions while solving the problems using FBS method. The experimenter cued the participants and urged them to verbalize their thoughts in case they don't engage with each other as intended. The records were transcribed as the main source of information for the rest of the study. Notes on the actions of the participants were also added to the transcriptions.

Recorded sessions were coded according to the mentioned method. Moreover, from the beginning to the end of each session, they were separately numbered into small sentences and then written down. Written information is available according to the simple decisions taken in a short period of time along with the codings. Segmentation and encoding was implemented by two separate coders after recording all the protocols.

Four sets of encoded protocols were arbitrated using the Delphi method. The arbitration was considered as the main reliable source and also differences in initial encodings were evaluated. The average agreement between two coders in design protocols of designers is M=82% and non-design protocols of designers is M=84%. The average agreement in design protocols of non-designers is M=78% and non-design protocols of non-designers is M=82%. The lower agreement between the two coders was in the design protocols from non-designers which might be a result of their lack of professional vocabulary as they solve the design problem. After arbitration between the two coders, non-design codes were omitted.

Table 1 to 3 present short sections from some of the protocols; they were translated from Persian to English only for presentation here — the coding was originally implemented in Persian as it was the native language for the two coders.

Table 1: *Protocol (No.4) designer non-design sample section.*

47	*Then put them inside bread.*	S
48	*We can put fried potatoes at the bottom of the dish.*	S
49	*Then put egg and a layer of potatoes.*	S
50	*It should not be a high-calorie meal because it is a snack.*	Be
51	*We can fry this and then put it on bread.*	S
52	*It is good but we don't have bread.*	Bs
53	*We can use ingredients of a sandwich.*	S

Table 2: *Protocol (No.4) non-designer non-design sample section.*

73	*For the appearance of the meal and because of the time needed.*	Be
74	*First potatoes, then put other stuff together.*	S
75	*Now I don't think we missed anything, just slice the potatoes.*	S
76	*Ingredients are cooked.*	S
77	*The egg will be scrambled and it doesn't need a long time.*	S
78	*Of course, it is mixed with a little milk.*	S
79	*It might be ready in five minutes.*	Bs
80	*I think the mushrooms are cooked. Action: Picking up frying pan.*	Bs
81	*So we fried the potato. Action: Pouring oil in the frying pan.*	S

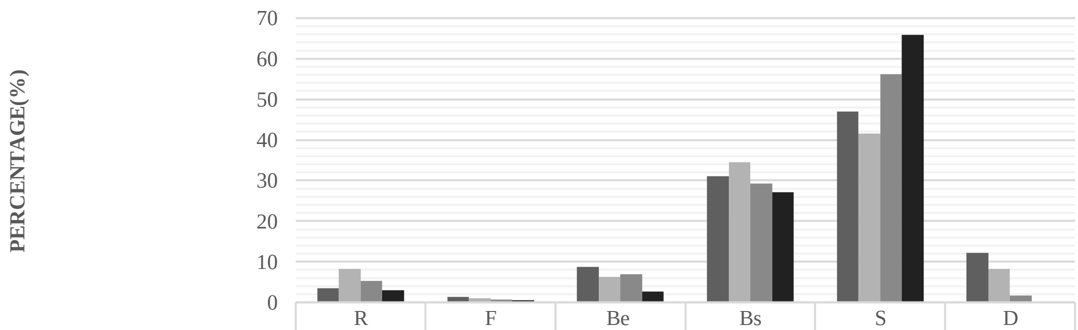
Table 3: *Protocol (No.2) designer design sample section.*

87	*I think important options are …, Then one is garbage disposal and I don't know.*	F
88	*Replacement.*	F
89	*The capacity of the tank is important.*	Be
90	*These bags or anything else for putting out rubbish.*	S
91	*Did you write it down? Action: Dump.*	F
92	*It is better to write that for the person who replaces garbage bags.*	Bs
93	*Disposal can be handled in different ways.*	S
94	*Primary material is ...*	S
95	*So, the material is obvious.*	Bs

Results

All protocols were coded using FBS-based coding scheme and, after removing the non-FBS segments, were initially analyzed using statistical distribution metrics. The average number of sections in design protocols of designers is M=736 and the average number of sections in non-design protocols of designers is M=369. The average length of design protocols of Non-designers is M=178 and the average length in non-design protocols of non-designers is M=242. Table 4 illustrates the percentage distribution of the FBS codes in different groups.

Table 4: *Percentage distribution of the FBS codes in the four different categories.*



	R	F	Be	Bs	S	D
Designers / Design	3.52	1.4	8.8	31.1	46.96	12.22
Non-Designers / Design	8.27	1.1	6.25	34.57	41.5	8.32
Designers / Non-Design	5.27	0.67	6.9	29.2	56.2	1.7
Non-Designers / Non-Design	3.02	0.5	2.6	27.1	65.9	0

In order to investigate variation of the Problem-Solution index in the protocols, sessions were divided into four sections and the P/S index was calculated for each section individually. Results of design and non-design protocols were compared using statistical test (t) and regression.

Table 5: *P/S index in the protocols of designers.*

P/S index in four parts for each designer's design protocol				
Sections	**1**	**2**	**3**	**4**
Team 1	0.41	0.14	0.20	0.16
Team 2	0.48	0.21	0.08	0.21
Team 3	0.7	0.11	0.07	0.15
Team 4	0.14	0.14	0.05	0.08
Average	0.43	0.15	0.1	0.15
Standard Deviation	0.2308	0.0424	0.0678	0.0535
P/S index in four parts for each designer's non-design protocol				
Sections	**1**	**2**	**3**	**4**
Team 1	0.27	0.17	0.05	0.06
Team 2	0.15	0.13	0.1	0.08
Team 3	0.52	0.21	0.08	0.07
Team 4	0.31	0.01	0.13	0.05
Average	0.31	0.13	0.09	0.065
Standard Deviation	0.1541	0.0864	0.0336	0.0129

Table 6: *P/S index in the protocols of non-designers.*

P/S index in four parts for each non-designer's design protocol				
Sections	**1**	**2**	**3**	**4**
Team 1	0.31	0.06	0.2	0.29
Team 2	0.2	0.03	0.03	0.12
Team 3	0.15	0.04	0.13	0
Team 4	0.2	0.18	0.03	0
Average	0.21	0.7	0.09	0.1
Standard Deviation	0.0675	0.0694	0.08301	0.1372
P/S index in four parts for each non-designer's non-design protocol				
Sections	**1**	**2**	**3**	**4**
Team 1	0.2	0.13	0.05	0.16
Team 2	0.05	0	0.05	0.01
Team 3	0.107	0.05	0	0.03
Team 4	0.09	0.04	0.02	0
Average	0.111	0.05	0.03	0.05
Standard Deviation	0.0635	0.0544	0.0244	0.0741

Table 7: *Comparison of P/S index average number between designers' design and non-design protocols.*

t-Test	Section 1	Section 2	Section 3	Section 4
Probability	0.336	0.727	0.850	0.027 ($p<0.05$)

In the first phase, the difference of P/S Index in sections of design and non-design protocols was calculated. Table 7 indicates a significant difference comparing the average of P/S index between designers' design and non-design protocols according to t-test in the fourth section of design and non-design protocols. This reflects the attitude of designers in the design process where they tend to question their synthesized solutions towards the end of the session. Lawson (2004) believes that each design solution can be the subject for other designers and eventually create new problems and hypothesis. Predicting the end of a design process is impossible because there is not a comprehensive description for design problem and design process. The end of the design process is recognizable if a designer adopts experience and judgment. In the second phase, P/S index line of each group was measured to determine the best logarithmic regression. The average of difference in P/S index was evaluated on the basis of normalization during protocols. Results were used to compare the variations of P/S indices between groups.

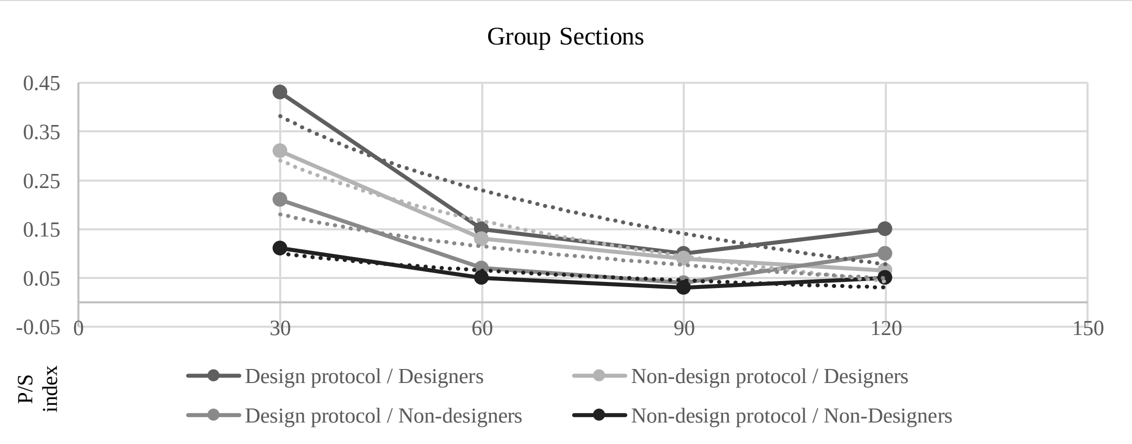


Figure 2: *P/S index average of four sections for each group.*

According to Figure 2, the P/S index is reduced during the sessions but it is not zero which reflects the designerly aspects of protocols. Arrangement of the lines indicates that the P/S index in protocols recorded from designers is higher than those of non-designers.

Table 8: *The logarithmic regression of average P/S index analysis in designers' protocols.*

Regression	Design Problem / Designers	Non-Design Problem / Designers
Equation	Y = 0.98 – 0.88Ln(x)	Y = 2.60 – 1.11Ln(x)
R^2	0.727	0.996

Table 9: *The logarithmic regression of average P/S index analysis in non-designers' protocols.*

Regression	Design Problem / Non-Designers	Non-Design Problem / Non-Designers
Equation	Y = 0.78 – 0.76Ln(x)	y = -0.024 – 0.62Ln(x)
R^2	0.441	0.489

Cumulative Incidence

The cumulative incidence graph of different FBS codes was calculated for all the protocols. The following is the result graphs along with the comparison charts (Gero & Kannengiesser, 2013; Pourmohamadi & Gero, 2011).

1. *Function Issues*

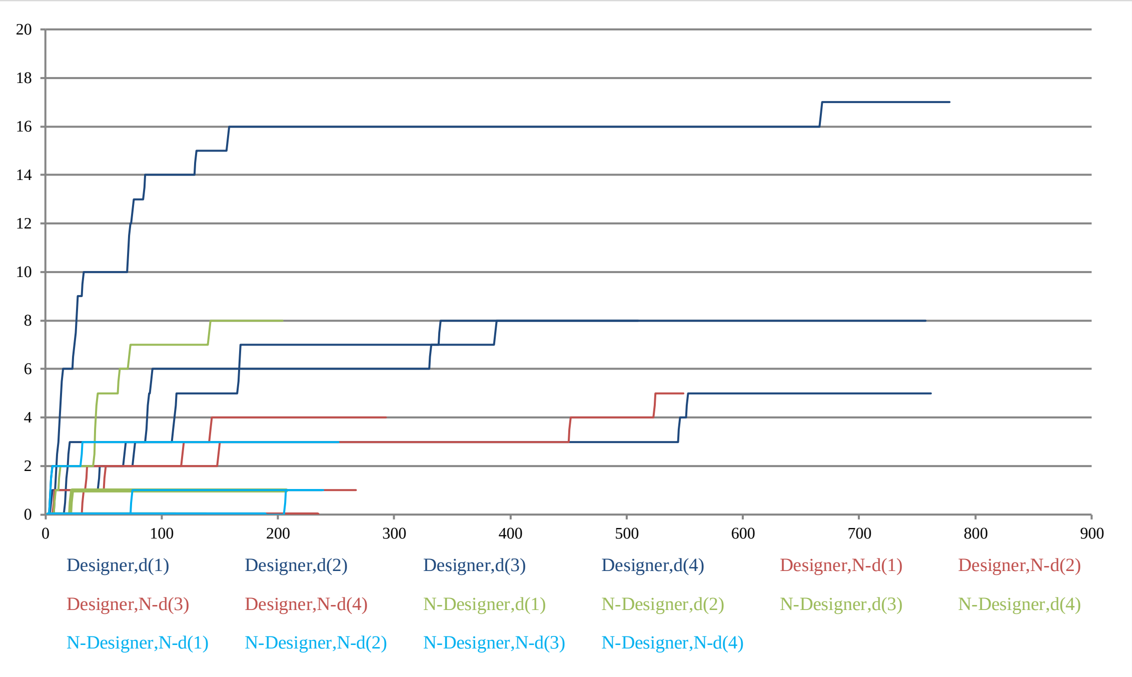


Figure 3: *Cumulative incidence of Function issues in design and non-design groups of designers and non-designers.*

In Figure 3, the cumulative incidence of Function issues is presented. Most of the sessions are not linear, whereas, the Function issues are initially generated towards the beginning of the sessions but reduced through the protocols.

2. *Expected Behavior Issues*

In Figure 4, the results of quantitative and qualitative Expected Behaviour issues are clarified. Expected Behavior issues are the first to occur at the start of the designers' design protocols but they tend to continue as well. Slope of designers' design protocols are more than others.

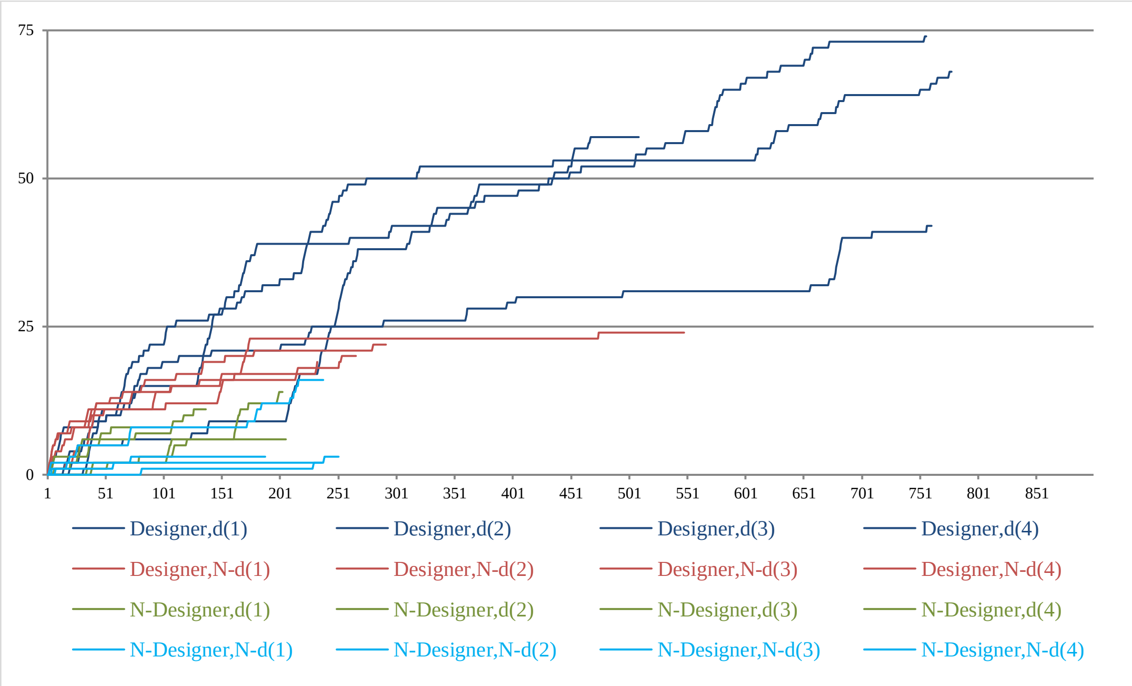


Figure 4: *Cumulative incidence of Expected Behavior issues in design and non-design groups of designers and non-designers.*

3. *Structure Behavior Issues*

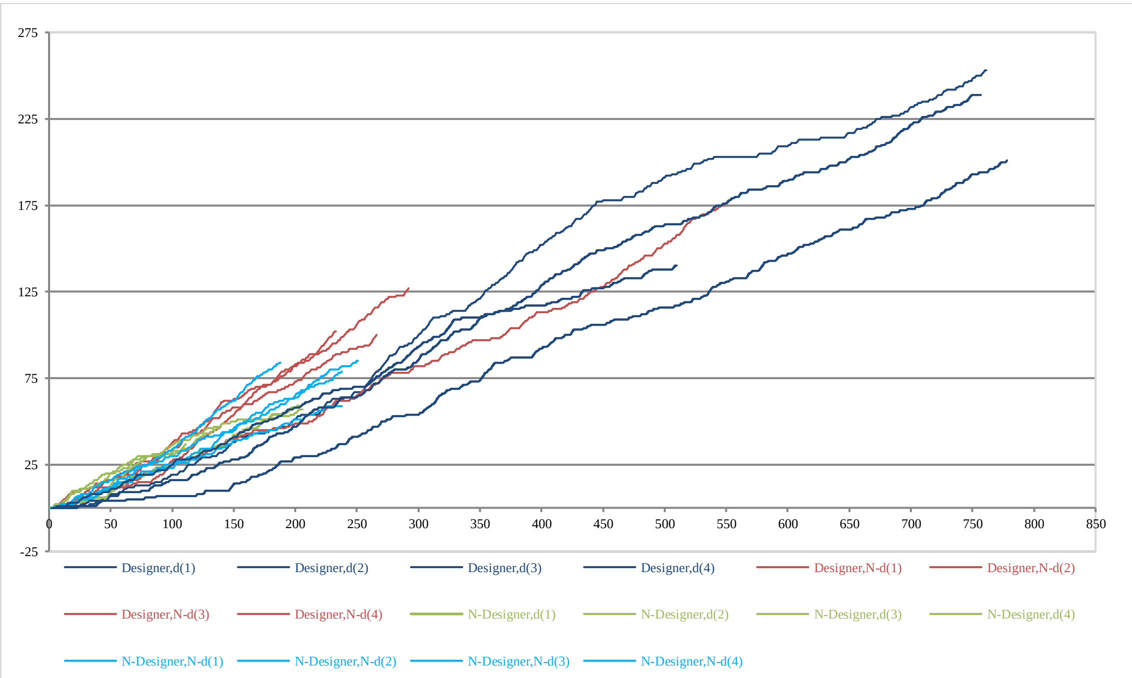


Figure 5: *Cumulative incidence of Structure Behavior issues in design and non-design groups of designers and non-designers.*

Cumulative incidence trend of Structure Behavior issues is presented in Figure 5. Most of the graph lines are almost linear. In most protocols of Bs, issues do not occur at the beginning of the protocols but continue a linear trend throughout the session.

4. *Structure Issues*

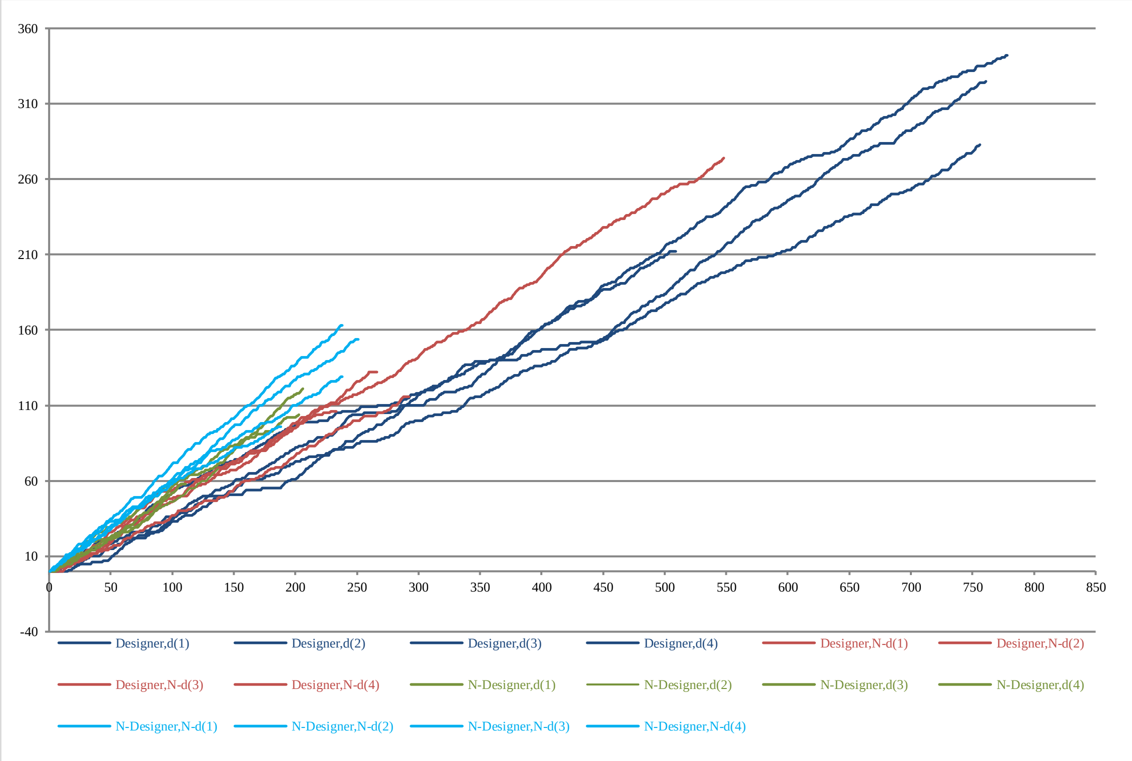


Figure 6: *Cumulative incidence of Structure issues in design and non-design groups of designers and non-designers.*

Table 10: *Quantitative and qualitative measures related to the cumulative incidence of Structure issues.*

No	Protocols	Slope	RSQ	First Occurrence at Start	Continuity	Shape
1	*Designer, d(1)*	0.410	0.992	No	Yes	Linear
2	*Designer, d(2)*	0.368	0.997	No	Yes	Linear
3	*Designer, d(3)*	0.467	0.995	Yes	Yes	Linear
4	*Designer, d(4)*	0.398	0.981	Yes	Yes	Linear
5	*Designer,N-d(1)*	0.507	0.998	Yes	Yes	Linear
6	*Designer,N-d(2)*	0.491	0.992	No	Yes	Linear
7	*Designer,N-d(3)*	0.402	0.996	Yes	Yes	Linear
8	*Designer,N-d(4)*	0.485	0.994	No	Yes	Linear
9	*Non-designer, d(1)*	0.523	0.993	No	Yes	Linear
10	*Non-designer, d(2)*	0.481	0.994	Yes	Yes	Linear
11	*Non-designer, d(3)*	0.596	0.994	Yes	Yes	Linear
12	*Non-designer, d(4)*	0.502	0.967	Yes	Yes	Linear
13	*Non-designer,N-d(1)*	0.546	0.996	Yes	Yes	Linear
14	*Non-designer,N-d(2)*	0.681	0.999	Yes	Yes	Linear
15	*Non-designer,N-d(3)*	0.624	0.998	Yes	Yes	Linear
16	*Non-designer,N-d(4)*	0.508	0.99	Yes	Yes	Linear

Cumulative incidence trend of Structure issues is shown in Figure 6. According to Table 10, the first instances of Structure issues happen in the beginning of the protocols and follow a linear tendency of growth along the length of the sessions.

Discussion and Conclusion

In this study, the cognitive activities of designers while solving design and non-design problems were evaluated. Eight senior design students and eight students from non-design backgrounds were recruited to solve two given problems. One of the given problems was a typical design subject that was taken from other protocol studies on designers. The other given problem was a cooking question which intentionally missed some of the characteristics of design problems. All the participants took on the given problems in teams of two and were asked to think aloud while doing so. The results obtained from this research are limited to specifically defined laboratory conditions in this project and controlled factors.

There is a lot of variety in the activities of designers; as such, just one specific status was surveyed in this paper. Other limitations were considered according to the factors. The examination in less organizational view towards the issue was dependant on the controlled terms as well as the existing limitations.

The verbal protocols were recorded and processed using FBS coding scheme. The final protocols were stripped from non-design segments and analyzed using two main measures. The average Problem-Solving index was calculated for all protocols as well as their quarter sections. The cumulative incidence of all the FBS codes was graphed and the slope and linearity of the graph lines were calculated.

The findings of this study are in line with previous studies on novice and expert designers. The non-designer participants show the same cognitive behaviors as the ones listed by others for novice designers. For example, the participants from non-design majors tend to come up with solutions faster and mostly work on the Structural aspects of the problem solving. However, the designers show an interesting cognitive behavior in solving the non-design problem. Even though the problems are generally solved in shorter steps, the designers use the same problem-solving strategies they use for solving design problems to deal with the cooking problem. According to Figure 2, the participants with non-design major solved both problems in a lower level of Problem-Solving index, meaning, they formulated less problem issues and were mostly focused on the solution. The same characteristic is visible when designers were asked to solve a less designerly problem.

The second observable property in the Problem-Solving index graph is the order of the lines, as the lower Problem-Solving index belongs to the non-designers doing a non-design task. In comparison, the highest Problem-Solving index belongs to designers doing a design task. Increasing Problem-Solving index in the fourth line represents the main feature of the design problem. According to Table 7 the t-test between the fourth section of design and non-design protocols have a significant difference and represents increasing Problem-Solving index of design protocols.

The variations of the Problem-Solving index in all cases suggest the existence of a design problem-solving activity even when non-designers are engaged with a non-design problem. This could be interpreted in two ways. First, as Simon (1996) says, basically any human activity involves designing to some extent. Second, the FBS coding scheme might not be exclusive to designing activities. The latter majorly affects the claims about FBS model as ontology of design and needs further investigation.

To inspect the properties of the non-design protocols further, the cumulative incidence of the FBS codes were used. Gero et al. (2012) suggest this measure as a method to compare the commonalities across design protocols. The cumulative incidence of the FBS codes was graphed for all the protocols and compared as per instructions of Gero et al. (2012). The generation of FBS codes across all the protocols show the same characteristics in terms of their generation rate — i.e., the slope and linearity of the graph lines.

This study compared the cognitive behaviors of the designers in solving both design and non-design problems. It benefits from the ontological basis of the FBS coding scheme to process verbal protocols from both design and non-design groups. The results show commonalities across all the protocols with differences corresponding to both the expertise of the designers and the characteristics of the problems.

The results of the study presented in this paper, show that studying design can change the way students solve other non-design problems. Different design problem solving strategies were used by design students to solve non-design problems, for instance, a cooking task in case of this study. The findings suggest that educating students with design thinking methods can increase their capability to tackle other non-design problems in their life. This research was carried out as a simple step to get more clarified information about designers' deep way of thinking. Today, the expansion of systemic studies will lead to do new research on designers' effectiveness from academic trainings and also personal designing styles. Accordingly, an approved and systemic methodology of ontology and linkography will be a new window to achieve the labyrinth of designers' minds.

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