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ANALYSIS OF EYE TRACKING DATA OBTAINED BY CUSTOMERS' PRODUCT EVALUATIONS

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EVALUATIONS

For the degree of Master of Science

Is approved by the final examining committee:

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04/14/2013

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ANALYSIS OF EYE TRACKING DATA OBTAINED BY CUSTOMERS' PRODUCT
EVALUATIONS

A Thesis

Submitted to the Faculty

of

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by

Shweta Sanjay Sareen

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

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West Lafayette, Indiana

To my parents who have loved me unconditionally and supported me in every endeavor.

To my younger brother for always being there for me.

To Prateek Jindal, who is a very special person in my life for supporting me through

tough times and motivating me in every way possible.

To god for always showing me the light and giving me strength.

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LIST OF ABBREVIATIONS

2D	Two dimensional
3D	Three dimensional
CSV	Comma separated values
HCI	Human Computer Interaction
SQL	Structured Query language

GLOSSARY

Analysis Tool-The separation of an intellectual or material whole into its constituent parts for individual study (Analysis tool, 2014).

Case study - The act or an instance of analyzing one or more particular cases or case histories with a view to making generalizations (Case study, 2014).

Cognitive process - (psychology) the performance of some composite cognitive activity; an operation that affects mental contents; "the process of thinking"; "the cognitive operation of remembering". (Cognitive Process, 2013).

Eye tracker- Eye tracker is a device that monitors eye movements (Reid, MacDonald & Du, 2012).

Human Computer interaction (HCI) - HCI Refers to the way that people use computer technology to perform a task (Fallman, 2003).

Learning curve- The learning curve is a graph of increase in learning (vertical y-axis) with experience (horizontal x-axis). Graphical representation of the common sense principle that more one does something the better one gets at it. Learning curve shows the rate of improvement in performing a task as a function of time, or the rate of change in average cost (in hours or dollars) as a function of cumulative output. (Learning curve, 2013).

ABSTRACT

Sareen, Shweta S. M.S., Purdue University, May 2014. Analysis of Eye Tracking Data Obtained by Customers' Product Evaluations. Major Professor: Brandeis Marshall.

Within the mechanical engineering discipline, product representational studies have been used to inform engineers on the suitability of their product designs for prospective customers. Mainly based in customers' oral responses, engineers would modify the product design accordingly. The incorporation of eye tracking data, in addition to the oral responses, in these product representational studies is a recent addition. This case study performs data analysis of a product representational study conducted by Reid, MacDonald and Du (2012), which considers the impact of 2D and 3D product representation on customer judgments with associated eye gaze patterns. The aim of this thesis is to act as a set of guidelines for analyzing other eye tracking studies that deal with product evaluations by discussing some of the possible analysis techniques to use the eye tracking data to obtain interesting facts and patterns. The thesis presents these five guideline characteristics: (1) question-based analysis, (2) question and category dependencies, (3) product and category dependencies, (4) gender impact and (5) experiment repeatability situations. In addition, a brief comparison of the 2D and 3D product representation experiments is described for each guideline characteristic.

CHAPTER 1. INTRODUCTION

The current chapter introduces the framework for this study, which is analyzing eye fixation data obtained by customers' evaluations of product representations and uncovering interesting patterns. The aim is to present a general analysis technique for similar eye tracking data sets. The chapter begins by providing a statement of the problem and then moves to the scope and significance of this study. The chapter then outlines the assumptions, limitations and delimitations. The last section is the chapter conclusion, which provides a final summary.

1.1 Statement of Problem

In human computer interaction (HCI) studies, experimentation has been conducted on how people observe and interact with various kinds of digitally represented products. The different roles of product appearance have been studied to elicit consumer choices (Creusen & Schoormans, 2005) and similar work has been done to test the validity and usability of product designs in various fields. The product representation and studies associated with them have a wide variety of applications and have the potential to provide interesting facts and patterns. The eye-fixation research in cognitive psychology (Just & Carpenter, 1976) is another interesting study because people's thought process is related to what they view, which is also called mind-eye hypothesis. The eye gaze data generated

from a subject's observation of products has been studied in order to elicit their opinions, emotions, preferences etc. These product observations have proven very useful in providing recommendations in the field of HCI and product design. The eye gaze data can be handled in many ways for different purposes. The proposed study provides a set of guideline characteristics for handling eye tracking data obtained from subject's evaluations of products from separate categories and designs. The research aims to forming a more standardized procedure for handling eye tracking data, e.g., data cleaning, data modeling, database design and implementation and finding relevant data patterns.

1.2 Scope

The eye tracking data used in this study was obtained from the study by Reid, MacDonald and Du (2012) that produced two samples of eye tracking data from two separate experiments and these samples are used in the current study. The query analysis is restricted to those two samples for the current study but intended to be generalized for similar experiments. The participants involved in the study were divided into two groups for the two experiments from which the eye tracking data was procured. The age range of the both group 1 and group 2 candidates was 18-65. Each participant group had a range of education completed, professions and mostly evenly split in the gender demographic. The proposed study is basing its guidelines on these two experiments with the understanding that a standardized set would be achievable with more eye-tracking experiments.

The proposed study deals with eye tracking data where product representation is limited to two representation modes. First one called version one, which shows products as computer sketches and FSV silhouettes and version two that shows products as simple and realistic renderings (Reid, MacDonald and Du, 2012). The products used in the eye tracking study were cars, coffee carafes, golf tees and some miscellaneous products.

In the current eye tracking data set in hand (Reid, MacDonald & Du, 2012), the product evaluation questions used to assess subject understanding were restricted to six categories of questions: preference questions, stylishness questions, width questions, length questions, height questions and two sets of inference questions. These questions together with the products formed many scenes that were viewed by the subjects. The research scope is to provide a set of guidelines for similar studies involving human subjects evaluating products from one or more categories with a predefined set of questions. The analysis is based on general queries which cover different aspects of data and does not concentrate majorly on any one single fact alone and provides possible uses of this eye tracking data.

1.3 Significance

The eye tracking data has the potential to uncover previously hidden commonalities amongst the participants and/or products. It becomes relevant in predicting subjects' understanding and preferences in order to better inform the product design process. This research's significance lies in laying the groundwork in providing product designers scientific evidence as to how to better interpret participant feedback about products in the designing process. Mechanical drawings can become complicated and difficult to

understand. Some designs may be better and easier to understand than the others. The mechanical engineering field is an example discipline that could benefit from this research. The eye tracking data can have multiple uses and there could be multiple ways of dealing with it. The proposed study aims to provide one such methodology of dealing with eye tracking data and presents some possibilities and recommendations as an outcome.

1.4 Assumptions

The current study has access to the dataset obtained from the study by Reid, MacDonald and Du (2012). Hence the assumptions made in this study are dependent on the previous study from which the data was obtained. The assumptions are as follows:

- The author of the current study assumes that the random division of subjects into two groups for viewing two separate representations of the products did not influence the outcome and hence did not reflect in the eye fixation data that was received
- The subjects were completely focused on the products while viewing them and were involved completely and enthusiastically in the study
- The subjects possess a good eye sight and could view the products clearly
- The eye tracker tracked the eye movements of the subjects accurately and gave the correct eye movement data
- The types of products were relevant to the subjects in day to day life and the subjects were acquainted with them (or at least had some knowledge about those products previously)

- The types of questions were sufficient in eliciting the subject's opinion and covered most aspects of product
- The eye tracking studies for product evaluation with a similar setup can use this study as a prototype for handling eye tracking data

1.5 Limitations

Following are some of the limitations of this study:

- The results obtained about the subject's understanding, preference, reactions are restricted to the subjects in the study and their learning, understanding abilities and choices
- The data is the only direct source that the author of this study has to uncover facts and patterns, there is no way of communicating with the subjects in the study directly
- The subject's previous knowledge and experience may have influenced his opinion and the data may reflect that influence, but we have no method to uncover that
- The study makes recommendations to handle eye tracking data and provides general analysis steps but does not aim to provide an all-inclusive list of ways to deal with eye tracking data and does not aim to cover all possible results
- The proposed study does not provide an exact process code to run for eye tracking data, but aims to provide some guideline characteristics that can be referred by other eye tracking studies

1.6 Delimitations

The following factors delimit this study:

- The data from the eye tracker and the subject's demographic data are the only chosen sources of information
- The current study is handling and querying the data using a relational database management system only
- The eye tracking data being used in the study was obtained by an eye tracker which captured eye movements of the subjects viewing two different representations of products (computer sketches and FSV silhouettes) and hence the comparison of design is solely based on those
- The only products used in the eye tracking data set in hand are cars, coffee carafes, golf tees and some miscellaneous products
- The question types in the eye tracking data set in hand are restricted to six categories of questions which are preference questions, stylish questions, width questions, length questions, height questions, two sets of inference questions
- The study aims to provide some but not all possible outcomes of dealing with eye tracking data

1.7 Summary

This study focusses on uncovering interesting facts and patterns from eye tracking data and present its various aspects. The data obtained from the eye tracker is an interesting source of information. To summarize, the proposed exploratory study will be significant in the following areas-

- 1) Act as a basic analysis tool for similar eye tracking studies and provide them with a simple prototype for handling eye tracking data and running various queries on it

2) Provide a working example of exploring eye tracking data for other general eye tracking studies

3) Present some general characteristics and possibilities that can be studied effectively by using eye tracking data and show an implementation of the same on the current data set

The author of the current study will be querying the data using MYSQL as it turns out to be a suitable and sufficient tool for the eye tracking data in hand. The next part of the study deals with the literature review. The study of related work will help the author show the various pieces of literature associated with product representation studies and eye tracking studies of different types. The further sections include the methodology, results and a final conclusion about this study.

CHAPTER 2. LITERATURE REVIEW

2.1 Background

The current study aims to provide general recommendations and an appropriate analysis technique for handling eye tracking data involving product evaluations. It would be interesting to see the various topics of research in the fields of product representation, product evaluation and eye tracking research separately. Researchers have previously studied these fields individually and presented different aspects of research within these areas. These topics have also been studied in pairs; as an example, product representations of different kinds were viewed by customers and eye tracking data was used to support their views (Reid, MacDonald & Du, 2012). It would be interesting to see the vast amount of literature on product representation and eye tracing studies and find out how the two have been related in the past. This literature review will also help the researchers of the proposed study understand which factors about the product, subject, categories and questions are of most interest when handling eye tracking data and hence make recommendations accordingly. This chapter is divided into the following sections- the first/current section provides background for the literature review; the second section studies the literature concerning the product representations, the third section studies the literature concerning eye tracking and eye fixation research in

general, the fourth section presents some mixed literature including repeatability of scenarios when viewing products and some unique pieces of literature that motivated the researchers to present this general prototype for handling eye tracking data.

2.2 Studies involving product representations

The study involving product representation and its impacts has been carried out for different purposes in different areas of research. Researchers have studied this phenomenon not only to elicit consumer's choices, opinions, judgments and buying preferences but also to obtain design recommendations for obtaining a better product design. Researchers often conduct such studies as a part of usability testing in the field of human computer interaction (HCI). Products presented digitally and their observation leads to uncovering patterns of usability and interest, for both the product and the viewer.

One aspect of using product representations of different types, which is studied by Artacho-Ramírez, Diego-Mas and Alcaide-Marzal (2008) , is to help designers uncover the flaws in product design in early stages so that they can come up with product designs that convey aesthetics to viewers more effectively. They have propagated through their study that “Different ways of representing a product can affect the ability to transmit the product's symbolic value to the observer. These product representations should succeed in inducing the same feelings and emotions in humans as a real product does. This helps create designs close to reality” (p.1). The human subject's verbal opinion is used to make the design better in such studies but it's important to note that eye tracking information would definitely add weight to their verbal opinion.

Creusen and Schoormans (2005) used product representation to elicit consumer choices, this would help the people manufacturing these products to increase profits as they would be able to design and manufacture products conforming to user's choice. They determined six different roles of product appearance for consumers and then suggested how appearance of a product plays a role in consumer product evaluation and choice and hence this is an example of how product representations are used to determine choices of people that can impact the business of these products. Similar studies have also been done to see what captures people's attention and hence transfer that to advertising, which will help the product sale in turn (Pieters & Wedel, 2004).

The interaction that a user has with a product has also been used as a strong source of information. Maeng, Lim and Lee (2012) suggested an approach that can search for user's needs and functions through the exploration of movement within the proposed interaction concepts instead of determining functions through the technology needs or use cases and this user-product interaction is powerful and has potential for further research. The User learns and infers based on what he views and analyzes during such studies and the product designers also benefit from user opinions. Hence the product evaluation studies by human subjects would be beneficial in many ways and with the eye tracking data supporting verbal opinions, it would definitely be interesting to explore opportunities.

Other aspect of product design and representation has been studied by Lai, Chang and Chang (2005) in their study, which tries to analyze the human affection to a product by using a car and its different representations. There are very few methods when it comes to measuring the consumer's affection towards product and hence this study

develops the concept of “feeling quality to concretize the feeling effects evoked by products “(p.1). The study succeeds in providing a novel approach because as shared by Lai, Chang and Chang (2005),” initially there were no suitable criteria available to measure consumer affection, there was variance in customer evaluations and no practicable design process was available” (p.1). Their work will help product designers improve their product design and achieve proximity to target feelings and target specific markets. People’s interpretations can also be influenced and analyzed by their emotion/affection to products. It becomes interesting to see that even emotions are affected in this way while viewing products. Thus, the interaction between subjects and products is a rich source of information and has many dimensions.

User shape preferences have also been studied for design optimizations (Kelly, Maheut, Petiot & Papalambros, 2011). These studies also use product representations and sketches of various product designs and use analysis techniques to get recommendations for design.

The above studies have used various product representation to study different outcomes. The consumer’s response to the visual domain in product design has been studied in literature. Crilly and Clarkson (2004) have provided a literature review structured around integrated conceptual framework to discuss the consumer response to product visual form. Their paper reviews a vast amount of literature on response to product appearance. One is able to infer many aspects of product evaluation through studying such literature. Something that can enhance the concept of product representational studies by providing a solid proof of observation is eye tracking data.

The proposed study stresses on using the product representation in collaboration with eye tracking data and aims to present various possibilities and benefits of handling this data. The above literature shows the various benefits of the product representation and evaluation studies and hence the proposed study would be useful in exploring the possibilities of performing similar research with eye tracking data and also study the impacts of such studies on the human subjects.

2.3 Eye tracking and eye fixation research

The verbal experience of the subject can be supported if his visual movements are tracked and one can determine what he is looking at exactly. Researchers have also used eye tracking as a tool to determine what the person actually perceives and thinks, which helps make stronger recommendations about the product, its design and usability. Human eye tracking has been effectively used in collaboration with above studies. One notable study in this area effectively studies the impact of Product Design Representation on Customer Judgment with Associated Eye Gaze Patterns (Reid, MacDonald & Du, 2012). This study hypothesizes that “customer judgments including opinions (refers to product evaluations for which there is no right or wrong), objective evaluations (product evaluations of a measurable quantity) and inferences (conclusions that cannot be made by observation alone) will be different for different representation modes of products” (p.2).

Reid, MacDonald and Du (2012) also used products from different categories and represented them in different ways and depicted scenes with different levels of questions. The survey questions were answered by a total of 62 subjects and their verbal experience was supported by eye gaze data. An eye tracker was used to obtain the eye movements of

the subjects and eye fixation times for each x-y coordinate that the subject was looking at were recorded. The study concluded that the product representations matter when measuring the customer's judgment.

The proposed study uses the same eye gaze data mentioned above and tries looking at different aspects of this data and provides a set of guideline characteristics to handle eye tracking data by the implementation of various queries. The 'mind eye' hypothesis is mentioned by Reid, MacDonald and Du (2012) in their study, which was originally discussed by Just and Carpenter (1980) in their study and it states that, "people have a tendency to look at what they are thinking about" (p.2). Thus the eye tracking data gives a direct access to a person's thought process and understanding and this helps to make more accurate product evaluations. Results become more concrete when the researchers are not merely trying to get a verbal account of something but are in fact trying to analyze what the person is thinking about and actually looking at, in a particular instance of time.

Eye fixation research in cognitive psychology dates to the mid 1970's (Just & Carpenter, 1976), which proposed that "the rapid mental operations of the central processor (active memory) can be revealed by analysis of eye fixation during a task involving visual input and hence it is possible to understand various memory tasks by studying this model" (p.1). This area of research definitely proves that a person's thought processes to a great extent are defined by what they are viewing at that point in time. This piece of research showed possibilities of analysis of eye fixation data in interpreting interesting facts not only about the product being viewed but also the subject viewing it. The study by Just and Carpenter (1976) explains that eye fixations can depict thought process and hence prove useful in making many recommendations about the subject.

The impact eye movement monitoring has also been studied by Glaholt and Reingold (2011) as a Process Tracing Methodology in Decision Making Research. Eye tracking studies have the potential of reading minds and the above study maps that to human decision making. Decisions are made as an outcome of thought process and the above study also reinstates this, which further creates interest in evaluating the possibilities of a learning curve in subjects. The paper directly relates the eye movements to producing a process tracing mathematical model and in turn infer how humans make decisions. The study signifies the new direction of using the eye tracking data for analyzing human thought process along with high end techniques like neuroimaging.

Eye tracking studies draw interesting perspectives to various phenomena. The fields of human computer interaction and usability also benefit from the eye tracking study (Strandvall, 2003). An eye tracking system records the eye movements while a subject is completing a task for example on a web site. By analyzing these eye movements, one is able to gain an objective insight into the behavior of that person and this kind of study is relevant (Strandvall, 2003). The behavioral reactions have been studied and applied to understand usability preferences of people. This is another very beneficial aspect of eye tracking data as it can help us understand behavioral aspects of a subject viewing a product and come up with usability patterns.

Another relevant aspect pointed out by Şahin, Bøe, Terpenney and Bøhn (2007) in their study is that of analyzing how perceptual discrepancies change across different media and design groups. Sahin et al. (2007) states that, “designers’ perceptual model evaluation efficiencies change across the selected representation media” (p.1). The study mentioned above is different because it focusses on changes in designer’s evaluation with

changing media unlike other studies that focus on gathering customer preferences to improve designs rather than understanding the designer's perception. So the novelty factor in the study comes from the fact that the designer's point of view is evaluated and not the subjects and hence this study is another example of how product representation and visual analysis is used to address a specific problem.

Looking at and specifically studying the various aspects of this section of literature, we can state that the eye fixation research and its impacts have been of great interest to researchers. Support to product representation studies has been added by the eye tracking and eye movement capture studies. These studies discuss various aspects of subject's reactions, as well as designer's evaluation (Sahin et al., 2007). So presenting a general tool for dealing with eye tracking data will be of relevance as this tool can be used by similar eye tracking studies as a starting point to analyze the eye tracking data. The above literature review demonstrates that this data does have the potential to come up with interesting facts and this is the main focus of the proposed study. The researchers of the proposed study aim to present one of the methodologies of handling eye tracking data and present some of the interesting possibilities and results that cover various aspects of this eye tracking data including the product, questions, designs and the subjects.

2.4 Additional related literature

A very interesting study by Veryzer and Hutchinson (1998) puts forward some interesting facts about individual's aesthetic response to new product designs. They state that this response is influenced by many factors out of which most notable ones are unity

and prototypicality. “Unity encompasses any aspect of a visual display that connects its parts in a meaningful way” (p.3). It is suggested by the authors that the aesthetic response for products exhibiting high unity is more positive. “Prototypicality, or typicality, is the degree to which an object is representative of a category” (p.4). The study states that the subjects respond most favorably to highly prototypical objects as opposed to less prototypical objects (Veryzer & Hutchinson, 1998). The authors study this aspect by performing four uniquely designed experiments.

The proposed study aims to present some interesting characteristics from eye tracking data and the one discussed above is one of them. When one repeats similar scenes that make sense together and unity is established and when the products are more prototypical, the researchers of the proposed study aim to analyze if the subjects answers to the questions regarding products vary more favorably or not and the time they spent fixating on the product fluctuates or not. The repeated exposure is one of the interesting phenomenon that the proposed study aims to analyze and present along with other results.

When the two group of subjects are shown exactly the same product in different designs and asked to answer similar questions, the choices they make would also be interesting to see as their answers (if different) would then solely be based on the changed design. The proposed study also tries to deal with this characteristic. “The results suggest that preferences for visually complex product designs tend to increase with repeated exposure, while preferences for visually simple product designs tend to decrease with repeated exposure.” (Cox & Cox, 2002, p.1). The proposed study deals with some preference questions and the above phenomenon is also one of the relevant

characteristic that the study will discuss. The eye tracking data obtained by product evaluations has many possible benefits and this is definitely one of them.

A lot of eye tracking studies have been conducted, not only for product evaluation, but for various other purposes. Duchowski (2002) has performed a breadth first survey of eye tracking applications which shows its various applications in neuroscience, psychology, industrial engineering and human factors, marketing/advertising, and computer science. This shows that eye tracking data is a source of a lot of rich information in many ways. The proposed study aims to present a an analysis tool, inspired by these studies that can be used as a basic prototype by other studies involving eye tracking data and helps them explore its relevant aspects.

Another eye tracking study that did not involve product evaluation was done by Cutrell and Guan (2007) for analyzing information usage in web search. This study proposed an interesting aspect of eye tracking data and explored the effects of changes in the presentation of search results. The authors claimed that “adding information to the contextual snippet significantly improved performance for informational tasks but degraded performance for navigational tasks.” (Cutrell & Guan, 2007, p.1). Eye tracking measures were used to understand the reason for such differences. The eye fixation data and scan paths helped this study more than the mere verbal account of the where the subjects were looking because eye tracking data provides with exact eye fixation times. Mind eye hypothesis, as mentioned earlier does say that people’s thought process and eye movements are related and thus the author of the proposed study feels that when this is applied to product, design and subject evaluation, a more interesting analysis of all the features is possible.

Eye tracking data is a very good accurate measure of user attention. Usability features and design analysis has been done in the past using eye tracking data as a source of information. A study by Goldberg, Stimson, Lewenstein, Scott and Wichansky (2002) was conducted to evaluate specific design features for a prototype web portal application. Their study gathered eye tracking information from seven subjects while they were made to perform six specific tasks on the prototype oracle web application. While the subjects performed various activities like editing, maintenance and clicks, their eye movements were tracked to understand how they go about performing those tasks through multiple screens. This study (Goldberg et al., 2002) was one of its kind because it dealt with multi-scene eye tracking and establishes the usage of eye tracking data in usability studies. The proposed study is also dealing with multi- scene eye tracking, but for product evaluation. Hence the prototype presented by the proposed would be beneficial for both, product design evaluation and multi-scene eye tracking studies.

Another study in the list of eye tracking studies to study user's interaction with websites is the study by Granka, Joachims and Gay (2004) to analyze user behavior in WWW (World Wide Web) search. "The goal is to gain insight into how users browse the presented abstracts and how they select links for further exploration. Such understanding is valuable for improved interface design, as well as for more accurate interpretations of implicit feedback (e.g. click through) for machine learning "(p.1). The study particularly signifies that user behavior and inference of usage patterns is possible and would be interesting to see with respect to product evaluations. Thus, the proposed study also aims to discuss user related behavior while viewing various products as one of the possibilities

of handling eye tracking data and make recommendations for the same as this would be a unique concept with respect to a product evaluation study.

Salvucci and Goldberg (2000) performed a study to identify fixations and saccades in eye tracking protocols. They performed fixation identification which basically is separating and labelling fixations. “The study proposes a taxonomy of fixation identification algorithms that classifies algorithms in terms of how they utilize spatial and temporal information in eye-tracking protocols“(p.1). Thus, a lot of work has been done to handle this eye tracking data in various studies. Some recent studies have also used eye tracking data to study the mental operations of schizophrenic patients.

Jacob (1995) has used eye tracking to derive an advanced interface design, which is another example of eye tracking data being a rich source of information of the interaction between human subjects and computer or any digitally represented media.

The various eye tracking studies and the varied work done in this field inspires the author of the proposed study to present a set of guideline characteristics to handle the eye tracking data and present a set of possibilities that can be explored with the data in hand and study various of its benefits.

2.5 Chapter summary

The literature involving product representations and evaluations, their impacts, outcomes etc. for both designers and customer, have covered a wide variety of topics like eliciting preferences, opinions, judgments, design recommendations, interpretation of design aesthetics etc. These product representational studies generally take into account the verbal opinions of subjects. The product or design evaluation performed with the

support of subject's eye tracking data helps one provide a deep perspective into the design, product, its intricacies and the subjects thought process, understanding and choice will be analyzed better in this way.

The eye tracking studies show the vast amount of work done in the field. Some eye tracking studies have dealt with products and studied customer judgments (Reid, Macdonald & Du, 2012). Eye tracking data has also been used for understanding human cognition and thought process. These studies have covered various aspects of eye tracking data. The aim of the proposed study is to present a general prototype for analyzing eye tracking data for product/design evaluation and present characteristics that can be derived from the dataset. Subject's opinion of products and their designs can be best explored with eye tracking data.

Additional literature shows interesting characteristics like repeatability of scene, multi scene eye tracking, eye tracking research for web usability, which help the proposed study develop the characteristics associated with products, designs and subjects that would be most interesting to other eye tracking studies. These various studies try to derive an insight into what goes in a person's head, the subject's behavior and finally the subject's interest, opinion or understanding of what is being viewed and analyzed. The proposed study is an attempt to present some guideline characteristics for an eye tracking data set and is inspired by the above rich plethora of literature.

The above studies along with the requirements of the subject matter experts have inspired the author of the proposed study to determine and work on the relevant characteristics of eye tracking data and present this basic analysis tool. The first author of the study- Impact of product design representation on customer judgment with associated

eye gaze patterns, Dr. Tahira Reid has guided the author of the proposed study for deriving many of the characteristics of interest related to eye tracking data involving product evaluations.

Further sections present the methodology for the research, the results and a conclusion for the study.

CHAPTER 3. METHODOLOGY

In this section, the process of data cleaning, data modeling, database design and implementation are described using the two participant studies performed by Reid, MacDonald and Du (2012). Then, the characteristics that could be incorporated into a generalized eye-tracking set of guidelines for mechanical engineering experiments are presented.

3.1 Data processing

The original experiment (Reid, MacDonald & Du, 2012) divided the participants into two groups of 31 subjects each randomly based on intuition. These two groups were subjected to two different experiments. Group 1 viewed the FSV silhouettes and computer sketches (2D renderings) and the Group 2 viewed the realistic and simplified renderings (3D renderings) as depicted in Figure 3.1

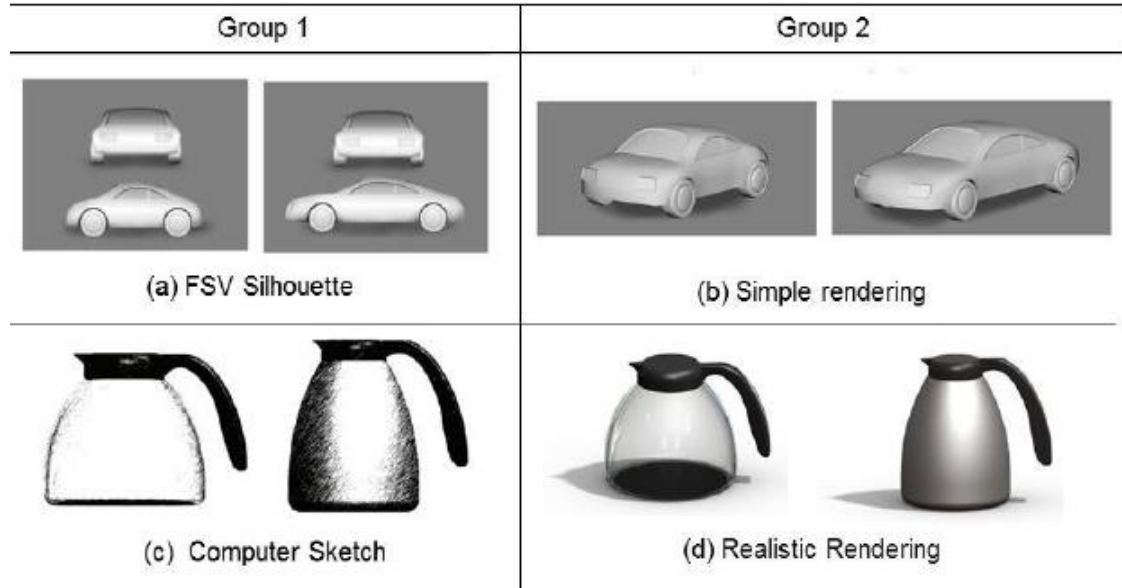


Figure 3.1 Product representations

The proposed study also uses the demographic information of both male and female participants and these participants belong to different age groups, professions and educational backgrounds. The proposed study deals with gender analysis as a characteristic of studying eye tracking data and so it will be interesting to see the gender grouping and their educational background together, which will help understand the upcoming results better. The Figure 3.2 below contains a summary of 2D and 3D demographic data.

	Total Females	Total Males	Total College Degrees	Total Advanced Degrees
Two Dimensional (2D) study	15	16	17	14
Three Dimensional (3D) study	15	16	19	12

Figure 3.2 Demographic summary

The above data provides an overview of the range of participants' backgrounds. The group one participated in the 2D version of the study that contained the product sketches as two dimensional FSV silhouettes or computer sketches. The subjects viewed a total of 73 scenes, where each scene had an associated question from table 3.1.

Table 3.1 *Question categories*

Decision/Question category	Question ID	Question type
Opinions	100	Preference
	200	Stylishness
Objective evaluations	300	width
	400	length
	500	height
Inferences	600/700	Recyclability
		Heat Retention
		Fuel Efficiency

Single product was shown for objective evaluation and products were shown in pairs for inference and opinion category questions. The product categories are shown in table 3.2.

Table 3.2 *Product categories*

Product category ID	Product category name
25	Cars
35	Coffee carafes
45	Golf tees
55	Miscellaneous products

The Tobii eye tracker was used to capture the subject's eye movements while they were taking the survey. As stated by Reid, MacDonald and Du (2012), "product pairs were always the same representation modes within each version of the survey and the subjects were randomly assigned to each group" (p.5). The data generated by the eye tracker was the input to the current proposed study. The table 3.3 shows a small subset of the raw unprocessed data set, which was obtained initially for group 1/2D version.

Table 3.3 *2D version unprocessed data*

FixIn	Time	FixT	MF_X	MF_Y	Stim	ProdNo	SubjectNo
367	123625	658	439	397	New_Scene_14	10055.12	SU01

Similarly the group 2 had 31 subjects but they viewed realistic and simplified renderings (three dimensional images). They viewed a total of 78 scenes. The rest of the procedure followed for this group was the same.

The above data set (see table 3.3), which emerged as an output of the experiment by Reid, MacDonald and Du (2012) is a small subset of the actual data that was used as input for the proposed study. The Tobii eye tracker gave data output in the form of CSV

files. The following is an explanation of each column in table 3.3, which will help understand the next sections comprehensively.

The first three columns were redundant and not required. The fourth column FixT gives the total fixation time of the subject for the current (x,y) coordinate on the screen in milliseconds. MF_X and MF_Y are the (x,y) coordinates of the screen where the subject is staring at that point in time. Stim is the scene number. ProdNo has a number which depicts the question, category and product ID in combination. First three digits are the question ID. Next two digits are the category ID. Digits after the point are product/products ID depending on if there are one or two digits after the dot. The two digits after the dot depict two separate products in the scene. The last column is the subject number.

The above data had some redundancy and extra columns. Also as observed in the column description, the product number is one single number which contains the product, category and question number. So the first step was to clean and process the data. A relational database management system was used to store the data and perform statistical and query analysis on the data as next steps. A similar procedure was followed for processing both the CSV files (2D and 3D version). 2D version contained 61,034 rows and 3D version contained 60,399 rows. The CSV files were opened using Microsoft Excel. Firstly, all the white spaces between rows were removed. A mathematical function was used to process the Prod no. and split it to question, category and product. The first five digits were divided with 10. For example take 10025.35, the product ID after '.' was obtained, then 10025 was divided by 100. Quotient gave the question ID and remainder gave the category ID. This is how the version one presented in table 3.3 looked

after processing (see table 3.4). The version two was also cleaned and processed in the same way.

Table 3.4 2D version one processed data

FixT	X	Y	Scene	Question	Category	Product	Subject
658	439	397	New_Scene_14	100	55	12	SU01

The above processed table 3.4 has the first three redundant columns removed. The question, product and category ID were now separated and all the white spaces were removed. The CSV file was now ready to be loaded into the database. The database was designed as shown in figure 3.3.

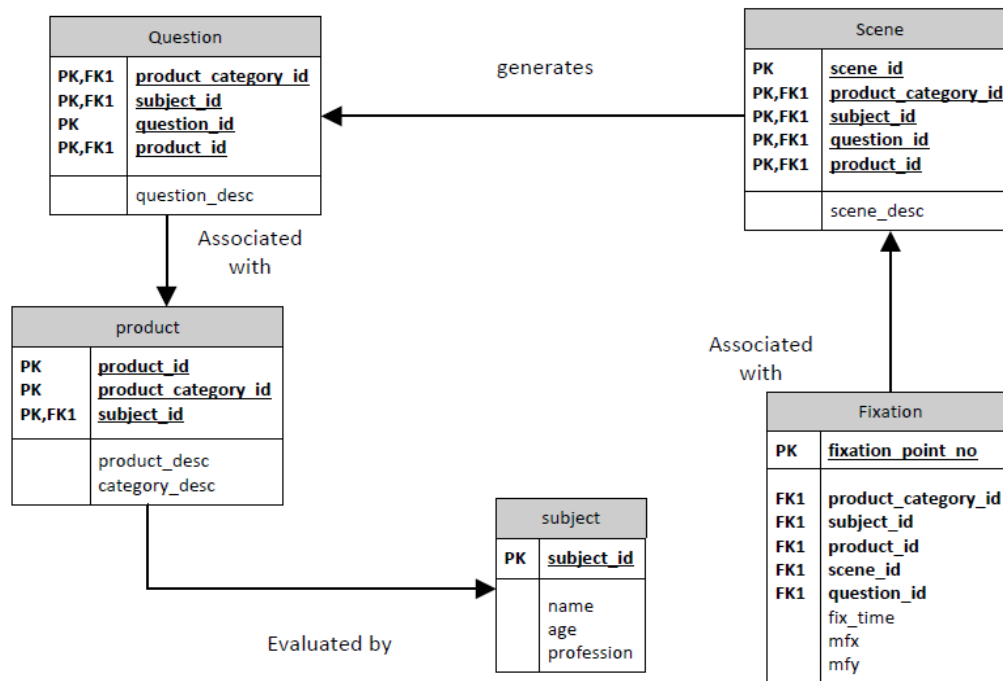


Figure 3.3 Entity relationship diagram (ERD)

The entity relationship diagram (ERD) ensures that subject ID is carried on as a part of every table because subject understanding will be analyzed throughout this study. The database used was MYSQL.

SQL *loader was used to load the cleaned files into the database. The author of the proposed study created the tables named Test and Test one for the 2D and 3D version respectively and loaded the data into these tables. All columns were loaded except for the void column in the processed data. The cleaned CSV files were read only once and the data was loaded into the Test and Test one tables. The MYSQL command for the loader was:

```
LOAD DATA LOCAL INFILE "c:/users/prateek/desktop/shweta/main.csv"(file location)
INTO TABLE eye_tracking.test fields
TERMINATED BY "," ignore 1 lines
```

The next steps after designing the database and loading all the desired data into the tables was to actually start working on this eye gaze data to determine specific analysis steps and build a template of interesting characteristics.

3.2 Template characteristics

In the current section, the author of the proposed study presents interesting guideline characteristics that analyze various aspects of the eye tracking data. These characteristics depict various facets of the eye tracking data. The proposed study uses average fixation times as a standard metric across all characteristics as averages can be compared and contrasted. The averages may be analyzed with five number summaries (minimum, quartile one, median, quartile two and maximum). This can also depict outliers, which can help interpret the deviant behavior of the subjects while evaluating

products. It is important to note that there are many more possibilities of dealing with the eye tracking data. The metrics like standard deviation, variation etc. could be chosen for studies that aim to analyze eye tracking data differently for other specific purposes. The proposed study uses average as a metric for most queries and evaluates various characteristics of eye tracking data involving product evaluation studies and aims at being useful as reference to similar studies. The sections 3.2.1 to 3.2.6 present the main guideline characteristics presented by the proposed study. The characteristics discussed in the template are summarized in the figure 3.4 below along with the corresponding characteristic numbers, which makes it easier to locate them.

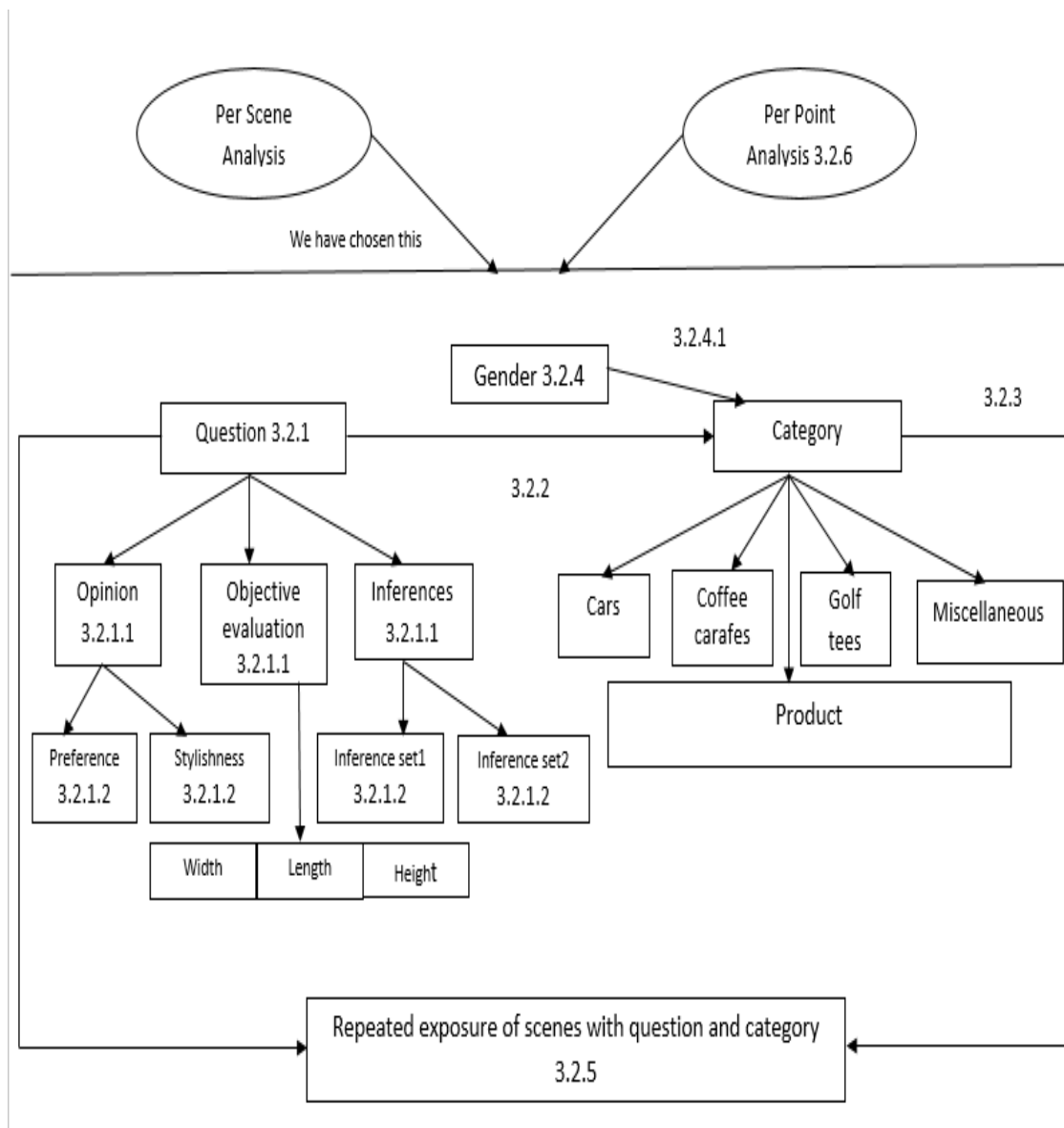


Figure 3.4 Summary of template characteristics

The figure 3.4 above can help find the characteristics of interest from the sections below and it also describes the flow of characteristics.

3.2.1 Question Analysis

The first relevant characteristic presented by the study was that of question analysis. Any product evaluation study would use some set of questions for evaluating

the product or design under consideration. These questions would definitely play an important role in evaluating the product and understanding how the subjects interpret the eye tracking data. It would be interesting to see the average time spent on each question while evaluating the products. This would help understand the impact that the questions can have on the product as well as the subject. The proposed study used the eye tracking data, which had questions belonging to three separate categories and there were seven question types in all.

3.2.1.1 Analyzing main question categories

Current analysis helps evaluate average times spent on each major question category (opinions, objective evaluations and inferences). A particular type of judgment may take more time than some other form. People may in general take more time to make objective evaluations than to state their preference. This aspect of analysis can help an eye tracking study infer if certain groups of questions impact the study or subjects more than the others and how eye tracking data can help depict this phenomenon.

3.2.1.2 Analyzing all question types

These set of results would help evaluate the average time spent on each of the seven question types (preference, stylishness, width, length, height, inference set one and two) overall used in the proposed study. On the lines of this type of question analysis, eye tracking studies can also derive interesting facts about customer interpretation that can help depict what kinds of questions impact them more in general. The high fixation times spent on a particular question type could indicate their increased interest or difficulty in answering a question. The average time spent on each question overall could help depict

this characteristic. The proposed study aims to present the average times spent on each type of question for 2D and 3D data, which will also help depict if the design change impacts the time spent on question. If the time spent on questions reduces, this could be either due to repeated exposure or ease of design interpretation. Studies working on the above lines can use this characteristic for further analysis.

3.2.2 Question and category analysis

Splicing the data further brings forth another interesting relationship. That would be to see the relation between times spent on all the seven types of questions against the specific category of product. This could help interpret which category of products for each question take most time to be evaluated, which in turn helps us interpret if people's acquaintance of a category of products matters when answering questions. For example, between opinion, inferences and objective evaluation, subjects may find it easier to give an opinion about a familiar category like a car but for the same familiar category, they may take more time to objectively evaluate. This questions analysis associated with different categories, when done in 2D and 3D, can help draw a comparison between these two different designs on the basis of question and category.

3.2.3 Product and Category Analysis

The subject matter experts found it interesting to see which products the people spent most time on while fixating. As mentioned earlier, in the current eye tracking data, the products from the four major categories were in pairs for most questions, except when the subjects had to answer questions based on objective evaluation. Comparing the

average fixation times spent on each product or product pairs from both 2D and 3D versions helps depict not only which of these took the most time for evaluating but also see if this time spent varies with design. There could be three possible interpretations for products where the average fixation time spent is more –

- a) The product/ product pair is more interesting to the subject
- b) The product/product pair or its features are difficult to interpret
- c) The question associated with the product/product pair at that time was difficult

The interpretation depends upon the motive with which the study using this characteristic for evaluation is designed. This kind of analysis will definitely be useful in understanding both, the product and design features. The proposed study aims to present average fixation time spent on each unique product or product pair by using the eye tracking data in hand, in both 2D and 3D and then discuss the findings of the same. The proposed study will also aim to look for outliers to detect any deviant behavior in the observations. Five number summaries will help provide an insight into the results obtained. This analysis step and the associated method and results would be beneficial for various product evaluation studies, which focus on specific products or product dimensions.

Building upon the information obtained by analyzing which specific unique product/product pairs in the study take most time, a simple analysis involving the various categories of products in an eye tracking study could be conducted. Average fixation time spent depicts average time spent on each product while viewing the product from a specific category. Averages can be compared amongst themselves. Hence, it would be interesting to see if average time spent on each category of product being viewed and

then compare this across designs. Studies comparing certain day to day products, which belong to separate categories, could use this analysis to see how fixation time varies across categories and whether it depicts patterns of interest or not. Inferences like which category is familiar and which design makes the category look simpler can definitely be made by working on such analysis. On the recommendation of subject matter experts, the proposed study compares the car, coffee carafe, golf tees and miscellaneous products.

The results obtained from the above product and category analysis can be checked for further alignment. It would be interesting to see that the product or product pair which appears to have taken more time for evaluation aligns with the category that has taken the most time overall. The main focus of product evaluation studies is to understand various aspects of a product and this analysis will be useful in such endeavors.

3.2.4 Gender Role Analysis

Another perspective that has not been studied in literature supporting eye tracking studies is that of genders role in choice while evaluating products, as depicted by eye tracking data. The gender role in product evaluation would draw an interesting perspective to the product evaluation study because same scenes (comprising of the product and question) may take more time for females than males in general. The 62 participants in the study by Reid, MacDonald and Du had a mix of both, males and females. The participants were divided into 2 groups of 31 subjects for 2D and 3D experiments and each of these 31 subjects were a mix of males and females. The proposed study did not have a very huge number of subjects to make an exact hypothesis

about gender role in an eye tracking study, but this step of analysis will be beneficial in laying a foundation for related studies that aim to do so.

The proposed study depicts the time spent on all scenes by male and female participants separately and then checks the difference in time spent on those scenes collectively amongst them. The 2D and 3D experiments had 73 and 78 scenes respectively and majority of the subjects viewed all the scenes. Thus, it would be interesting to see, who amongst the males and females spent more time in viewing these scenes. This can help us determine if gender plays a role in product selection and also determine if eye tracking data is a suitable source of information for the same. Same analysis can be performed on both the designs in the study to see if gender is as significant while evaluating both designs.

3.2.4.1 Gender category analysis

Analyzing this concept further, the proposed study also analyzes the gender role while viewing separate categories of product. For example, it was interesting to check facts like male participants spending more time on golf tees than females, since men are known to be more interested in golf. Breaking down the gender analysis into various product categories will draw an interesting perspective on how category preferences may vary with gender. The proposed study provides this as an example to depict how gender plays a role in selection (or not). Further possibilities of analysis are studying gender-question, gender- product etc. with context to current study, which can be considered by other studies interested in the same, but are not a part of the proposed study.

3.2.5 Repeated Exposure Analysis

Studies mentioned in the literature review like the repeated exposure and its impacts on choice (Cox & Cox, 2002) and the study involving unity and prototypicality (Veryzer & Hutchinson, 1998) are of great interest because of the unique concepts that they discuss and propagate. Similar characteristics can be studied by using eye tracking data too. For instance, when the subjects view similar scenes over and over, the repeated exposure may impact their opinion or choice and they may start preferring the complex design more (Cox & Cox, 2002). One can see the impact of similar scenes on a person's preference by using eye tracking data. At the same time, the scenes that are related and have unity of content can also impact the subject's opinion. The eye tracking studies involving product evaluation, which are interested in understanding the impact of repeated features or scenarios can use similar analysis to derive such facts.

For the preference and stylishness questions, which are collectively called opinion questions, the study (Reid, MacDonald & Du, 2012) uses same car and coffee carafe products for both 2D and 3D data but two different groups of subjects are exposed to exactly the same scene instead of same set of subjects. The exact repeated scenes being viewed by two different sets of subjects and in two separate design forms would be useful in understanding the unity and repeatability of the scene being viewed but not the impact on subject's choice as the subjects are different. One could analyze the changes in opinion of different subjects when they are made to view exactly the same scene. The difference in time and choice patterns could hence be an indication of the choices of different subjects or solely the change in design, for the same exact scene.

It would be interesting to see how a study can be designed with similar outcomes regardless of participants. Different eye tracking studies, which strive to achieve similar outcomes could benefit through this characteristic. Even though the participants will be different, these studies could study similar outcome by using this characteristic.

Studies interested in the impact of repeated exposure on subjects particularly, can use the same set of participants for participating in such experiments and then expose them repeatedly to similar scenes and the impact of this exposure on subject's choice can be studied effectively. Comparing the fixation times in these scenarios would help evaluate whether the repeated exposure impacts the design preference of the subjects or not, as in such situations, the products, the question being viewed and the subjects in the study remain the same and only the design changes.

3.2.6 Fixation point analysis

Some studies maybe interested in the average time spent per fixation point while studying eye tracking data unlike the proposed study, which uses the average fixation time per scene for analyzing the corresponding questions, products, categories etc. To answer questions like which product is most viewed? Or which gender views cars for a longer time? , we definitely need to sum the fixation time spent on a particular product overall and divide it with the unique occurrences (scenes containing that product) to obtain average time spent on a product. The studies that are interested in specific product locations or specific screen areas may want to know average time spent per fixation point, which is the x-y coordinate on the screen. For example, the table 3.5 below depicts the average fixation time spent per fixation point across all categories when inference set

one questions were being viewed. The proposed study focuses on the average time spent on the scene where question was an inference set one question and not a single point as the focus was overall product, category and question analysis as opposed to one fixation point or few regions on the screen. Thus, the proposed study performs per scene analysis, which means while computing averages, the total time spent on a product, question or category is divided by its occurrences and each unique scene containing that product, question or category is counted as an occurrence.

Table 3.5 *per point analysis*

Category	Average fixation time per fixation point (milliseconds)
Cars	282.510
Coffee carafes	296.203
Golf tees	289.503
Miscellaneous	269.120

The above table 3.5 is interpreted as the average fixation time spent per fixation point on cars, when the question being viewed is an inference question. The query in this case is a SQL query which gives average directly from fixation table (sums all fixation times for the given conditions and divides it by the total points that satisfy the given condition).

Query-

```
SELECT category_id ,avg (fixation_time)
FROM eyetracking1.fixation
WHERE question_id= x group by category_id; (where x could be any question ID)
```

3.3 Chapter summary

The above logical framework helps the author of the proposed study present a general template of guideline characteristics that could be useful for similar product evaluation eye tracking studies. Various dimensions of interest of an eye tracking data set are discussed in the proposed template. The author of the proposed study uses the eye tracking data set and presents a working model of these characteristics through the results and discussion that follows this chapter.

The eye tracking data set that the proposed study is dealing with contains two relevant design types and the results will be presented for both the result types. Hence, a discussion on how these eye tracking studies could be relevant for comparisons of design types will also be provided in the upcoming sections.

Further sections will cover all the queries corresponding to the characteristics above, results and discussions and a conclusions along with some final recommendations on how the proposed template will be beneficial for handling eye tracking data. The above described methodology and technique will be used further to obtain more relevant results that help the author establish a systematic template and a strong case study for similar eye tracking studies.

CHAPTER 4. RESULTS

The characteristics described in the methodology above help build this template for analyzing eye tracking data obtained as a result of product evaluation studies. The Results section presents the implementation of the characteristics described in the methodology section on the eye tracking data set in hand. All the results discussed below, are discussed for 2D and 3D data set both. As mentioned before, average was used as a metric of comparison to present the results. Various statistical techniques could be used to analyze and evaluate this data further and obtain the desired information. Upcoming sections 4.1 to 4.5 describe the results associated with each major characteristic described.

4.1 Question analysis

The following tables 4.1 and 4.2 depict the average time spent per question type and includes all the seven question types. To obtain these results, firstly the total time spent on each question was obtained by getting the sum of fixation times spent on each point of the scene containing the specific question from fixation table. The number of unique scenes containing these questions were obtained from the scene table in the database where in the scenes represent the unique instances at which the subjects viewed these questions. The queries for the same are as shown below-

Query to get the total time-

```
SELECT question_id , sum(fix_t)
FROM eyetracking1.fixation
GROUP BY question_id;
```

Query to get the count-

```
SELECT question_id , count(scene_id)
FROM eyetracking1.scene
GROUP BY question_id;
```

The total time was divided by the count using excel functionality and below averages were obtained. The same process was conducted on both 2D and 3D data sets.

Table 4.1 *Average time spent per question (2D)*

Question ID	Average time spent per question (sec)
Preference	7.980
Stylishness	6.250
Width	15.764
Length	14.663
Height	12.258
Inference set one	6.997
Inference set two	6.304

Table 4.2 *Average time spent per question (3D)*

Question ID	Average time spent per question(sec)
Preference	8.240
Stylishness	5.907
Width	14.289
Length	12.651
Height	11.889
Inference set one	6.321
Inference set two	6.578

As seen from the table above, the highest time is spent on width questions overall. The objective evaluations also seem to have taken more time overall. This can be confirmed by the next analysis step.

As seen in the table 3.1 of methodology section, the questions were divided into 3 major categories. The Figure 4.1 below show the average time spent on each of the 3 main categories of questions in both 2D and 3D. This confirms the inference that the average fixation time spent by subjects in the current eye tracking study is highest for objective evaluations. The product evaluation is based on viewing the images for these products on a computer and maybe, the questions which ask a subject to objectively evaluate something (find width, height, and length) are difficult to be worked out by just seeing the image of the product under consideration. Such analysis can help similar studies test the validity and suitability of the questions they are using to conduct the study.

Question category	Average time spent (sec)	Question category	Average time spent (sec)
Opinions	7.188	Opinions	7.283
Objective evaluation	14.184	Objective evaluation	13.016
Inferences	6.769	Inferences	6.414

2D dataset **3D dataset**

Figure 4.1 Average fixation time per question category

The above results depict the fact that the objective evaluations indeed take more time than opinions and inferences overall. Another interesting fact observed is that time spent on the question types and the question groups both does not vary either with 2D or 3D product representations and remains nearly consistent in spite of the changed design.

4.2 Question category analysis

The previous results look at the questions in a broader spectrum. If one slices down the data further, one can infer if the time spent on the various questions varies with category or not. The average time spent on the scene for a specific question is calculated against all the four categories used in the eye tracking data. The figures 4.2 and 4.3 below show the average time spent per question across all categories in 2D and 3D respectively.

The specimen queries to find the total and count for this analysis step are-

Query for total:

```
SELECT product_category_id , sum(fix_t)
FROM eyetracking1.fixation where question_id=x
GROUP BY product_category_id; (where x is question ID)
```

Query for count:

```
SELECT product_category_id , count(scene_id)
FROM eyetracking1.scene where question_id=x
GROUP BY product_category_id; (where x is question ID)
```

The average is simply obtained by dividing the results of the first query with results of the second query.

Preference Questions		Stylishness Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	8.906	Cars	6.980
Coffee carafes	6.559	Coffee carafes	5.608
Golf tees	8.555	Golf tees	5.724
Miscellaneous	9.193		

(a) (b)

Width Questions		Length Questions		Height Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	18.835	Cars	14.663	Coffee carafes	11.624
Coffee carafes	14.224			Golf Tees	12.494
Golf tees	12.625			Miscellaneous	12.773

(c) (d) (e)

Inference set one Questions		Inference set two Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	6.940	Coffee carafes	6.348
Coffee carafes	6.878	Golf tees	6.047
Golf tees	7.816		
Miscellaneous	7.245		

(f) (g)

Figure 4.2 Average fixation time per question 2D (category wise)

From figure 4.2 above, for 2D (as also seen previously) objective evaluations take higher average times and at the same time, cars take most time under objective evaluations. On the other hand, inferences take less time for cars and coffee carafes as compared to golf tees, the difference is small but notable. Overall for the 2D data, the cars have taken most time, when the question being asked was about the width of the product (see 4.2 c).

Preference Questions		Stylishness Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	8.270	Cars	6.522
Coffee carafes	7.496	Coffee carafes	5.290
Golf tees	7.772		
Miscellaneous	11.083		

(a) (b)

Width Questions		Length Questions		Height Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	14.940	Cars	14.663	Coffee carafes	10.680
Golf tees	12.644			Golf Tees	11.944
Miscellaneous	14.462			Miscellaneous	13.072

(c) (d) (e)

Inference set one Questions		Inference set two Questions	
Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	6.065	Coffee carafes	6.459
Coffee carafes	5.984	Golf tees	6.820
Golf tees	6.500		
Miscellaneous	9.354		

(f) (g)

Figure 4.3 Average fixation time per question 3D (category wise)

From figure 4.3 above, for 3D also the objective evaluations across categories also take more time. An interesting point that one can note instantly is the similarity in average times spent on each question across all categories remains similar (if not exactly the same) across 2D and 3D data both even though the sketches viewed by the subjects were actually different.

4.3 Product category analysis

The eye tracking studies involving product evaluations may find the question analysis interesting, but more focus would still be on the products and categories under consideration. The figures 4.4 to 4.7 below, which are bar charts, represent the average time spent on each single product /product pair as shown to the subjects in both 2D and 3D studies respectively. There were 33 unique product combinations viewed by the subjects in both the experiments. The specimen queries to find the total and count for the products in this analysis step are-

Query for total:

```
SELECT product_category_id ,product_id ,sum(fix_t)
FROM eyetracking1.fixation
GROUP by product_category_id,product_id;
```

Query for count:

```
SELECT product_category_id ,product_id ,count(scene_id)
FROM eyetracking1.scene
BY product_category_id,product_id;
```

The results obtained from first query were divided by the results obtained from second query using excel to get the average time spent per product/product pair, which is depicted by the bar charts. The figure 4.4 and 4.5 below depict the bar charts for average time spent per unique single product and product pair respectively in 2D study and figure 4.6 and 4.7 depict the same for 3D study.

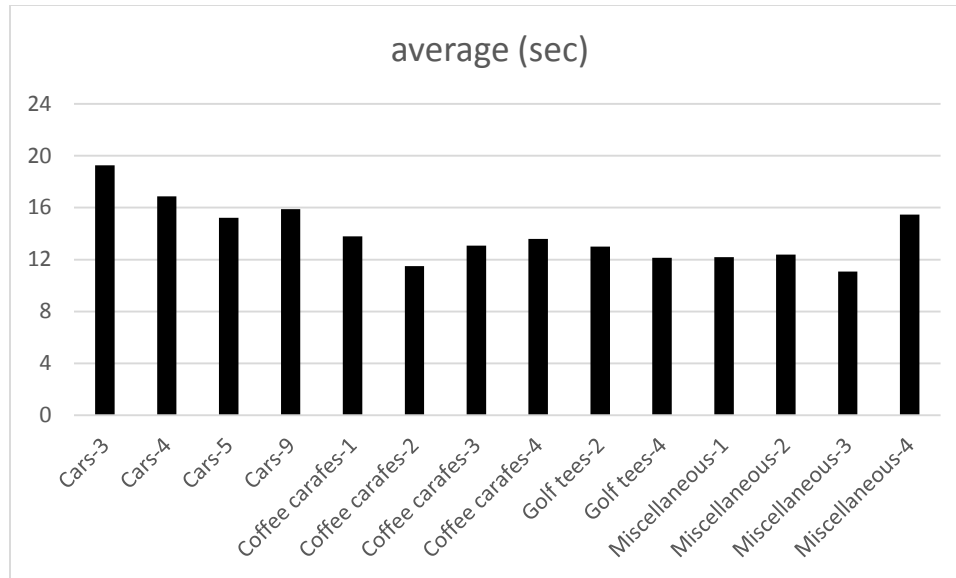


Figure 4.4 Bar chart for average time per unique single product 2D

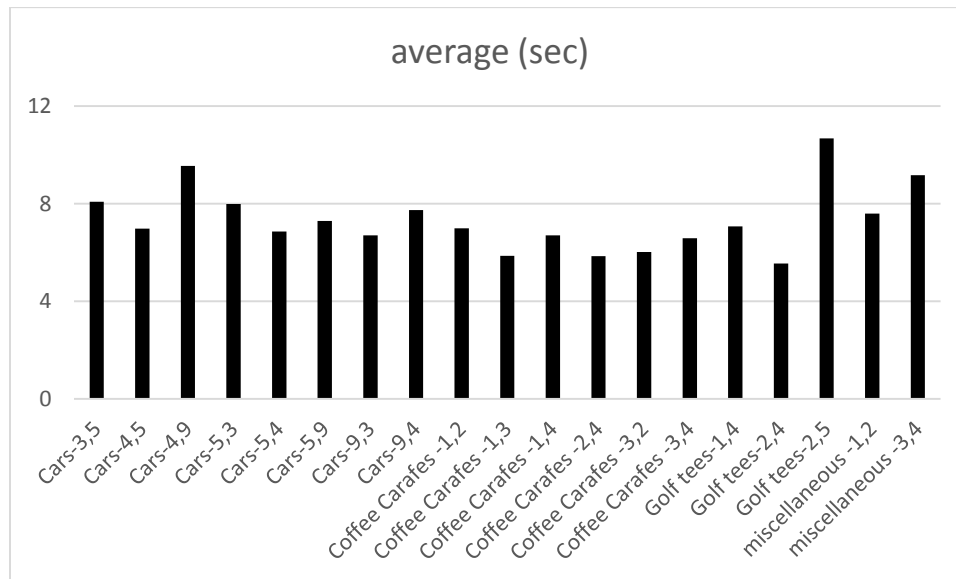


Figure 4.5 Bar chart for average time per unique product pair 2D

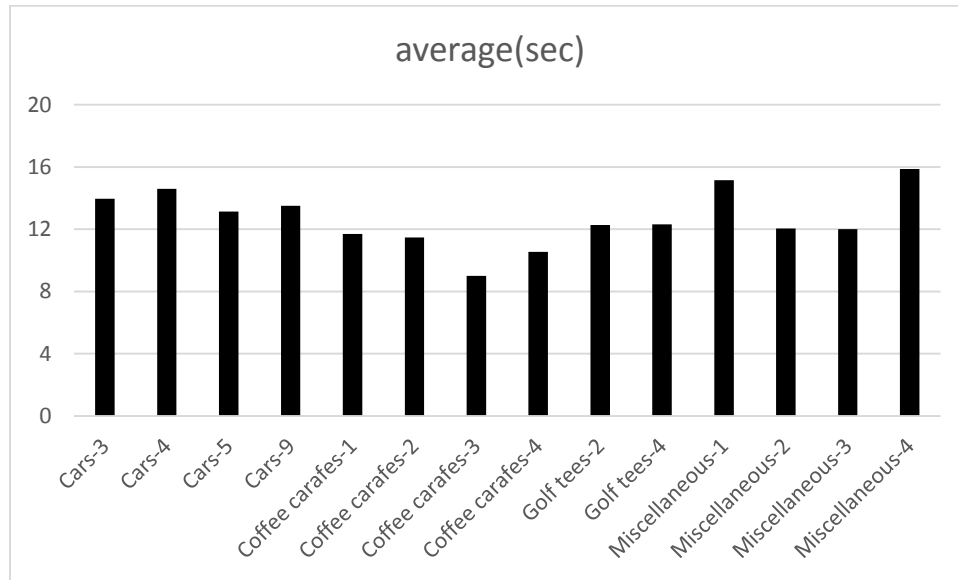


Figure 4.6 Bar Chart for average time per unique single product 3D

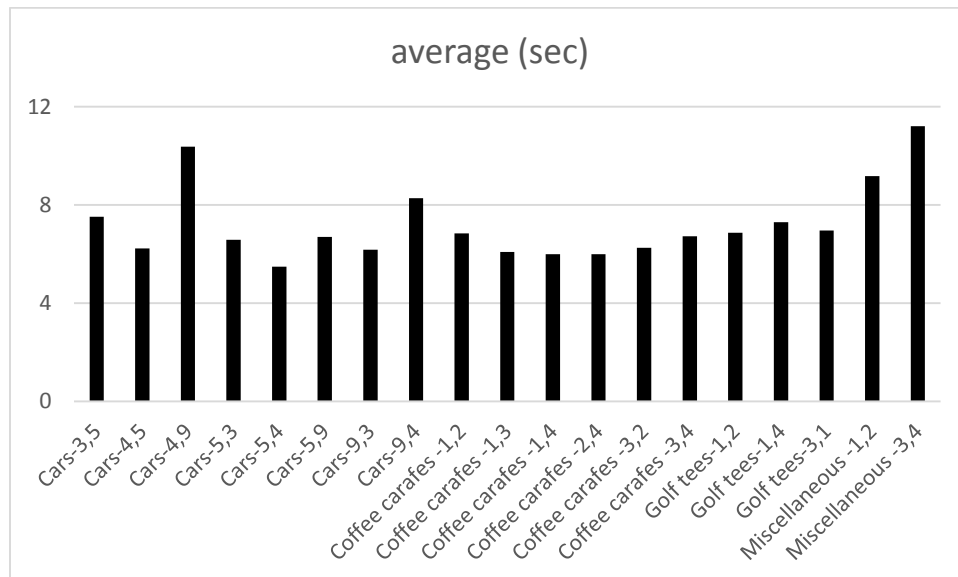


Figure 4.7 Bar Chart for average time per unique product pair 3D

To make sense of the 33 averages for both 2D and 3D, the author of the proposed study performs five number summaries. Below is the five number summary for 2D product /product pair averages as depicted in the figure 4.4 and 4.5.

Minimum- 5.547 Quartile 1(Q1) =6.973 Median=9.171

Quartile 3(Q3) =12.993 Maximum=19.258

Interquartile Range=Q3-Q1=6.02

Outliers are greater than $Q3 + 1.5 * IQR$ or less than $Q1 - 1.5 * IQR$

Hence, Outliers are > 22.023 or < -2.057 .

The above data has no outliers statistically, which implies the subjects did not spend exceptionally more or less time on any product. Some points of interests are that the highest time spent in the 2D experiment is on the product 3 from car category. Single product also implies it was an objective evaluation questions. Linking above question analysis to this, one could also infer the higher average time has something to do with the question being an objective evaluation as a single product means the question was some kind of objective evaluation. As mentioned earlier, the proposed study uses eye tracking data from the study by Reid, McDonald and Du (2012) and the results of various analysis steps strongly depict the difficulty in answering objective evaluation questions. This is inferred by studying various facets of the data. Other eye tracking studies could use this prototype for drawing similar interesting inferences.

Below is the five number summary for 3D product /product pair averages as depicted in the figure 4.6 and 4.7.

Minimum- 5.481 Quartile 1(Q1) =6.699 Median=9.007

Quartile 3(Q3) =12.045 Maximum=15.878

Interquartile Range =5.346

Outliers are greater than $Q3 + 1.5 \cdot IQR$ or less than $Q1 - 1.5 \cdot IQR$

Hence, Outliers are > 20.064 or < -1.32 .

Again, there are no observed outliers. The highest average time spent is on the product 4 in miscellaneous category (question would again be an objective evaluation as it is a single product). The minimum time is spent on the product pair 2,4 from golf tees category in 2D and the product pair 5,4 from car category in 3D respectively. Looking at the figure 4.8 below, we see that the categories where minimum average time is spent are coffee carafes for both 2D and 3D but the product pairs where least time is spent are not coffee carafes. These particular products could be studied further to obtain detailed information on why such behavior is depicted. When eye tracking studies choose products, they can evaluate what causes deviant behavior for certain products and focus on one feature more than the other.

Figure 4.8 below depicts average time spent per category in 2D and 3D overall. It is interesting to see that the coffee carafes take least time in both the designs and the rest of the ordering changes. The design change has not the changed the fact that people spend less time in evaluating coffee carafes overall and this may have something to do with the fact that people are more familiar with coffee carafes in general day to day life.

Category	Average Time (seconds)	Category	Average Time (seconds)
Cars	10.438	Cars	9.038
Coffee carafes	7.976	Coffee carafes	6.930
Golf Tees	9.785	Golf Tees	8.643
Miscellaneous	10.916	Miscellaneous	12.867

Figure 4.8 Average time per Category 2D (left) and 3D (right)

The query used to obtain above results is as follows-

```
Query for total: SELECT product_category_id , sum(fix_time)
FROM eyetracking2.fixation
GROUP BY product_category_id;
```

```
Query for count: SELECT product_category_id , count(scene_id)
FROM eyetracking1.scene
GROUP BY product_category_id;
```

The averages were obtained by dividing the total by count in excel.

4.4 Gender role analysis

The 2D and 3D version of the study had male and female participants both. Hence this step provides some interesting results relevant to gender analysis as elaborated in the methodology earlier. The studies whose focus is gender wise evaluation of products using eye tracking data should focus on this analysis step. The Figure 4.9 shows the average time spent by both male and female participants in 2D study and 3D study both. The total fixation time that the male and female participants spent on the study is obtained by the following query and the fixation table was updated with subject gender before executing this query-

```
SELECT subject_id,sum(fix_t)
FROM eyetracking1.fixation where gender=x
GROUP BY subject_id; (where x is male or female)
```

This total time was divided by the number male participants, which is 16 and the number of female participants, which is 15 to obtain the average time spent on the study by male and female participants respectively. The average time is in milliseconds initially, considering all the fixation times are per coordinate and in milliseconds. This time is divided by 1000 to obtain the average time in seconds. Average time spent by females is more in the 2D study, as depicted by the figure 4.9.

Similar analysis was conducted on 3D study and the average time spent by females on the study was found to be significantly higher again, as depicted by figure 4.9. The total male participants was 16 and female participants was 14 (Subject 9 who was a female did not participate in the study). Also notable is the fact that the average time spent on the study spent by both male and female participants increases in 3D study as compared to 2D study. The study whose main focus is analyzing gender role in design or product evaluation can use this step as a base for further analysis.

Gender	Male	Female	Gender	Male	Female
Average in 2D(sec)	613.365	648.280	Average in 3D(sec)	645.376	691.697

Figure 4.9 Average time spent on 2D and 3D study gender wise

Proceeding forward with Gender- category analysis, the figure 4.10 and figure 4.11, are bar charts that show the gender wise breakdown of average time spent per category of product for 2D study and 3D study respectively. This analysis step and results could be beneficial for studies that aim to study gender role in product preference and evaluation by using eye tracking data. The bar charts depict the average time spent by male and female participants on the three major categories in the study. For example, in 2D experiment, the males fixate more on all categories while in 3D experiment, the females fixate more on all categories. Another interesting observation is that the average time spent per category does not show many variations after being broken down gender wise, as design changes from 2D to 3D. The bar charts depict a very similar trend.

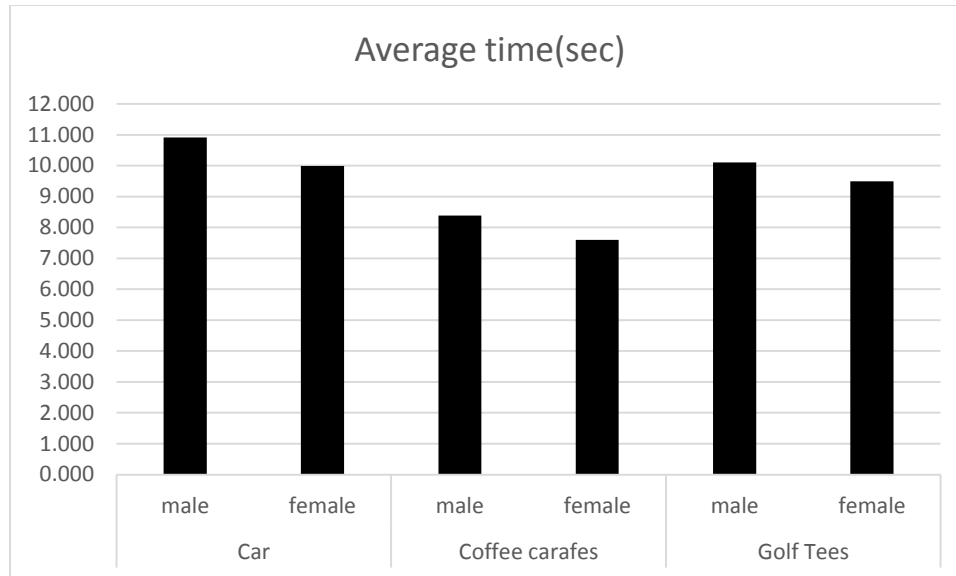


Figure 4.10 Gender-Category analysis for 2D

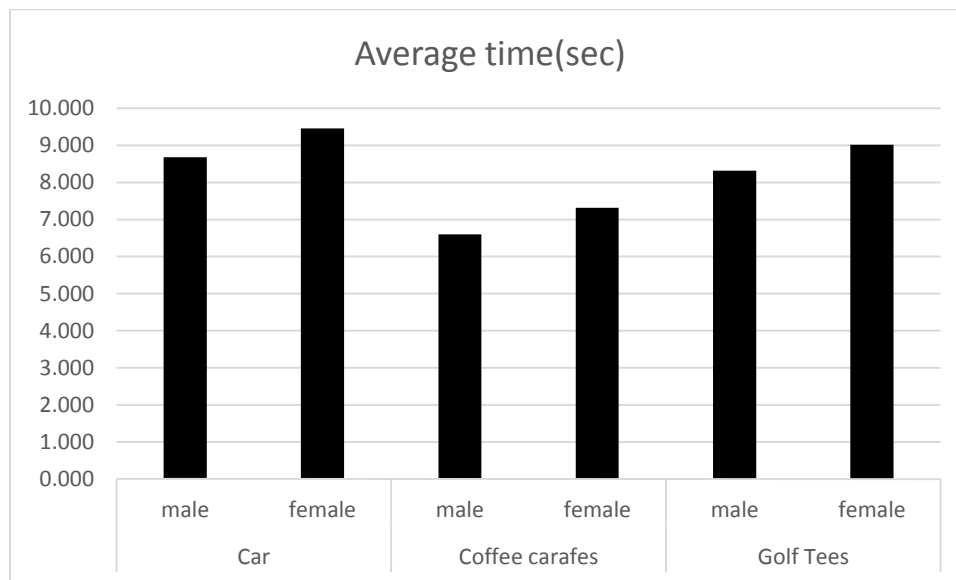


Figure 4.11 Gender-Category analysis for 3D

The following steps were followed to obtain the results whose pictorial representation is depicted in figure 4.10 and 4.11 above -

- 1) The fixation table was updated with gender

- 2) Following queries were used to obtain the fixation time and count for each male or female participant and after executing these queries, the mathematical calculations from step 3 to 6 were performed
 - a) Query for total time:
 SELECT subject_id, count(distinct scene_id)
 FROM eyetracking1.fixation
 WHERE gender=x and product_category_id=y
 GROUP BY subject_id; (where x is gender and y is the category)
 - b) Query for count:
 SELECT subject_id, sum(fix_t)
 FROM eyetracking1.fixation
 WHERE gender=x and product_category_id=y
 GROUP BY subject_id; ; (where x is gender and y is the category)
- 3) The scenes containing the corresponding category were counted and added for all male and female participants after executing the above queries
- 4) Then, the total fixation time spent on the corresponding category was counted and added for all male and female participants
- 5) The total time was divided by corresponding total counts and the average time spent per category for male and female participants was obtained
- 6) All calculations were performed using MS Excel

4.5 Repeated exposure analysis

The proposed study presents an example of repeated exposure analysis by using the current eye tracking data in hand. According to Dr. Reid who was a part of the team that conducted the experiment, the same car and coffee carafes were shown for 2D and 3D experiments while answering preference and stylishness question. This implies that the whole scene remained same (the product, category, question remains the same) and

only the design changes. Two different group of subjects viewed these repeated scenes in the 2D and 3D form respectively. Studies can use this phenomenon to design experiments to obtain similar results and outcome. It would be interesting to see if only the design change impacts the opinions (preference and stylishness) of the group of subjects viewing them.

The specimen queries used to obtain the results depicted in the bar charts from figure 4.12 to 4.15 are as follows-

Query for total time-

```
SELECT product_id, product_category_id, sum(fix_t) as total
FROM eyetracking1.fixation
WHERE question_id=x and product_category_id=y
GROUP BY product_id,product_category_id ; (where x is question id and y is category )
```

Query for count of scenes-

```
SELECT product_id, product_category_id, count(scene_id)
FROM eyetracking1.scene
WHERE question_id=x and product_category_id=y
GROUP BY product_id,product_category_id ; (where x is question id and y is category)
```

The total was divided by count using MS excel to obtain the results below.

The question ID, category ID and the 2D and 3D databases were changed accordingly in the queries to obtain different results.

Figure 4.12 below is the bar chart for first repeated scene, which is of cars while answering preference questions in 2D and 3D respectively.

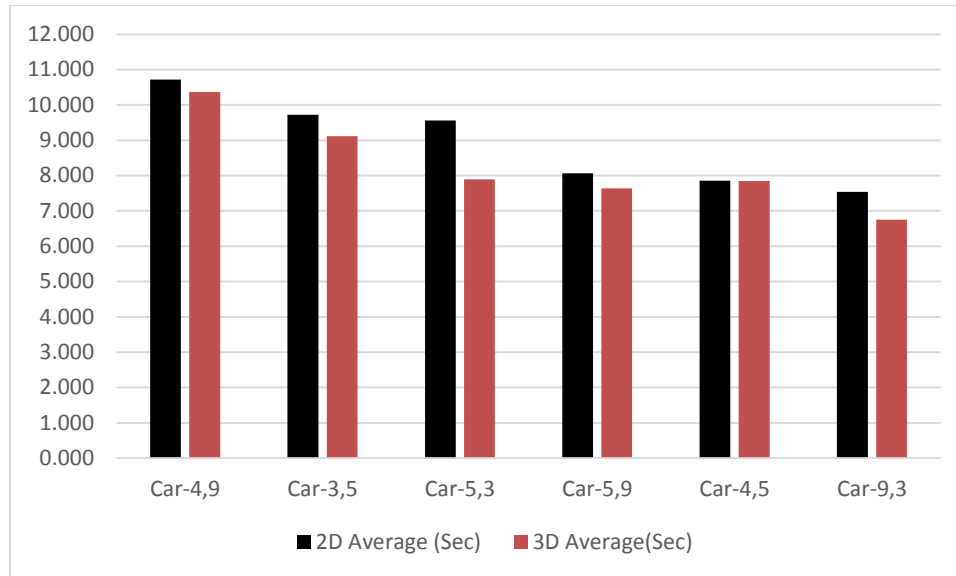


Figure 4.12 Car scenes with preference questions in 2D and 3D

The above figure 4.12 depicts the unique car products from 2d and 3d data and gets the average time spent on each pair of products for the Preference questions. The most notable point here is that the average time spent is almost similar between repeated 2D and 3D scenes and the average time changes by only one second or less for most cases. The time spent by subjects on preference questions for each pair of products does not change with 2D and 3D designs. An interesting point depicted here is that when the product pair 35 is flipped and shown to the same subjects as 53, the time remains almost same in 2D, but it changes by two seconds in 3D. Studies interested in similar analysis could explore many such interesting facts by using this analysis.

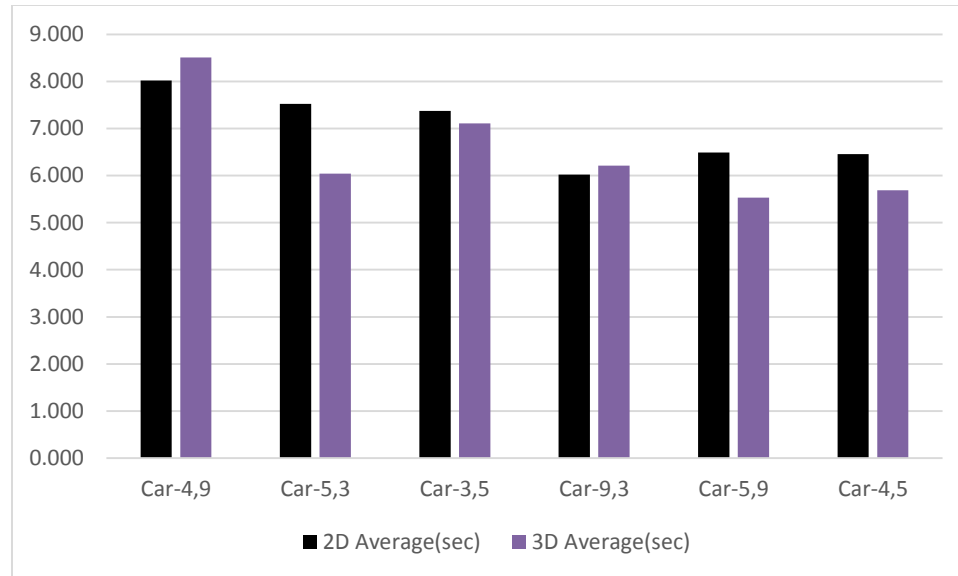


Figure 4.13 Car scenes with stylishness questions in 2D and 3D

The above figure 4.13 shows the bar chart for unique car products from 2D and 3D data and depicts the average time spent on each product for the Stylishness questions. Again, the average time spent is almost similar between repeated 2D and 3D scenes and the average time changes by only one second or less for most cases. The time spent by subjects on preference questions for each pair of products does not change much with 2D and 3D designs.

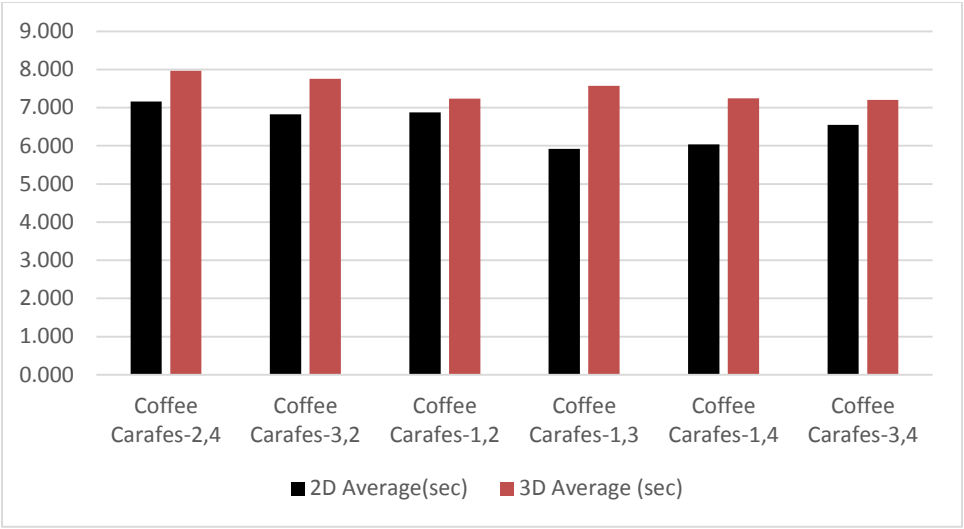


Figure 4.14 Coffee carafes scenes with preference questions in 2D and 3D

The above figure 4.14 shows the bar chart for unique coffee carafe products from 2D and 3D data and depicts the average time spent on each product for the Preference questions. The preference for coffee carafes does change slightly with designs. Overall time spent in choosing products increases when viewing 3D products. For example choosing more preferred coffee carafe out of 1 and 2 (product pair 12) takes lesser time in 2D than 3D.

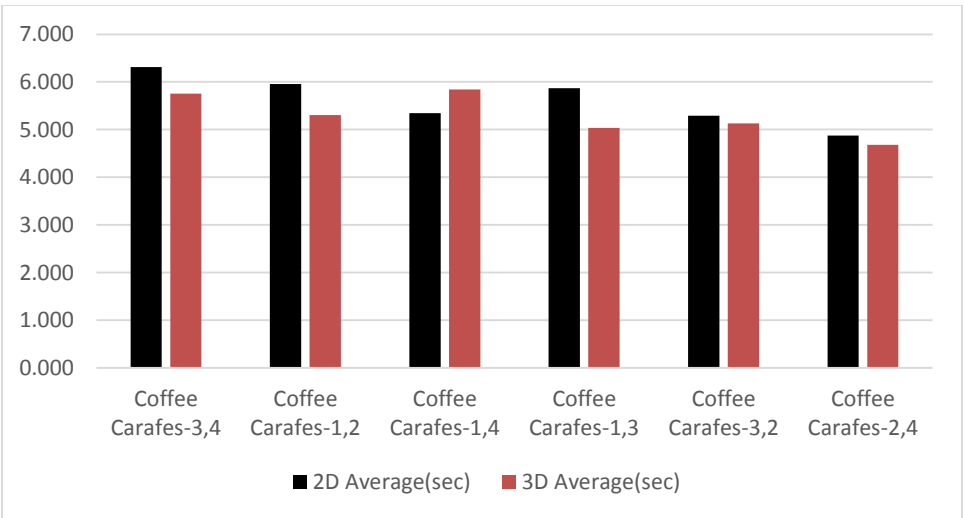


Figure 4.15 Coffee carafes scenes with stylishness questions in 2D and 3D

The above figure 4.15 depicts the bar chart for the average time spent per unique coffee carafe products from 2D and 3D product for the Stylishness questions. The ordering for stylishness for coffee carafes does not seem to vary with design for these repeatable scenes. The product pair 24 takes the least average time across both the designs.

The author of the proposed study had access to a smaller data set with only 62 subjects, thus the author presents a prototype for handling eye tracking data with a few interesting guideline characteristics, which the other eye tracking studies can build on. The proposed study does not dig deep into any particular analysis. Studies that have specific goals while handling eye tracking data could benefit greatly from the guidelines provided in the proposed study.

CHAPTER 5. CONCLUSION

The proposed study is a sincere attempt to build a template that can help analyze and evaluate various aspects of eye tracking data, obtained as a result of product evaluation studies. The proposed study successfully presents various interesting facts and characteristics that can help other eye tracking studies by performing analysis steps on the eye tracking data in hand obtained by the study by Reid, MacDonald and Du (2012). The proposed study can help in analyzing questions for the product evaluation studies by presenting a characteristic , which studies seven types of questions (preference, stylishness, width, length, height, two sets of inferences) and evaluates them using average time as criterion. This characteristic also reveals the impact that the questions can have on the study overall. The major categories of questions (opinions, objective evaluations and inferences) are also studied to present a more generalized view of the same. Both of these characteristics showed that objective evaluations are indeed the most time consuming questions while evaluating products. The data is further spliced and it is observed that the impact of the questions chosen does not necessarily vary with changing categories of products (objective evaluations still take more time).

The products chosen for such a study and the category they belong to definitely impacts the outcome of the product evaluation study and eye tracking data can depict that

successfully. The proposed study looks at various products from different categories individually and statistically evaluates the average time spent on each product to understand if there is a pattern and no outliers were observed during the process.

The genders role in eye tracking study is also evaluated and it is concluded that male and female participants have different patterns of evaluating products and eye tracking data can depict that, but the results vary when design changes.

Some eye tracking studies that are interested in repeated exposure analysis, can use this analysis step to study the variation in average time spent by participants on repeated scenes. This can also help other researchers design similar studies with different participants that achieve the same effect. The proposed study observes some consistency in the observation patterns when viewing similar scenes even though the designs are different in both experiments and so are the participants.

The proposed study also presents an interesting per point analysis step, which would be useful to the eye tracking studies performing analysis on some specific part of the whole product or some area of the scene.

The author of the proposed study began the analysis of eye tracking data from the data dump that was obtained as a result of eye tracking by Tobii eye tracker. Searching the relevance of such data, cleaning, determining the possible uses, performing literature review, providing a template of characteristics of eye tracking data for product evaluation studies and providing a working example of the same, are the most useful outcomes of this study. The process followed in this study can be useful to other studies that deal with eye tracking data analysis and product evaluation. Some characteristics like question, product or category analysis would be more useful in the product and design evaluation

studies in the field of engineering, manufacturing and web user interface design. The gender's impact on products or categories, as depicted by eye tracking data, can be useful in marketing products specific to a gender and promoting them to a particular sector, in the field of advertising and promotions.

Repeatability analysis can be useful for studies that aim to design experiments with similar outcome or want to know the impact of repeated exposure on subjects and products both while designing products, websites etc.

The eye tracking product evaluation studies can use the proposed study as a reference for their research. The proposed study does not dive in deeply to any of the characteristics; it rather tries to present an over view of some of the possibilities of handling eye tracking data. Other studies interested in these possibilities can then use these steps and characteristics to develop their research. Hence the proposed study successfully presents a case study for handling eye tracking data obtained by product evaluation studies, by presenting some of the possibilities of analyzing.

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APPENDIX

APPENDIX: DATA DEFINITION LANGUAGE

The following is the DDL (data definition language) for the database used in the thesis. The table definitions presented below are from the schema named eyetracking1, which contains data from the 2D experiments. The eyetracking2 schema contained data from 3D experiments and was designed in the exact same manner. These figures depict the table schema information as depicted in MYSQL, which is the database tool used in this study.

The figure A.1 shows the test table that was used to initially load all the data from the CSV (comma separated values) file to the database.

Table: test**Columns:**

fixt	int(11)
mfx	int(11)
mfy	int(11)
sceneid	varchar(45)
redundant	int(11)
questionid	int(11)
categoryid	int(11)
productid	int(11)
subjectid	varchar(45)

Figure A.1 Schema for test table

The remaining tables from figure A.2 to figure A.6 are the main tables depicted in the ERD (entity relationship diagram) and were populated from the above test table using insert statements.

```
Table: subject1  
  
Columns:  
subjects      varchar(45) PK  
age_range      varchar(45)  
gender         varchar(45)  
education      varchar(45)  
occupation     varchar(45)
```

Figure A.2 Schema for subject table

```
Table: product  
  
Columns:  
subject_id      varchar(45) PK  
product_id      int(11) PK  
product_category_id int(11) PK  
product_desc   varchar(45)  
category_desc  varchar(45)
```

Figure A.3 Schema for product table

Table: question**Columns:**

<u>subject_id</u>	varchar(45) PK
<u>product_id</u>	int(11) PK
<u>product_category_id</u>	int(11) PK
<u>question_id</u>	int(11) PK
question_desc	varchar(45)

Figure A.4 Schema for Question table**Table: scene****Columns:**

<u>subject_id</u>	varchar(45) PK
<u>product_id</u>	int(11) PK
<u>product_category_id</u>	int(11) PK
<u>question_id</u>	int(11) PK
<u>scene_id</u>	varchar(45) PK
scene_desc	varchar(45)

Figure A.5 Schema for scene table**Table: fixation****Columns:**

<u>fixation_no</u>	int(11) AI PK
subject_id	varchar(45)
product_id	int(11)
product_category_id	int(11)
question_id	int(11)
scene_id	varchar(45)
fix_t	int(11)
mfx	int(11)
mfy	int(11)
gender	varchar(45)

Figure A.6 Schema for fixation table