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Development of a Database-Driven Management System for Retail Food Packaging Eye Tracking Studies

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DEVELOPMENT OF A DATABASE-DRIVEN MANAGEMENT SYSTEM FOR RETAIL FOOD PACKAGING EYE TRACKING STUDIES

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ABSTRACT

Within the past three years, approximately two hundred one-off studies have occurred in developing eye tracking methodologies for quantifying consumer attention on packaging design preference. Due to restricted time and resources, most research analyzes consumer attention regarding a relatively small amount of products within specific planogram. However, larger questions concerning category trends and insights are not possible with these smaller, one-off studies. Broad data aggregation and analysis is important for understanding packaging design per product category in order to understand category-wide design trends and insights. Considering the excessive effort in manual data retrieval, analysis, and reporting, a method that can improve efficiency and data aggregation would be of tremendous benefit to all researchers studying consumer behavior on relevant product categories. Ultimately, the application of the relational database management system fits this need.

The work herein describes a procedure of developing a database-driven management system for retail food packaging eye tracking studies and the data analytics. A relational database of eye tracking studies associated with a web portal was designed and created to aggregate, store, access, share, and analyze eye tracking data based on studies in an immersive retail environment. The comparison between this system and the file-based methods was discussed, includes eye tracking study procedure, data usage efficiency, and data analysis methodology.

This body of work covers 14 eye tracking projects in aggregate, involving 34 planograms comprised of a total of 421 consumer product goods. When using this database-driven system compared to the traditional file-based process in terms of time, it was found that the developed system reduced the time of the eye tracking study process by 48%.

DEDICATION

This dissertation is dedicated to my parents, Kai Zhao and Wenjin Li, for their constant love and support.

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TABLE OF CONTENTS

Page

TITLE PAGE i

ABSTRACT ii

DEDICATION iv

ACKNOWLEDGMENTS v

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER

I. INTRODUCTION 1

References 4

II. LITERATURE REVIEW 6

Introduction 6
Food product development and launching 6
Importance of packaging design 7
Eye movements and visual attention 8
Eye tracking 8
Applications of eye tracking in consumer research 10
Applications of databases 12
Research Objectives 13
References 15

III. RELATIONAL DATABASE DESIGN BASED ON EYE TRACKING STUDIES 19

Abstract 19
Introduction 19
Methods and materials 20
Results and discussion 38
Conclusion 43

Table of Contents (Continued)

Page

References 44

IV. WEB PORTAL DEVELOPMENT FOR DATABASE MANAGEMENT 45

Abstract 45
Introduction 45
Method 47
Implementation results 50
Conclusion 60
References 61

V. INTEGRATION OF ADVANCED FEATURES 62

Abstract 62
Introduction 62
Method 63
Implementation results 65
Conclusion 78
References 80

VI. COMPARISON OF THE DBMS METHOD WITH THE FILE-BADED METHOD 81

Abstract 81
Introduction 81
Method 83
Results 85
Conclusion 88
References 90

VII. CONCLUSIONS AND RECOMMENDATIONS 91

Conclusions 91
Recommendations and future research 93

LIST OF TABLES

Table Page

3.1 Summary list of requirement analysis..27

6.1 The comparison of the average time consumption
between two methods per study phase..86

LIST OF FIGURES

Figure Page

2.1 The CUshop^{TM} consumer experience laboratory 9

2.2 Mobile eye tracking glasses 9

3.1 Eye tracking devices 22

3.2 Eye tracking raw data of TTFF for a cereal planogram 23

3.3 Eye tracking raw data of TTFF for a rice planogram 23

3.4 Eye tracking raw data of TTFF for a granola planogram 23

3.5 Eye tracking raw data of TFD for cereal planogram 24

3.6 Eye tracking raw data of TFD for a rice planogram 24

3.7 Eye tracking raw data of TFD for a granola planogram 24

3.8 Eye tracking raw data of FC for a cereal planogram 24

3.9 Eye tracking raw data of FC for a rice planogram 25

3.10 Eye tracking raw data of FC for a granola planogram 25

3.11 The structure of eye tracking raw data sheet 25

3.12 Users E-R diagram 29

3.13 Participant E-R diagram 30

3.14 Project E-R diagram 30

3.15 Planogram E-R diagram 31

3.16 Product E-R diagram 31

3.17 Time to First Fixation (TTFF) data E-R diagram 32

3.18 Total Fixation Duration (TFD) data E-R diagram 32

List of Figures (Continued)

Figure		Page
3.19	Fixation Duration (FC) data E-R diagram	33
3.20	E-R diagram of the database	34
3.21	SQL commands for creating tables in the database	35
3.22	Result of columns from the project table	36
3.23	Result of columns from the planogram table	36
3.24	Result of columns from the product table	36
3.25	Result of columns from the TTFFdata table	36
3.26	Result of columns from the TFDdata table	37
3.27	Result of columns from the FCdata table	37
3.28	Result of columns from the users table	37
3.29	SQL commands used in creating views	39
3.30	Columns of View PJ_PL_AGG	39
3.31	Results Returned for Project No.43	40
3.32	SQL commands for creating the category data views	41
3.33	Retrieved Results from View CATEGORY_AGG	42
4.1	The two-tier model	46
4.2	The three-tier model	46
4.3	The structure of the system design	48
4.4	Process for generating category results	50
4.5	Home page	51

List of Figures (Continued)

Figure Page

4.6 User registration forms 52

4.7 Login form 53

4.8 The authorization process 53

4.9 Web page for importing the excel file 54

4.10 Web page for importing the planogram information 55

4.11 Web page for selecting the products from a category list 56

4.12 Result outputs of the selected category and products 57

4.13 Web page of the project management list 58

4.14 Web page for editing project information 58

4.15 Web page of the product management list 59

4.16 Web page for editing product information 60

5.1 Survey dashboard 66

5.2 Tableau category aggregate dashboard 67

5.3 Aggregate eye tracking results sorted by category 68

5.4 Tableau planogram aggregate dashboard 69

5.5 Eye tracking results of sorted by planogram 70

5.6 Tableau product aggregate dashboard 71

5.7 Result of the survey responses 72

5.8 Selecting category and products for A/B report 72

5.9 Result of eye tracking key metrics in A/B report 73

List of Figures (Continued)

Figure Page

5.10 TTFF Summary table and statistical results....74

5.11 TFD Summary table and statistical results 75

5.12 FC Summary table and statistical results....76

5.13 Generated A/B report cover....76

5.14 Steps for generating a project report....77

5.15 Outputs of project report....78

6.1 Structure of the database-driven management system....83

6.2 The comparison of the average total time and cost between two methods per study....87

CHAPTER ONE

INTRODUCTION

Packaging design performs a key function in the marketplace, from both economic and competitive perspectives. In respect to its role in differentiation and segmentation for the commercial goods, packaging communicates with the consumer directly and serves as the carrier of the brand identity. The packaging works to conveys the important product characters for brands, commercialization, and innovation (Mendonca, 2004; Holt, 2010). However, packaging design is often involved in the later stages of product development and is relatively compact within this period to fit into the swift product launching timeline (Rudolph, 1995; Roy, 2009; Imram, 1999). Nevertheless, a rising number of consumer behavior researchers are focused on packaging design and related branding strategies, providing actionable insight and attempting to ensure business success, often through eye tracking (Bojko, 2013). Eye tracking is a technique that enables researchers to measures a consumer's point of gaze. It is a widely used technology to quantitatively evaluate the effectiveness of the packaging design (Piqueras-Fiszman, 2013; Hurley, 2017). By utilizing eye tracking devices in a simulated retail environment, researchers are able to capture the eye movements of participants to determine how their packaging design performs against the competitive array (Snyder, 2015; Hurley, 2016).

There are many examples of how eye tracking technology can be used to obtain information on consumer behavior for specific items within set planograms. A study conducted by A. Snyder et al. investigated the effect of display trays in a simulated retail environment on consumer preference (Snyder, 2015). R. A. Hurley et al. analyzed carbonated soft drinks in reusable shells by using eye tracking technology to test the role of secondary packaging on brand awareness (Hurley, 2017). Even though eye tracking studies are a major evaluation method for package design research, the larger questions concerning category trends and insights have yet to answered by using the one-off studies that are more typical in most eye tracking work (Clement, 2007; Graham, 2012). Thus broad data aggregation and analysis is crucial to understand category-wide design trends and insights. Considering the excessive effort in manual data retrieval, analysis, and reporting, the efficiency of the statistical analysis process is a crucial factor, due to typical new product development timelines. If faster feedback could be provided; the faster the next round of packaging design modifications could be conducted to quicken the product launch phase. Ultimately, time is a key factor to win in the market. However, with a typical eye tracking study requiring considerable effort, less time is available for design modifications before the product needs to be at market. Therefore, a method leveraging a database-driven management system in eye tracking studies that improves efficiency and data aggregation would be a tremendous benefit to all researchers studying the consumer behavior on relevant product categories.

This work was designed to assist in maintaining and utilizing big data, making the preceding tasks easier. The need for such systems, as well as their use, is growing rapidly. By storing eye tracking data in a relational database rather than as a collection of separate files, the features of the database management systems can be used to manage the data in a more robust and efficient manner (Ramakrishnan, 2000). The developed database-driven management system (DBMS) utilized the MySQL database server, equipped with a user-friendly web portal for accessing data. Using this system, every step of the eye tracking experiment can be conducted in a single place along with surveys. A refined and logical data analysis section is designed for generating final reports automatically from the raw data exported directly from the eye tracking device. With this tool, researchers will be able to have a better overall understanding regarding the performance of packaging design in the marketplace by making the data analysis portion more accurate and efficient. Overall, the application of the system can be taught and will be greatly beneficial to students and researchers who embrace the usage, as well as entrepreneurs and designers who are not familiar with eye tracking methodology but are fully capable of understanding results through its use.

References

Bojko, A. (2013). *Eye tracking the user experience: A practical guide to research*. Rosenfeld Media.

Clement, J. (2007). Visual influence on in-store buying decisions: an eye-track experiment on the visual influence of packaging design. *Journal of marketing management*, *23*(9-10), 917-928.

Graham, D. J., Orquin, J. L., & Visschers, V. H. (2012). Eye tracking and nutrition label use: A review of the literature and recommendations for label enhancement. *Food Policy*, *37*(4), 378-382.

Holt, D., & Cameron, D. (2010). *Cultural strategy: Using innovative ideologies to build breakthrough brands*. Oxford University Press.

Hurley, R. A., Rice, J. C., Cottrell, D., & Felty, D. (2016). Effect of Metal Can Labels on Consumer Attention through Eye Tracking Methodology. *Journal of Food Research*, *5*(6), 1.

Hurley, R. A., Rice, J. C., Koefelda, J., Congdon, R., & Ouzts, A. (2017). The Role of Secondary Packaging on Brand Awareness: Analysis of 2 L Carbonated Soft Drinks in Reusable Shells Using Eye Tracking Technology. *Packaging Technology and Science*, *30*(11), 711-722.

Imram, N. (1999). The role of visual cues in consumer perception and acceptance of a food product. *Nutrition & Food Science*, *99*(5), 224-230.

Mendonça, S., Pereira, T. S., & Godinho, M. M. (2004). Trademarks as an indicator of innovation and industrial change. *Research Policy*, *33*(9), 1385-1404.

Piqueras-Fiszman, B., Velasco, C., Salgado-Montejo, A., & Spence, C. (2013). Using combined eye tracking and word association in order to assess novel packaging solutions: A case study involving jam jars. *Food Quality and Preference*, *28*(1), 328-338.

Ramakrishnan, R., & Gehrke, J. (2000). *Database management systems*. McGraw Hill.

Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., & Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of food engineering*, *90*(1), 1-10.

Rudolph, M. J. (1995). The food product development process. *British Food Journal*, *97*(3), 3-11.

Snyder, E., Hurley, R. A., Tonkin, C. E., Cooksey, K., & Rice, J. C. (2015). An eye-tracking methodology for testing consumer preference of display trays in a simulated retail environment. *Journal of Applied Packaging Research*, *7*(1), 6.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

Eye tracking methodology and relational database management systems serve as the foundation of this work. Current one-off eye tracking studies typically lack systematic data aggregation, which not only cause issues with analysis but also in retrieval and storage. Through a thorough literature review, this chapter seeks to understand the benefits and the theory behind creating a database-driven management system for eye tracking studies, as well as the goals of this research.

Food Product Development and Launching

In the past decades, the scientific and technological developments have given rise to global-scale food production and distribution, making an ever-increasing food supply readily available globally (Cordell, 2009). Thus, consumers now can buy exactly what they want to eat, instead of what is just readily available or affordable to them, which is becoming the driving element of the food chain (Costa, 2006; Cordell, 2009).

New product development is a strategy to develop a competitive advantage and long-term financial success in today's global food markets (Costa, 2006). Product innovation plays a key role to maintain the sale growth, spread the market risk, enhance the company's stock market value and increase competitiveness (Buisson, 1995; Lord, 2000; Meulenberg & Viaene, 1998; Costa, 2006). However, it is a generally accepted fact that far too many food product introductions fail (Costa, 2006). It was estimated that about 40% to 50% of new product launching failed within a year (Costa, 2006; Costa, 2003).

Importance of Packaging Design

The basic role of a package is to provide functions involving protecting, containing, and preserving a product during the manufacturing, handling and distribution processes (Coles, 2003). Packaging in the retail market has been defined as the "silent salesman" since 1957, performing an important role at the point of purchase (Wells, 2007).

Consumers are becoming more demanding in terms of quality and choice (Doherty, 2005) and are constantly seeking a product tailored to their wants and needs (Wells, 2007). More and more consumers making their initial choice of food products based on the aesthetic value, since the products are generally expected to be tasty at the point of purchase (Schmitt and Simonson, 1997; Wells, 2007).

As the views extended in recent years, good packaging is believed to be a flag of brand recognition and a symbol of product value (Wells, 2007; Underwood, 2003). With the fact that only a small portion of brands can afford the national advertising, packaging acts as one of the most important vehicles to convey the brand message directly to the target consumers for the majority of the brands (Wells, 2007). As the retail environment becomes saturated with competitors in tracking attention from the consumers, the importance of the packaging design has to be emphasized more than ever in order to stand out from the competitive products (Milton, 1991; Wells, 2007).

Eye Movements and Visual Attention

Attention is defined as the act of one's conscious focus on an object or event in the environment at any moment in time (Carver, 2012). Humans make unconscious decisions about what to focus on based on the activity that they are currently engaged in (Soon, 2008). Eye movements under normal conditions are strongly and directly connected to high-order cognitive processes, and attention plays a much more central role in communication processing (Wedel, 2008; Torralba, 2006). It has been found that eye movements are tightly coupled with the visual attention which makes them eminent indicators of the covert visual attention process (Wedel, 2008; Muller, 2006).

With the eye-movement recordings and the theory of visual attention and stimulus-based decision making, further research can be investigated on visual marketing for packaging (Payne, 1991). These developments on consumer research provide richer opportunities for market researchers (Wedel, 2008).

Eye Tracking

Eye tracking is a technique that can measure a person's point of gaze (Morimoto, 2006). It is a widely used method to quantitatively evaluate the effectiveness of package design (Duchowski, 2007). The technology follows the eye of the subject, tracking their exact eye movements while looking at an object or area, and identifying where a person looks (Duchowski, 2007). To differentiate and maintain relevance with market demands, designers and product developers leverage eye tracking to observe and analyze how consumers shop within the grocery store (Hurley, 2013; Hurley, 2017). This method allows researchers to generate various nonconscious biometrics data regarding the planogram. The CUshop™ Consumer Experience Laboratory (Figure 2.1) on Clemson University's campus has conducted a great number of studies by eye tracking method within a simulated retail environment for various categories of products (Hurley, 2013; Snyder, 2015; Hurley, 2017).

Figure 2.1. The CUshop™ Consumer Experience Laboratory (Hurley, 2017)

In those studies, groups of participants, wearing eye-tracking glasses (Figure 2.2), shop for the products with different packaging in the simulated environment. Data collected from the eye-tracking devices was further analyzed in post-experiment studies to find out the influence of packaging design on consumer behavior.

Figure 2.2. Mobile Eye Tracking Glasses (Tobii Pro Glasses 2, 2017)

By utilizing eye tracking technology and an immersive retail environment, researchers can capture the 'nonconscious' preference of consumers through their eye movements, before launching a product to market (Tonkin, 2011).

Applications of Eye Tracking in Consumer Research

Daily, consumers are exposed to a host of advertisements and marketing pieces (Calvert, 2008). Companies track closely what consumers see, to help understand what visual marketing efforts are most effective (Zaltman, 2003). Therefore, the commercial applications of eye-tracking have rapidly grown in the United States and Europe (Wedel, 2008). The growth of eye-tracking is largely attributed to technological innovations in the development of eye-tracking devices and the decreased costs of these devices (Duchowski, 2007). Until recently, the commercial use of eye tracking was cumbersome and time-consuming (Wedel, 2008). The eye tracking glasses of today now records eye movements of consumers under natural exposure conditions, with large amounts of stimuli, at high precision (Tobii Pro Glasses 2, 2017).

Recent eye tracking studies have focused on gathering data for the understanding of how varying packaging design, type, label, material, printing technique, and color harmonies factors influence attention and purchase preference (Orth, 2008; Behe, 2014; Hurley, 2017). From those studies, quantitative consumer attention can be collected in a specific retail environment for specific categories and attributes of said packaging. These findings allow packaging designers to justify using less expensive processes to produce and manufacture packaging (Boothroyd, 2001).

There are many examples of utilizing eye tracking technology to gauge information on consumer behavior for specific items within the actual planograms setup in the grocery store per study requirement (Hurley, 2017; Tokin, 2011). Even with more and more package analysis studies being conducted as specific one-off studies, what is currently lacking in this field of research is an aggregation of all the specific biometric data from previous studies to compare new products against without the limitation of a project based specific planogram.

For example, if a food company is interested in launching a new cereal product to the market, a research firm could provide a series of information concerning the consumer appeal, biometric responses, and survey data. Though this data may be interesting to the company who conducted the study, it would fail to compare the collected data to a referenced benchmark of aggregate biometric data within the cereal category. Thus, the business would be unable to use the data collected to understand how the product and packaging performed before launching to the actual market.

Eye tracking study as the consumer research applied in product launching process, the efficiency of the statistical analysis process is a crucial factor. The faster that can be provided; the faster the next round of packaging design modification can be conducted. However, a typical eye tracking study usually takes more than a month to complete from ideation to reporting, which does not leave much time for additional packaging design modifications per client suggestions from iterative testing. Thus, an efficient method for improving the study process and assist with data reporting is in demand.

Applications of Databases

Databases today are ubiquitous in various modern business and applications (Cheung, 2014). A database can be considered to be a collection of related data (Connolly, 2005). Databases can be used to maintain internal records and present data to different users on the World-Wide-Web (Ullman, 1997; Wang, 2003). The use of databases is likely to be found at scientific investigation since it can serve for big data aggregation (Ullman, 1997; Bliese, 2000). For example, they can present the data gathered by astronomers, by investigators of the human genome, and by biochemists exploring the medicinal properties of proteins, along with other scientists (Ullman, 1997).

A database management system is a powerful tool to maintain and utilize large collections of data (Ramakrishnan, 2000). It can be used to manage the data more robustly and efficiently, compared to store data as a collection of operating system files (Ramakrishnan, 2000). It consists of a collection of interrelated data and a set of programs to access that data (Elmasri, 2008). It allows the user to do many things to the data, including inputting, editing, sharing, and display the data in the database (Ramankrishnan, 2000).

There are many advantages of using databases, especially in big data management. The features of database management systems can enforce integrity constraints on the data and control the access of different classes of users regarding what data is visible (Ramakrishnan, 2000; Elmasri, 2010). By utilizing sophisticated techniques, database management systems can store and retrieve data efficiently

(Ramakrishnan, 2000). When several users share the data, centralizing the administration of data can offer significant improvements (Ramakrishnan, 2000).

Research Objectives

1. Relational Database Development Based on Eye Tracking Studies
    a. Requirements Collection and Analysis:
        i. Interview eye tracking researchers and potential users
        ii. Review data resource to decide elements (entity, attributes, relations) for design database
    b. Conceptual Database Design
        i. Identify entities, attributes, relations
        ii. Create an E-R model for each entity
        iii. Create combined E-R model for entire database
    c. Logical Database Design
        i. Decide primary and foreign keys for tables
        ii. Refine tables considering functional dependency
        iii. Decide field types for storing data
    d. Physical Database Design
        i. Create tables and attributes using SQL
        ii. Insert data into tables using SQL
2. Web Portal Development for Database Management
    a. Requirement collection and analysis
    b. Design web page layout

c. Create SQL queries for required data retrieval from the database

d. Create web pages using HTML, PHP, Javascript, CSS

e. Implementation of web pages

3. Integration of Advanced Features: Survey, Data Dashboards, and Automatic Report Generation

a. Integrate survey using LimeSurvey

b. Integrate data dashboard using Tableau

c. Integrate automatic report generation using Dompdf

4. Comparison of DBMS Method vs. File based Method

a. Running eye tracking study using the designed system

b. Report generation using the designed system

c. Interview with eye tracking researchers for collecting feedbacks

d. Summarize the comparison results

References

Behe, B. K., Campbell, B. L., Khachatryan, H., Hall, C. R., Dennis, J. H., Huddleston, P. T., & Fernandez, R. T. (2014). Incorporating eye tracking technology and conjoint analysis to better understand the green industry consumer. *HortScience*, *49*(12), 1550-1557.

Bliese, P. D. (2000). Within-group agreement, non-independence, and reliability: Implications for data aggregation and analysis.

Boothroyd, G., Dewhurst, P., & Knight, W. A. (2001). *Product Design for Manufacture and Assembly, revised and expanded*. CRC press.

Brun-Buisson, C., Doyon, F., Carlet, J., Dellamonica, P., Gouin, F., Lepoutre, A., ... & Régnier, B. (1995). Incidence, risk factors, and outcome of severe sepsis and septic shock in adults: a multicenter prospective study in intensive care units. *Jama*, *274*(12), 968-974.

Calvert, S. L. (2008). Children as consumers: Advertising and marketing. *The future of children*, *18*(1), 205-234.

Carver, C. S., & Scheier, M. F. (2012). *Attention and self-regulation: A control-theory approach to human behavior*. Springer Science & Business Media.

Cheung, A., Madden, S., Solar-Lezama, A., Arden, O., & Myers, A. C. (2014). Using Program Analysis to Improve Database Applications. *IEEE Data Eng. Bull.*, *37*(1), 48-59.

Coles, R., McDowell, D., & Kirwan, M. J. (Eds.). (2003). *Food packaging technology* (Vol. 5). CRC Press.

Connolly, T. M., & Begg, C. E. (2005). *Database systems: a practical approach to design, implementation, and management*. Pearson Education.

Cordell, D., Drangert, J. O., & White, S. (2009). The story of phosphorus: global food security and food for thought. *Global environmental change*, *19*(2), 292-305.

Costa, A. A. (2003). *New insights into consumer-oriented food products design*.

Costa, A. I., & Jongen, W. M. F. (2006). New insights into consumer-led food product development. *Trends in Food Science & Technology*, *17*(8), 457-465.

Dean, W. R. J., & MILTON, S. J. (1991). Disturbances in semi-arid shrubland and arid grassland in the Karoo, South Africa: mammal diggings as germination sites. *African Journal of Ecology*, *29*(1), 11-16.

Doherty, B., & Tranchell, S. (2005). New thinking in international trade? A case study of The Day Chocolate Company. *Sustainable Development*, *13*(3), 166-176.

Duchowski, A. T. (2007). Eye tracking methodology. *Theory and practice*, *328*.

Elmasri, R. (2008). *Fundamentals of database systems*. Pearson Education India.

Elmasri, R., & Navathe, S. (2010). *Fundamentals of database systems*. Addison-Wesley Publishing Company.

Hurley, R. A., Galvarino, J., Thackston, E., Ouzts, A., & Pham, A. (2013). The effect of modifying structure to display product versus graphical representation on packaging. *Packaging Technology and Science*, *26*(8), 453-460.

Hurley, R. A., Randall, R., O'Hara, L., Tonkin, C., & Rice, J. C. (2017). Color harmonies in packaging. *Color Research & Application*, *42*(1), 50-59.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., ... & Rutter, M. (2000). The Autism Diagnostic Observation Schedule—Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of autism and developmental disorders*, *30*(3), 205-223.

Meulenberg, M. T. G., & Viaene, J. (1998). Changing food marketing systems in western countries. In *Innovation of food marketing systems* (pp. 5-36). Wageningen Pers.

Müller, H. J., & Krummenacher, J. (2006). Visual search and selective attention. *Visual Cognition*, *14*(4-8), 389-410.

Nijssen, E. J., & Van Trijp, H. C. (1998). Branding fresh food products: exploratory empirical evidence from the Netherlands. *European Review of Agricultural Economics*, *25*(2), 228-242.

Orth, U. R., & Malkewitz, K. (2008). Holistic package design and consumer brand impressions. *Journal of marketing*, *72*(3), 64-81.

Payne, J., Bettman, J. R., & Johnson, E. J. (1991). Consumer decision making. *Handbook of consumer behaviour*, 50-84.

Ramakrishnan, R., & Gehrke, J. (2000). *Database management systems*. McGraw Hill.

Simonson, A., & Schmitt, B. H. (1997). *Marketing aesthetics: The strategic management of brands, identity, and image*. Simon and Schuster.

Snyder, E., Hurley, R. A., Tonkin, C. E., Cooksey, K., & Rice, J. C. (2015). An eye-tracking methodology for testing consumer preference of display trays in a simulated retail environment. *Journal of Applied Packaging Research*, *7*(1), 6.

Soon, C. S., Brass, M., Heinze, H. J., & Haynes, J. D. (2008). Unconscious determinants of free decisions in the human brain. *Nature neuroscience*, *11*(5), 543.

Tobii Pro Glasses 2. (2017). Available at https://www.tobiipro.com/product-listing/tobii-pro-glasses-2/#Features. Accessed October 13, 2017.

Tonkin, C., Ouzts, A. D., & Duchowski, A. T. (2011, May). Eye tracking within the packaging design workflow: interaction with physical and virtual shelves. In *Proceedings of the 1st Conference on Novel Gaze-Controlled Applications* (p. 3). ACM.

Torralba, A., Oliva, A., Castelhano, M. S., & Henderson, J. M. (2006). Contextual guidance of eye movements and attention in real-world scenes: the role of global features in object search. *Psychological review*, *113*(4), 766.

Ullman, J. D. (1997). *A first course in database systems*. Pearson Education India.

Underwood, R. L. (2003). The communicative power of product packaging: creating brand identity via lived and mediated experience. *Journal of Marketing Theory and Practice*, *11*(1), 62-76.

Wang, J., & Lochovsky, F. H. (2003, May). Data extraction and label assignment for web databases. In *Proceedings of the 12th international conference on World Wide Web* (pp. 187-196). ACM.

Wedel, M., & Pieters, R. (2008). A review of eye-tracking research in marketing. In *Review of marketing research* (pp. 123-147). Emerald Group Publishing Limited.

Wedel, M., & Pieters, R. (2008). Eye tracking for visual marketing. *Foundations and Trends® in Marketing*, *1*(4), 231-320.

Wells, L. E., Farley, H., & Armstrong, G. A. (2007). The importance of packaging design for own-label food brands. *International Journal of Retail & Distribution Management*, *35*(9), 677-690.

Zaltman, G., Dotlich, D. L., & Cairo, P. C. (2003). *How customers think*. Audio-Tech Business Book Summaries.

CHAPTER THREE

RELATIONAL DATABASE DESIGN BASED ON EYE TRACKING STUDIES

Abstract

Broad data aggregation and analysis for packaging design research is needed to understand category-wide design trends and insights. Considering the excessive effort in manual data retrieval, analysis, and reporting, a method that can improve efficiency and data aggregation would be of tremendous benefit to the many sectors involved in package/product development. A novel relational database was designed based on the eye tracking key metrics framework, aimed to aggregate the data across eye-tracking studies of various packaging designs. A wide range of data results across studies was retrieved using a structured query language (SQL), which can greatly improve the efficiency of data analysis.

Introduction

A database is a collection of data, while a relational database is a database based on the relational model of data (Chen, 1988). A relational database can assist in maintaining and utilizing large collections of data, making the preceding tasks easier. The data in databases is well organized and structured, and related, which makes it possible to be accessible in different orders without great difficulty (Maier, 1983). By storing eye tracking data in a relational database rather than as a collection of operating system files, the database management system (e.g., MySQL server) can be used to manage the data robustly and efficiently.

This research seeks to leverage the use of a relational database to the current eye tracking method by investigating the hypothesis that the involvement of the relational database can lift the data analysis efficiency via proper database structure design and application of data retrieval queries. The main design process can be divided into requirement analysis, conceptual database design, logical database design, and physical database design (Connolly, 2005).

Requirements Analysis: The first stage to design a database is to collect and understand the performance requirements, including the most frequent operations, data to be stored, and potential applications to be built on top (Ramakrishnan, 2000). In other words, what the users want from the database must be found out in this process. The process of the requirement analysis usually involves the analysis of available data resource, discussions with users, a study of the current operating environments and how it is required to change (Ramakrishnan, 2000).

Conceptual Database Design: By collecting the requirements from the first stage, a high-level description can be developed for defining the data to be stored and the constraints that can hold the data relations (Batini, 1992).

Logical Database Design: To implement the database design, the conceptual database design is converted into a database schema in the data model of a chosen database server. The task in the logical design step is to convert an ER schema into a relational database schema. The outcome of this process is a conceptual schema, sometimes called the logical schema, in the relational data model (Chen, 1991; Ramakrishnan, 2000).

Physical Database Design: This is the process of transforming a data model into the physical data structure in the database management system (Ramakrishnan, 2000).

In summary, the database design is the process by which entities and requirements from the real world are transformed to a model of a database, a key step in building database applications (Connolly, 2005). This process allows the application developer to focus on core, data related aspects of the requirements, making it easier to spot an unreasonable design that might limit the ability to change and extend the functionality of the resulting application (Ramakrishnan, 2000). In this chapter, the important database design processes are discussed in detail.

Methods and Materials

Eye Tracking Data Collection

Apparatus

Tobii™ Pro Eye Tracking Glasses were utilized in the studies to record the participants' eye movements and collect data. These glasses are monocular video-based pupil and corneal reflection glasses with a sampling rate of 50Hz (Tobii Pro Glasses 2, 2017; Hurley, 2016). A Tobii™ Recording Controller gathers the eye tracking data and guides the researcher through the calibration process, showing if the calibration is successful for each participant (Hurley, 2016).

Procedure

For each eye tracking study, the participants were asked to wear the Tobii™ Pro eye tracking glasses (Tobii Pro Glasses 2, 2017), which were connected to a live view tablet and a recording device (Figure 3.1). The participants were told to stand on a target placed and to look straight to a sign. Once the instrument found the location of the subject's pupil, the controller software live view tablet displayed "calibration success." After the researchers hit "Record" on the tablet, the instrument started to collect eye tracking data.

Figure 3.1. Eye Tracking Devices (Tobii Pro Glasses 2, 2017)

When the calibration was complete, the participant was given a shopping list. The participants were then instructed to shop for each product on the list in the store and write down the number of the product they purchased (Hurley, 2016). Areas of Interest (AOI's), which are used in the eye tracking software to collect fixation data, were designed for the stimuli and used to determine three measurements metrics of eye movement (Hurley, 2016): Time to First Fixation (TTFF), Total Fixation Duration (TFD), and Fixation Count (FC). TTFF is the time in seconds, which measures from when an area of interest first enters the field of view until they fixate on it. TFD is the time in seconds, which measures the duration of fixating on an area of interest spent by participants. FC in the total number of times a participant's scan of the planogram crossed into a particular area of interest (Hurley, 2011; Hurley, 2014; Hurley, 2016).

Data Resource

A glance at the raw data from an organic products eye tracking study was shown in Figure 3.2 to Figure 3.10.

cereal								
Time To First Fixation	Participant	Brown Rice Crisps	Honey Nut	Organic Cereal	Average	Median	Count	Total Recording Duration
Recording001	1A	14.60	16.12	6.80	12.50	14.60	3	214.96
Recording002	3A	15.94	15.30	15.78	15.67	15.78	3	267.65
Recording002	2A	2.54	9.24	8.50	6.76	8.50	3	161.85
Recording003	4A	0.24	5.48	1.58	2.43	1.58	3	189.89
Recording004	5A	0.38	0.02	0.00	0.13	0.02	3	175.51
Recording005	6A	0.48	2.48	1.06	1.34	1.06	3	232.49
...	...	...	...	...	...	...	...	...
Recording057	59A	0.62	22.11	20.32	14.35	20.32	3	187.88
Recording058	60A	9.80	11.68	11.32	10.93	11.32	3	249.95

Figure 3.2. Eye tracking raw data of TTFF for a cereal planogram

rice								
Time To First Fixation	Participant	Organic Rice Pilaf	Whole Grain Rice	Brown Rice Pilaf	Average	Median	Count	Total Recording Duration
Recording001	1A	0.04	3.12	0.26	1.14	0.26	3	214.96
Recording002	3A	6.68			6.68	6.68	1	267.65
Recording002	2A	0.16	4.38	1.26	1.93	1.26	3	161.85
Recording003	4A	1.18	1.74	1.70	1.54	1.70	3	189.89
Recording004	5A	2.12	12.22	0.74	5.03	2.12	3	175.51
Recording005	6A	4.12	2.02	4.26	3.47	4.12	3	232.49
Recording006	7A	7.32	10.58	9.36	9.08	9.36	3	218.13
...	...	...	...	...	...	...	...	...
Recording055	57A						0	232.43
Recording056	58A	0.82	6.10	9.78	5.57	6.10	3	141.01
Recording057	59A	0.14	0.70	0.36	0.40	0.36	3	187.88
Recording058	60A	18.76	48.57	18.78	28.70	18.78	3	249.95

Figure 3.3. Eye tracking raw data of TTFF for a rice planogram

granola								
Time To First Fixation	Participant	Organic Chewy	Vanilla Chip	Organic Roasted Nut	Average	Median	Count	Total Recording Duration
Recording001	1A	3.40	0.80	0.56	1.59	0.80	3	214.96
Recording002	3A	17.60	6.20	17.24	13.68	17.24	3	267.65
Recording002	2A	9.46	6.72	8.00	8.06	8.00	3	161.85
Recording003	4A	4.24	1.58	1.40	2.41	1.58	3	189.89
Recording004	5A	11.74	1.76	4.56	6.02	4.56	3	175.51
Recording005	6A	6.28	3.52	4.28	4.69	4.28	3	232.49
Recording006	7A	8.18	5.82	7.58	7.19	7.58	3	218.13
Recording007	8A	5.58		3.00	4.29	4.29	2	202.92
Recording009	10A	5.82	3.24	4.08	4.38	4.08	3	154.96
...	...	...	...	...	...	...	...	...
Recording055	57A	0.86	1.74	0.88	1.16	0.88	3	232.43
Recording056	58A	6.02	5.60	5.82	5.81	5.82	3	141.01
Recording057	59A	6.82	5.70	5.64	6.05	5.70	3	187.88
Recording058	60A	6.54	0.88	3.02	3.48	3.02	3	249.95

Figure 3.4. Eye tracking raw data table of TTFF for a granola planogram

cereal									
Total Fixation Duration	**Participant**	**Brown Rice Crisps**	**Honey Nut**	**Organic Cereal**	**Average**	**Median**	**Sum**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	1.18	0.90	4.40	2.16	1.18	6.48	38.37	214.96
Recording002	3A	1.58	1.86	2.18	1.87	1.86	5.62	92.76	267.65
Recording002	2A	3.26	2.74	1.50	2.50	2.74	7.50	41.19	161.85
Recording003	4A	2.72	10.58	8.38	7.22	8.38	21.67	44.61	189.89
Recording004	5A	7.24	2.40	11.70	7.11	7.24	21.33	49.79	175.51
Recording005	6A	2.68	3.20	7.44	4.44	3.20	13.32	36.71	232.49
...	...	...	...	...	...	...	...	...	...
Recording055	57A	1.96	4.20	1.96	2.71	1.96	8.12	74.14	232.43
Recording056	58A	0.88	0.22	0.10	0.40	0.22	1.20	31.89	141.01
Recording057	59A	6.82	7.62	10.44	8.29	7.62	24.87	65.08	187.88
Recording058	60A	5.84	3.44	1.12	3.47	3.44	10.40	39.17	249.95

Figure 3.5. Eye tracking raw data of TFD for cereal planogram

rice									
Total Fixation Duration	**Participant**	**Organic Rice Pilaf**	**Whole Grain Rice**	**Brown Rice Pilaf**	**Average**	**Median**	**Sum**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	1.34	1.20	0.18	0.91	1.20	2.72	37.53	214.96
Recording002	3A	0.02			0.02	0.02	0.02	19.10	267.65
Recording002	2A	4.10	0.90	0.80	1.93	0.90	5.80	30.03	161.85
Recording003	4A	0.54	1.38	0.04	0.65	0.54	1.96	34.39	189.89
Recording004	5A	0.70	1.50	0.88	1.03	0.88	3.08	15.00	175.51
Recording005	6A	1.78	1.22	4.34	2.45	1.78	7.34	19.86	232.49
...	...	...	...	...	...	...	...	...	...
Recording055	57A							26.85	232.43
Recording056	58A	0.10	4.82	0.36	1.76	0.36	5.28	29.59	141.01
Recording057	59A	6.42	7.36	2.46	5.41	6.42	16.24	32.37	187.88
Recording058	60A	0.02	0.04	0.32	0.13	0.04	0.38	65.68	249.95

Figure 3.6. Eye tracking raw data of TFD for a rice planogram

granola									
Total Fixation Duration	**Participant**	**Organic Chewy**	**Vanilla Chip**	**Organic Roasted Nut**	**Average**	**Median**	**Sum**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	2.38	4.62	2.62	3.21	2.62	9.62	21.59	214.96
Recording002	3A	1.20	0.56	1.14	0.97	1.14	2.90	55.59	267.65
Recording002	2A	1.14	1.30	1.40	1.28	1.30	3.84	15.60	161.85
Recording003	4A	4.86	4.86	1.72	3.81	4.86	11.44	35.11	189.89
Recording004	5A	1.30	4.62	7.30	4.41	4.62	13.22	28.03	175.51
Recording005	6A	0.04	0.62	3.16	1.27	0.62	3.82	15.08	232.49
...	...	...	...	...	...	...	...	...	...
Recording055	57A	2.54	1.56	2.02	2.04	2.02	6.12	33.95	232.43
Recording056	58A	0.06	1.44	0.16	0.55	0.16	1.66	13.04	141.01
Recording057	59A	1.02	0.64	3.18	1.61	1.02	4.84	21.85	187.88
Recording058	60A	0.96	5.48	1.92	2.79	1.92	8.36	21.81	249.95

Figure 3.7. Eye tracking raw data of TFD for a granola planogram

cereal										
Fixation Count	**Participant**	**Brown Rice Crisps**	**Honey Nut**	**Organic Cereal**	**Average**	**Median**	**Sum**	**Total Analysis Set Fixation Count**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	59	45	220	108.00	59.00	324	849	38.37	214.96
Recording002	3A	79	93	109	93.67	93.00	281	2517	92.76	267.65
Recording002	2A	163	137	75	125.00	137.00	375	1248	41.19	161.85
Recording003	4A	136	529	419	361.33	419.00	1084	1563	44.61	189.89
Recording004	5A	362	120	585	355.67	362.00	1067	1647	49.79	175.51
Recording005	6A	134	160	372	222.00	160.00	666	1303	36.71	232.49
...	...	...	...	...	...	...	...	...	...	...
Recording053	55A	66	22	263	117.00	66.00	351	890	34.67	149.06
Recording054	56A	209	416	722	449.00	416.00	1347	2503	81.94	236.09
Recording055	57A	98	210	98	135.33	98.00	406	1550	74.14	232.43
Recording056	58A	44	11	5	20.00	11.00	60	523	31.89	141.01
Recording057	59A	341	381	522	414.67	381.00	1244	1755	65.08	187.88
Recording058	60A	292	172	56	173.33	172.00	520	1102	39.17	249.95

Figure 3.8. Eye tracking raw data of FC for a cereal planogram

rice										
Fixation Count	**Participant**	**Organic Rice Pilaf**	**Whole Grain Rice**	**Brown Rice Pilaf**	**Average**	**Median**	**Sum**	**Total Analysis Set Fixation Count**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	67	60	9	45.33	60.00	136	1462	37.53	214.96
Recording002	3A	1			1.00	1.00	1	679	19.10	267.65
Recording002	2A	205	45	40	96.67	45.00	290	1201	30.03	161.85
Recording003	4A	27	69	2	32.67	27.00	98	1324	34.39	189.89
Recording004	5A	35	75	44	51.33	44.00	154	653	15.00	175.51
Recording005	6A	89	61	217	122.33	89.00	367	755	19.86	232.49
...	...	...	...	...	...	...	...	...	...	...
Recording053	55A	123	1	29	51.00	29.00	153	629	13.06	149.06
Recording054	56A	44	74	479	199.00	74.00	597	1618	36.47	236.09
Recording055	57A							940	26.85	232.43
Recording056	58A	5	241	18	88.00	18.00	264	1188	29.59	141.01
Recording057	59A	321	368	123	270.67	321.00	812	1389	32.37	187.88
Recording058	60A	1	2	16	6.33	2.00	19	2376	65.68	249.95

Figure 3.9. Eye tracking raw data of FC for a rice planogram

granola										
Fixation Count	**Participant**	**Organic Chewy**	**Vanilla Chip**	**Organic Roasted Nut**	**Average**	**Median**	**Sum**	**Total Analysis Set Fixation Count**	**Total Analysis Set Duration**	**Total Recording Duration**
Recording001	1A	119	231	131	160.33	131.00	481	926	21.59	214.96
Recording002	3A	60	28	57	48.33	57.00	145	1640	55.59	267.65
Recording002	2A	57	65	70	64.00	65.00	192	759	15.60	161.85
Recording003	4A	243	243	86	190.67	243.00	572	1417	35.11	189.89
Recording004	5A	65	231	365	220.33	231.00	661	1164	28.03	175.51
Recording005	6A	2	31	158	63.67	31.00	191	558	15.08	232.49
...	...	...	...	...	...	...	...	...	...	...
Recording053	55A	12	125	81	72.67	81.00	218	793	28.17	149.06
Recording054	56A	108	237	315	220.00	237.00	660	1522	37.73	236.09
Recording055	57A	127	78	101	102.00	101.00	306	1217	33.95	232.43
Recording056	58A	3	72	8	27.67	8.00	83	322	13.04	141.01
Recording057	59A	51	32	159	80.67	51.00	242	658	21.85	187.88
Recording058	60A	48	274	96	139.33	96.00	418	886	21.81	249.95

Figure 3.10. Eye tracking raw data of FC for a granola planogram

As shown in Figure 3.2-3.10, the raw data exported from eye tracking are consistent in table headers which can be summarized as Figure 3.11.

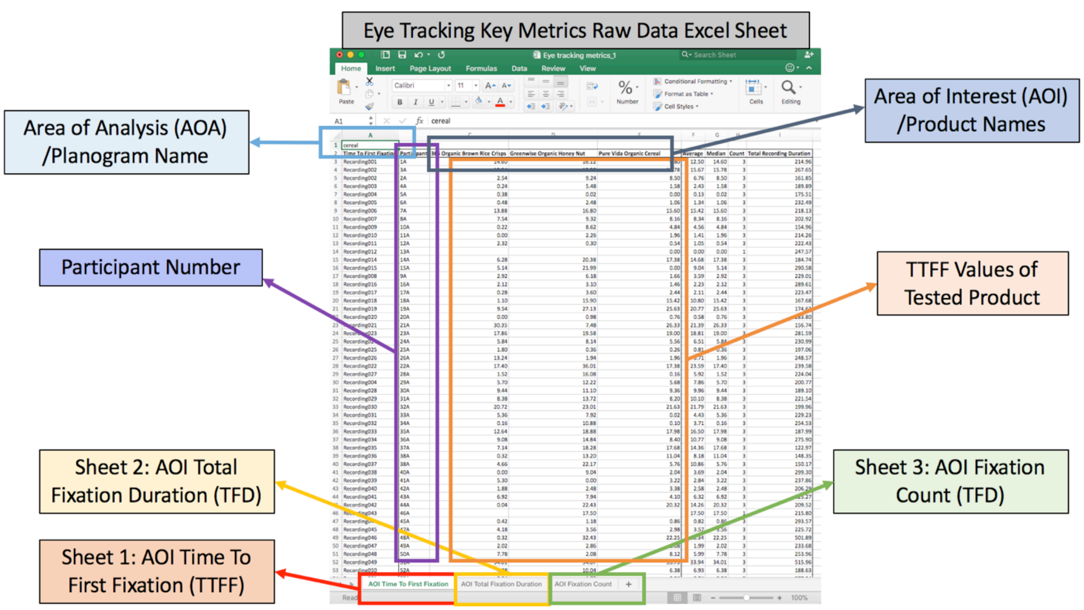


Figure 3.11. The structure of eye tracking raw data sheet

The understanding of the data sheet structure and the elements consist of the eye tracking data is the important step to continue the further database design. It will be discussed in detail how to design the database to well organize and storage each element of the eye tracking data for creating the relationships between tables in the designed database.

Database Design

Requirements Collection and Analysis

The first step in designing this database is to understand what data is to be stored, and what operations are most frequent and subject to performance requirements. This process involves reviewing available data source and discussions with the eye tracking researchers how the data results are to be retrieved by the database. This step is in preparation for further conceptual database design. A summary list of information collected from the requirement analysis process is shown in Table 3.1.

Table 3.1. Summary List of Requirement Analysis

Items	Statement of Requirements
Main Elements	● Projects; ● Planograms; ● Products; ● Eye tracking key metrics (TTFF, TFD, FC); ● Participants.
Data Relations	● Every project consists of single or multiple planograms; ● Every planogram consists of multiple products; ● Participants participate in projects and generate key metrics; ● Every TTFF data belongs to a specific product in a specific planogram by a specific participant; ● Every TFD data belongs to a specific product in a specific planogram by a specific participant; ● Every FC data belongs to a specific product in a specific planogram by a specific participant.
Expected Results	● Be able to show eye tracking results of a selected project ● Be able to show eye tracking results of a selected planogram ● Be able to show eye tracking results of a selected product category ● Be able to show eye tracking results of aggregated category means

As seen from the above eye tracking data resource, there are three key metrics for each product tested in eye tracking studies. They are time to first fixation (TTFF), total fixation duration (TFD), and fixation count (FC). Data results are divided into these three key metrics in the Excel files, which are directly exported from the data analyzer software. In each key metric, product names are listed in the first row of data records. Participant numbers are listed in the second column of the data sheets to identify where a specific record comes from.

By understanding the data processing and reporting from the experienced eye tracking researchers, there is a list of content also required to consider in the database:

- Project name
- Project date
- Project description
- Participant ID
- Participant gender
- Participant email
- Participant birthday
- Area of Analysis (AOA) images
- Area of Interest (AOI) images
- Product category

Conceptual Database Design: ER Model

By collecting the information in the requirements analysis, the Entity-Relation (ER) model can be created to show the framework consists of objects with attributes, as well as to indicate their relations in the database. ER diagram is a diagram represented the ER model. It can be described by entities, attributes, and relationships. In the diagram, the rectangle represents an entity set; an ellipse represents an attribute; a diamond represents a relationship; lines represent linking of attributes to entity sets and entity sets to relationship sets.

Users ER model (Figure 3.12): Three types of user accounts can be used to access the database via corresponding passwords. The user types include administrators, clients, participants. The administrators cannot register through the web application; their accounts must be configured directly in the database.

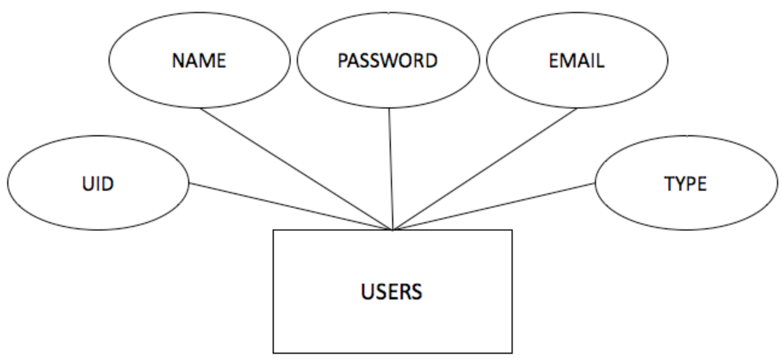


Figure 3.12. Users E-R diagram

Participant ER model (Figure 3.13): Once a participant is registered by filling a registration form, the information can be saved in the database. Because a participant may also be a client or administrator, a unique participant ID is needed here and is different from the user ID. The administrator may contact the participant by email. The gender and birthday are used to determine inclusion and exclusion criteria specific eye tracking studies, especially those with client restrictions.

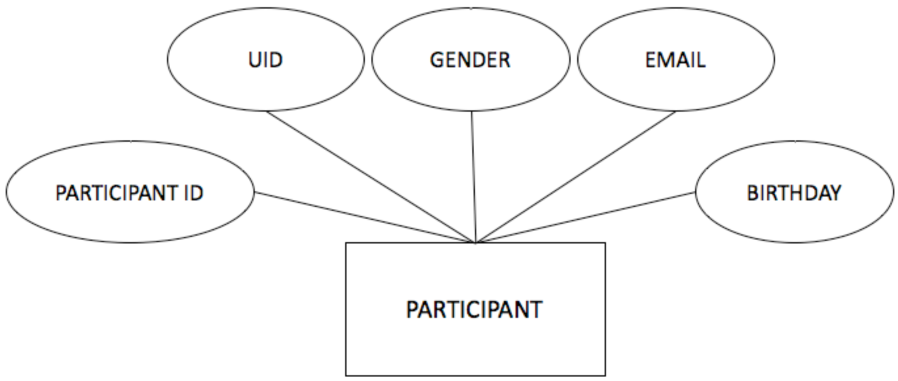


Figure 3.13. Participant E-R diagram

Project ER model (Figure 3.14): Project name, project detail, and running data are used to define the eye tracking studies. A project ID is needed here to specify a project.

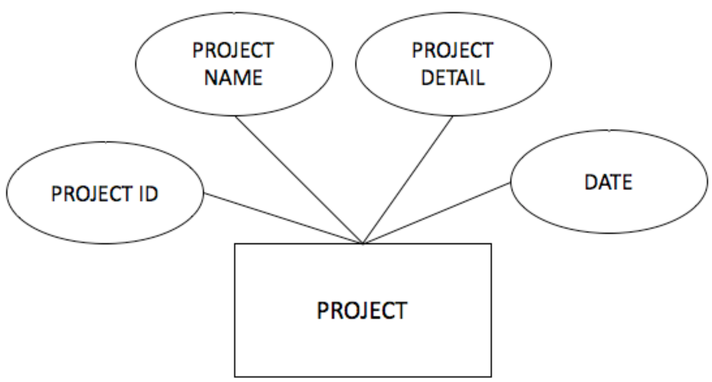


Figure 3.14. Project E-R diagram

Planogram ER model (Figure 3.15): Planogram name, image, category and the project it belongs to are used to define the planograms of eye tracking studies. The ID is needed here to specify the planogram.

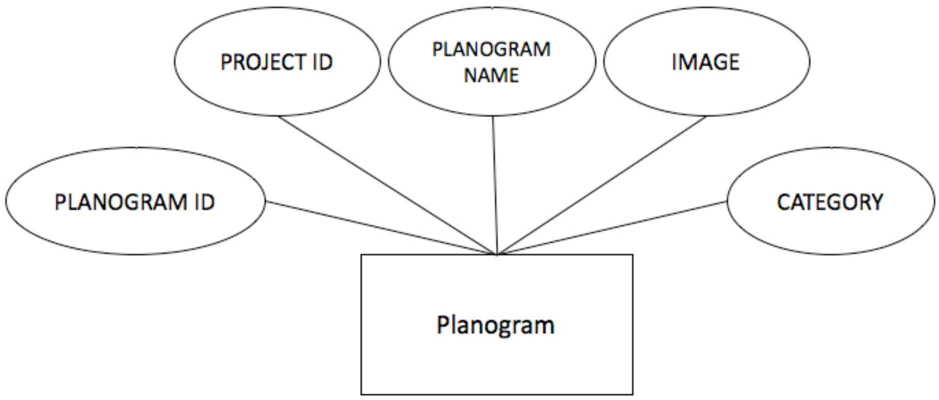


Figure 3.15. Planogram E-R diagram

Product ER model (Figure 3.16): Product name, image, and the AOI type are used to define the AOIs in eye tracking studies. The AOI ID is needed here to specify the AOI.

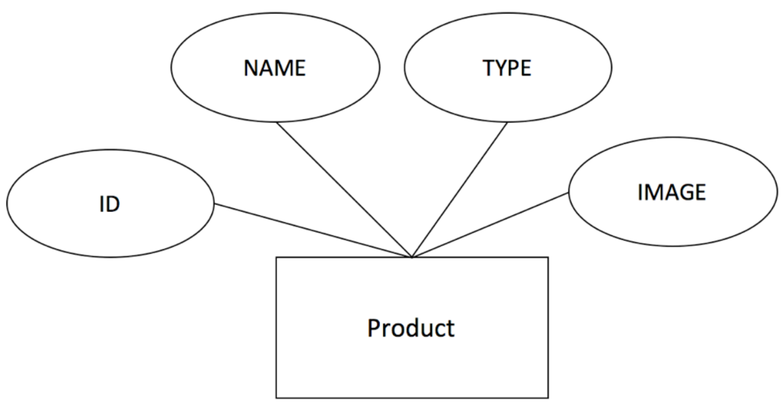


Figure 3.16. Product E-R diagram

Time to First Fixation (TTFF) Data ER model (Figure 3.17): Participant ID, TTFF, product ID and planogram ID are used to define the TTFF data in eye tracking studies. The TTFF ID is needed here to specify the TTFF data.

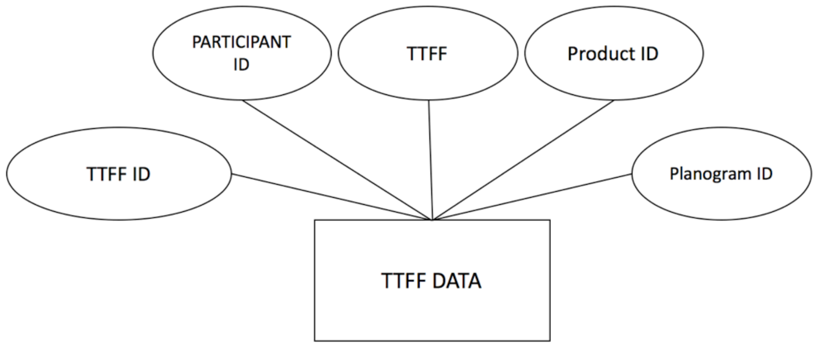


Figure 3.17. Time to First Fixation (TTFF) data E-R diagram

Total Fixation Duration (TTFF) Data ER model (Figure 3.18): Participant ID, TFD, product ID and planogram ID are used to define the TFD data in eye tracking studies. The TFD ID is needed here to specify the TFD data.

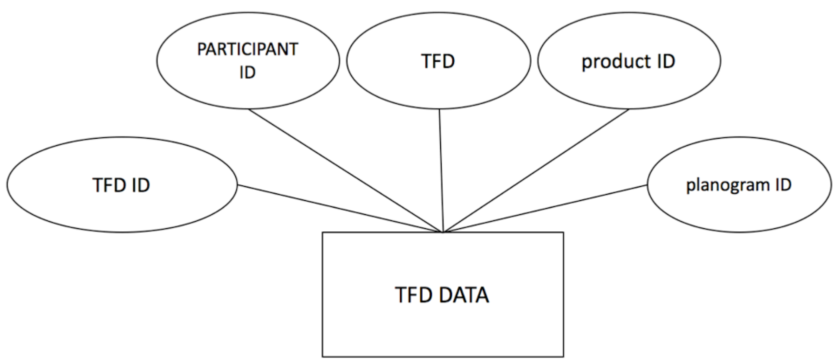


Figure 3.18. Total Fixation Duration (TFD) data E-R diagram

Fixation Count (FC) Data ER model (Figure 3.19): Participant ID, FC, product ID and planogram ID are used to define the FC data in eye tracking studies. The FC ID is needed here to specify the FC data.

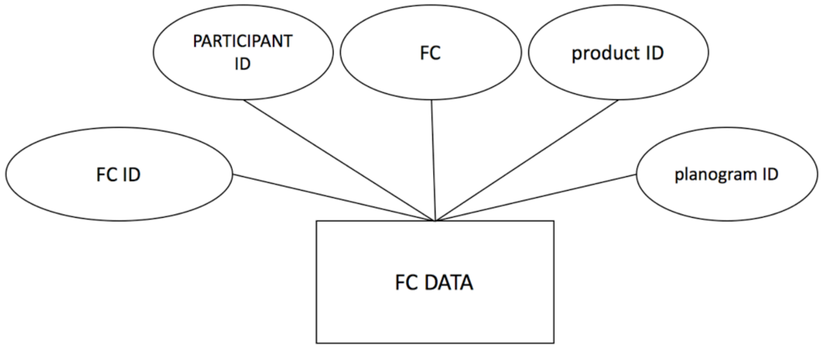


Figure 3.19. Fixation Duration (FC) data E-R diagram

According to the conceptual design, the database design can be optimized by reducing redundancy and enabling the relationship to meet 3NF. Figure 3.20 shows an integrated ER diagram including all entities in the database.

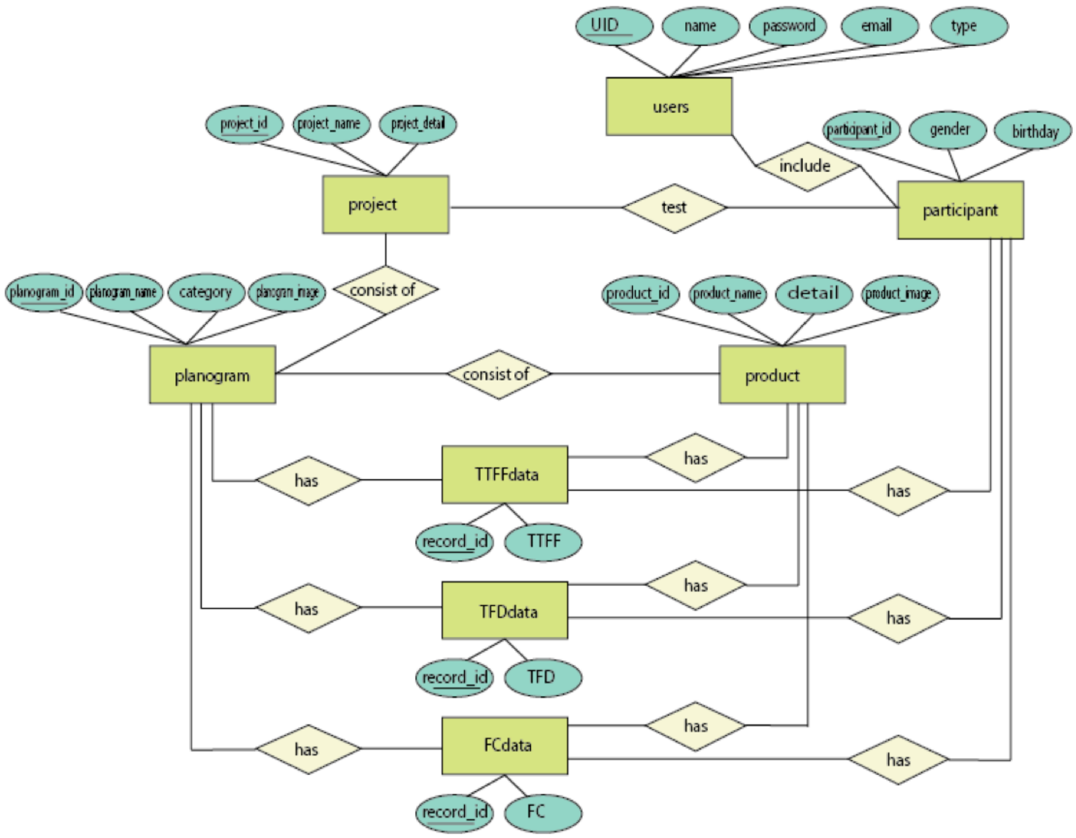


Figure 3.20. E-R diagram of the database

Logical Database Design: Logical Schema

To implement the database design, the conceptual database design was converted into a database schema of the relational data model. The task in the logical design step is to convert an ER schema into a relational database schema. In this process, the primary keys and foreign keys were enhanced to the conceptual design.

Physical Database Design

After the database model was designed, the database can be created using SQL commands. As an example shown in Figure 3.21, the planogram table was created using the “CREATE TABLE” command. In the planogram table, one planogram has exactly one ID. Hence, the planogram_ID may be used for primary key, as it can identify a planogram uniquely. Foreign keys are used to create a link between two related tables, which can be an attribute or a combination of attributes. For instance, project_ID is a foreign key in the planogram table. In the project Table, it will become primary key, enforcing that the corresponding data has to be same in the planogram Table and project Table.

```
CREATE TABLE `planogram` (
`planogram_id` int(11) NOT NULL,
`planogram_name` varchar(255) NOT NULL,
`project_id` int(11) NOT NULL,
`category` varchar(255) NOT NULL,
`planogram_image` varchar(255) NOT NULL,
FOREIGN KEY (project_id) REFERENCES project(project_id);
```

Figure 3.21. SQL commands for creating tables in the database

Eight tables were created in the database, including “project” table (Figure 3.22), “planogram” table (Figure 3.23), “product” table (Figure 3.24), “TTFFdata” table (Figure 3.25), “TFDdata” table (Figure 3.26), “FCdata” table (Figure 3.27), “participant” table and “users” table (Figure 3.28). The structures of these tables are described as below.

```
mysql> show columns from project;
+----------------+--------------+------+-----+---------+----------------+
| Field          | Type         | Null | Key | Default | Extra          |
+----------------+--------------+------+-----+---------+----------------+
| project_id     | int(11)      | NO   | PRI | NULL    | auto_increment |
| project_name   | varchar(255) | NO   | UNI | NULL    |                |
| project_detail | text         | NO   |     | NULL    |                |
| project_date   | varchar(25)  | YES  |     | NULL    |                |
+----------------+--------------+------+-----+---------+----------------+
4 rows in set (0.00 sec)
```

Figure 3.22. Result of columns from the project table

```
mysql> show columns from planogram;
+-----------------+--------------+------+-----+---------+----------------+
| Field           | Type         | Null | Key | Default | Extra          |
+-----------------+--------------+------+-----+---------+----------------+
| planogram_id    | int(11)      | NO   | PRI | NULL    | auto_increment |
| planogram_name  | varchar(255) | NO   |     | NULL    |                |
| project_id      | int(11)      | NO   | MUL | NULL    |                |
| category        | varchar(255) | NO   |     | NULL    |                |
| planogram_image | varchar(255) | NO   |     | NULL    |                |
+-----------------+--------------+------+-----+---------+----------------+
5 rows in set (0.00 sec)
```

Figure 3.23. Result of columns from the planogram table

```
mysql> show columns from product;
+---------------+--------------+------+-----+---------+----------------+
| Field         | Type         | Null | Key | Default | Extra          |
+---------------+--------------+------+-----+---------+----------------+
| product_id    | int(11)      | NO   | PRI | NULL    | auto_increment |
| product_name  | varchar(255) | NO   | UNI | NULL    |                |
| detail        | text         | NO   |     | NULL    |                |
| product_image | varchar(255) | NO   |     | NULL    |                |
+---------------+--------------+------+-----+---------+----------------+
4 rows in set (0.00 sec)
```

Figure 3.24. Result of columns from the product table

```
mysql> show columns from TTFFdata;
+----------------+-------------+------+-----+---------+----------------+
| Field          | Type        | Null | Key | Default | Extra          |
+----------------+-------------+------+-----+---------+----------------+
| TTFF_id        | int(11)     | NO   | PRI | NULL    | auto_increment |
| participant_id | int(11)     | NO   | MUL | NULL    |                |
| TTFF           | float(10,2) | NO   |     | NULL    |                |
| product_id     | int(11)     | NO   | MUL | NULL    |                |
| planogram_id   | int(11)     | NO   | MUL | NULL    |                |
+----------------+-------------+------+-----+---------+----------------+
5 rows in set (0.00 sec)
```

Figure 3.25. Result of columns from the TTFFdata table

```
mysql> show columns from TFDdata;
```

Field	Type	Null	Key	Default	Extra
TFD_id	int(11)	NO	PRI	NULL	auto_increment
participant_id	int(11)	NO	MUL	NULL	
TFD	float(10,2)	NO		NULL	
product_id	int(11)	NO	MUL	NULL	
planogram_id	int(11)	NO	MUL	NULL	

```
5 rows in set (0.00 sec)
```

Figure 3.26. Result of columns from the TFDdata table

```
mysql> show columns from FCdata;
```

Field	Type	Null	Key	Default	Extra
record_id	int(11)	NO	PRI	NULL	auto_increment
participant_id	int(11)	NO	MUL	NULL	
FC	float(10,2)	NO		NULL	
product_id	int(11)	NO	MUL	NULL	
planogram_id	int(11)	NO	MUL	NULL	

```
5 rows in set (0.00 sec)
```

Figure 3.27. Result of columns from the FCdata table

```
mysql> show columns from users;
```

Field	Type	Null	Key	Default	Extra
UID	int(11)	NO	PRI	NULL	auto_increment
name	varchar(255)	NO	UNI	NULL	
password	varchar(255)	NO		NULL	
email	varchar(255)	NO	UNI	NULL	
type	tinyint(11)	NO		NULL	

```
5 rows in set (0.00 sec)
```

Figure 3.28. Result of columns from the users table

Results and Discussion

In this section, eye tracking data was uploaded into the database, which was collected from eye tracking studies. The expected results from requirement analysis were retrieved from the database using SQL. Views in the database were created based on tables in the database, which present the calculated results. The views are not tables in the database but act as result sets of a stored query on the data in designed tables. Views can also update automatically when the data is changed in related tables. Therefore, views can be used as virtual tables for eye tracking data aggregation and a convenient method to save the data retrieval queries that frequently used by eye tracking researchers. The data retrieval tasks, SQL queries for the implementation, and returned results are listed below.

Eye Tracking Data Retrieval by Projects and Planograms

To show the eye tracking results for project and planograms, the project, planogram, TTFFdata, TFDdata, FCdata tables can be aggregated as a view for further select queries. The SQL commands used in creating the required views are shown in Figure 3.29. The result of the created view PJ_PL_AGG is shown in Figure 3.30.

```
CREATE VIEW PLANOGRAM_TTFF AS
SELECT planogram_id AS `PLANOGRAM ID`, COUNT(DISTINCT product_id) AS
        `NUMBER OF PRODUCTS`,AVG(TTFF) AS `TTFF MEAN` FROM TTFFdata
        WHERE TTFF_id IN(SELECT * FROM (SELECT TTFF_id FROM TTFFdata INNER
        JOIN product ON product.product_id = TTFFdata.product_id INNER JOIN planogram
        ON TTFFdata.planogram_id = planogram.planogram_id) AS t2) GROUP BY
        planogram_id;
CREATE VIEW PLANOGRAM_TFD AS
SELECT planogram_id AS `PLANOGRAM ID`, COUNT(DISTINCT product_id) AS
        `NUMBER OF PRODUCTS`,AVG(TFD) AS `TFD MEAN` FROM TFDdata WHERE
        TFD_id IN(SELECT * FROM (SELECT TFD_id FROM TFDdata INNER JOIN product
        ON product.product_id = TFDdata.product_id INNER JOIN planogram ON
        TFDdata.planogram_id = planogram.planogram_id) AS t3) GROUP BY planogram_id;
CREATE VIEW PLANOGRAM_FC AS
SELECT planogram_id AS `PLANOGRAM ID`, COUNT(DISTINCT product_id) AS
        `NUMBER OF PRODUCTS`,AVG(FC) AS `FC MEAN` FROM FCdata WHERE FC_id
        IN(SELECT * FROM (SELECT FC_id FROM FCdata INNER JOIN product ON
        product.product_id = FCdata.product_id INNER JOIN planogram ON
        FCdata.planogram_id = planogram.planogram_id) AS t3) GROUP BY planogram_id;
CREATE VIEW AGGREGATE_PLANOGRAM AS
SELECT X.`PLANOGRAM ID`, X.`NUMBER OF PRODUCTS`, X.`TTFF MEAN`, Y.`TFD
        MEAN`, Z.`FC MEAN` FROM PLANOGRAM_TTFF X
LEFT JOIN PLANOGRAM_TFD Y ON X.`PLANOGRAM ID`=Y.`PLANOGRAM ID`
LEFT JOIN PLANOGRAM_FC Z ON X.`PLANOGRAM ID`=Z.`PLANOGRAM ID`;
CREATE VIEW PJ_PL_AGG AS
SELECT project.project_id,AGGREGATE_PLANOGRAM.`PLANOGRAM ID`,
        planogram.planogram_name,AGGREGATE_PLANOGRAM.`TTFF
        MEAN`,AGGREGATE_PLANOGRAM.`TFD
        MEAN`,AGGREGATE_PLANOGRAM.`FC MEAN` FROM
        AGGREGATE_PLANOGRAM
LEFT JOIN planogram ON AGGREGATE_PLANOGRAM.`PLANOGRAM
        ID`=planogram.planogram_id
LEFT JOIN project ON planogram.project_id=project.project_id;
```

Figure 3.29. SQL commands used in creating views

```
mysql> show columns from PJ_PL_AGG;
+----------------+--------------+------+-----+---------+-------+
| Field          | Type         | Null | Key | Default | Extra |
+----------------+--------------+------+-----+---------+-------+
| PROJECT ID     | int(11)      | YES  |     | 0       |       |
| PLANOGRAM ID   | int(11)      | NO   |     | NULL    |       |
| PLANOGRAM NAME | varchar(255) | YES  |     | NULL    |       |
| TTFF MEAN      | double(14,6) | YES  |     | NULL    |       |
| TFD MEAN       | double(14,6) | YES  |     | NULL    |       |
| FC MEAN        | double(14,6) | YES  |     | NULL    |       |
+----------------+--------------+------+-----+---------+-------+
6 rows in set (0.00 sec)
```

Figure 3.30. Columns of View PJ_PL_AGG

By having this aggregated view, results from selected planograms or projects can be simply retrieved (unlike the file-based method). For example, the result of planogram id, planogram name, TTFF means, TFD means, FC means can be returned by specified the project id. The SQL query and the output of this example are shown in Figure 3.31.

```
mysql> select `PLANOGRAM ID`,`PLANOGRAM NAME`,`TTFF MEAN`,`TFD MEAN`,`FC MEAN` FROM PJ_PL_AGG WHERE `PRO
JECT ID`=43;
+--------------+---------------------+-----------+----------+----------+
| PLANOGRAM ID | PLANOGRAM NAME      | TTFF MEAN | TFD MEAN | FC MEAN  |
+--------------+---------------------+-----------+----------+----------+
|           19 | Baby food           | 12.323096 | 1.706795 | 3.904110 |
|           20 | Baby Food Label     | 14.622371 | 2.004544 | 4.266998 |
|           21 | Frozen Treats       |  3.543007 | 1.265882 | 3.513072 |
|           22 | Natural Fruit Drink |  7.285372 | 1.220106 | 2.513298 |
|           23 | Ready to eat meal   | 15.866541 | 1.148158 | 2.633459 |
|           24 | Sunscreen           |  7.513898 | 3.368814 | 7.508475 |
|           25 | Sunscreen Label     |  5.045714 | 4.386548 | 8.607143 |
|           26 | Tuna                | 10.527428 | 1.053942 | 2.441624 |
+--------------+---------------------+-----------+----------+----------+
8 rows in set (0.11 sec)
```

Figure 3.31. Results Returned for Project No.43

As the eye tracking key metrics retrieved from Figure 3.31, the means of TTFF, TFD, FC were calculated using SQL and sorted by different planograms. This result can be used to understand the performance of packaging design in a specific project and planogram setup. For example, the TFD means from planogram No.19 to planogram No. 26 ranged from 1.15s (planogram 23) to 4.39s (planogram 25), indicating a difference in average total fixation duration for each of the products tested in varying planograms.

Eye Tracking Data Retrieval by Product Category

The attribute “category” was listed in “planogram” table, which is not mentioned in eye tracking key metric table. However, the attribute “planogram_id” acted as the foreign key in “TTFFdata”, “TFDdata”, and “FCdata” tables. In order to aggregate eye tracking data by category across different projects and planograms, related tables were required to join. The SQL commands and the view CATEGORY_AGG created for category-wide data aggregation is shown in output in below Figure 3.32 and Figure 3.33.

```
CREATE VIEW PRODUCT_TTFF AS
select `EYETRACK_DB`.`TTFFdata`.`TTFF_id` AS `TTFF_id`,`EYETRACK_DB`.`TTFFdata`.`participant_id`
        AS `participant_id`,`EYETRACK_DB`.`TTFFdata`.`TTFF` AS
        `TTFF`,`EYETRACK_DB`.`TTFFdata`.`product_id` AS
        `product_id`,`EYETRACK_DB`.`TTFFdata`.`planogram_id` AS
        `planogram_id`,`EYETRACK_DB`.`planogram`.`category` AS `category` from
        (`EYETRACK_DB`.`TTFFdata` left join `EYETRACK_DB`.`planogram`
        on((`EYETRACK_DB`.`TTFFdata`.`planogram_id` = `EYETRACK_DB`.`planogram`.`planogram_id`)))
        order by `EYETRACK_DB`.`TTFFdata`.`product_id`
CREATE VIEW PRODUCT_TFD AS
select `EYETRACK_DB`.`TFDdata`.`TFD_id` AS `TFD_id`,`EYETRACK_DB`.`TFDdata`.`participant_id` AS
        `participant_id`,`EYETRACK_DB`.`TFDdata`.`TFD` AS
        `TFD`,`EYETRACK_DB`.`TFDdata`.`product_id` AS
        `product_id`,`EYETRACK_DB`.`TFDdata`.`planogram_id` AS
        `planogram_id`,`EYETRACK_DB`.`planogram`.`category` AS `category` from
        (`EYETRACK_DB`.`TFDdata` left join `EYETRACK_DB`.`planogram`
        on((`EYETRACK_DB`.`TFDdata`.`planogram_id` = `EYETRACK_DB`.`planogram`.`planogram_id`)))
        order by `EYETRACK_DB`.`TFDdata`.`product_id`
CREATE VIEW PRODUCT_FC AS
select `EYETRACK_DB`.`FCdata`.`FC_id` AS `FC_id`,`EYETRACK_DB`.`FCdata`.`participant_id` AS
        `participant_id`,`EYETRACK_DB`.`FCdata`.`FC` AS `FC`,`EYETRACK_DB`.`FCdata`.`product_id` AS
        `product_id`,`EYETRACK_DB`.`FCdata`.`planogram_id` AS
        `planogram_id`,`EYETRACK_DB`.`planogram`.`category` AS `category` from
        (`EYETRACK_DB`.`FCdata` left join `EYETRACK_DB`.`planogram`
        on((`EYETRACK_DB`.`FCdata`.`planogram_id` = `EYETRACK_DB`.`planogram`.`planogram_id`)))
        order by `EYETRACK_DB`.`FCdata`.`product_id`
CREATE VIEW CATEGORY_TTFF AS
select `PRODUCT_TTFF`.`category` AS `CATEGORY`,count(distinct `PRODUCT_TTFF`.`product_id`) AS
        `NUMBER_OF_PRODUCTS`,avg(`PRODUCT_TTFF`.`TTFF`) AS `TTFF MEAN` from
        `EYETRACK_DB`.`PRODUCT_TTFF` group by `PRODUCT_TTFF`.`category`
CREATE VIEW CATEGORY_TFD AS
select `PRODUCT_TFD`.`category` AS `CATEGORY`,count(distinct `PRODUCT_TFD`.`product_id`) AS
        `NUMBER_OF_PRODUCTS`,avg(`PRODUCT_TFD`.`TFD`) AS `TFD MEAN` from
        `EYETRACK_DB`.`PRODUCT_TFD` group by `PRODUCT_TFD`.`category`
CREATE VIEW CATEGORY_FC AS
select `PRODUCT_FC`.`category` AS `CATEGORY`,count(distinct `PRODUCT_FC`.`product_id`) AS
        `NUMBER_OF_PRODUCTS`,avg(`PRODUCT_FC`.`FC`) AS `FC MEAN` from
        `EYETRACK_DB`.`PRODUCT_FC` group by `PRODUCT_FC`.`category`
CREATE VIEW CATEGORY_AGG AS
SELECT
        CATEGORY_TTFF.CATEGORY,CATEGORY_TTFF.NUMBER_OF_PRODUCTS,CATEGORY_TTFF
        .`TTFF MEAN`, CATEGORY_TFD.`TFD MEAN`,CATEGORY_FC.`FC MEAN` FROM
        CATEGORY_TTFF
LEFT JOIN CATEGORY_TFD ON CATEGORY_TTFF.CATEGORY=CATEGORY_TFD.CATEGORY
LEFT JOIN CATEGORY_FC ON CATEGORY_TTFF.CATEGORY=CATEGORY_FC.CATEGORY;
```

Figure 3.32. SQL commands for creating the category data views

```
mysql> select * from CATEGORY_AGG limit 13;
+--------------------+--------------------+------------+----------+------------+
| CATEGORY           | NUMBER_OF_PRODUCTS | TTFF MEAN  | TFD MEAN | FC MEAN    |
+--------------------+--------------------+------------+----------+------------+
| BABY FOOD          |                 63 |  13.755393 | 1.892273 |   4.130165 |
| BAKING MIX         |                165 |  20.935262 | 4.300046 | 215.030030 |
| CANDLE             |                 14 | 103.719058 | 0.724493 |   2.065217 |
| COFFEE MACHINE     |                  3 |  25.431810 | 1.147414 |   4.293103 |
| FOOD STORAGE       |                 16 |  49.737087 | 0.817661 |   2.917431 |
| FROZEN TREATS      |                  8 |   3.543007 | 1.265882 |   3.513072 |
| FRUIT DRINK        |                 16 |   7.285372 | 1.220106 |   2.513298 |
| READY-TO-EAT MEAL  |                 30 |  15.866541 | 1.148158 |   2.633459 |
| SUNSCREEN          |                  3 |   6.064056 | 3.966643 |   8.153846 |
| TOASTER            |                  3 |  29.829510 | 1.637843 |   6.166667 |
| TUNA               |                 28 |  10.527428 | 1.053942 |   2.441624 |
| WAFFLE MAKER       |                  3 |  18.187705 | 1.695082 |   6.639344 |
| WATER BOTTLE       |                 16 |  72.019016 | 1.040287 |   3.395492 |
+--------------------+--------------------+------------+----------+------------+
13 rows in set (0.10 sec)
```

Figure 3.33. Retrieved Results from View CATEGORY_AGG

From the eye tracking key metrics retrieved from Figure 3.16, the means of TTFF, TFD, FC were calculated using SQL and sorted by different categories. These results can be used to understand the performance of packaging design in specific categories. For example, the TFD means from category “BAKING MIX” (4.3s) and “SUNSCREEN” (3.9s) ranked the top two among the listed 13 categories. TFD means in other categories were with a range between 0.81s to 1.89s. These findings indicate a difference in average total fixation duration for each product categories. Participants spent more attention (TFD) on the baking mix and sunscreen products, compared to the baby food, candle, coffee machine, food storage container, frozen treats, fruit drink, ready-to-eat meal, toaster, tuna, waffle maker, water bottle products on average.

Discussion on Data Retrieval Efficiency

The data retrieval of the project-wide and the category-wide results took approximately 0.1 seconds. Considering the excessive effort of manual data retrieval from spreadsheets across projects and categories, the data retrieval from the designed database was significantly faster than manual searching and calculating the results by using file-based systems (e.g., working with spreadsheets). As the data sets of the eye tracking studies become larger, the advantages of using the designed database are increasingly obvious. Compared to traditional data cleaning and data organization by copying and pasting between tons of excel sheets, this database method can effectively reduce potential human errors.

Conclusion

By using a relational database system, the eye tracking data that was collected and added to the database becomes more accessible, providing convenience for further statistical analysis and reporting, which significantly improves the efficiency of the project as a whole. Data aggregation of eye tracking studies using a DBMS can provide a greater wide-range comparison and analysis of the packaging design compared to the more conventional file-based methods. These learnings are important for the future of packaging science, specifically the design aspect, to provide the packaging industry a more comprehensive method of consumer behavior research.

References

Batini, C., Ceri, S., & Navathe, S. B. (1992). *Conceptual database design: an Entity-relationship approach* (Vol. 116). Redwood City, CA: Benjamin/Cummings.

Chen, P. (1991). *The entity-relationship approach to logical database design* (No. 04; QA76. 9. D26, C4.).

Chen, P. P. S. (1988). The entity-relationship model—toward a unified view of data. In *Readings in artificial intelligence and databases* (pp. 98-111).

Connolly, T. M., & Begg, C. E. (2005). *Database systems: a practical approach to design, implementation, and management*. Pearson Education.

Gomes, T., Hurley, R. A., Duchowski, A., Darby, D., & Ouzts, A. (2014). The effect of full body versus partial body graphic labelling on beverage packaging. Packaging Technology and Science, 27(12), 933-943.

Hurley, R. A. (2011). Persuasive packaging: An eye-tracking approach to design. Clemson University.

Hurley, R. A., Rice, J. C., Cottrell, D., & Felty, D. (2016). Effect of Metal Can Labels on Consumer Attention through Eye Tracking Methodology. *Journal of Food Research*, *5*(6), 1.

Maier, D. (1983). *The theory of relational databases* (Vol. 11). Rockville: Computer science press.

Ramakrishnan, R., & Gehrke, J. (2000). *Database management systems*. McGraw Hill.

Tobii Pro Glasses 2. (2017). Available at https://www.tobiipro.com/product-listing/tobii-pro-glasses-2/#Features. Accessed October 13, 2017.

CHAPTER FOUR

WEB PORTAL DEVELOPMENT FOR DATABASE MANAGEMENT

Abstract

By having data structured as designed database model in Chapter Three, eye tracking results from this database can be retrieved and managed by using SQL queries. These database operations require sufficient knowledge of database management and SQL programming. However, the database was designed to be used by members of academia and industry, who do not have specialized training in database management and SQL programming. To solve this problem, a user-friendly web portal for managing and accessing the database was developed. In this chapter, the web portal was designed and created by using PHP, HTML, JavaScript, and CSS, along with SQL queries for data retrieval from the database. The implementation of the designed web portal is detailed herein, which include the user registration process, data import, and result generation.

Introduction

Most of the services people enjoy on the web are provided by web database applications, such as online shopping and forums (Willams, 2004). While browsing the web, the web browser is used to request resources and receive responses from a web server (Willams, 2004). Figure 4.1 illustrates how a web browser communicates with a web server to retrieve a web page, which represents a classic two-tier model used on the web.

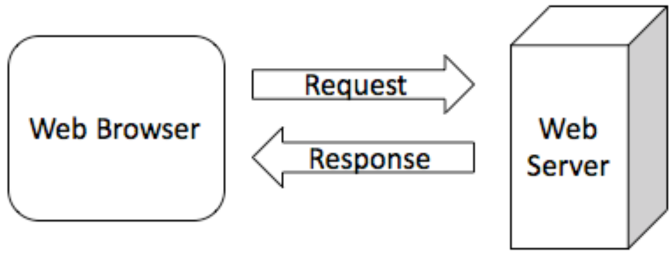


Figure 4.1. The two-tier model

A web server is not a sophisticated storage software (Willams, 2004). A separate database should be involved in handling the complicated dynamic operations, which forms a three-tier model. In addition to the two-tier model, the database becomes the third tier in the three-tier model (Willams, 2004). Figure 4.2 shows how the requests and responses are conveyed by the web browser, the web server, and the database server.

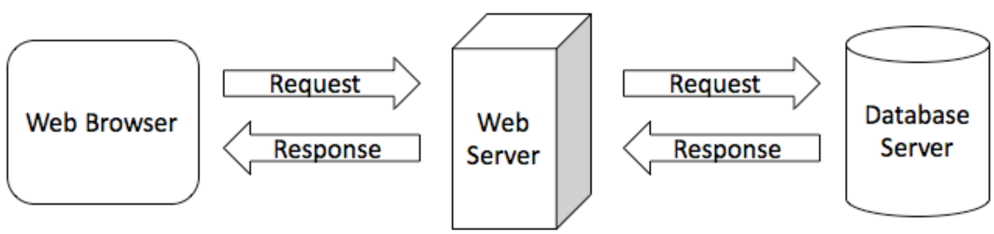


Figure 4.2. The three-tier model

The database tier acts as a base of a database-driven application. In the database tier, a database management system can be used by users for data management operations, such as data modification and query (Frolund, 2002; Willams, 2004). The most of the application logic is included in the web server tier, which is built on top of the database tier (Willams, 2004). The web browser software usually serves to interacts with the application, which is the web browser tier on top (Willams, 2004).

In this work, the three-tier model was used to build the database-driven management system. This chapter details how to design the web portal on top of the database with this three-tier model. The implementation results are also shown and discussed accordingly.

Method

Requirements Collection and Analysis

The database-driven management system was developed to meet academic and industry research requirements. It can be summarized as a platform allowing researchers, participants, and clients to manage and access the eye tracking studies from different aspects. Researchers can use the system to build and design surveys, manage projects, search for previously analyzed data and generate reports. The participants can take the survey created by researchers and view the upcoming studies. The profile information from the participant can be used to replace screening and demographic capture currently done through a different program. Figure 4.3 shows the structure of the system design.

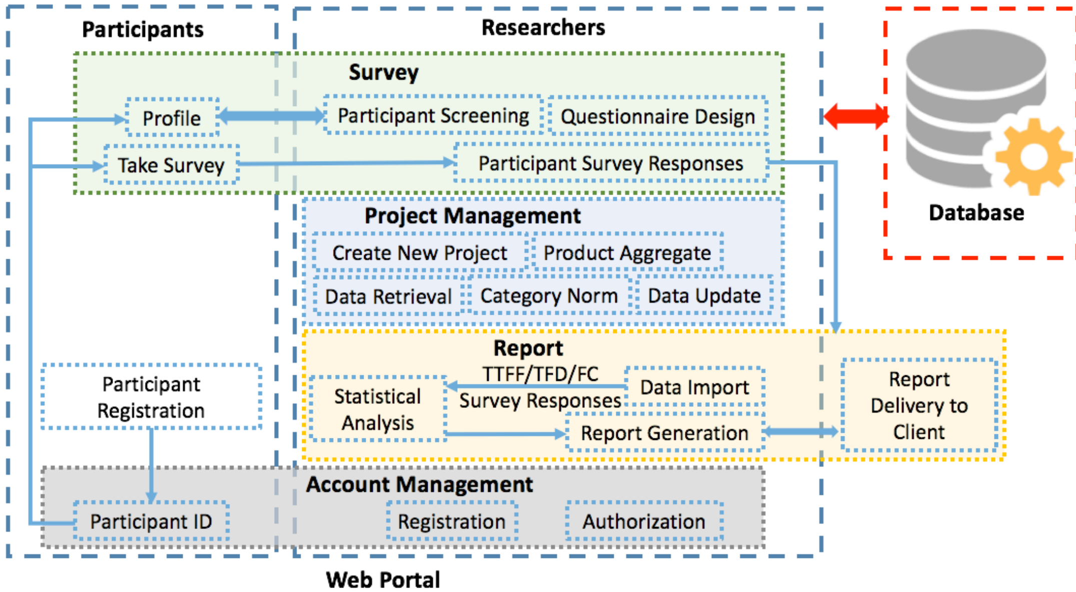


Figure 4.3 The structure of the system design

It is a web database-driven application that developed using the HTML, CSS, JavaScript, PHP, and SQL languages. In the further section, the key components of this work were discussed in detail, including the conceptual design and the partial PHP code or SQL query for implementation.

Hyper Text Markup Language (HTML)

HTML is the language used for defining the web page structure (Lakshmanan, 1996). Tags in HTML can represent the elements of the page content for building blocks (Castro, 2003; Refsnes Data, 1999).

Cascading Style Sheets (CSS)

CSS is primarily used in this work for the presentation of web pages (Bos, 1998). It provides instructions to HTML tags regarding the layout of the elements and how they are displayed (Lie, 2005). CSS includes some behavioral interactions components like hover and click actions (Bos, 1998).

JavaScript

JavaScript is primarily for behavioral interaction, which enables interactive web pages (Crockford, 2008). JavaScript is used in developing the web portal in this work, mainly for making interactive elements (e.g., clickable buttons, popup menus, etc.).

Querying Web Database Using PHP and SQL

Hypertext Preprocessor (PHP) is a web scripting language, which is widely used for building database-driven web applications (Willams, 2004). Many PHP libraries also provide functions for executing SQL statements, such as managing data returned from database queries (Willams, 2004).

Data Analysis Methods

The statistical analysis (t-test, ANOVA) is conducted by the PHP/JavaScript libraries (Math-php and jStat v 1.7.1) to determine the data significance (alpha =0.05). Figure 4.4 illustrates how to retrieve eye tracking results for a selected category. There are two steps for users to input from the web page: select category and select product. When users select two products from the product list within a certain category, a t-test is applied within the statistical analysis. When users select more than two products from the product list within a certain category, an ANOVA test is applied in the statistical analysis. Mean, standard deviation, and standard error of eye tracking key metrics are also calculated.

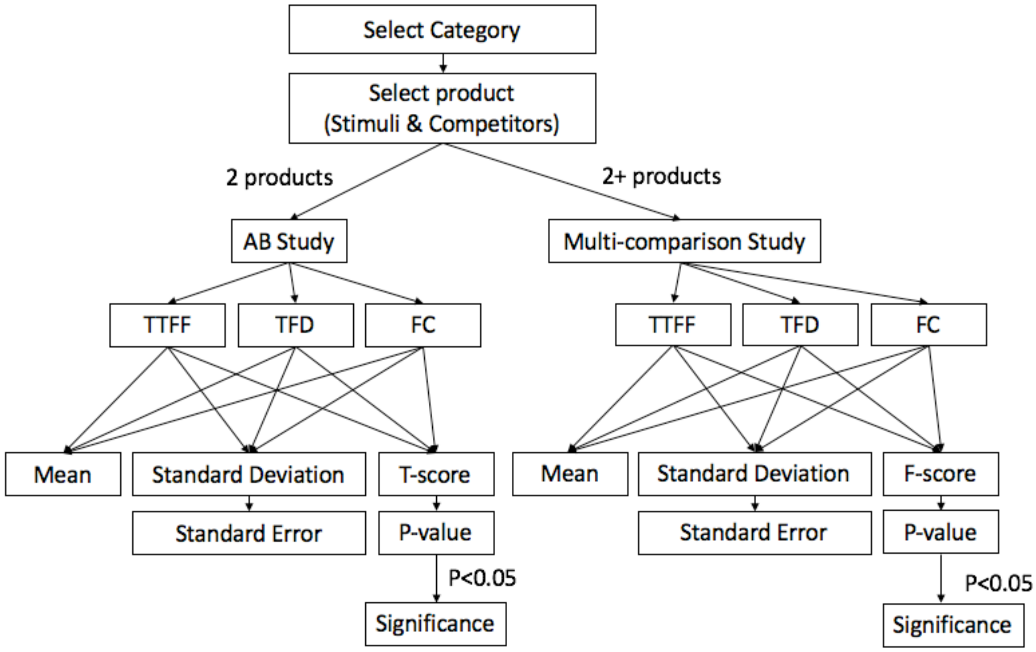


Figure 4.4. Process for generating category results

Implementation Results

The developed database web portal mainly consists of the following sections, which are further explained accordingly with the implementation results.

Home Page

When the user types the web address in the browser, the main page of the application is displayed, as shown in Figure 4.5. This page consists of four functional areas including the menu area, the navigation area, the search area and the content area. The search area in the home page is a convenient way for a user to retrieve the related information.

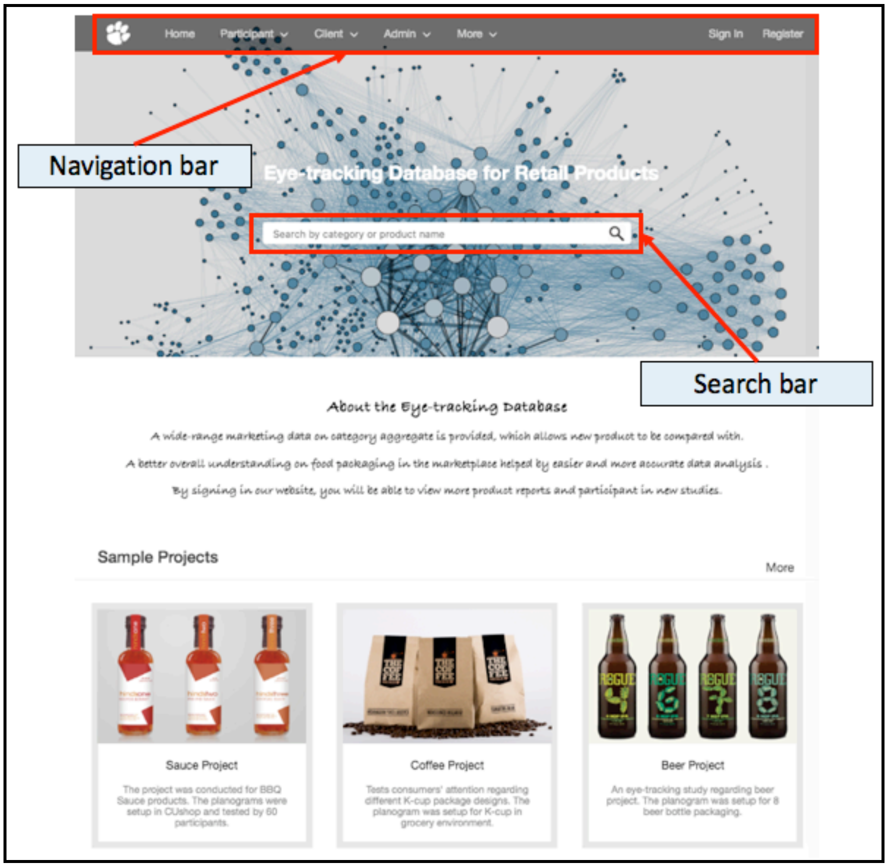
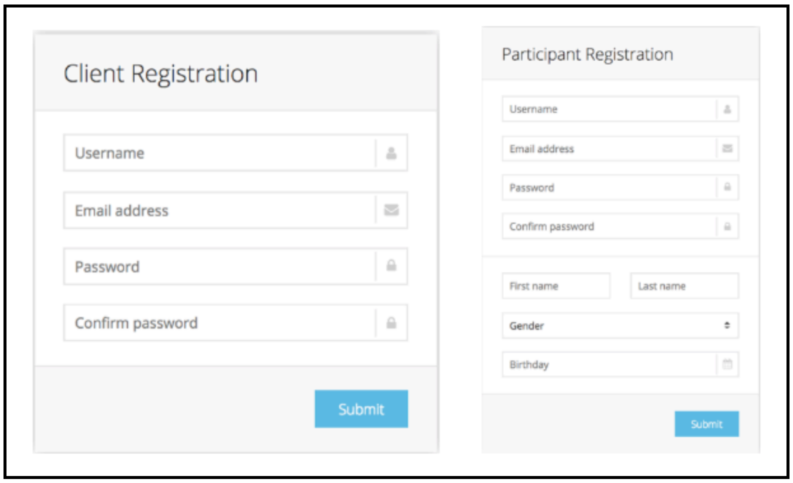


Figure 4.5. Home page

User Account Registration

Registration is a part of the account management which allows the user to create a participant or client account to become a user of this system. After the registration step, the clients and participants will be assigned a user ID, and their profile information will be stored in the database. For client registration, username, email, and password are information required to create the account. Username and password are used to login back to the website for verifying the identity. Email addresses are saved for contacting purpose on potential inquiries regarding projects. For participant registration, username, email address, and password are used for verifying the identity and log in. The birthday and gender are required and saved in the participant table of this database to used as participant screening factors. For example, for eye tracking studies with baby food as the product of interest, female participants aged 25 are ideal to be included in the study as they represent the primary shopper for this category. The client registration and participant registration forms are shown in Figure 4.6.



4.6. User registration forms

Authorization

The authorization process is divided according to the user types (administrator, participant, and client) in this system. The registration forms are provided for the user to enter their email address and password, which is shown in Figure 4.7.

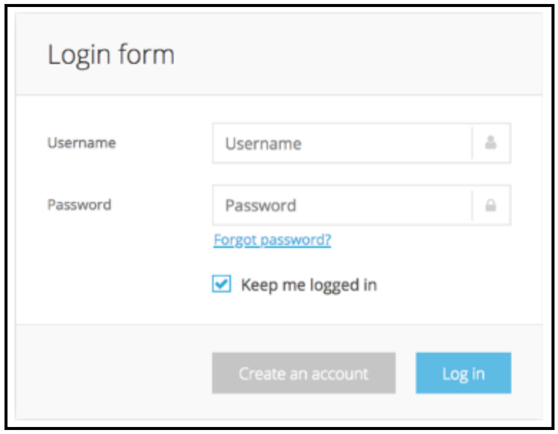


Figure 4.7. Login form

By submitting the login form, the email address and password can be used to determine the role of the user. If the login process succeeds, the user can be forward to the target page. If the login process fails, users will be returned to the index page with an error displayed. Figure 4.8 also shows the three scripts that interact with the login and logout process.

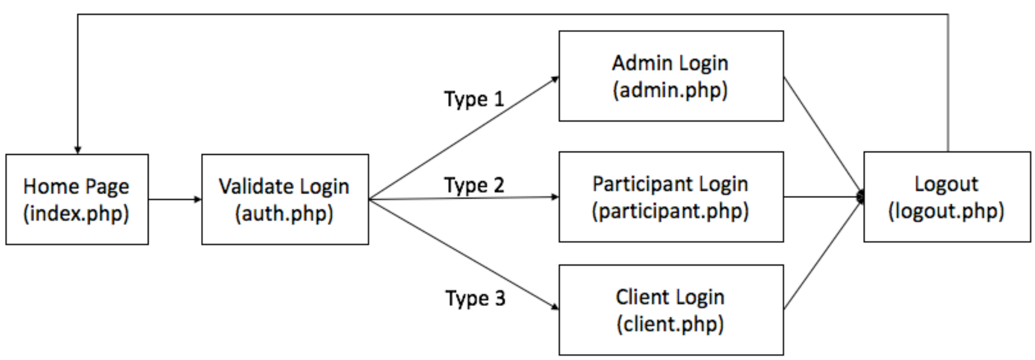


Figure 4.8. The authorization process

Data Import

The data import process consists of two steps. First, the users login with an admin account to use the data import entry. Raw data sheets used in this import entry can be generated from the eye tracking data analyzer. Users can create a project by entering a project name and the project description in the web page shown in Figure 4.9. The raw data sheet or Excel file can be browsed and selected from the local machine, then attached to the excel file import page and uploaded.

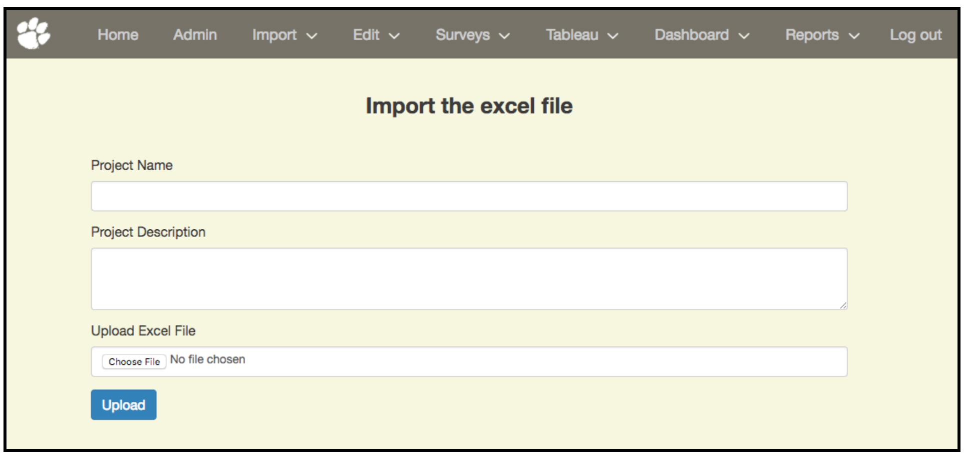
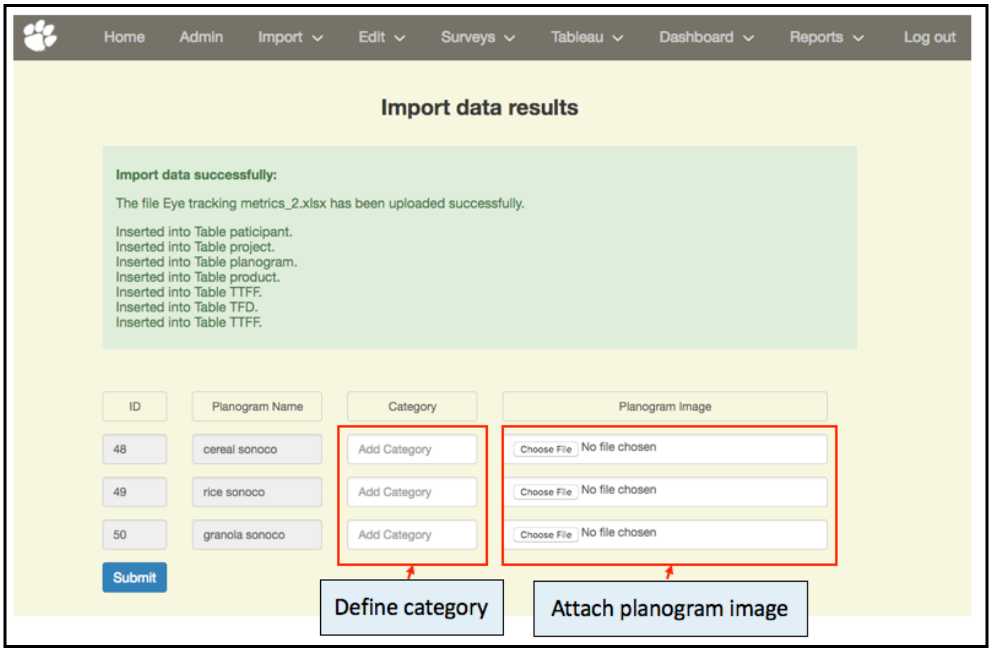


Figure 4.9. Web page for importing the excel file

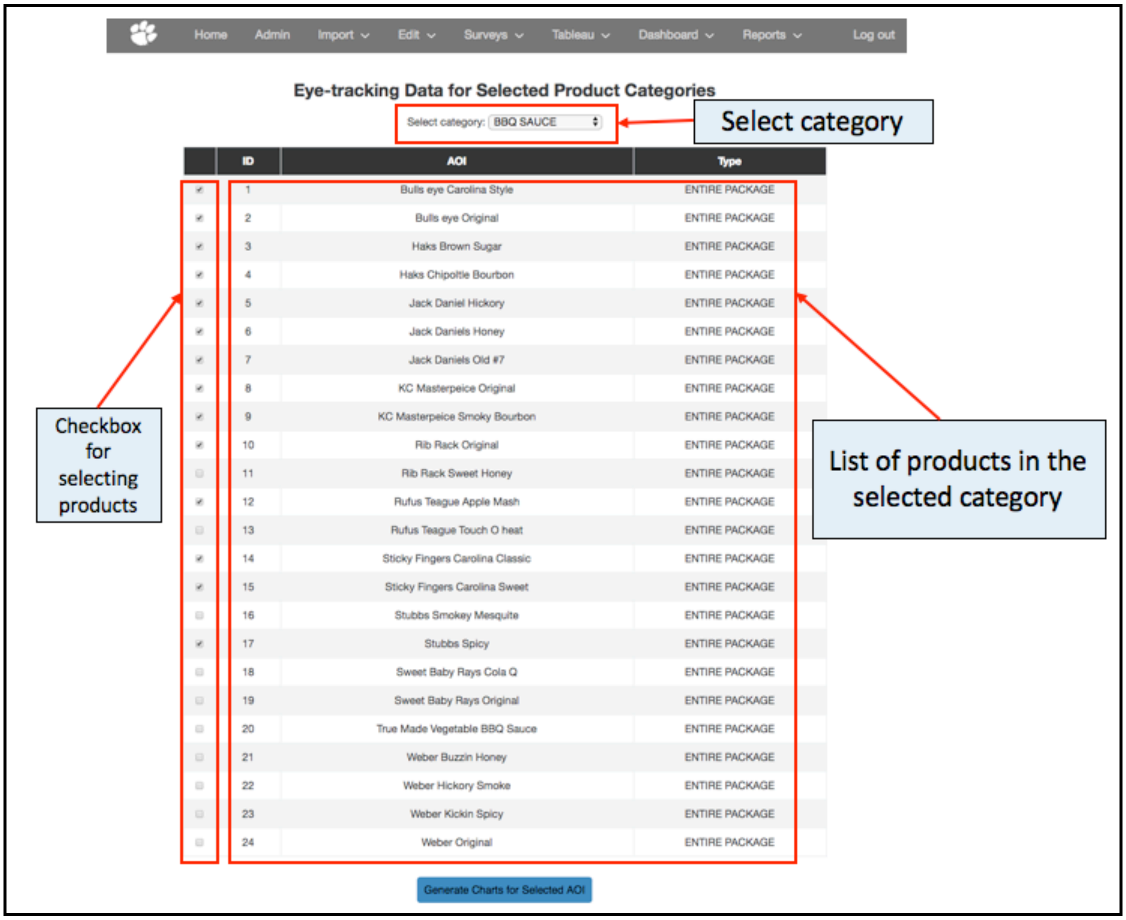
Second, the user will advance to the next page to enter category names and attach images for each planogram within the submitted raw data sheet (Figure 4.10). As shown in the import data results (Figure 4.10), the submitted data can be inserted into seven tables in the database, including Table “participant”, Table “project”, Table “planogram”, Table “product”, Table “TTFF”, Table “TFD”, Table “FC”. Once the information is submitted in the second step, the uploading process is finally completed.



4.10. Web page for importing the planogram information

Browsing Results

Results can be browsed by entering the searching criteria. For example, when selecting the "BBQ sauce" in the category dropdown list, the products tested within BBQ sauce category can be displayed as product list shown in Figure 4.11. Users can select the products from the list to generate eye tracking results.



4.11. Web page for selecting the products from a category list

If two products are selected from the product list, the t-test yields a p-value to determine if a significant difference exists between the two products. If multiple products are selected from the product list, the ANOVA test yields a p-value to decide the significance. If the p-value is smaller than 0.05, then a significance is identified for the selected products. TTFF, TFD, FC data results can be shown in a histogram with error bars and a summary table. TTFF, TFD, FC results can be displayed on the final result page by switching the TTFF, TFD, FC tags on top of the charts. The result outputs for this BBQ example are shown in Figure 4.12.

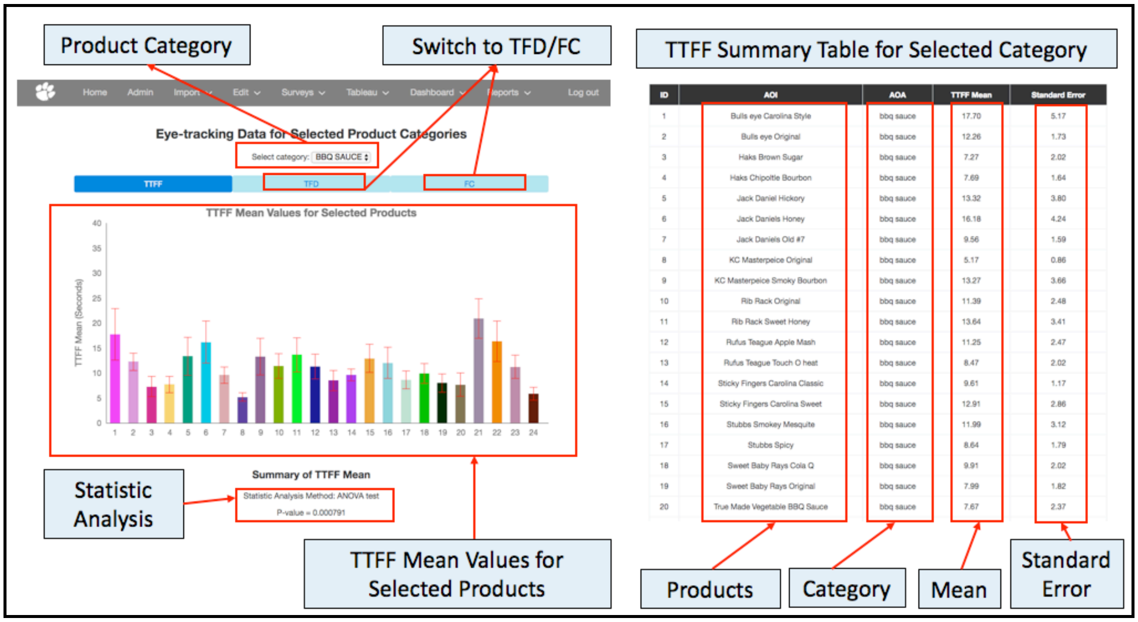


Figure 4.12. Result outputs of the selected category and products

By retrieving eye tracking metrics in a category, researchers are able to search and browse results across projects. Since users can interact with data through web pages and results in real time, the accessibility and efficiency of data analysis are greatly improved compared to manual calculations with spreadsheets and statistical software.

Manage Records in Database Tables

In the web portal, functions of the project and product list management are built in the "Edit" page and accessible by admin users. Project lists can be visualized within the web page (Figure 4.13). Users can search project using keywords, which can be entered in the text box on the top of the web page.

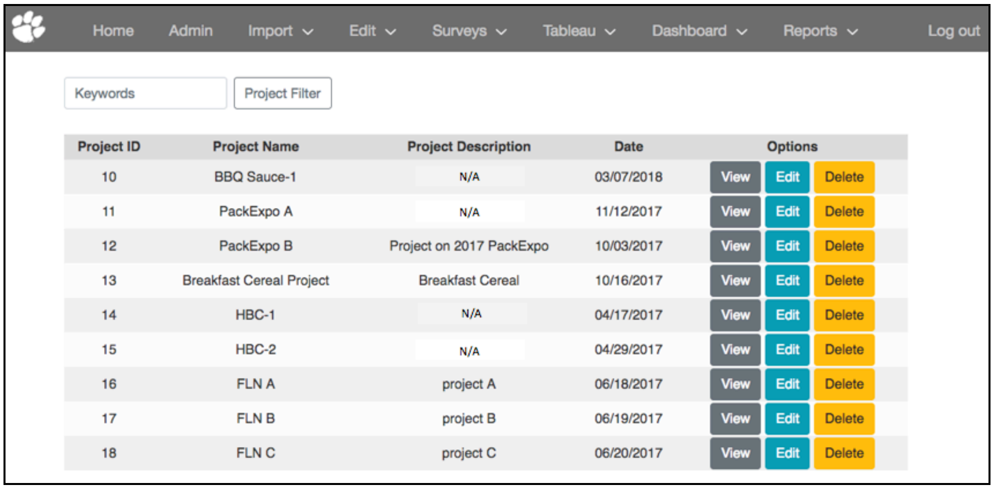


Figure 4.13. Web page of the project management list

By selecting the edit button for a specific project record, project information can be updated for selected projects. The users were then forward to the next page as shown in Figure 4.14. The project name, project description, and date can be updated accordingly in each text box and submit as a form by click on the "update project" button.

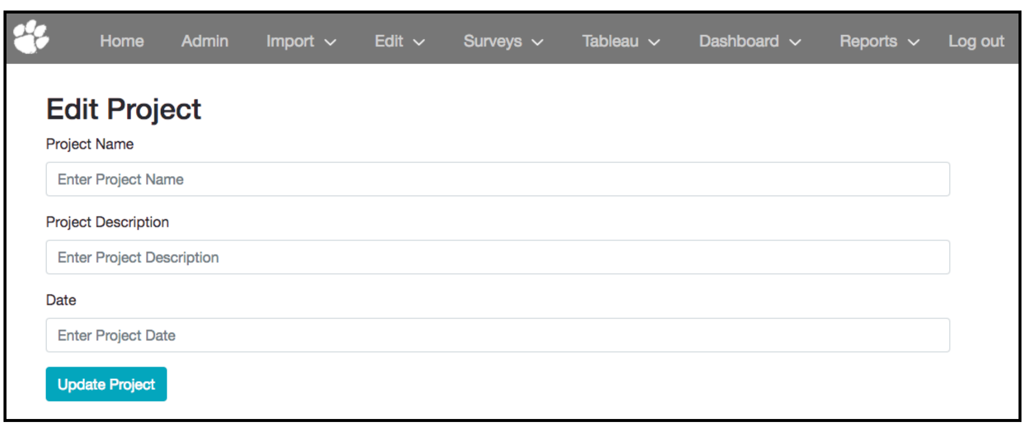


Figure 4.14. Web page for editing project information

Similar operations are also available for the product table. By selecting "product" from the "edit" tag in admin navigation bar, the following page (Figure 4.15) was able to display with a list of existing products stored in “product” table of the database. The product id, product name, AOI type, and product image are shown in the product list.

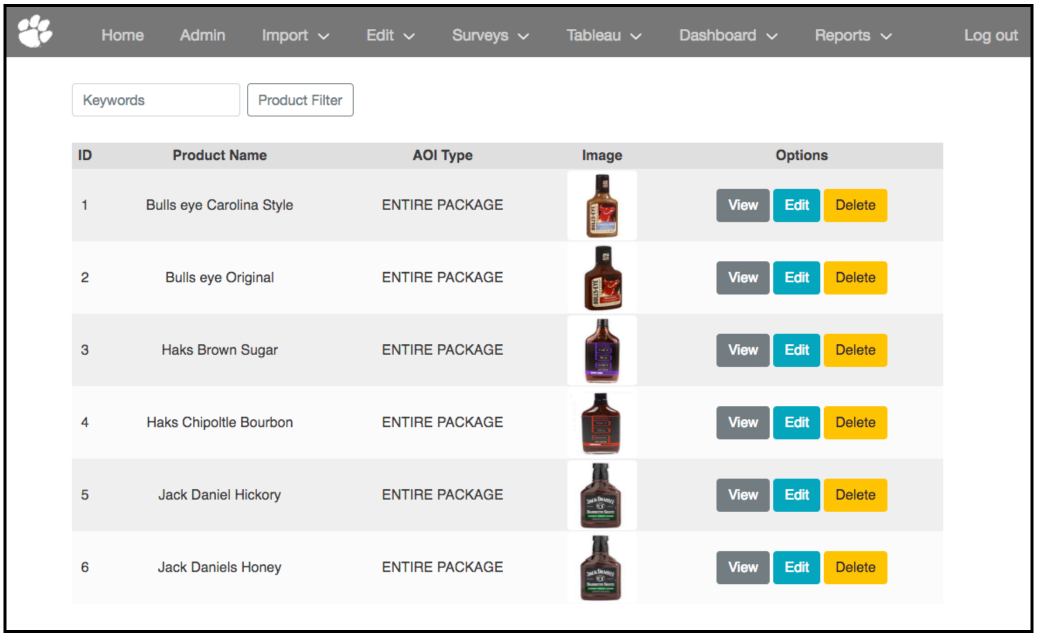


Figure 4.15. Web page of the product management list

Options for viewing product detail, editing product information, and deleting product are provided at the end of each product record. By selecting on the “edit” button of a specific product record, users are forward to another page as shown in Figure 4.16 for editing the product information.

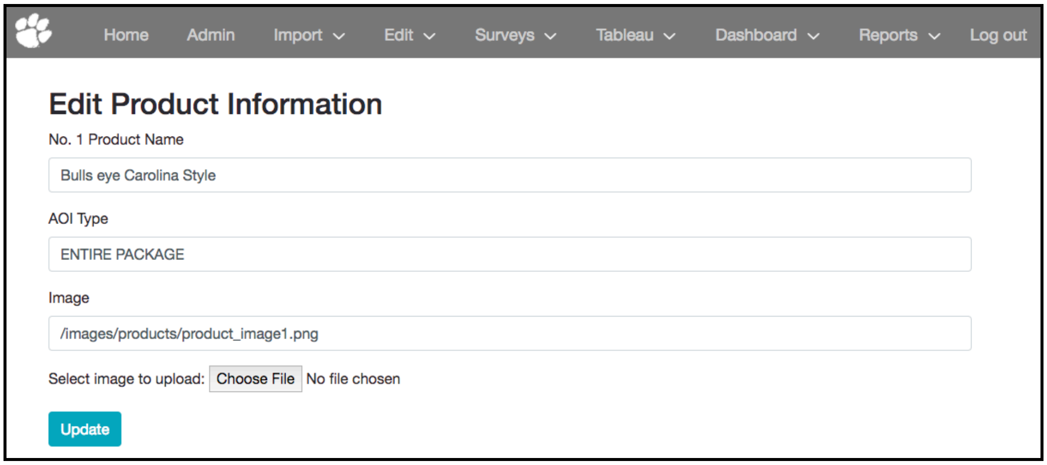


Figure 4.16 Web page for editing product information

Conclusion

The web portal associated with the database allows the data to be easily accessible by researchers than file-based methods. The implemented interface pages presented here demonstrate how the web portal can be used to manage and browse eye tracking data from multiple perspectives. The data import process allows researchers upload raw data sheet directly from the web portal to the database without additional data cleaning process. The imported data can also be managed from the web portal using project and product list pages. The eye tracking key metrics can be queried by selecting products in a category or project. The New findings can be made available almost instantly, rather than being delayed for months by lengthy manual work.

<u>References</u>

Bos, B., Lie, H. W., Lilley, C., & Jacobs, I. (1998). Cascading style sheets, level 2 CSS2 specification. *Available via the World Wide Web at http://www. w3. org/TR/1998/REC-CSS2-19980512*, 1472-1473.

Castro, E. (2003). *HTML for the world wide web*. Peachpit Press.

Crockford, D. (2008). *JavaScript: The Good Parts: The Good Parts*. " O'Reilly Media, Inc.".

Elmasri, R. (2008). *Fundamentals of database systems*. Pearson Education India.

Frolund, S., & Guerraoui, R. (2002). e-Transactions: End-to-end reliability for three-tier architectures. *IEEE Transactions on Software Engineering*, *28*(4), 378-395.

Lakshmanan, L. V., Sadri, F., & Subramanian, I. N. (1996, February). A declarative language for querying and restructuring the Web. In *Research Issues in Data Engineering, 1996.*

Lie, H. W., & Bos, B. (2005). *Cascading style sheets: designing for the Web*. Addison-Wesley Professional.

Refsnes Data. (1999). Available at https://www.w3schools.com/html/html_intro.asp. Accessed at December 12, 2017.

Williams, H. E., & Lane, D. (2004). *Web Database Applications with PHP and MySQL: Building Effective Database-Driven Web Sites*. " O'Reilly Media, Inc.".

CHAPTER FIVE

INTEGRATION OF ADVANCED FEATURES

Abstract

The requirements and methods of three advanced features: surveys, data dashboard, and automatic report generation are introduced and described in this chapter. With the survey tool, researchers are able to combine qualitative data into the web application. By implementing a data dashboard for category-wide and planogram-wide eye tracking data aggregation, researchers can easily customize, disclose, and visualize data. The automatic report generation feature is powerful in improving data analysis and reporting by generating three different types of reports according to the user's specification.

Introduction

By using the designed database and web portal discussed in Chapter Four, eye tracking data can be stored and retrieved more efficiently. However, when running a full eye tracking study with a mixed methods approach, a survey tool is needed for collecting qualitative results to increase the breadth and depth of the findings (Duchowski, 2007; Galesic, 2008). For example, coupling an eye tracking study with open and closed survey questions can help researchers not only know *what* a participant looked at, but also *why* they looked at it (Hurley, 2013; Hurley, 2015). By integrating a survey tool into this system, data collected from surveys can be combined with eye tracking key metrics for a deeper understanding of participant behavior.

Data visualization tools have been proved to support rapid decision-making by Shim in 2002 (Shim, 2002). As a powerful graphical system for data analysis and visualization, Tableau was founded in Mountain View, California in January 2003 by Christopher Stolte (Stolte, 2013).

Tableau provides a solution for efficiently exploring and visualizing data resources (Schmidt, 2007; Murphy, 2015). Especially for handling a large amount of data collection, Tableau significantly enhances the users' ability to quickly add, sort, highlight, and perform many other actions to interact with the data (Baader, 2001; Tableau, 2018). By utilizing Tableau on the developed web database, the data sets within the database can be used to easily create an aggregation view to enhance the result visualization.

The automatic report generation feature is robust in the data analysis process. By generating the report automatically, researchers can gain the eye tracking results within seconds for the selected report type and products. This feature brings the researchers a method to have an instant report after collecting the eye tracking raw data without the extended analysis period compared to the traditional method.

Method

Integration of Survey Feature

Surveys are an important tool in eye tracking methodology. LimeSurvey is a survey software that can be installed on a web server to organize, collect, and report data from as many surveys as needed, without extra fees (LimeSurvey, 2018). With

LimeSurvey integrated on the web server, users can post surveys and collect responses for enriching the eye tracking results with qualitative data.

Embed Data Dashboards

Data dashboards can be created using the Tableau desktop and uploaded to an online platform, called Tableau Public. The dashboards can be embedded into web pages of the developed web database application. The embed code can be generated from the Tableau Public and integrated into the PHP script of the web page to display on the web page. In this chapter, three different Tableau dashboards were created and embedded in the web database application.

Automatic Generation of Data Report

The report generation functions in the developed system can significantly improve the data report efficiency. A uniform report template can barely apply to all types of eye tracking analysis if it is highly customized for a particular study. Therefore, the automatic report was designed as a simplified template that can be widely used for the eye tracking studies. To allow researchers adding comments, comment boxes were created under each report blocks.

In each report, an introduction is given at the beginning to brief the eye tracking study procedure. Then, a project description is provided to detail the planogram set-up. In the section of main results, the stimuli product can be selected to compare with the competitive brands. The eye tracking key metrics are displayed by histograms with error bars for each selected product, along with a summary table of all the values used in the diagram. The statistical analysis is conducted for products either by using a t-test or ANOVA test, depending on the number of products. An explanation of the results regarding eye tracking performance among the comparisons and the significance is provided at the end of each data group. In summary, the report feature offers an aggregation of the result dashboards which can easily create by users and export as a PDF file. The scripts for generating the report on the web application was built by using a PHP library called DOMPDF (Dompdf, 2018). The required data values can be passed through variables within the PHP files.

Implementation Results

Implementation of Survey Design and Response Collection

In order to combine qualitative data to provide additional explanation for the eye tracking studies, LimeSurvey was used as the survey tool in this work since it offers various question types and is flexible to integrate with the developed system (LimeSurvey, 2018). Admin users can create a survey, display a survey, and manage the existing surveys from the survey dashboard (Figure 5.1).

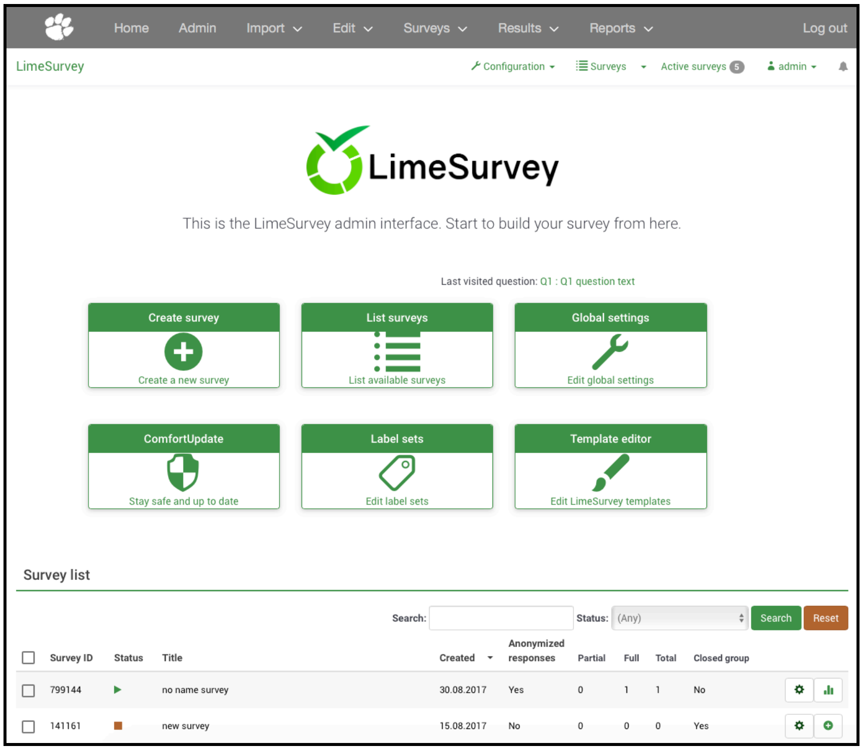


Figure 5.1. Survey dashboard

This survey tool supports both anonymous (participants are not required to be the registered users) and not anonymous (participants are required to registered before taking surveys, which provides traceable responses) surveys. It offers most common question types including long free text, scale, and multiple choice. The new survey can be added by creating, importing or copying. The typical steps to create a survey are creating survey, creating question group, creating question, and creating sub-questions. At the end, a URL can be generated for participants to take the survey.

Implementation of Data Visualization Using Tableau Dashboards

Three types of results were designed in the developed Tableau dashboards. For comparison within categories, the tableau category dashboard was created and shown as

Figure 5.2. The category dashboard shows the eye tracking key metrics in aggregate as the category means. The three eye tracking key metrics are shown in both histograms. The category names are listed on the right side of the dashboard.

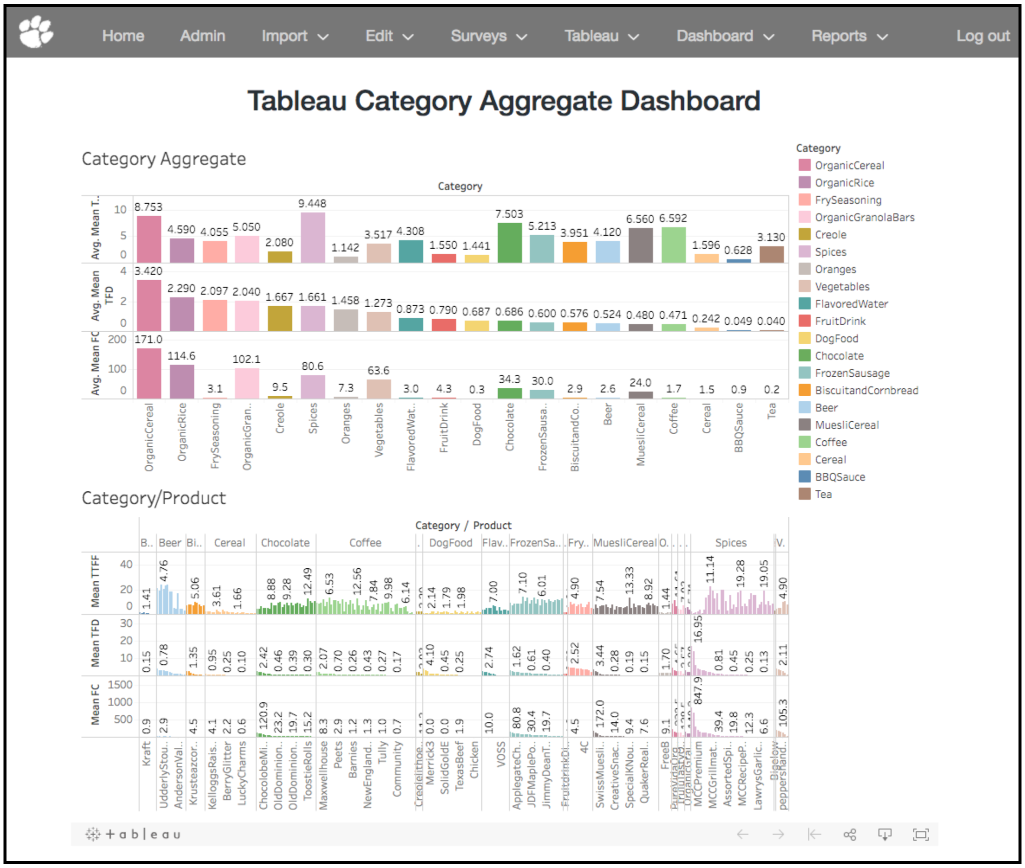


Figure 5.2. Tableau category aggregate dashboard

By selecting a specific category bar in the chart on top, the second bar chart data is filtered by the selected category. For example, if selecting the coffee category on the top chart, the eye tracking data for the entire category is displayed in Figure 5.3. This Tableau dashboard allows users to dynamically interact with the data. It provides the category data to key metrics means (TTFF, TFD, and FC). Comparing the traditional method of manually retrieving the same amount of results, the designed dashboard can complete the work without excessive effort in searching among spreadsheets.

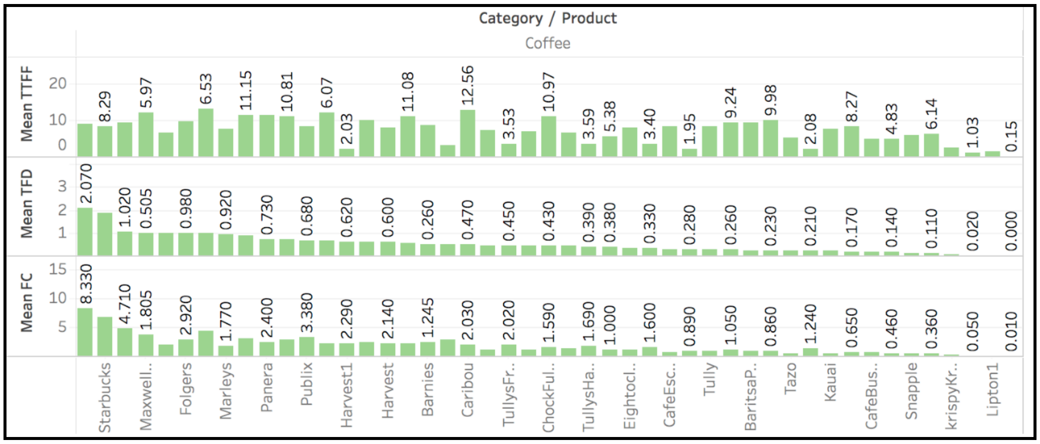


Figure 5.3. Aggregate eye tracking results sorted by category

A Tableau dashboard for aggregating by planogram was created as Figure 5.4, showcasing the aggregate eye tracking data for planogram means. TTFF, TFD, and FC data are shown in both the histograms. The planogram names are listed on the right side of the dashboard.

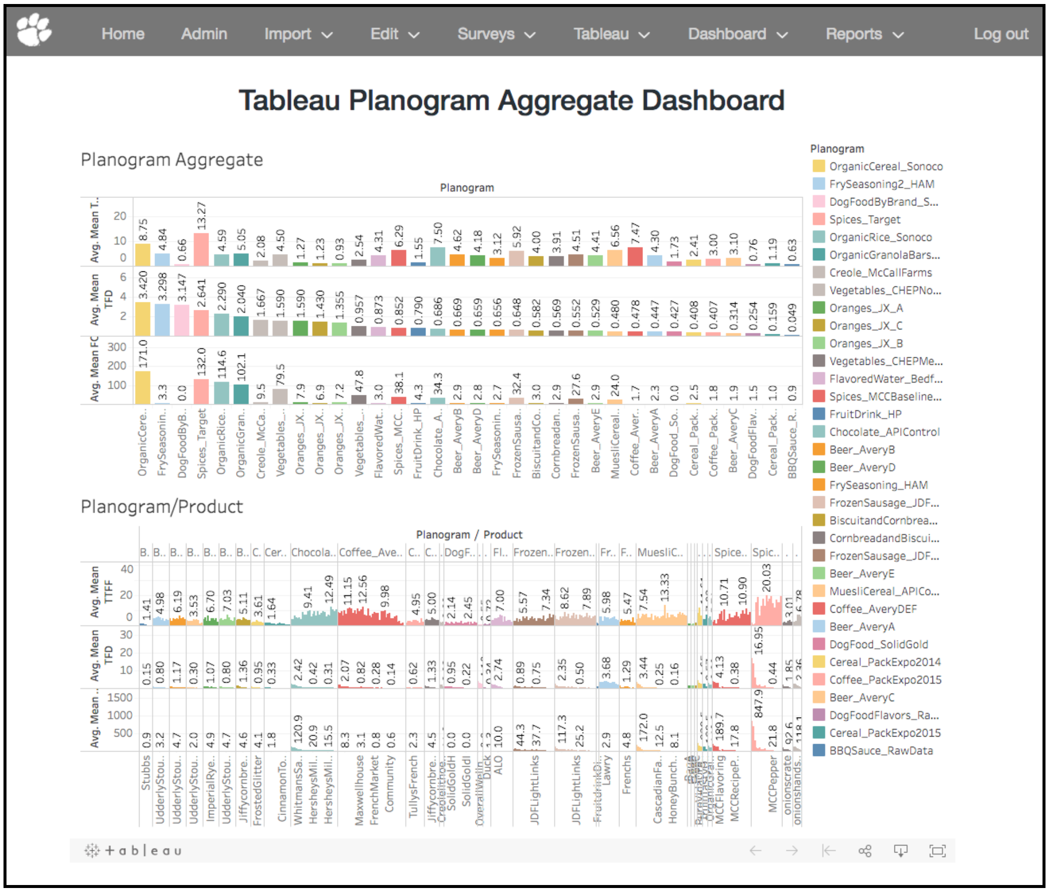


Figure 5.4. Tableau planogram aggregate dashboard

By selecting on specific planogram bar in the chart on top, the second bar chart data can be filtered by the selected planogram. For example, if selecting the coffee_packexpo2015 planogram on the top chart, the eye tracking data for the entire planogram can be displayed as below. As in Figure 5.5, eleven products were retrieved by the planogram name, which displayed the planogram wide result for the eye tracking key metrics of TTFF, TFD, and FC means.

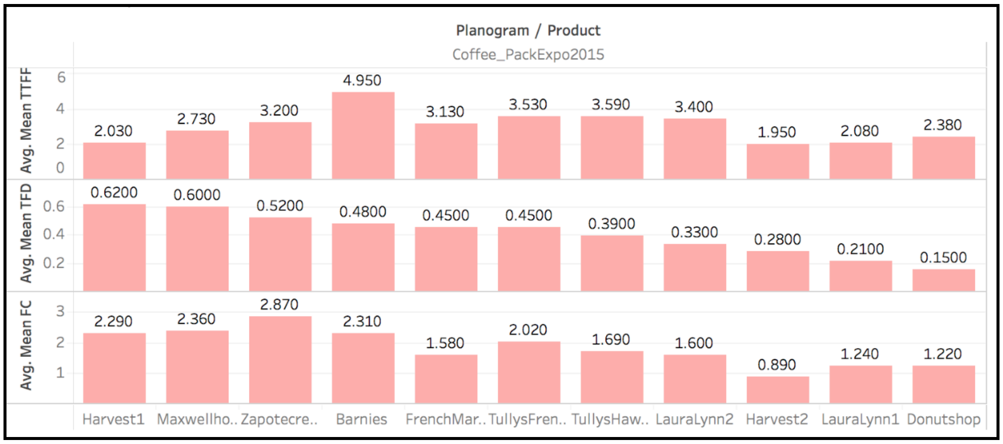


Figure 5.5. Eye tracking results of sorted by planogram

The third type Tableau dashboard was created for viewing three eye tracking key metrics for products by choosing specific planograms. The layout of the dashboard is shown in Figure 5.6. As shown in this figure, two planograms were selected on the right side of the dashboard. Products within the planograms were displayed in the charts. The three histograms represented TTFF, TFD, FC means separately in blue color, along with the standard error in orange. This dashboard allows researchers to compare the performance of same products tested in multiple planograms.

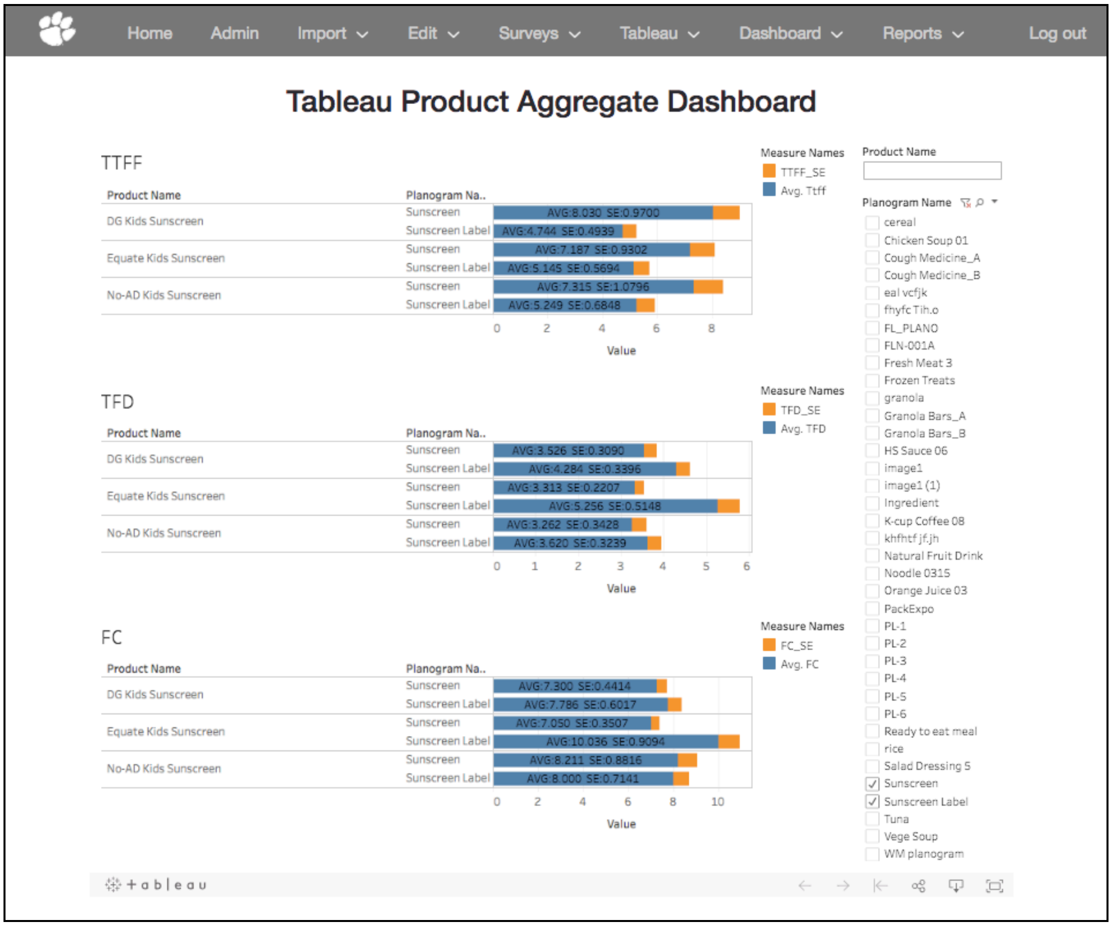


Figure 5.6. Tableau product aggregate dashboard

Automatic Report Generation for Eye Tracking Studies

Three report types have been developed in the system, including the survey report, the A/B comparison report, and the project report.

For generating a survey report, users are required to select the survey from a list of available surveys. The survey results are shown in Figure 5.7, which mainly consist of the body of the question, a diagram visualized the results, and a summary table listed the response counts and percentages.

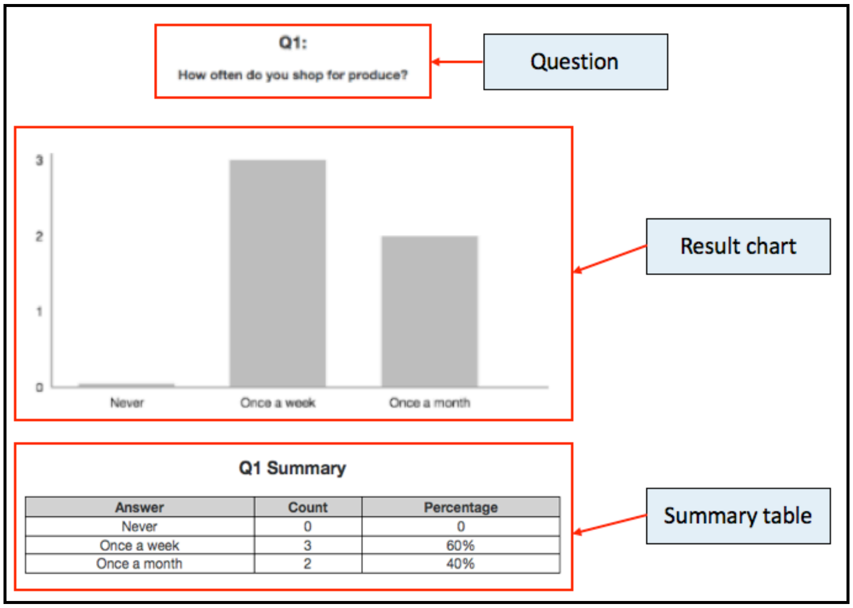


Figure 5.7. Result of the survey responses

To generate an A/B report to compare two products, users can select products within a particular category. For example, the category of frozen treats was selected in Figure 5.8, where the product list can be retrieved within this category and displayed on the page for the further selection of products.

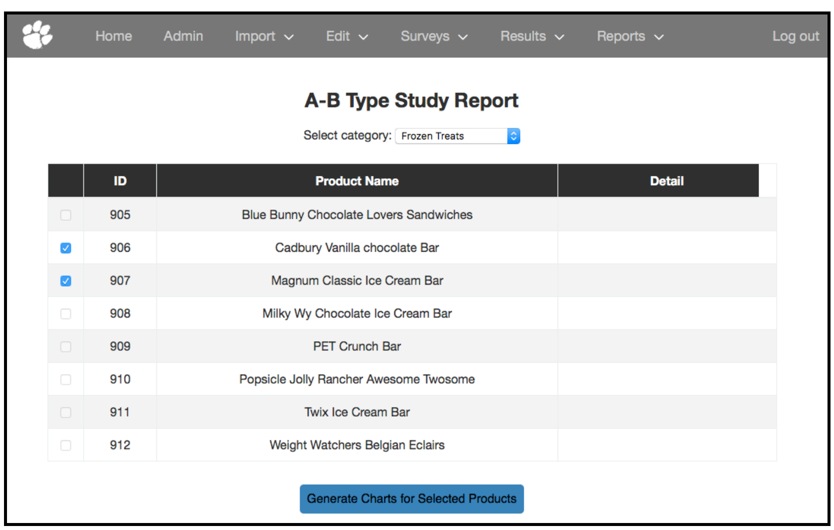


Figure 5.8. Selecting category and products for A/B report

After specifying the chosen products from the product list, three eye tracking key metrics were shown as three histograms with error bars in Figure 5.9.

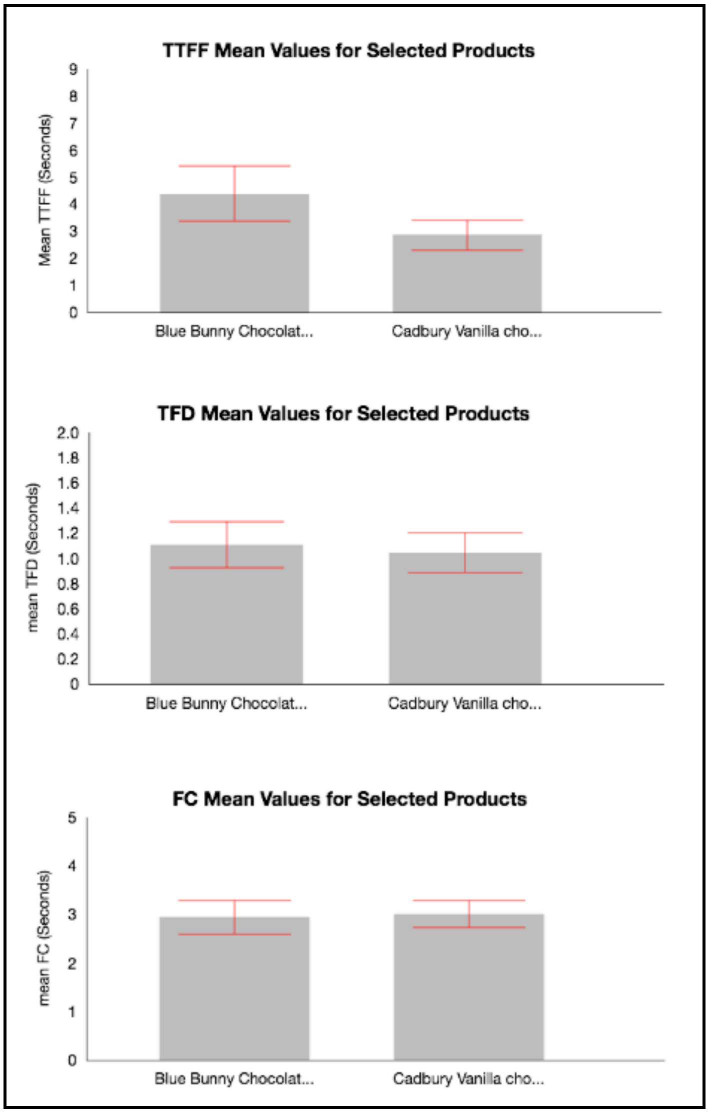
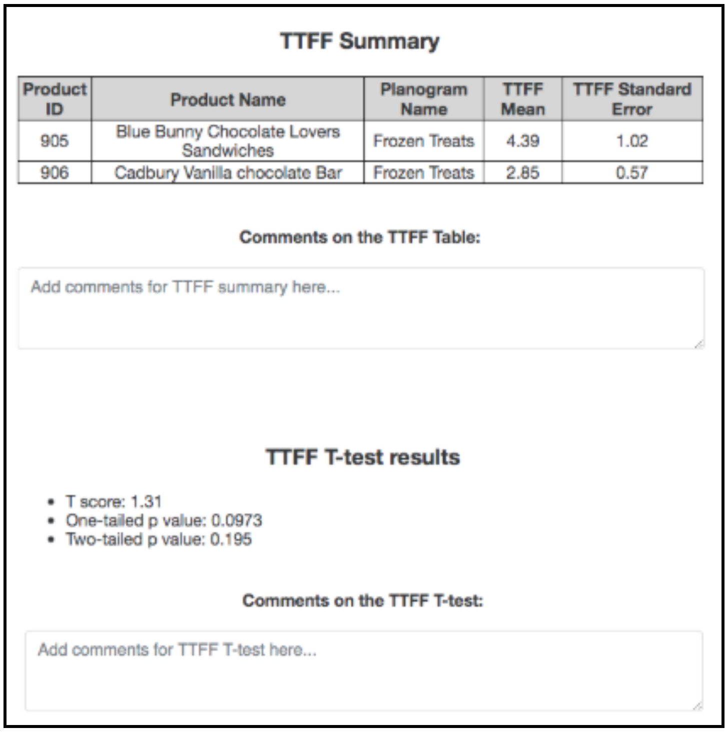


Figure 5.9 Result of eye tracking key metrics in A/B report

The summary tables and statistical analysis results for the selected products are also provided after the key metrics charts. In Figure 5.10, the TTFF summary table displayed information including product names, key metrics means, and standard errors. A t-test result was listed including the t score, one-tail p-value, two-tailed p-value. A comment box was also provided for adding additional explanations for the generated results.



TTFF Summary

Product ID	Product Name	Planogram Name	TTFF Mean	TTFF Standard Error
905	Blue Bunny Chocolate Lovers Sandwiches	Frozen Treats	4.39	1.02
906	Cadbury Vanilla chocolate Bar	Frozen Treats	2.85	0.57

Comments on the TTFF Table:

Add comments for TTFF summary here...

TTFF T-test results

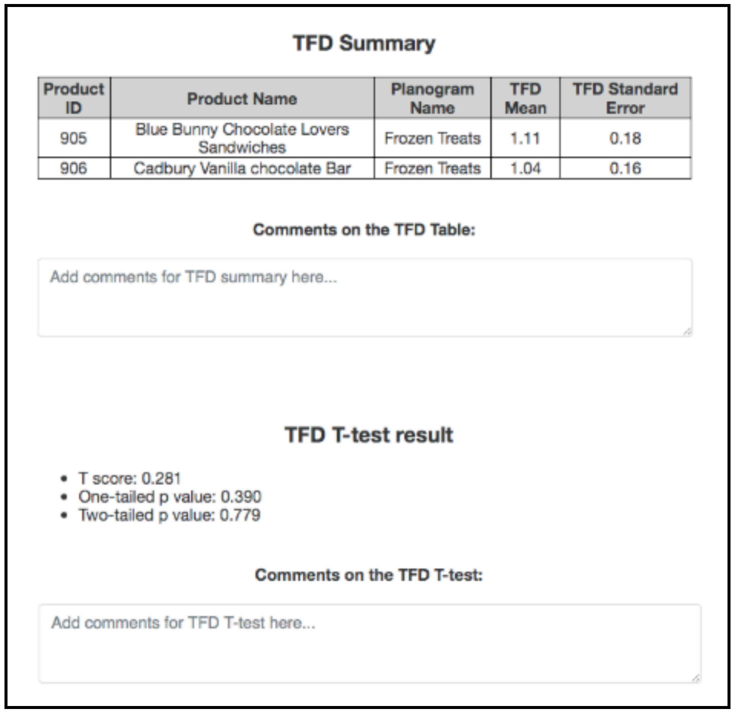
- T score: 1.31
- One-tailed p value: 0.0973
- Two-tailed p value: 0.195

Comments on the TTFF T-test:

Add comments for TTFF T-test here...

Figure 5.10. TTFF Summary table and statistical results

In Figure 5.11, the TFD summary table displayed information including product names, key metrics means, and standard errors. A t-test result was listed including the t-score, one-tail p-value, two-tailed p-value. A comment box was also provided for adding additional explanations for the generated results.



TFD Summary

Product ID	Product Name	Planogram Name	TFD Mean	TFD Standard Error
905	Blue Bunny Chocolate Lovers Sandwiches	Frozen Treats	1.11	0.18
906	Cadbury Vanilla chocolate Bar	Frozen Treats	1.04	0.16

Comments on the TFD Table:

Add comments for TFD summary here...

TFD T-test result

- T score: 0.281
- One-tailed p value: 0.390
- Two-tailed p value: 0.779

Comments on the TFD T-test:

Add comments for TFD T-test here...

Figure 5.11 TFD Summary table and statistical results

In Figure 5.12, the TFD summary table displayed information including product names, key metrics means, and standard errors. A t-test result was listed including the t-score, one-tail p-value, two-tailed p-value. A comment box was also provided for adding additional explanations for the generated results.

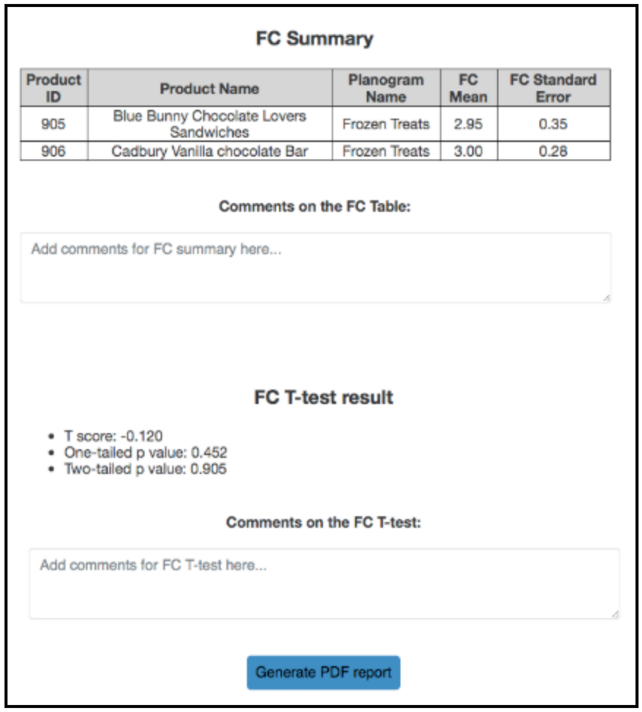


Figure 5.12 FC Summary table and statistical results

By selecting the "Generate PDF Report" button at the bottom of this web page, the displayed results along with the comments can be combined into a multiple-page PDF report with a premade format. The Figure 5.13 shows the cover page of the generated PDF report.

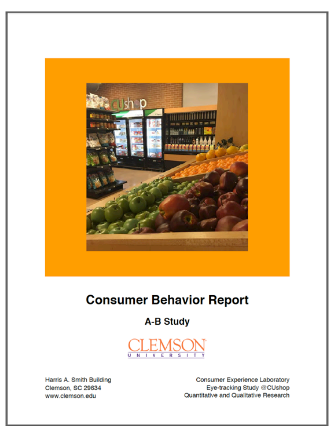


Figure 5.13 Generated A/B report cover

The project report not only reports the eye tracking key metrics results but also aggregates the associated survey results. As shown in Figure 5.14 and Figure 5.15, to create a project report requires four steps. First, users are required to select the project from a dropdown list. Second, the planograms need to be specified. Third, products are selected to retrieve the eye tracking key metrics. Last, the associated survey is selected by survey id or survey name for finally generated the combined project report.

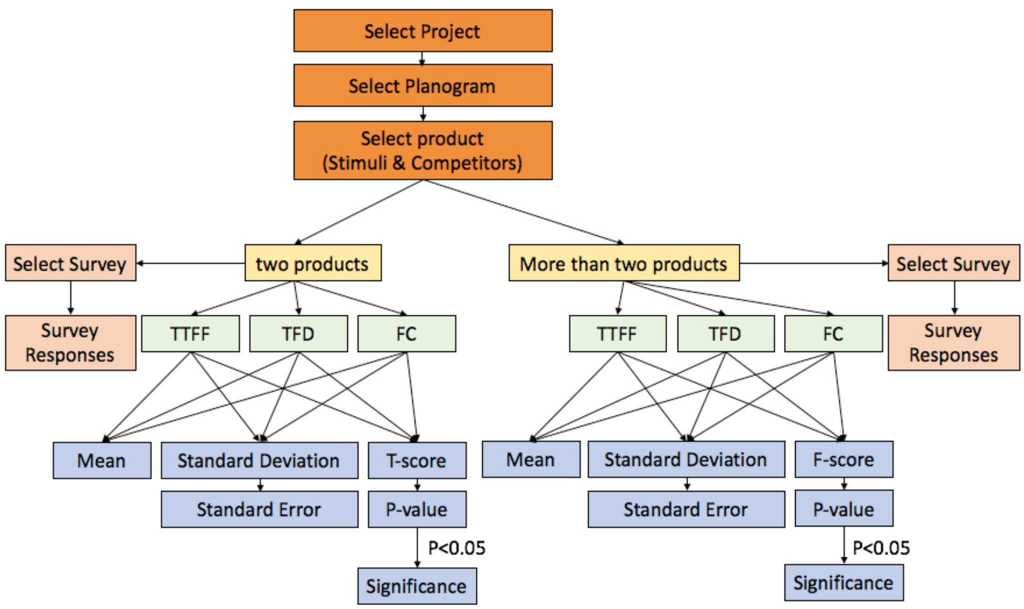


Figure 5.14 Steps for generating a project report

The result outputs of the project report are shown in Figure 5.15, which consists of two parts. In the first part, the charts of eye tracking key metrics display the means with error bars. In the second part, the summary tables are provided for each metric, showing the means and standard errors used in the previous charts, along with statistical analysis results.

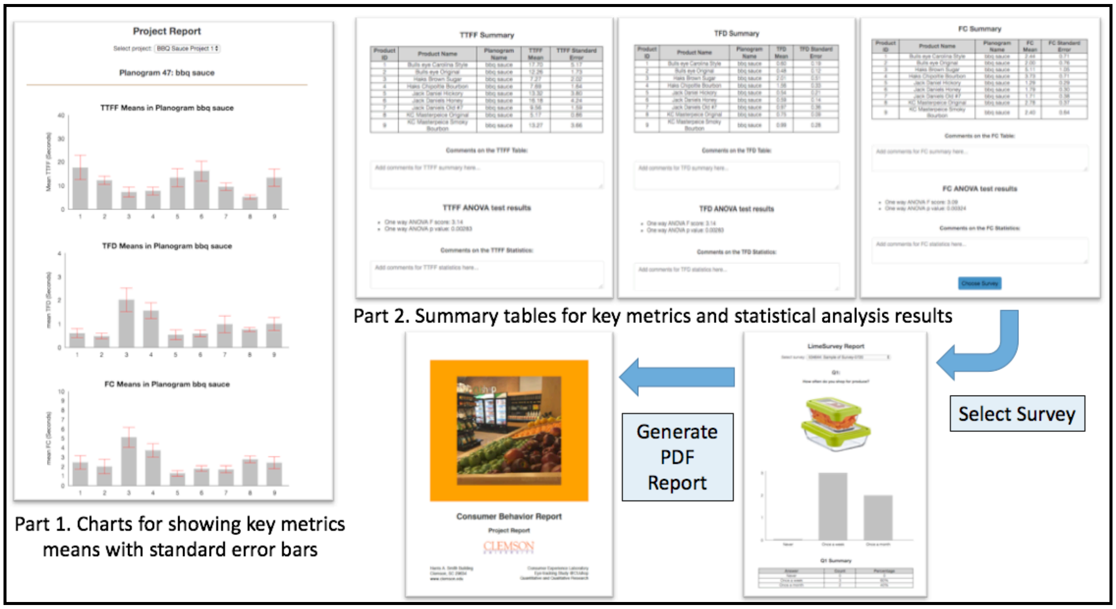


Figure 5.15 Outputs of project report

Conclusion

In this chapter, the methods to integrate the advanced features include survey, data dashboards, and automatic report generation are discussed.

With the integrated survey feature, qualitative research methods can be combined with quantitative eye tracking methods. This feature extends the usability of this eye tracking management system by providing the post-survey data as the additional explanation of the eye tracking data. The implementation results of the survey tool showed that the web system meets the expectation to conduct qualitative research using LimeSurvey and successfully collected the responses.

By embedding the dynamic Tableau dashboards into the web portal, three types of data aggregation views are enabled for researchers, including the category means aggregation, the planogram means aggregation, and the product key metrics aggregation.

These dashboards provide an easy interactive data visualization for a better understanding of the eye tracking data across categories and projects.

The integration of an automatic report generation feature brings the researchers a powerful method to have an instant report after collecting the eye tracking raw data. Three types of reports can be generated for the selected data from the web portal. This feature significantly improves the data analysis and report efficiency for researchers in the eye tracking field.

References

Baader, F., & Sattler, U. (2001). An overview of tableau algorithms for description logics. *Studia Logica*, *69*(1), 5-40.

Dompdf (2018). Available at https://github.com/dompdf/dompdf. Accessed March 10, 2018.

Duchowski, A. T. (2007). Eye tracking methodology. *Theory and practice*, *328*.

Galesic, M., Tourangeau, R., Couper, M. P., & Conrad, F. G. (2008). Eye-tracking data: New insights on response order effects and other cognitive shortcuts in survey responding. *Public Opinion Quarterly*, *72*(5), 892-913.

Hurley, R. A., Galvarino, J., Thackston, E., Ouzts, A., & Pham, A. (2013). The effect of modifying structure to display product versus graphical representation on packaging. *Packaging Technology and Science*, *26*(8), 453-460.

Hurley, R. A., Rice, J. C., Conlon, G., Tonkin, C. E., & O'Hara, L. (2015). The Impact of Simulated Kraft Substrates on Consumer Attention at the Point of Sale. *Journal of Applied Packaging Research*, 7(1), 4.

Murphy, S. A. (2015). How data visualization supports academic library assessment: Three examples from The Ohio State University Libraries using Tableau. *College & Research Libraries News*, *76*(9), 482-486.

Schmidt, R. A., & Tishkovsky, D. (2007). Using tableau to decide expressive description logics with role negation. In *The Semantic Web* (pp. 438-451). Springer, Berlin, Heidelberg.

Shim, J. P., Warkentin, M., Courtney, J. F., Power, D. J., Sharda, R., & Carlsson, C. (2002). Past, present, and future of decision support technology. *Decision support systems*, *33*(2), 111-126.

Stolte, C., (2013). Available at http://www.graphics.stanford.edu/~cstolte/. Accessed October 3, 2017.

Tableau (2018). Available at https://www.tableau.com/learn/training. Accessed December 1, 2017.

CHAPTER SIX

COMPARISON OF THE DBMS METHOD WITH THE FILE-BASED METHOD

Abstract

In this chapter, the application of the database-driven management system was compared to the method using the traditional file-based system. An eye tracking study was conducted using this system for testing different packaging design of home goods study during the 2017 Packaging Exposition, located at Las Vegas, NV. Forty-three participants were instructed to shop for six product categories. The tested product categories include food container, coffee machine, toaster, candle, water bottles, and waffle makers. By interviewing experienced researchers, feedback was collected for the designed system. An average 48% of time reduction and 17% of cost saving were found when using the database-driven management system for processing an eye tracking data compared to the file-based method.

Instruction

In general, the amount of data generated by eye-tracking devices is enormous because it contains information from about 30-120 participants per project depending on the scale (Snyder, 2015; Hurley, 2013). File-based methods have been used for many years by eye tracking researchers as their main tool for data analysis. In the past, researchers worked with spreadsheets to analyze data. The average, standard deviation, standard error and other basic parameters of key metrics have to be calculated for further statistical analysis in every study (Tonkin, 2011; Hurley, 2013). The analysis in this manner takes about two weeks to organize, extract the key metrics, and run statistics, which is a significant portion of the total time required to conduct the research project. Manual data analysis also increases the chance of manual errors, which can potentially cause serious problems in subsequent studies. Additionally, since manually collected data has poor reusability, it is difficult to access experimental data generated in the past. With the designed database-driven management system, eye tracking studies were able to run in a more efficient way by reducing the time consumption in pre-survey, data analysis, and report generation.

In this chapter, an eye tracking study of home goods was conducted using this database-driven management system for testing the overall implementation performance of the designed system. By having data stored in this system (Figure 6.1), eye tracking results from the associated relational database can be retrieved and managed by using SQL queries. These database operations require sufficient knowledge of database management and SQL programming. To provide a more user-friendly interface, a web portal for managing and accessing the database was built on top of the database. In this research, the management system was developed based on a relational database by using PHP, HTML, JavaScript, and CSS, along with SQL queries for data retrieval from the database. Users of the web portal can conduct operations for the eye tracking data import, aggregation, retrieval, and report generation.

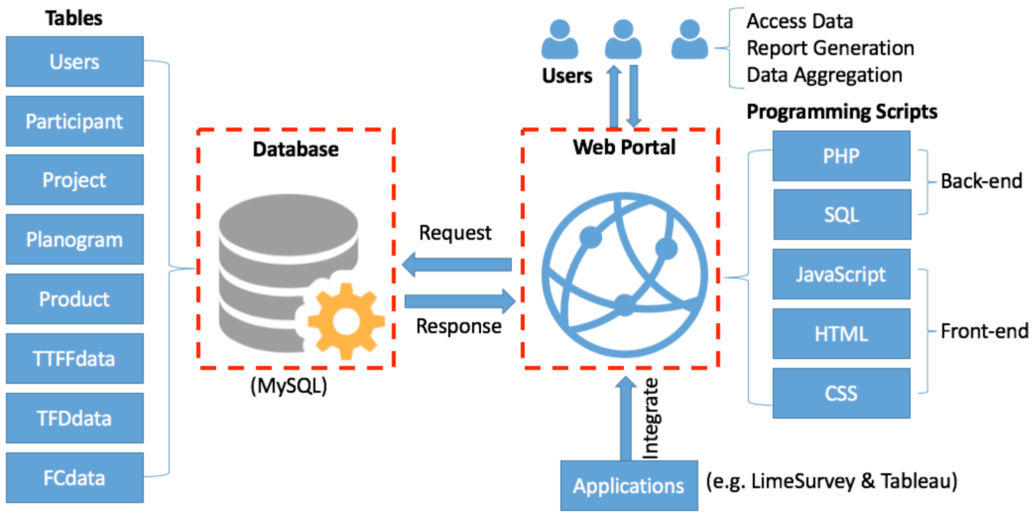


Figure 6.1 Structure of the database-driven management system

In this study, the designed system was applied in an eye tracking study during the 2017 Packaging Exposition, located at Las Vegas, NV. The study tested six product categories, including food storage containers, water bottles, waffle makers, toasters, coffee makers, and candles. Eye tracking data and survey data were collected from forty-three participants over three days. The time for each study phase was recorded to compare with the traditional file-based method. Feedback on the implementation performance and the comparison between the two methods were collected from the eye tracking researchers who are the main users of this work.

Method

Location

The study was conducted on the during the 2017 Packaging Exposition, located at Las Vegas, NV. Approximately 3,000 packaging professionals attended this conference. The simulated shopping environment was built in a booth of the exposition, which is an open shelving of the home goods, including food containers, coffee machines, toasters, candles, water bottles, and waffle makers.

Participants

Forty-three participants were recruited from the attendees during the days of the exhibition, based on willingness to participate in the study. Participants were instructed to shop for the six product categories.

Apparatus

The Tobii™ Pro Eye Tracking Glasses were used to gather data of the participants' eye movements. These glasses are monocular video-based pupil and corneal reflection glasses with a sampling rate of 50Hz (Tobii Pro Glasses 2, 2017; Hurley, 2016). A controller was connected to the glasses and used to record the eye tracking data.

Procedure

During the study, the participants were asked to wear the eye tracking glasses (Tobii Pro Glasses 2, 2017), which were connected to a live view tablet and a recording device. The participants were required to look straight ahead at a target for calibrating the eye tracking device before starting the study (Hurley, 2016). Once the glasses located the participant's pupil, the controller software live view tablet displayed "calibration success." The researcher then hit "Record" on the tablet to start the data collection.

When the calibration was complete, the participant was given a shopping list. The participants were instructed to shop for the products on the list and write down the product number they purchased on the list (Hurley, 2016). Areas of Interest (AOI's), which were the area of analysis used in the eye tracking software to collect fixation data, were designed for the stimuli and used to determine three measurements metrics of eye movement (Hurley, 2016): Time to First Fixation (TTFF), Total Fixation Duration (TFD), and Fixation Count (FC). The TTFF represents the time in seconds that starts from a product shows in the field of view until the participant fixates on it. The lower the number, the better the package performed in this instance. The TFD measures how long the participant is fixating on a specific item in seconds. The higher the TFD value, the better the package performed. FC in the total number of times a participant's scan of the planogram crossed into a particular area of interest (Hurley, 2016).

A post-survey regarding the entire shopping experience was also collected by interviewing participants and inputted to the management system by researchers, to gain more insights about participant's purchase preference.

Feedback on the implementation of the database-driven management system (DBMS) was collected by interviewing experienced eye tracking researchers regarding using the survey design, data import, and report generation features on this designed web database application. The advantages of the designed system are summarized in the results section along with the efficiency compared with the file-based method for running said eye tracking studies.

Results

A comparison demonstrating the average time in hours it takes for the complete the eye tracking study analysis using a file-based method versus using the database-driven management system is shown in Table 6.1 and Figure 6.2. Results were collected by recording time consumption of each step of the study, as well as interviewing experienced researchers. When comparing the file-based system to the DBMS system regarding time, it was found that the entire process takes significantly less time (48% reduced) using the DBMS system. The time consumption of pre-survey, report writing, and statistical analysis has been significantly decreased (>95%) between the comparison of two methods.

Table 6.1 The comparison of the average time consumption between two methods per study phase

	File-based Method (hour)	DBMS Method (hour)	Reduced Percentage (100%)
Planogram Setup	10	10	0
Questionnaire Design	5	5	0
Pre-survey	5	0	100
Eye Tracking	10	10	0
Post-survey	10	10	0
Statistical Analysis	10	0.5	95
Report Writing	20	0.5	97.5

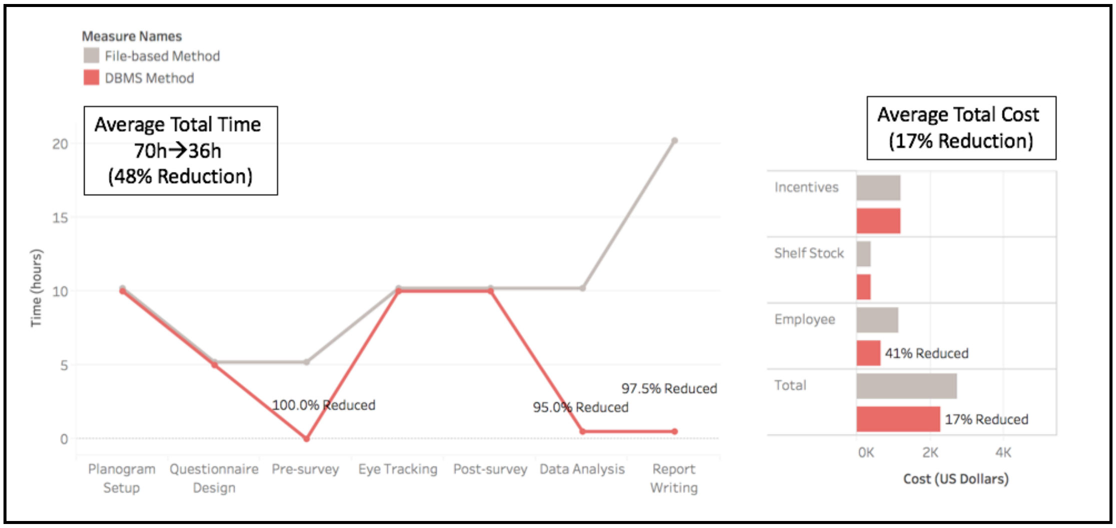


Figure 6.2 The comparison of the average total time and cost between two methods per study

With respect to collecting participant demographic and shopping frequency, there is no need to repeat the pre-survey for every eye tracking study. As long as inviting the participants from participant pool, the background investigation of each participant is completed before each study occurs and responses are thus saved in the database. Therefore, compared to the file-based method, there is a 100% decrease of time for the pre-survey phase, since direct data retrieval from stored data can replace the pre-survey.

For report writing specifically, which typically encompasses the most time for the researcher at 20 hours, the DBMS's ability for auto-reporting has been shown to decrease 97.5% of time consumption compared to a file-based method. The DBMS method associated with analysis programming, has a significant positive effect on data access and process. A customized template of a study report has been designed and utilized in the linked web portal, providing various ways for users to generate the report according to different study types. The statistical analysis has been considered as the most crucial and difficult step among all the key procedures of eye tracking study. This portion of work does not only require the skillful statistical analysis knowledge but also the need to maintain the accuracy while working with a large set of quantitative (e.g., eye tracking key metrics) and qualitative (e.g., survey responses) results. Human errors are more likely using the file-based method, with a relatively high possibility due to the excessive workload. By using the DBMS method, the time consumption has been reduced by 95% compared to the file-based method. Additionally, human errors are avoided through the use of direct data retrieval from a data source to ensure the accuracy of the data process. Regarding cost saving per study, comparisons could extend to incentives, shelf stocking, and salaries for employees (Figure 6.2). The cost for employees has been reduced by 41%, due to the time saving for the manual workload. As a consequence, the total cost was reduced by 17% on average.

Conclusion

By using a relational database system, the eye tracking data that is collected and added to the database becomes more accessible and easily integrated, providing convenience for further statistical analysis and reporting, which significantly improves the efficiency of the study as a whole. Managing information using a database allows for researchers to have a more strategic method to manipulate various data analysis required operations. The automatic reporting feature improves the efficiency of having eye tracking results without a long period of data analysis, which averages a 48%-time reduction and a 17%-cost saving per study. Data aggregation of eye tracking studies using a DBMS can provide a greater wide-range comparison and analysis of packaging design compared to the conventional one-off study methods. These findings are crucial for the future of packaging science, specifically the design aspect, to provide the packaging industry a comprehensive method of consumer behavior research that can help improve the success of product launches.

References

Hurley, R. A., Galvarino, J., Thackston, E., Ouzts, A., & Pham, A. (2013). The effect of modifying structure to display product versus graphical representation on packaging. *Packaging Technology and Science*, *26*(8), 453-460.

Hurley, R. A., Holmes, J. L., Tonkin, C. E., Cooksey, K., & Rice, J. C. (2016). The effect of decorative foil stamping on consumer attention. *Journal of Applied Packaging Research*, *8*(2), 5.

Hurley, R. A., Ouzts, A., Fischer, J., & Gomes, T. (2013). Effects of private and public label packaging on consumer purchase patterns. *Packaging Technology and Science*, *26*(7), 399-412.

Snyder, E., Hurley, R. A., Tonkin, C. E., Cooksey, K., & Rice, J. C. (2015). An eye-tracking methodology for testing consumer preference of display trays in a simulated retail environment. *Journal of Applied Packaging Research*, *7*(1), 6.

Tobii Pro Glasses 2. (2017). Available at https://www.tobiipro.com/product-listing/tobii-pro-glasses-2/#Specifications. Accessed October 13, 2017.

Tonkin, C., Ouzts, A. D., & Duchowski, A. T. (2011, May). Eye tracking within the packaging design workflow: interaction with physical and virtual shelves. In *Proceedings of the 1st Conference on Novel Gaze-Controlled Applications* (p. 3). ACM.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This dissertation contributes to creating a new vehicle for the eye tracking research. By utilizing this system, result retrieval and reporting can be completed within seconds, which significantly improves the data accessibility compared to the traditional file-based data storage methods.

In this dissertation, a relational database of retail food packaging eye tracking studies associated with a web portal was designed and created to aggregate, store, access, share, analyze eye tracking data based on studies conducted by CUshop™ Clemson University Consumer Experience Lab in the past seven years. Experiment data of eye tracking projects were collected and aggregate by projects and categories. Partial datasets were refined and complemented for uniformly formatting and data integrity. A web portal was designed on top of the database with user-friendly interfaces, in order to allow users easily conduct data retrieval.

Eye tracking results were sorted by planograms and categories. Data dashboards were created using visualization software, which can provide the interactive data visualization. Mean, standard deviation, and standard error of eye tracking key metrics were calculated for further data reporting. General investigation on participants' background was integrated into participant registration required information and reusable instead of taking a pre-survey per study.

Report generation has been automated to shorten the time used in data analysis, which improves product launching process. Only by uploading raw data and selecting report type, a PDF report was able to be generated. Three types of report templates were developed: survey, A/B comparison, and overall project. Statistical analysis includes t-tests and ANOVA, which were integrated by using PHP/JavaScript to determine the data significance (p-value <0.05). When comparing the file-based system to the database-driven management system, it was found that the entire process takes significantly less time (48% reduction) and less cost (17% reduction) using the developed system.

In conclusion, researchers will be able to have a better overall understanding regarding the performance of packaging design in the marketplace by using this tool. The application of the system can be taught and will benefit students and researchers who embrace the usage, as well as entrepreneurs and designers who are not familiar with eye tracking methodology but are fully capable of understanding results through its use.

Recommendations and Future Research

This dissertation aims at creating a database-driven platform for future researchers to access and manage eye tracking data efficiently. With the limitation of time and data resource, the data aggregation results shown in this dissertation were based on the available studies, which can be continuously updated by integrating additional eye tracking studies. As the data size increased, the accuracy of the aggregation results tends to increase accordingly.

To reduce eye tracking bias caused by different display positions within the planogram, it is suggested to involve product position in further revisions of the database. By having the position such as the level of the shelf, researchers can have options to compare and aggregate products within their choices of a particular area on the shelf.

In some occasions, outliers might show up in eye tracking studies. For example, participants who spend extraordinarily long or short time to make a purchase decision due to personal shopping habits or special emotion, which might significantly influence the average data. Therefore, some criteria for eliminating the data outliers can be further defined in future research, to reduce the errors not specially related to the particular study to improve the result accuracy.

As discussed earlier, the general investigation of participant background information is used for screening participants, sorting the response and providing supported explanation to the eye tracking key metrics. The current database only stored gender and age for participants. However, more participant information is beneficial to keep collecting in the future, such as shopping frequency, education level, color preference, and searching strategy. This information is useful not only in screening participants but also in studying the shopping pattern of a particular participant in order to provide an in-depth explanation for future eye tracking research.