



A Consumer Neuroscientific Method For Assessing Usability: Eye-Tracking Visual Fatigue In
Visually Complex M-Commerce Applications

by

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ABSTRACT

Purpose: Mobile commerce (m-commerce) applications (apps) need to be studied in terms of their visual element richness, usability and how these impact the visual fatigue that is felt by users and their overall system usage. The purpose of this paper is to present and discuss a conceptual model that seeks to establish a method for measuring visual fatigue using eye-tracking and examine its relationship with usability across varying levels of visual complexity in m-commerce apps. It aims to develop and extend existing research on the design of m-commerce apps in terms of the amount of visual elements to needed to satisfy users while mitigating the effect of visual fatigue and usability issues.

Study Design/Methodology/Approach: The study utilised a mixed-methods approach to gather data through utilising consumer neuroscience techniques, specifically eye tracking technology to develop an understanding between usability, visual fatigue and visual complexity when the users engage and experience a m-commerce app. This research explored 96 consumer reactions and responses to different visually complex m-commerce apps. Mixed methods is needed to compliment both qualitative and quantitative results and gather a deeper understanding of the complex data.

Findings: A model measuring visual fatigue through eye-tracking technology is established to better understand the impact on users within the 18-35 South African cohort when exposed to different visually complex applications. Relationships between the dimensions of visual fatigue, usability, visual complexity, phone usage and context of use are explored through hypothesis testing.

Research limitations/ implications: The first contribution of this study is the addition of research on how users from South Africa experience m-commerce applications. The second contribution stems from the model established to measure visual fatigue through eye-tracking techniques to better understand users and how they navigate and experience an application. Third we established the impact of visually complex, visually simple and visually moderate designs on users satisfaction and wellbeing. Finally the study revealed important elements to users of a m-commerce application through the mixed-methods approach.

Originality/Value: The findings of this study have numerous implications for both marketing managers, app developers and user experience experts. The findings supply valuable insight into how multiple visual elements impact a user's experience and satisfaction when navigating a m-commerce application. The study found that a more visually complex system did not hinder a user's experience but instead encouraged positive feedback from users.

Keywords: *Eye-tracking, Visual Fatigue, M-commerce, Usability, Visual Complexity*

LIST OF ABBREVIATIONS

B2B	Business to Business
B2C	Business to Consumer
UCT	University of Cape Town
GUI	Graphical User Interface
App	Application
EEG	Electroencephalography Scans
fMRI	Functional Magnetic Resonance Imaging
NMR	Nuclear Magnetic Resonance
GSR	Galvanic Skin Response
ISO	International Standard Organisation
MAUEM	The Mobile Application Usability Evaluation Metrics model
PACMAD	People at the Centre of Mobile Application Development model
GQM	The Goal Question Metric
UXEM	User Experience Evaluation
DSA	Department of Student Affairs
UEQ-S	User Experience Questionnaire for Satisfaction
UCT	University of Cape Town
SPSS	Statistical Package for the Social Sciences
JASP	Jeffrey's Amazing Statistics Program
ANOVA	Analysis of Variance
VF	Visual Fatigue
GMUI	Graphical Mobile User Interface
GUI	Graphical User Interface
AR	Augmented Reality
VR	Virtual Reality
HMD	Head Mounted Devices
AI	Artificial Intelligence
GDP	Gross Domestic Product
RG	Revenue-generating Apps
USD	United State Dollar
UX	User Experience
UI	User Interface
CFFF	Critical Flicker Fusion Frequency
C2C	Customer to Customer

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1. CHAPTER 1: INTRODUCTION

1.1. Background of the Study

The Graphical User Interface (GUI) of an application is vital in enticing the consumers to investigate a brand's product offering and possibly buy it. Colour, iconography, shapes, layout, and typography all affect user experience; thus, they must be consistent for a good consumer brand experience (Magrath & McCormick, 2013; Qi & Xue, 2020). The design of an interface also influences consumer opinions. The quantity of visual elements in a GUI is termed visual complexity and it must be understood to satisfy the users. Thus, knowing the level of visual complexity the customers can withstand before becoming uncomfortable, dissatisfied, and developing negative feelings towards the brand is vital (Bhandari *et al.*, 2017; Michailidou *et al.*, 2021; Pal Kapoor & Vij, 2019:102). Positive reviews of an application (app) within the App Store reflect properly designed interfaces whereby all the visual components are cohesive. Through these the users are assured that the app is satisfying and that the brand will keep its promises. This reliability makes the consumers less inclined to stop interacting with the company, highlighting the importance of a well-designed app (Li, 2018).

Mobile apps are used worldwide, but the research on usability, visual fatigue, and visual complexity in developing nations is lacking (Priya & Subramaniyam, 2020). Approximately 22 million South Africans rely on mobile phones for financial transactions. Increasing consumer engagement, information delivery, and value creation in online mobile shopping is important for retailers (Thusi *et al.*, 2020; Kemp, 2023). One of the most understudied groups for mobile internet use and behaviours toward branded mobile apps is within the young adult cohort (Axcell & Ellis, 2023). Mobile applications have become popular, so the businesses must place user satisfaction first to sustain and grow their customer base. One way to understand this consumer experience is by utilising Saleh *et al.* (2020) usability model. This model focuses on a user experience of an application's design using objective and subjective metrics. Usability, according to ISO 9241-11 is the extent to which the users may utilise an object to fulfil goals in a way that is effective, efficient, and satisfying (Green & Pearson, 2006).

Recent research has focused on the long-term effects of excessive digital device usage with specific interest in the term 'visual fatigue'. Visual fatigue describes the strain, the tiredness and the pain felt on an individual's eyes. One's ease and wellbeing are negatively affected by visual tiredness (Wang *et al.*, 2018b; Wang *et al.*, 2018a; Xie, *et al.*, 2021; Kaur, *et al.*, 2022). Since the eyes are the primary receptors for sensory information, the consumers who are overstimulated may find it difficult to use any highly visually complex mobile app. To better understand the physiological repercussions of marketing decisions, consumer neuroscience applies neuroscience methods to these matters (Hubert & Kenning, 2008). In the field of consumer behaviour research, eye tracking technology is one of the most accessible pieces of neuroscientific hardware (Adhikari, 2023). Likewise, eye tracking is among the best ways to objectively evaluate eye strain through physiological responses such as the blink rate, fixation frequency, and the change in pupil diameter.

This study aimed to better understand the impact of visual complexity on usability and visual fatigue, as well as the relationship therefrom. To ensure the validity of the study, mediating (i.e., context of use) and moderating (i.e., phone usage) variables were taken into consideration. The phone usage of the participants prior to the experiment is predicted to moderate the relationship of visual complexity on

the usability of the mobile app (Aqeel, 2021; Lee *et al.*, 2021). Since it is not possible to strictly manage how people use their phone prior to the experiment it is important to understand visual fatigue before and after the experiment to account for this. The context of use (free exploration vs task orientated) that the participants have with the application is predicted to mediate the effect of the visual complexity of the app on visual fatigue (Aqeel, 2021; Gross & Bongartz, 2012). The reason behind someone's exploration of an application is important as it indicates intention and thus differing purposes would potentially result in a different behaviour. This section provides a brief overview of the study by outlining the background research, research question, aim, and the objectives pertaining to important concepts within the study. After that, the methodology of the study is explained and a brief outline of the structure of this thesis paper is discussed.

1.2. BACKGROUND RESEARCH

Chapter 1's introduction provides a brief explanation of the key concepts and the constructs that are necessary to understand the study's purpose and aim. Eye-tracking and consumer neuroscience, eye-tracking and visual fatigue, visual fatigue, mobile shopping apps, the visual complexity of the mobile graphical interface, mobile application usability as well as the overall conceptual framework are focused on in this section. The literature review is discussed in further detail in Chapter 2 which includes the theoretical framework and the literature review.

1.2.1. Eye-Tracking and Consumer Neuroscience

A number of studies have utilised consumer neuroscientific techniques to better understand consumer behaviour. Consumer neuroscience (or neuromarketing) is relatively new, and it was established in 2005 to explain the combination of neuroscience and marketing research (Shahriari *et al.*, 2020). The broad term has thus far been used to understand behavioural decision making, consumption processes, unconscious responses and consumer preferences in a number of marketing and advertising fields through neuroscience techniques as well as theories. The field uses a number of techniques to understand the physiological reactions and responses of the respondents to different stimuli, namely to, Electroencephalography Scans (EEG), eye tracking, Functional Magnetic Resonance Imaging (fMRI), Nuclear Magnetic Resonance (NMR), Galvanic Skin Response (GSR), heart rate monitoring, and respiratory monitoring (Shahriari *et al.*, 2020; Duque-Hurtado *et al.*, 2020).

Through these techniques, the researchers have either sought to find innovative methodologies to try to understand consumer behaviour or relevant theoretical contributions. The main objective is not to replace traditional marketing research but to rather complement them (Duque-Hurtado *et al.*, 2020). For this study, eye tracking was utilised to better understand how consumers interact with the visually complex m-commerce apps and how these affect the user through visual fatigue. Eye tracking is a measure of a user's eye movement and gaze location through time and task. Video-based eye trackers, such as the ones utilised in this study measure the position of the corneal reflection of an infrared light relative to the pupil, with high accuracy (Xie *et al.*, 2021: 35915; Kaur *et al.*, 2022; Wang *et al.*, 2018a; Vinnikov *et al.*, 2016; Guo *et al.*, 2020).

Eye tracking has become largely popular over the last few years due to the technological advancements and the development of more adaptable eye tracking methods (Carter & Luke, 2020; Hang *et al.*, 2018; Motoki *et al.*, 2021). The eye movements can be categorised as fixations or saccades and have often been used as indicators of visual attention. Specifically, eye tracking measures include blinking, fixation, pupil diameter and dilation, gaze movement, saccade and micro saccade (Carter & Luke, 2020; Hang *et al.*, 2018; Motoki *et al.*, 2021). For this study, pupil diameter, fixation dispersion and the blink rate in accordance with other prior studies were used to measure visual fatigue.

1.2.1. Visual Fatigue

Visual fatigue also known as digital eye strain is the term that is used to explain the negative impact of prolonged engagement with an electronic screen. Visual fatigue is explained by those who experience it as blurry vision, discomfort, dryness, and the tiredness of the eyes (Xie *et al.*, 2021: 35915; Kaur *et al.*, 2022; Wang *et al.*, 2018a; Vinnikov *et al.*, 2016; Guo *et al.*, 2020). It also has been shown to account for the decreased performance of the visual system due to varied illumination conditions and visual tasks. There are several studies that have tried to understand this phenomenon and its impact on productivity, usage, and overall wellbeing (Xie *et al.*, 2021; Kaur *et al.*, 2022; Wang *et al.*, 2018a; Vinnikov *et al.*, 2016; Guo, *et al.*, 2020). A number of studies have also investigated other versions of visual fatigue such as mental fatigue or mental workload, computer work fatigue, and feature fatigue when explaining what was experienced from the interaction with a digital screen.

There is also a number of methods that have been used to investigate visual fatigue such as self-reporting (Wang *et al.*, 2018a; Ren *et al.*, 2022; Fang *et al.*, 2022; Palavets & Rosenfield, 2019; Moore *et al.*, 2021; Shi *et al.*, 2020), physiological signals (Fang *et al.*, 2022; Lin *et al.*, 2022; Li *et al.*, 2021; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022) and critical flicker fusion frequency (Priya & Subramaniyam, 2020; Mankowska *et al.*, 2021; Yu & Akita, 2020; Lin *et al.*, 2022). For this study, specifically physiological signals (i.e., eye tracking) were used to measure visual fatigue.

1.2.2. Eye-Tracking and Visual Fatigue

Eye-tracking metrics were used in this study to better understand the physiological responses to stimuli, namely the differing visual complexity levels of mobile commerce applications. Prior studies have used the blink rate as an indicator of visual fatigue. Blink frequency could potentially be related to cognitive processes during consumer attention and decision making. The research is built on the basis that the blink rate reduces during extended computer usage, causes drier eyes and higher visual fatigue (Li *et al.*, 2021; Li *et al.*, 2020a ; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018, Kaur *et al.*, 2022; Fan *et al.*, 2023).

The change in pupil diameter is also another common eye tracking measurement that is used to measure visual fatigue. Researchers have used the notion that the changes in the pupil indicate the activity of the autonomic nervous system (Fang *et al.*, 2022; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka,

2003; Tian *et al.*, 2022). These papers use the logic that when a user is exposed to a certain stimulus over time, the pupil diameter will gradually decrease as visual tiredness sets in. It was also found that the viewing time and the pupil diameter have a negative relationship (Koo *et al.*, 2018). Another study by Fang *et al.*, (2022) utilised fixation dispersion whereby the number of fixation points decreases, and dispersion expands as fatigue is experienced and the visual system becomes less focused. Fixation dispersion has been used in a number of other studies to understand the concepts such as the cognitive workload, visual fatigue, mental fatigue and visual discomfort (Llanes-Jurado *et al.*, 2020; Fang *et al.*, 2022; Wang *et al.*, 2019; Urruty *et al.*, 2007; Zhang *et al.*, 2024; Jiang *et al.*, 2017). All these metrics were used to quantifiably better understand the impact of visually complex mobile graphical user interface.

1.2.3. Mobile shopping apps

For developing economies, the Fourth Industrial Revolution (4IR) represents an exciting opportunity to provide enhanced products and services to the consumers. The popularity of mobile devices over the years has meant that mobile usage has increased. Although this has occurred, little research has been done on the citizens of the developing world, even though an opportunity presents itself for investors, inventors, marketers and business owners (Xu *et al.*, 2018; Cullen & Kabanda, 2018). Buying and selling online is referred to as e-commerce, and when this is done on a mobile device, this is referred to as m-commerce (Lin & Wang, 2006; Chopdar & Balakrishnan, 2020; Akram *et al.*, 2021). The recent coronavirus pandemic has spurred the consumers to translate ordinary in-person shopping behaviour to online shopping behaviour.

Purchases became more dependent on factors such as quality, availability, and convenience. This has an impact on how the marketers advertise their content, brands, and products to reach the appropriate consumers (Akram *et al.*, 2021; Thangavel & Chandra, 2023; Eger *et al.*, 2021). Within South Africa, the most popular online retailer Take-a-lot has managed to effectively utilise their mobile application to generate almost half of the South African online purchases, thereby highlighting the importance of optimising online mobile applications to ensure proper engagement and communication for all the consumers (Gopaldas, 2023). The growth of the e-commerce industry over the next few years will be greatly due to the revenue originating from mobile transactions. This therefore highlights the importance of mobile transactions for business owners and marketers (Statista, 2023). Marketers also need to leverage this platform better to communicate effectively with the consumers. Creating a comfortable, engaging and enticing environment for the consumers to stay as long as needed on an application can encourage loyalty and purchase through an effective graphical user interface.

1.2.4. Visual Complexity of mobile graphical interface

How information is displayed can greatly impact a user's journey, experience, and overall impression of a brand. Visual complexity is an essential term in the computer-human interaction realm that explains the visually perceived richness of an interface (Kumar *et al.*, 2018; Wang & Hsu, 2020). The processing of information is often done quickly, thus making visual information and stimuli essential for the consumers to comprehend the data and information that is presented to them. This coupled with the

users' experience which is often based on memories, means marketers must create advertising that grabs the users' attention, leaves a lasting impression on them and invites them to stay for a prolonged period (Andronie *et al.*, 2021; Mishra *et al.*, 2021; La Źa Źroiu *et al.*, 2020; Barari & Surachartkumtonkun, 2020; Lee, 2018; Adval *et al.*, 2019).

Too many visually distinguishable features can hinder a user's experience. With graphical user interfaces that are straightforward, minimalist, and intuitive to use, most shopping apps have been successful. When created attractively, the user interface should adapt to users, process information, and facilitate interaction (Punchoojit & Hongwarittorn, 2017; Jylh  & Hamari, 2020; Soui *et al.*, 2022a; Soui *et al.*, 2022b; Soui *et al.*, 2020). To improve usability, satisfy user needs, offer functionalities, and interest users, the design elements are crucial in the mobile applications. The survival of m-commerce depends on visually appealing design elements and features (Dubois *et al.*, 2022; Deng & Poole, 2012). Due to the goal orientated nature of most mobile shopping apps, it is important that usability is prioritised to encourage the continued usage of the app and the brand (Ahmad & Ibrahim, 2017:70; Molinillo *et al.*, 2022:8; Tang, 2019; Raphaeli *et al.*, 2017:9; Barari & Surachartkumtonkun, 2020).

1.2.5. Mobile App(s) Usability

Usability has been defined as the manner by which a product or system can be used by the intended users to achieve objectives with effectiveness, efficiency and satisfaction. The term is of importance within human-computer interaction research as a well working system can be described as being usable and thus suitable to meet the required objectives and goals (International Standard Organisation, 1998; Standardization, 2018; Bevan *et al.*, 2015). The usability of a mobile application is essential for its adoption. A number of studies have investigated what contributes to the usability of an app and they have used a number of different models, mainly the self-reporting or automated evaluation of a system, product or even the app's usability (Bhandari *et al.*, 2017; Michailidou *et al.*, 2021; Kumar *et al.*, 2018; Zaki & Islam, 2021; Bevan *et al.*, 2016; Goldstein & Hajaj, 2022; Wiese & Humbani, 2020; Boateng, 2019; Lewis & Sauro, 2009; Kano, Huang & Guan, 2012; Ho & Tzeng, 2021; Lewis & Sauro, 2021).

Saleh *et al.*, (2020) build on an earlier model which used subjective and objectives metrics to understand efficiency, effectiveness and the satisfaction of the user experience related to a mobile application. This paper specifically investigated efficiency, effectiveness and satisfaction in terms of the productive period, the number of touches and self-reporting measures respectively. Efficiency is defined as the resources a user needs to accurately complete a goal and it has been investigated by a number of other studies to investigate the usability of a system (Weichbroth, 2020:55569; Alturki & Gay, 2017:100; Hornbaek, 2006:82-85; Harrison *et al.*, 2013:4; Bevan *et al.*, 2016; Bevan *et al.*, 2015; Ferreira *et al.*, 2020; Khamaj *et al.*, 2019; Sauer *et al.*, 2020).

Effectiveness has been defined as the effort taken for the users to achieve a goal with ease and accuracy and it has also been used to better understand the usability of a system (John & Marks, 1997; Ferreira *et al.*, 2020; Alexander *et al.*, 2021; Khamaj *et al.*, 2019; Hornbaek, 2006; Harrison *et al.*, 2013; Weichbroth, 2020; Bevan *et al.*, 2016:270-272; Sauer *et al.*, 2020). The final metric, satisfaction, is defined as the overall pleasure or the displeasure that is felt from all the benefits that one is expected to receive when interacting with a system and it has been used in a number of prior studies to better understand usability (Saleh *et al.*, 2020; Luna-Perejon *et al.*, 2019; Hajesmaeel-Gohari *et al.*, 2022;

Sibarani, 2021; Hornbaek, 2006; Harrison *et al.*, 2013; Weichbroth, 2020; Bevan *et al.*, 2016:270-272; Sauer *et al.*, 2020).

The final conceptual model was constructed using the previously mentioned literature as a foundation. This model combines several concepts in an attempt to explain how a user's visual fatigue affects the usability of a mobile commerce application. Furthermore, how visually complicated an application is affects not only its usability but also the visual fatigue that the users experience when using it for various tasks.

1.2.6. Conceptual Framework

The model encompasses the original ISO 9241-11 definition of usability whereby efficiency, effectiveness and satisfaction are outlined, and each is quantified through the measures established by Saleh *et al.*, (2020), from the UXEMs model. Visual fatigue was quantified by a multitude of relevant studies and builds upon the research done by Fang *et al.*, (2022), Cheng (2011), Wang *et al.*, (2018a), and Wang *et al.*, (2018b) whereby fixation dispersion, pupil diameter and the blink rate were used to measure visual fatigue over time, through eye tracking technology. To comprehend the visual complexity of an interface and how that affects both visual fatigue and usability in accordance with the industry of interest, the visual design components (background colour, font style, button colour, etc.) of a mobile application were utilised. Usability was first broken down into its core metrics, efficiency, effectiveness, and satisfaction, based on reasoning from the first principles. Each of those metrics was then further broken down to determine how each metric is related to the visual fatigue metrics, and ultimately to establish the relationship between the two. A conceptual model was created to depict this study, this can be found in section 2.10.

The next section outlines the justification and the importance of this study regarding its contribution to research. The research question, the objectives and the hypotheses are outlined thereafter. Following that, is a summary of the methodology that was used to obtain the results that were necessary to draw adequate conclusions regarding the constructs and this overall conceptual model.

1.3. PROBLEM STATEMENT, AND PURPOSE OF STUDY

Since the coronavirus pandemic began two years ago, consumers' online engagement and visibility have increased. Of particular interest is the behaviour of the adults in regard to their online engagement and the technological impact on them (Akram *et al.*, 2021; Amatulli *et al.*, 2023). The consumers within this cohort (young adults) have a strong desire to search for pleasant experiences that align with their specific beliefs, and they are able to alter their evaluation of an application depending on the promised and delivered services. They can have their well-being influenced by the m-commerce apps and have a higher potential to purchase hedonic products online (Amatulli *et al.*, 2023; Zou *et al.*, 2023:8). The research area pertaining to mobile application experience is of importance to the businesses catering to those in the young adult cohort, as they make up the majority of most app user bases (Zou *et al.*, 2023:8). A study by Ligaraba *et al.*, (2022), investigated the behaviour of young adults in South Africa in regard

to mobile grocery retail applications. The study highlighted the need to further investigate how the e-commerce platforms impact consumer behaviour, especially within the young adult group.

Developing countries such as South Africa where m-commerce is on the rise, demonstrate the need for more research into the most appropriate method of serving consumers digitally (Sordrager, 2021; Mofokeng, 2021). Research on the mobile app experience and its impact on developing country consumers is currently lacking. Priya and Subramaniyam (2020) conducted India's first study on smartphone usage and visual fatigue. This is concerning given the rising mobile phone penetration (especially smartphones) in developing countries, which has helped companies such as Uber to grow (Aguilera & Boutueil, 2019:169-172). The necessity to add to consumer behaviour literature for developing countries is also highlighted.

Thus, it is crucial to examine how online content may affect the consumers' visual processes. Businesses should consider how their apps affect customer relationships and ethically pique the customers' interest (Kozlenkova *et al.*, 2017; Wichmann *et al.*, 2022; Hoffman *et al.*, 2022; Amatulli *et al.*, 2023; Zou *et al.*, 2023). Visual fatigue is important for the marketers who want to encourage regular use of their digital product (Kaur *et al.*, 2022:1655; Sheppard & Wolffsohn, 2018). Light intensity, task difficulty and duration, attentional focusing, cognitive load, as well as work have all been studied as factors that affect visual fatigue (Fang *et al.*, 2022; Oner, 2018; Sheppard & Wolffsohn, 2018; Yano *et al.*, 2002; Kalra & Karar, 2023; Maffei & Angrilli, 2018; Park *et al.*, 2017; Priya & Subramanivan, 2020; Park *et al.*, 2019; Park *et al.*, 2022; Souchet *et al.*, 2022). Reliable eye tracking technology is needed to assess visual fatigue (Souchet *et al.*, 2022).

Since eye tracking is non-invasive and provides comprehensive data, it has been widely used. Most studies calculate visual fatigue using one eye tracking method (Maffei & Angrilli, 2018; Souchet *et al.*, 2022) or self-reporting methods (Yano *et al.*, 2002; Kuze & Ukai, 2008; Kim *et al.*, 2018; Tao, 2024; Ren *et al.*, 2022). Marketing scholars use the mixed methods approach to create relevant and substantial research that is not limited by empirical requirements (Hoffman *et al.*, 2022). Understanding how visual fatigue and visual complexity affects mobile app usability and user experience is essential to creating a long-lasting app that excites and connects with consumers. Furthermore, it is crucial because a poorly executed brand application could weaken the relationship that exists between the business and its patrons, highlighting how significant these concepts are.

Finally, to quantify visual fatigue, a mixed method approach using multiple eye tracking metrics was necessary. This study used a model to examine how visual fatigue affected mobile app visual complexity and usability. The study builds on Saleh *et al.* (2020), Fang *et al.*, (2022), Wang *et al.*, (2018a), and Wang *et al.*'s (2018b) studies on visual fatigue and it devised a comprehensive model. Thus, the research question and the objectives outlined within the next section were formulated to address the aforementioned problems in current literature while achieving the aim is to develop a neuroscientific method for evaluating the usability of m-commerce apps by examining the relationship between eye-tracking based visual fatigue metrics and usability across different levels of visual complexity for the South African 18-35 cohort.

1.4. RESEARCH QUESTION AND OBJECTIVES

1.4.1. Research Question

How does visual fatigue, as measured through eye-tracking, relate to the usability of m-commerce apps with varying levels of visual complexity?

1.4.2. Research Objectives

1.4.2.1. Primary

To address the research question, the present study addressed the following primary objective:

- To determine the relationship between usability and visual fatigue in regard to differing visually complex m-commerce applications and Cape Town's 18 - 35 consumers/users.

1.4.2.2. Secondary

To address the research question, the present study addressed the following secondary objectives with regards to Cape Town's 18 - 35 m-commerce users:

- To understand the relationship between the usability metrics of a m-commerce application and eye tracking visual fatigue metrics to establish a neuroscientific method in which to measure the usability of a m-commerce app.
- To investigate how the visual complexity of a m-commerce app interface affects the visual fatigue of the users.
- To understand how the three-usability metrics of a m-commerce app relate to the visual complexity of the app's interface.
- To determine if the context of use within the experiment mediated the effect of the visual complexity of the interface on the visual fatigue of user.
- To determine if the time spent on a mobile device before the experiment moderates the effect of visual complexity of the interface on the visual fatigue of user.

1.5. METHODOLOGY

This sections briefly explains the methods, the techniques, and the procedure within which the current study was conducted. Specifically, the research design, the target population, sampling design, data collection and the analysis are discussed briefly in this section. The methodology is also discussed further in Chapter 3.

1.5.1. RESEARCH STRATEGY

The research utilised a mixed-method approach with quantitative research methods to measure the response to stimuli and the qualitative methods, to gather a deeper understanding of the investigated

topics (Dawadi *et al.*, 2021; Baskarada & Koronios, 2018). To gain a comprehensive understanding of the data collected, a concurrent triangulated mixed-method approach was adopted.

1.5.2. Research Design

The research methodology utilised a concurrent triangular mixed-method approach through conventional techniques which are namely self-reporting, and non-conventional techniques, i.e., the eye tracking methods to better understand the impact of visual complexity, mobile application usability and visual fatigue (Kroll & Neri, 2009; Creswell & Creswell, 2017; Adhikari, 2023). The quantitative portion of the study used a confirmatory methodology whereby the self-reporting questionnaires similar to that done by previous studies to measure visual fatigue and user satisfaction, were utilised (Koo *et al.*, 2018; Gonzalez-Perez *et al.*, 2017; Zheng *et al.*, 2021; Jahangiri *et al.*, 2022; Willson & Miller, 2014:16). For the eye tracking portion of this study, a causal experimental research design was applied, specifically a post-test control group design to understand visual fatigue within the users. The qualitative data was recorded through interviews and the Heatmap data for the pages on each app.

1.5.3. Target Population and Sampling Design

The target population consisted of respondents within the 18-35 year old cohort residing in the Cape Town residential area and who were familiar with a m-commerce application. The Cape Town metropolitan area was chosen due to proximity of research equipment, the venue and participants. The target population's age range was in line with prior research that has highlighted that different age groups interact with mobile applications differently and older eyes may become hooded, or drooped and individuals may develop eye problems, thus making it more difficult to measure the changes in the visual system such as pupil diameter change and this might impact the quality of the eye tracking data (Koo *et al.*, 2018; Lin *et al.*, 2021; Guillon *et al.*, 2016; Deloitte, 2020:8-9; Li & Luximon, 2020).

The study sample comprised of 96 individuals, of whom 34 engaged with the first application, 30 with the second, and 32 with the third. Given the nature of the study, this sample size was appropriate and consistent with previous research of a similar scope. The study was conducted on a volunteer basis. The non-probability sampling technique was used in this study, more specifically, convenience and snowball sampling were employed in the research. The recruitment of the participants took place via the UCT DSA invitation list. Based on their responses to the research invitation, a list of interested participants was established and they were chosen at random to take part in the study (Malhotra *et al.*, 2020).

1.5.4. Data Collection and Analysis

The study's data collection process consisted of self-reporting techniques, interviews and consumer neuroscience methods. The participants were initially asked a screening question, "Do you use e-commerce apps (such as Superbalist, Takelot, etc.)?" so as to streamline the sample group, all participants answered "yes". Self-report data was collected through an online questionnaire created through Google forms prior to the eye-tracking experiment and then again after the eye tracking experiment. The first structured questionnaire was presented prior to the exposure to the application. The initial questionnaire utilised Likert scale questions to measure the perceived visual fatigue that was

experienced before the experiment, as well as the phone usage prior to the experiment. The second questionnaire was presented after the exposure to the application, and it collected user data pertaining to the demographic data (gender and age). The Likert scale questions about the visual fatigue experienced from the app and a semantic differential scale questions adapted from the User Experience Questionnaire for Satisfaction (UEQ-S) questionnaire (Schrepp *et al.*, 2017) were used to measure user satisfaction, were within both the pre- and post- experimental questionnaires.

During the experiment, eye-tracking data was collected through the Tobii Pro Nano 60 Hz and recorded using the iMotions software to specifically measure the visual fatigue that was experienced by the users of each application. The eye tracking software was used to measure the blink rate, fixation dispersion and the pupil diameter change when interacting with the application. Objective data was collected during the experiment, and it was used to measure efficiency and effectiveness which are metrics of usability. After the engagement with the application, a questionnaire was issued, and an interview occurred whereby three questions were posed to the respondents. The interview allowed for deeper insights about the users' thoughts towards the application in terms of the initial impressions of the application, the experienced visual fatigue, and improvements to the visual elements which would enhance the user experience.

The quantitative data that was obtained in this study was prepared and analysed by using Microsoft Excel, the Statistical Package for the Social Sciences (SPSS version 4.2) and Jeffrey's Amazing Statistics Program (JASP version 0.16). The SPSS software assisted with the analysis of the descriptive statistics and the hypothesis testing. JASP is an open-source statistics program that allows for appropriate statistical analyses (Goss-Sampson, 2024). The qualitative data was prepared in Microsoft Word and analysed through an interpretive phenomenological analysis to identify and comprehend the themes from the interviews. The statistical methods that were employed in this study included; ANOVA, regression, correlation and the Hayes mediation/moderation analysis methods.

1.6. ETHICAL CONSIDERATION

Participants in this study were properly informed of the procedures, risks and benefits, type of findings that may be discovered by the study as well as the rights of test subjects and actions taken to ensure privacy and confidentiality (Lim, 2018). Those taking part were also properly informed of the purpose of the study, as well as their voluntary and anonymous right to participate in the study. If participants chose to participate, but later decide to withdraw, they were free to do so at any time, without negative consequences. Further, participants had to indicate their age as they needed to be 18 and older to take part in the study. The research proposal was additionally assessed by the University of Cape Town's Higher Degrees Committee, the Ethics in Research Committee as well as the Marketing Academic Committee to ensure the present study did not compromise any participants of the study throughout the research process.

1.7. JUSTIFICATION AND CONTRIBUTIONS TO THE STUDY

This study served to break new ground in visual fatigue (VF) experimentation within the field of understanding consumer wellbeing when engaging with a mobile application within the South African context. Prior visual fatigue research has mainly focused on how the workers' productivity is impacted by VF within the context of indoor lighting in the workplace (Xie *et al.*, 2021: 35915; Kaur *et al.*, 2022; Wang *et al.*, 2018a; Kuze & Ukai, 2008; Yu & Akita, 2020; Kim *et al.*, 2017; Ren *et al.*, 2022; Lambooj *et al.*, 2009; Priya & Subramaniam, 2020; Mankowska *et al.*, 2021; Yu & Akita, 2020; Lin *et al.*, 2022). This study differs as it aims to better understand VF experienced on a m-commerce application specifically for users with the 18-35 South African cohort. The research contributes to the current knowledge of VF experienced on a mobile application through the establishment of a unique model to measure usability and VF when investigating different visually complex apps. This study advances emerging scholarship by examining the potential impact of visual complexity in m-commerce applications on user wellbeing, thereby offering insights into strategies for enhancing user experience within the m-commerce domain.

In addition, the study uniquely utilised a combination of three neuroscientific techniques to measure the VF experienced by the user which has not been done in prior studies (Fang *et al.*, 2022; Lin *et al.*, 2022; Li *et al.*, 2021; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022; Feng & Chen, 2021). This acts as a valuable complement to prior studies on m-commerce usability, more traditional marketing measures and other prior studies of a similar nature as well as to VF studies by estimating a model that could measure VF and gather more concise data on measuring it, (Fang *et al.*, 2022; Xie *et al.*, 2021; Ren *et al.*, 2022; Feng & Chen, 2021; Wang *et al.*, 2018a; Wang *et al.*, 2018b).

1.8. ORGANISATION OF THE STUDY

The study is comprised of five chapters, which are organised as follows:

Chapter 1: Introduction - Delivers an overview of the contents of the study and it introduces one to the subject. Furthermore, this chapter establishes a basis for the subsequent chapters in this research, which are organised as follows.

Chapter 2: Theoretical Framework and Literature Review - Provides a synopsis of the prior research that is pertinent to the research problem, alongside the theoretical and conceptual framework. The review of the relevant literature establishes the significance of the various constructs outlined in the conceptual framework and offers an in-depth understanding of these concepts in relation to the aforementioned investigation. The research hypotheses for this study are then presented following the results of prior research. Issues pertinent to the subject at hand are presented in these discussions.

Chapter 3: Methodology - Explains in depth the techniques that were employed throughout the study and provides support for the choice of techniques that are deemed as the most appropriate for this research.

Chapter 4: Presentation of Results - Displays the results of the data analysis and the hypothesis testing findings which support or refute the study's hypotheses.

Chapter 5: Conclusions and Recommendations - Presents conclusions, the synopses of the data, and the management implications as well as the recommendations based on the data. There are also some recommendations for further research in this field as well as the research's limitations.

1.9. CONCLUSION

Overall, this introduction chapter served to provide the background information for the current research problem. The chapter assessed previous research on the visual complexity of the Graphical Mobile User Interface (GMUI) design, visual fatigue, and m-commerce usability. Additionally, the study's contextual background was described. Based on models by Wang *et al.*, (2018a), Saleh *et al.*, (2020), Fang *et al.*, (2022), and Wang *et al.*, (2018b), a conceptual framework was created to investigate these phenomes. This chapter summarised the study's purpose and it detailed the research questions, the objectives, and the methodologies that guided the investigation. The study's management and intellectual contributions were discussed next, and finally, the ethical issues were raised. A summary of the information included in the next chapters of this report was provided at the end of the chapter. A thorough explanation of the study's theoretical foundation is found in the next chapter.

2. CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. INTRODUCTION

The theoretical papers supporting this investigation are analysed in this chapter, along with how they were combined to create the framework that served as the research's compass. Subsequently, the literature review facilitates a more profound comprehension of the existing research in the field and provides a conclusive overview of the applicable results from the earlier studies that served as the foundation for the present one. The numerous constructs depicted in the conceptual and theoretical framework are further explained in the above discourse which also highlights the study's applicability and identifies the gaps in the literature. This chapter concludes with the conceptual model.

2.2. THEORETICAL FRAMEWORK

This study focused on the visual fatigue that is experienced from excessive visual stimulation within an m-commerce application. The purpose was to understand and quantify a model to measure the rendered visual fatigue and the usability of an m-commerce application. The existing theory on visual fatigue, visual complexity, human computer interaction (HCI), graphical user interface interaction and mobile application usability has not provided any empirically tested framework that specifically explores the relationship between the relevant concepts to this study (Fang *et al.*, 2022; Saleh *et al.*, 2020; Wang *et al.*, 2018a; Priya & Subramaniyam, 2020; Guo *et al.*, 2022; Ioannucci *et al.*, 2020). This study used a model to examine how visual fatigue affects mobile app visual complexity and usability. Therefore, this study has adapted a number of theoretical works to develop an integrated framework. The theoretical framework presented in this section has acted as the foundation on which this research was based and was used to guide the literature review of the study.

2.2.1. Foundational Literature Underpinning this Study

The concepts and the metrics that were utilised in this study were generated via the conceptual framework that was adapted from several supporting papers. The models in question originated from the following sources; Saleh *et al.*, 2020; Wang *et al.*, 2018a; Fang *et al.*, 2022. The usability metric that was used to quantify the visual complexity of the mobile applications was derived from a paper by Saleh *et al.*, (2017), which served as the basis for a subsequent publication by the same author, Saleh *et al.*, (2020) as seen in Figure 5 in the Appendix B, and which forms the basis of the usability section of the study which is shown below. These papers highlight the specific metrics that were used to understand the user experience of the consumer on a mobile application.

A variety of studies were used to construct the metrics to comprehend visual fatigue. The three VF measurements are the blink rate, pupil diameter, and the dispersion of fixation. The parameters for the blink rate are derived from multiple studies notably the study by Wang *et al.*, (2018a) as shown in Figure 7 (see Appendix B). Wang *et al.* (2018a) and Wang *et al.*, (2018b) showcase that visual fatigue

increased with time and that the eye blink was significantly influenced by time. The study by Fang *et al.*, (2022) is the source for both pupil diameter and the dispersion of fixation. The study's key finding is that as fixation dispersion grows, the number of fixation points reduces as fatigue increases. Additionally, Fang *et al.*, (2022) discovered a significant relationship between human weariness and the behaviour of the pupils. According to the study's underlying theory, when a person becomes fatigued, their pupil diameter shrinks, and their pupil size oscillates more. The study also discovered that when fatigue decreases, operational performance rises as Fang *et al.*, (2022) illustrate in Appendix B Figure 6 through the abstract model.

2.2.2. The Integrated Framework

The first principles theory was applied to study and develop an objective model that will help in precisely assessing the VF that is experienced by the users when interacting with a m-commerce application. Many early academics developed first principle thinking which is still currently widely applied to resolve problems and generate novel theories (Miles, 2020). A relationship that is independent of an activity or method and is always true under the right circumstances is called a principle. The first principles are defined as essential, universal facts or guidelines about a topic that applies to all individuals everywhere (Irwin, 1987; Merrill, 2002; Merrill, 2017; Merrill, 2021; Reiter, 1987; Rosenbaum, 2021; Carter, 2019). To better comprehend how and why something exists, it is generally characterised as the initial basis by which an aspect is known.

When one applies the first principles reasoning, the presumptions and traditions are eliminated, and everything is viewed through a cause-and-effect perspective (Allen, 2015; Reiter, 1987; Miller, 2019). One might discover commonalities and make inferences by comprehending the fundamental definitions or concepts of each idea. To better understand how both measures relate to one another over time, the first principles reasoning was applied to combine data from the eye tracking measures (which measure VF) and the usability measures (effectiveness and efficiency) (Gasser-Wingate, 2016; Irwin, 1977; Karbowski, 2019: 78-97; Golder *et al.*, 2023). Through an in-depth comprehension of how the consumers respond to visually complex stimuli in terms of usability and visual fatigue, marketers may make informed decisions about which design practices to use and which ones to refrain from using to foster long-term application usage and to avoid negatively impacting customer well-being. The GUI of a software program must balance usability with design. The necessity for additional research on the effects of changing the GMUI design features on usability and vice versa has been supported by a number of visual design studies (Soui *et al.*, 2022a; Wang *et al.*, 2020; Karampournioti & Wiedmann, 2022; Teufel & Nanay, 2017). As a result, visual complexity is justified when analysing software program usability difficulties.

A more thorough examination of the literature on the topics of visual fatigue, m-commerce application usability, visual complexity, and visual design is provided in the next sections. The way in which the consumers interact with an online landscape is important to understand within the current study and to the marketers crafting and improving the brand applications and websites. The proceeding section specifically covers the online retail shopping environment, with a focus on e-commerce, m-commerce, growth and usage within the m-commerce environment in the South African online retail landscape, and in the South African m-commerce landscape.

2.3. ONLINE SHOPPING

Humans develop over time in all facets of life in an effort to improve the world and everyone's standard of living. A lot of effort has been devoted to the development and advancement of technology over the past few years. The 4IR includes and makes use of novel techniques for connecting technology and society (Davis, 2016:2; Sutherland, 2020). In the world of HCI, many concepts have been looked at intensely to better understand how people understand and engage with machines, interface design, online content and other new technologies such as Augmented Reality (AR), Virtual Reality (VR), Head Mounted Devices (HMDs) and Artificial Intelligence (AI) (Makkonen *et al.*, 2009; Petit *et al.*, 2019; Fernandez-Rojas *et al.*, 2019). This section will unpack the significance of new technology, the e-commerce space, the m-commerce space and the South African m-commerce environment and all the implications these have for the businesses.

Although recently, many have focused on understanding how the consumers interact with new technology and if it could be used to replace traditional shopping experiences such as AR technologies, Petit *et al.* (2019) found that the consumers experience a higher sense of interactivity when exploring with a 3D imagery of a product than with an AR condition of the product. Thus, although these technologies could potentially lead to a new way for brands to interact with the consumers, it is not necessarily a better experience for the consumers (Petit *et al.*, 2019; De Cicco *et al.*, 2021, Ranaweera *et al.*, 2021).

2.3.1. E-commerce vs m-commerce

From the beginning of the coronavirus pandemic two years ago, the consumers' overall online activity and visibility have increased (Akram *et al.*, 2021; Thangavel & Chandra, 2023). This has had implications for the organisations and the marketers because it implied a shift from business as usual to a mode of operation that makes better use of technology to address problems. Increased technical innovation also expands the markets for innovators, strengthens the role of AIs, and enables the merging of various technologies (Xu *et al.*, 2018:91). For developing economies, the 4IR represents an exciting opportunity to provide enhanced products and services to consumers.

Computers, tablets, and smartphones are just a few examples of the many technological advances that have been made throughout the years. To buy and sell online is known as e-commerce, whereas to do so via a mobile device connected to the internet is known as m-commerce (Lin & Wang, 2006; Chopdar & Balakrishnan, 2020; Akram *et al.*, 2021). Any device can have a wide range of operating systems all of which must be optimised for the best user experience. This means that the mobile and desktop views of a website will be different depending on the characteristics such as the screen size and the processing capacity. According to the results of numerous studies, the level of customer involvement and consumption varies significantly depending on the employed medium (Goldstein & Hajaj, 2022; Sakas & Giannakopoulos, 2021).

The mobile devices with internet access empower the customers to rapidly disseminate and acquire knowledge through the electronic word-of-mouth (Akram *et al.*, 2021; Munsch, 2021, Giunta, 2020).

When compared to the developed nations, the developing nations typically have more costly internet access and less widespread availability of high-speed, broadband computer infrastructure. Further with the penetration of mobile phones, the communication patterns in the emerging nations have shifted (Cullen & Kabanda, 2018). The researchers in South Africa revealed that nearly all the urban residents and workers rely on their mobile phones as their primary means of connecting to the web and to other people (Cullen & Kabanda, 2018; Thangavel & Chandra, 2023; Kreutzer, 2009; Duffett, 2020).

2.3.2. M-commerce Growth, Usage, and Other

M-commerce is defined as the act of commercial transactions through a mobile device over the wireless telecommunication networks. Mobile devices have transformed conventional platforms while becoming more integrated into everyday life. Mobile commerce is an extension of e-commerce which has been around for years (Thangavel & Chandra, 2023). Brand marketers and the industry should try to understand the mobile app usage evolution to improve user experience and app effectiveness. The major trends over the last two years include but are not limited to mobile social commerce, mobile payment, mobile marketing, omnichannel, Fintech and live streaming commerce. A few apps dominate the app industry, and they are on practically every smartphone along with function apps (Li *et al.*, 2020c; Tang, 2019; Thangavel & Chandra, 2023).

The previous m-commerce articles focused on branded apps, revenue-generating company tools, and user mobile app behaviour. The branded apps are the mobile apps that are linked to a brand by appearance, experience, or name (Tang, 2019; Stocchi *et al.*, 2019). The Revenue-generating Apps (RG) stem from the brand and business to generate revenue. The current RG app models include paid, freemiums, paidmiums, and in-app advertising (Tang, 2019). M-commerce has changed the trading space, thereby giving the customers a unique experience and value. The m-commerce revenues will achieve USD 4.5 trillion globally by 2024 (Thangavel & Chandra, 2023). Although m-commerce is quite common in the developed countries, recently the more developing countries have been given access to more infrastructure and resources thus aiding in the growth of the m-commerce industry. This has highlighted the need to better understand the user interactions and the mobile consumer behaviour of those in the developing nations (Thangavel & Chandra, 2023; Sordrager, 2021).

2.3.3. South African Online Retail Industry

The shopping landscape has changed over the years to account for consumer preference, as well as the lifestyle and economic flexibility changes. Shopping behaviour is a habitual part of everyday life for the consumers and the consumer shopping behaviour studies highlight how individuals select, buy, use and dispose of goods, services, ideas, and experiences (Ramprabha, 2017; Fedorko *et al.*, 2018). Marketers are focused on understanding what drives decision-making when shopping to improve the shopping effectiveness. The behaviour of the consumers along the shopping journey depending on where the consumer is shopping, the involvement level with the act and other factors (Ramprabha, 2017).

Ever since the coronavirus outbreak, research has been more focused on consumer behaviour in the online retail environment. Consumer behaviour became more orientated on fear mongering, thus purchases have become more dependent on factors such as quality, availability and convenience (Eger *et al.*, 2021). Online shopping occurs on websites, applications and social media platforms. Most people spend at least over an hour on the internet. In developing countries, consumers use the internet to keep in touch with social circles, to conduct daily business and to do transactions (Fedorko *et al.*, 2018).

In South Africa, a number of factors including but not limited to customer satisfaction, quality, cost, ease of use, and social attractiveness impact mobile adoption and behavioural intention. Perceived cost is seen to be the most influential on the consumer behavioural intention to use the online shopping websites (Musikavanhu, & Musakuro, 2023). E-commerce penetration is expected to reach 50 billion users by 2025. Almost half of the South African online purchases originate from the popular online retailer Take-a-lot, which operates with both the e-commerce and m-commerce sectors (Gopaldas, 2023).

2.3.4. M-commerce in South Africa

Recently, South Africa's most popular retailers have developed mobile smartphone apps and websites to create more convenience for the consumers especially when movement was restricted (coronavirus outbreak). The retailers such as Checkers, Pick 'n' Pay, and Woolworths created applications like Checkers sixty60, Woolies Dash, and Pick 'n' Pay ASAP, thereby implying the growth to meet consumer needs within the e-commerce/m-commerce space (Gopaldas, 2023). The improved internet access in the developing nations has allowed the consumers to freely explore and consume a variety of devices.

Many emerging nations such as India have invested in broadband infrastructure building, and this has allowed the consumers in these nations access to smartphones, cheaper broadband connectivity and thus increased m-commerce penetration (Thangavel & Chandra, 2023). However, with the increase in penetration of the mobile phones, and the communication patterns in the emerging nations have shifted. The farmers, and the small business owners from the emerging nations such as Bangladeshi and Ivory Coast make extensive use of the m-commerce applications (Thangavel & Chandra, 2023).

The South African economy is expected to grow in GDP by about 2% over the next few years. The retail industry in particular can be used as an indicator of consumer consumption and has seen a sharp shift of online purchases over the last few years (Mogajane, 2022, Rossolov *et al.*, 2022). The e-commerce market in South Africa is expected to reach about 11% in revenue in the next few years and the number of users is expected to reach 37.6 million by 2027 (Statista, 2023). It is important to note that the m-commerce sales make up the majority of the e-commerce sales. Approximately 46% of the sector's revenue comes from the mobile app while only 25% emanate from the desktop and 9% from the tablets as reported in 2020 (Bayhack, 2020; Khaskheli *et al.*, 2017).

The mobile devices are easier for the consumers to access, and mobile banking has allowed online transactions to occur fast and seamlessly (Sissing *et al.*, 2017; Mundim *et al.*, 2023). Thus, focusing on how the consumers' behaviour in this space is of utmost importance to the brands and marketers, it was reported that in 2020 alone there was about 33.42 million internet users in South Africa which was

expected to increase steadily over the next few years (Sordrager, 2021; Mofokeng, 2021:3). M-commerce is of particular importance to industry due to the fact that the majority of the South Africans use internet enabled mobile devices to conduct online purchases (Sordrager, 2021).

The South African consumers believe order fulfilment to be more important than the tangible aspects of online shopping. It is also reported that the younger consumers in the emerging markets prefer using their smartphone to shop online and they have a large spending power especially in these markets (Heyns & Kilbourn, 2022; Giunta, 2020). Young adults primarily utilise their mobile devices to conduct online purchases, as well as to gather information and enjoy entertainment. While the older adults reported greater difficulty in operating technology compared to the younger adults (Lin *et al.*, 2020; Munsch, 2021; Melumad & Pham, 2020). Thus, the understanding of the optimisation of an online mobile application experience is essential in engaging and in communicating with all the consumers (Munsch, 2021; Sordrager, 2021; Van der Merwe, 2022:176; Melumad & Pham, 2020).

The mobile application landscape in South Africa and internationally is important to understand as more consumers change their buying patterns and behaviour. Comprehending how these applications are used is also important for the marketers to understand, as they will better connect with the consumers interacting with the brand applications. The next section outlines the literature pertaining to m-commerce usability, as well as the adoption, and the usage of mobile apps, and the specific model metrics (efficiency, effectiveness and satisfaction) that are used to measure the usability for the current study.

2.4. M-COMMERCE USABILITY

A fairly recent term that has started to be researched extensively in the human-computer interaction and ergonomics sphere is 'usability'. Although the term came into use in the early 1980s, it has only recently been used to understand a system or a program from the perspective of those who use the program (Lewis & Sauro, 2021). Usability is often explored in conjunction with user experience and the terms are even used interchangeably at times to understand how usable a software system is (Sauer *et al.*, 2020; Alexander *et al.*, 2021; Ferreira *et al.*, 2020). Usability testing is a key technique that is used in user-centric design to evaluate products through the direct feedback from the consumers.

This helps the developers by seeing what real people do, look for and explore as they engage with a product (Bergstrom, 2014). The term has a number of variable definitions, and it is used to understand how technological systems, devices and software have made life easier for humanity. Usability is notable and it is not an object but rather an emergent property that is dependent on a number of factors including the interactions with users, products, tasks, and environments. Often, usability testing is done on products for the companies to meet the usability objectives that were set for the system so as to achieve consumer goals and to satisfy the consumers (Lewis & Sauro, 2021).

The next section defines the term, and it outlines the importance of understanding and improving for user experience when engaging with a mobile system. Usability is often studied with a number of other topics such as an interface, mobile commerce, user experience, preferences, mobile application, design, education, and website interaction with an interface (Khamaj *et al.*, 2019; Lam Shin Cheung *et al.*,

2020; Li & Luximon, 2020; Aziz *et al.*, 2021; Alexander *et al.*, 2021; Weichbroth, 2020; Vlachogianni & Tselios, 2022, Sauer *et al.*, 2020; Tsai *et al.*, 2020).

2.4.1. Mobile App Adoption

Ordinarily, any type of technology enables an individual to complete tasks in a timely manner, thus increasing efficiency as well as productivity and the same is true for any mobile app. A mobile app is software that can be downloaded on a mobile device that displays a brand identity through customer experience and convenience (McClean *et al.*, 2020; Lucas *et al.*, 2023). A paper by Newman *et al.* (2017) found that the ease of use was critical to improve the consumers' personal connections to apps. The connection a consumer has to an app influences their purchase channel preferences and their actual purchasing behaviour (Newman *et al.*, 2017). In 2021 alone, about 90% of the new smartphone connections originated from the developing countries. A large majority of the digital time on smartphone devices is spent on the mobile apps (Ashraf *et al.*, 2021; McClean, 2020).

The usage of different technological systems has increased as technology has advanced. The user and device navigation of the web-enabled devices varies. Smartphone browsing is more task-oriented than exploratory on the computers (Raphaeli, *et al.*, 2017:11). Mobile apps are used across the generational groups but mostly they are used by those belonging to the younger adults cohort. The downloaded mobile apps are used for gaming, chatting and for social networking (Correia *et al.*, 2020; Chong, 2013). It is important to note that only the apps that are considered to be truly valuable to users are the ones that meet the expectations and thus they are seen as encouraging the initial downloads and returning the usage patterns. Thus, the use of mobile apps requires a high level of sustained consumer engagement (Lucas *et al.*, 2023).

A number of studies have explored the adoption of mobile apps by the consumers (Tandon *et al.*, 2021; Liu & Sese, 2022; Reeck *et al.*, 2023). The researchers have investigated a number of applications to understand what encourages usage and continued usage. McClean *et al.* (2020) investigated the consumer attitudes pertaining to the retailers' m-commerce applications. They found that the usage over time and the positive attitudes towards an app result in increased purchase frequency through the app, positive attitudes and loyalty towards the brand. They also found that a mobile smartphone's screen size impacts the consumer attitudes and behaviour (McClean *et al.*, 2020).

Tandon *et al.* (2021) found a number of other conclusions such as that the preference value positively influences purchase intention, thus the consumers have a desire to derive benefits through the consumption of food delivery applications. This has a wider overall implication for the retail applications as it indicates that the purchases on the retailer applications can be increased by influencing the consumer perceptions of the benefits such as free delivery, special pricing and the promotional offers (Tandon *et al.*, 2021). Another study by Liu and Sese (2022) found that app adoption aids in promoting additional purchases for the hedonic (pleasure) products and less cross-buying for utilitarian (functional) products, as app adoption occurs in a number of moments in time.

Andronie *et al.* (2021) investigated the consumer adoption of the mobile shopping apps and found that consumer behaviour and adoption intention are developed through perceived risk and trust implications when using the mobile shopping apps/websites. Gu and Kannan (2021) found that the impact of mobile

application adoption on the customers' overall spending was significant and negative. They also found that the consumers that adopt the app of interest in the study were more likely to adopt the competitor apps and search around more, thus leading to a decreased share of available money for the app of interest (Gu & Kannan, 2021). Below is a table summarising a number of other older studies that investigated mobile application adoption.

Table 1: Table Comparing Prior Research on Mobile Application Adoption

Reference	Context	Mobile search behaviour	Major findings
Liu <i>et al.</i> (2019)	Effect of adding mobile app channel to existing mobile website		App adoption increases purchase incidence, purchase frequency, and order size
Narang & Shankar (2019)	Mobile app adoption for an omnichannel retailer (app and offline stores)		App adoption increases both purchases and returns
Park <i>et al.</i> (2020a)	Mobile channel's impact sale distribution in online markets (Korean e-marketplace)	Mobile channel adopters search more products, but they are less likely to buy "tail" products	Mobile channel orders are more focused on 'head' products and overall impact wasn't obvious
Ba <i>et al.</i> (2022)	Effect of mobile app adoption on customer behaviour (for hotel group in China)	Following app acceptance, users choose less discounted options, book rooms sooner, and search less	Adoption of an app results in more revenue, more frequent purchases, and a decline in search volume. After app adoption, price-sensitive users are more likely to experience reduced search intensity
Reeck <i>et al.</i> (2023)	Effect of app features on app adoption and consumer decisions		The integration of multiple feature decisions, increased consumer decisions (decision noise reduction) and the prominence of individual features

2.4.2. Mobile App(s) Usability

The most prominent definition of usability is derived from the International Standard Organisation (ISO) quality standard, ISO 9241-11 as "the degree to which a product or system can be used by intended users to achieve goals with effectiveness, efficiency and satisfactions within a specific context" (International Standard Organisation, 1998; European Committee for Standardization, 2018; Bevan *et al.*, 2015). However, for understanding the user's attention, the measure that is often used is the cognitive load (Weichbroth, 2020; Harrison, Flood & Duce, 2013; Yus, 2021). Sandesara *et al.* (2022) recently proposed a framework that finds a solution to design and experience the mobile application in specific contexts.

It was found that the younger consumers tend to first view the brand logo, enjoy a minimally designed interface, prefer the dark mode, prefer an easy-to-use application especially when searching, find notifications to be annoying, value reviews and consider language as being potentially important in aiding the user interactions. Usability is a term that is considered very important in the human-computer interaction, thus, highlighting the continued importance in thoroughly understanding the concept and impact it has on people (Bhandari *et al.*, 2017; Michailidou *et al.*, 2021; Kumar *et al.*, 2018; Zaki & Islam, 2021; Bevan *et al.*, 2016; Goldstein & Hajaj, 2022; Wiese & Humbani, 2020; Boateng, 2019).

A number of methods have been utilised over the years to measure usability in a number of contexts. The Kano model measures specific attributes that elicit positive and negative feelings in the customers

through subjective and objective perspectives. The Kano model is just one method for assessing the qualities of a mobile application. Another is the System Usability Scale (SUS) which also uses self-reporting to measure perceived usability (Lewis & Sauro, 2009; Kano, 1984; Huang & Guan, 2012; Ho & Tzeng, 2021). This measure has been widely used to test perceived usability as a function of various independent variables (products, mobile apps, mobile platforms, etc.) (Lewis & Sauro, 2021). Although both are valid and reliable models to measure usability and mobile application quality, they utilise subjective measures only.

Multiple studies have developed different methods and models to measure and understand usability in the mobile devices. Hornbaek (2006) reviewed a variety of different papers to establish the common ways to measure the usability specifically through measuring the metrics of the efficiency, effectiveness, and satisfaction. The review found that effectiveness should measure the outcomes, and it is often objectively measured through expert assessment and comprehension, whereas the subjective measures use the users' perceptions of the outcome.

Efficiency and effectiveness look at the interaction process that users have with the interface. These objective measures focus on time, the usage patterns and the learnability on specific tasks, whereas the subjective measures include subjectively experienced duration, mental workload and the perception of task difficulty (Hornbaek, 2006:96). Finally, the satisfaction metric focuses on the users' attitudes and experience. The objective measures look at physiological usability and reflex responses while the subjective measures look at validated questionnaires (Hornbaek, 2006:96-97). More recent research looked at applying usability to mobile application.

2.4.3. The UXEM Model Metrics

For this study, the paper by Saleh *et al.* (2020) was used to quantify the usability concept and metrics. A paper by Saleh *et al.* (2017) investigated the different models that had been utilised to measure the usability of mobile applications and how successful the model can be measured by automated tools. The Mobile Application Usability Evaluation Metrics (MAUEM) model extends the People at the Centre of Mobile Application Development (PACMAD) model of usability and used the Goal Question Metric (GQM) to identify the most optimal metrics to improve the usability attributes (Saleh *et al.*, 2017). Saleh *et al.* (2020) established a later model that specifically used subjective and objective measures to look at efficiency, effectiveness and satisfaction based on previous models including the MAUEM model and the original ISO definition of usability. The model aimed to develop an automated tool to measure user experience on a mobile app. This was established to better understand user experience and was thus, coined as the User Experience Evaluation Model (UXEM) (Saleh *et al.*, 2020).

These metrics within the UXEM model are each calculated and measured in relation to mobile application usability (Saleh *et al.*, 2020). Efficiency is defined as the ability of a user to complete a task with speed and accuracy. To simplify, it is the time taken to accurately complete a task. Effectiveness is defined as the ability of a user to complete a task in a given context, i.e., it is the effort taken to successfully complete a task. Satisfaction is defined as the users' perceived level of comfort and pleasure, or a user's perceived fulfilment of one's expectations and needs (Weichbroth, 2020:55569; Alturki & Gay, 2017:100; Hornbaek, 2006:82-85; Harrison *et al.*, 2013:4; Bevan *et al.*, 2016; Bevan *et*

al., 2015) which can be simplified to the users' willingness to use the system. The time and exertion metrics within the effectiveness and efficiency definitions were utilised in the final proposed model.

The paper established the usability evaluation metrics for efficiency, effectiveness, and satisfaction to measure the user experience (Saleh *et al.*, 2020). The paper outlined the metric as follows:

Efficiency can be measured through task time (time duration from when participant presses start to end), task success percentage (number of successful tasks completed by subject, user's navigated path vs pre-determined path), and productive period (proportion of experiment time not spent on problems, obtaining help, and time of interruption (task time- (interruption time + time on help) = prod time)). The term is defined as the resources a user utilises to accurately complete specific goals (Ferreira *et al.*, 2020). A study by Ferreira *et al.* (2020) found that there is statistical significance in the adoption of the abort operation mechanism and that it does not improve user efficiency in terms of interactivity. It was also found that the abort operation mechanism improves user efficiency in terms of speed (Ferreira *et al.*, 2020). A highly efficient system require a little input from the users to obtain maximum output. Khamaj *et al.* (2019) found that respondents stated that it should take a minimal amount of time to complete a task on a weather interface, and the limited operational steps are key to limit the time taken to complete a task. Supporting this sentiment (Khamaj *et al.*, 2019).

Effectiveness can be measured through a number of navigational steps (number of fixation points during experiment), of errors (errors a participant makes when attempting to complete an experiment or looking at incorrect fixation point), of touches (on mobile touch-screen, participant makes when attempting to complete an experiment) and / or of navigational error count differences between the user's navigational path and the pre-determined path during experiment). Effectiveness is defined as the extent to which the users are able to adequately achieve a desired goal with ease and accuracy (John & Marks, 1997; Ferreira *et al.*, 2020).

A study by Alexander *et al.* (2021) focussed on the effectiveness of different cultures on different culturally congruent website designs. They found that the users can more effectively complete tasks on culturally congruent websites (i.e. Chinese users are less effective when navigating and using a Western designed website designs) (Alexander *et al.*, 2021). Another study by Khamaj *et al.* (2019) examined the effectiveness of the weather apps. The feedback suggests that the interface of a weather application can be optimised through the focus on the most important features to enhance consumer experience (Khamaj *et al.*, 2019).

Satisfaction looks at the users' subjective rating of the application after the use of the application. The UX Questionnaire was used in the study by Saleh *et al.* (2020). The users were asked about the ease of use (attitude towards operational easiness of prototype), the functions and capability expectations (satisfaction level towards precise, readable and explicit information, features and capabilities of prototype) and the average work load (attitude towards required workload and maintaining work progress).

A study by Luna-Perejon *et al.* (2019) aimed to address the way in which user satisfaction in terms of usability and playability through an app impacted smoking cessation. The study found that the motivational messages had a good satisfaction rate and that the other functionalities of a mobile device could hinder message reception (Luna-Perejon *et al.*, 2019). Another study found in regard to the most

used questionnaire when evaluating satisfaction and a number of other factors of a mobile health app; general questionnaires with less items but higher reliability were used by the researchers more frequently. The questionnaires such as the system usability scale were used by most papers within the mHealth space (Hajesmaeel-Gohari *et al.*, 2022). The study by Sibarani (2021) sort to measure the level of student satisfaction when using an E-Learning application. It also used self-reporting methods and found that the levels of satisfaction differed for each dimension of the app (Sibarani, 2021).

Multiple studies have reviewed or utilised previous metrics and measurements to study the usability of different systems (Hornbaek, 2006; Harrison *et al.*, 2013; Weichbroth, 2020; Bevan *et al.*, 2016:270-272). Sauer *et al.* (2020) found that a combination of dimensions of the usability concept (i.e., efficiency, effectiveness, satisfaction) allows a broader range of collected data, thus there are more reliable results. Thus, an adjusted UXEM model approach was used in this study to measure usability through the efficiency, effectiveness and the satisfaction metrics in accordance with the original ISO 9241-11 definition of usability.

The usability of a mobile application is important to comprehend and measure how the consumers experience and interact with the application. For marketers, these give unique insights to influence consumer behaviour and improve the customer experience. Creating a comfortable environment for the consumers is important to facilitate a prolonged experience with the mobile app. The next section details the literature pertaining to the visual fatigue which can impact consumer well-being when interacting with a system for a prolonged period of time. Visual fatigue, other fatigue metrics and the metrics to measure visual fatigue are outlined in this section.

2.5. VISUAL FATIGUE

Over the years, the increase in dependency on technological devices has encouraged research on a number of research topics with the most recent literature pertaining to visual fatigue. Visual fatigue is defined as the digital eye strain due to the impact of long-term electronic screen usage. It specifically refers to a decrease in the performance of the human visual system due to uncomfortable light sources and long-term visual tasks (Xie *et al.*, 2021: 35915; Kaur *et al.*, 2022; Wang *et al.*, 2018a; Vinnikov *et al.*, 2016; Guo *et al.*, 2020). It is important to understand how visual fatigue potentially impacts long-term usage and how brand marketers can improve the mobile apps to sustain consumer brand alignment.

2.5.1. Other Fatigue Metrics

Although the focus of this paper was on visual fatigue, it is also important to note the other studies that have been done to understand how other measures of fatigue impact the consumers. The other types of fatigue include but are not limited to computer work fatigue, general human fatigue, mental fatigue and feature fatigue. These other fatigue related concepts are often also adjusted to aid in measuring visual fatigue. Fang, *et al.* (2022) used both subjective and objective methods to understand computer work fatigue. Human fatigue was also found to negatively correlate to illumination and colour temperature thereof, on the computer. Zhao *et al.* (2020) found that both the eyes and the mouth are important features in fatigue detection in drivers.

Yamada and Kobayashi (2018) proposed a model to detect mental fatigue in the people of all ages within a natural viewing situation. Mental fatigue was found to have an effect on the way people watch and engage with innately watching video clips. Another study investigated mental fatigue in the construction workers to understand how to mitigate decreased performance and safety concerns on the site. This study much like the current study utilised a combination of blink behaviour, pupil measures and gaze point metrics to measure mental fatigue (Li *et al.*, 2020a). The term feature fatigue was developed by Thompson, Hamilton and Rust (2005) to define the addition of too many features which complicate use and therefore decreases product usability. This term helps to encompass both usability and capability to understand the user satisfaction of a product (Thompson *et al.*, 2005; Fu *et al.*, 2020).

2.5.2. Models Investigating Visual Fatigue

Wang *et al.*, (2018b) developed an integrated and accurate eye fatigue assessment model using eye tracking technology. They developed a model that used a number of different methods to collect information about visual fatigue, the first being one that used eye tracking technology to understand eye movement data (blink data, pupil diameter, accommodation response, and other optometry metrics). This aided in assessing if the users were suffering from eye fatigue and the extent to which they are visually fatigued. The other used methods included but were not limited to a subjective self-reporting metric to understand perceived visual fatigue and an EEG equipment to understand brain activity during a specific task (Wang *et al.*, 2018b).

Multiple studies investigated visual fatigue within a number of different circumstances. Kuze and Ukai (2008) found that the most significant factors when evaluating visual fatigue are general discomfort, nausea and headache factors. It was also found that general discomfort and nausea were greater in head mounted display usage compared to television usage. Xie *et al.* (2021) utilised a multidimensional approach to better understand visual fatigue when using tablets in a dark or light mode at night. The study found that reading in the dark mode reduced visual fatigue through measuring changes in the blink rate and in pupil accommodation, contrary, to the findings from self-reporting surveys.

Yu and Akita (2020) found that the low luminance ratios in accordance with the ambient lighting help to reduce visual fatigue and increase legibility. Li *et al.* (2021) conducted a study to understand the reading effectiveness on the mobile phones. It was found that the visual fatigue in the paging mode is lower than in the vertical scrolling mode. Lin *et al.* (2019) showcased that a solid interface demonstrated better accuracy and usability and less visual fatigue in comparison to the touch interface of the mobile devices. Kim *et al.* (2017) were able to establish the impact of smart mobile device viewing as well as visual fatigue and discomfort. The findings indicate that the excessive levels of the mobile device usage (more than 2 hours a day) significantly worsens visual fatigue (Kim *et al.*, 2017:390-392).

Ren *et al.* (2022) found a significant correlation between visual fatigue and the working hours. They also established a method to minimise the workers visual fatigue through longer rest time and shorter working time. Wang *et al.* (2018a) proposed a model to use both subjective and objective fatigue to predict long-term visual fatigue measurement through short-term measurement. This model helped to establish that visual fatigue increases with increasing time. Visual fatigue not only impacts comfort and

productivity, but it also causes harm to one's health, wellbeing and productivity, thus validating the need to further research this concept (Lambooj *et al.*, 2009).

2.5.3. Measuring Visual Fatigue

The majority of the studies that have investigated visual fatigue have either used subjective, objective or physiological measures. The Critical Flicker Fusion Frequency (CFFF) is defined as a measurement of visual fatigue when there is prolonged exposure to a digital medium. This measures the frequency at which the flickering light can be perceived as continuous (Priya & Subramaniyam, 2020; Mankowska *et al.*, 2021; Yu & Akita, 2020; Lin *et al.*, 2022). A more recent study by Singh *et al.* (2023), however, found that the CFFF cannot be considered as a useful surrogate for symptoms of visual fatigue, but this was based on a comparison to subjective measures of visual fatigue. The most popular and recent method that is used by the researchers is the consumer neuroscientific metrics that are utilised to understand the impact of visual fatigue (Fang *et al.*, 2022; Lin *et al.*, 2022; Li *et al.*, 2021; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022).

This section outlined all the relevant literature pertaining to visual fatigue, as well as other fatigue metrics and the measuring of visual fatigue metrics. Understanding and measuring visual fatigue is important for the marketers and for the businesses who aim to ensure that the consumers enjoy their experience with a system leading to subsequent visits and recommendation about the system or brand to others. While prior studies focused on subjective methods of measuring visual fatigue, this study will measure visual fatigue through consumer neuroscience techniques such as eye-tracking. The next section of this paper pertains to the literature about consumer neuroscience in terms of an overview of common consumer neuroscience techniques and how prior studies have utilised these methods. Eye-tracking is also explained and how it has been used in prior studies in conjunction with visual fatigue studies.

2.6. CONSUMER NEUROSCIENCE

Consumer neuroscience encompasses a number of different neuroscientific software, metrics and methods to understand consumer behaviour. In the current study, eye tracking technology was utilised to understand the amount of effort that the visual processing system goes through to better understand the point at which visual fatigue sets in. This section details both consumer neuroscience (the broader concept by which eye tracking falls under), the eye-tracking metrics and the studies that utilise eye-tracking metrics to measure and understand visual fatigue.

2.6.1. Overview of Consumer Neuroscience

This method of marketing research aids in finding certain information, which is intrinsically in the minds of the consumers. The study sought to understand the desires of the human mind so as to directly

reach the consumer's desire, need and longing thus bridging the gap between the societal cognitive changes (de Sousa & Macêdo, 2020; Shalender *et al.*, 2022). A study by Marqués Martínez (2021) showcased the application of neuromarketing and sensory marketing through the technological industry, testing multinational conglomerates of technology like Microsoft and Apple and platforms such as Netflix to better understand the conscious and the subconscious impact of visual and audio stimuli on brand recognition (Marques Martinez, 2021:53).

Consumer neuroscience has over the years aided in uncovering the subconscious processes involved with consumer decision making that assist the brand marketers in gathering a deep understanding of consumer behaviour. Prior research in this field has looked at advertising stimuli and communications, branding and product attributes, emotional responses and reactions, decision making processes and other areas in marketing research (Haidinger & Koller, 2023; Harris *et al.*, 2018; He *et al.*, 2021; Niedziela & Ambroze, 2021; Sánchez-Fernández *et al.*, 2021; Oliveira *et al.*, 2022). It is an important subsection within the marketing research world that adds a deeper and more accurate meaning to the data obtained by the studies.

Multiple other studies have utilised neuromarketing methods to better understand what drives the consumers with a particular focus on why the consumers react to certain stimuli and how that impacts decision making (Plassmann, Ramsoy & Milosavljevic, 2012; Rupini & Nandagopal, 2015; Ramsoy, 2020; Haidinger & Koller, 2023; Sánchez-Fernández *et al.*, 2021; Oliveira *et al.*, 2022; He *et al.*, 2021; Niedziela & Ambroze, 2021). Although utilising a number of neuroscientific techniques creates a more robust study, due to limited resources and availability of participants, it was not possible to implement with this study. There are a number of tools that are used by the neuromarketing experts to quantify how physiological activity is impacted from certain experiences. These tools and techniques are used in consumer neuroscience to measure, map and understand consumer reactions to expose varying stimuli (Marques Martines, 2021; Sánchez-Fernández *et al.*, 2021). These tools measure activity within the brain and in the peripheral nervous system. For this study, eye tracking technology was utilised to gain a better understanding of how to successfully apply visual cues to influence continued usage through limiting the experienced visual fatigue and usability issues.

2.6.2. Eye Tracking

Sight has allowed humans to interact, process, understand and process visual information/ stimuli and is used as one of the earliest neuroscientific measures used to better understand consumer behaviour through pupillary responses to understand affective processing (Hess & Polt, 1960; Hess, 1965). In fact, studies investigating the eye and the various related systems that help the eye to communicate visual information to the brain have been researched since the 17th century (Fletcher *et al.*, 2022:16; Hessels & Hooge, 2019; Valtakari *et al.*, 2020). The eye-mind link is the main reason why this method has been used so extensively to understand the allocation of visual attention. The eye-mind link basically explains that due to the visual system, effort is required thus non-conscious processing is needed to actively focus attention (Carter & Luke, 2020).

Eye tracking is used to study the capability of the eyes and the visual system to be able to process visual information, thus allowing for inferences to be made about the fundamental neurological or

psychological elements that impact the central nervous system and can be used to better comprehend an individual's views and objectives (Graham *et al.*, 2022:2-10; Fletcher *et al.*, 2022; Motoki *et al.*, 2021; Hessels & Hooge, 2019; Valtakari *et al.*, 2020). Eye tracking is one of the most cost effective, accessible and non-invasive neuroscientific measures used to understand consumer behaviour. Specifically looking at human-computer interaction, eye movement is used to quantify information about aspects of cognitive processing when interacting with devices (Graham *et al.*, 2022:3-8; Carter & Luke, 2020; Li *et al.*, 2024).

Pupillary response behaviour is one of the many measures derived from eye tracking that have been used to better understand consumer reactions and responses to stimuli stemming from the non-brain parts of the body to infer a change in neurological function. Eye tracking is defined as the analysing of consumer behaviour through general eye movement and fixation as an indication of voluntary and involuntary attention (Daugherty & Hoffman, 2017:7).

Researchers have used eye-tracking to understand a variety of different concepts and topics pertaining to consumer behaviour, specifically, in the realm of visual attention, tourism and hospitality, medicine, education, human performance as well as the usage of new technology (Brunye *et al.*, 2019; Clay *et al.*, 2019; Harezlak & Kasprowski, 2018; Carter & Luke, 2020; Li *et al.*, 2020a; Hessels & Hooge, 2019; Valtakari *et al.*, 2020). This study specifically used eye-tracking technology to understand how an m-commerce application is engaged with by the consumers and thus how the interplay of usability and visual fatigue impacts long-term usage of the application.

2.6.3. Eye Tracking and Visual Fatigue

Although other metrics to measure visual fatigue have been used for many years, more recent papers have utilised the eye-tracking technology to understand how visual fatigue impacts consumer behaviour (Souchet *et al.*, 2022; Tang *et al.*, 2024; Peker *et al.*, 2021; Hirota *et al.*, 2019). This section outlines the various studies that have utilised eye-tracking metrics to measure visual fatigue experienced by consumers. Fang *et al.* (2022) utilised eye tracking methods to better understand visual fatigue. They found that in a state of fatigue, the pupil diameter tends to decrease and the oscillation of the pupil size increases. This was processed into a time-series figure to better visually understand the data (Fang, *et al.*, 2022:12-14).

These researchers also proved that the dispersion of fixation expands while the number of fixation points decreases with fatigue and that the degree of gaze dispersion decreases as fatigue increases (Fang *et al.*, 2022:12-14). Another study used fixation time and fixation count to investigate the depth of visual information processing as well as gaze accuracy and gaze precision to understand gaze attention (Lin *et al.*, 2022). Fixation dispersion in terms of the fixation count has been used by a number of studies to measure cognitive workload, visual fatigue, mental fatigue, visual discomfort and general fatigue (Llanes-Juado *et al.*, 2020; Fang *et al.*, 2022; Wang *et al.*, 2019; Urruty *et al.*, 2007; Zhang *et al.*, 2024; Jiang *et al.*, 2017; Lin *et al.*, 2022). Within these aforementioned studies, the researchers' utilised a number of time and frequency metrics (namely fixation dispersion) to understand visual fatigue, which will also be utilised in this study.

Prior studies have also identified older participants as having smaller pupil diameters thus impacting a comparison of pupil diameter before and after the exposure to a visual stimulus (Guillon *et al.*, 2016; Koo *et al.*, 2018). One study by Feng and Chen (2021) used the fixation frequency and the saccade amplitude to quantify visual fatigue. The fixation frequency is defined by the authors as the frequency of fixation events in a specific task and the saccade amplitude as the distance from one fixation to the other. The study found that the fixation frequency was best used to measure visual fatigue during the search task (Feng & Chen, 2021). They also found that the saccade amplitude is best measured in the exploration tasks.

Most studies use frequency as an indicator of visual fatigue. The research is built on the basis that lower blink frequencies are due to drier eyes and higher visual fatigue (Li *et al.*, 2021; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018; Bafna *et al.*, 2021). It was found by Bafna *et al.*, (2021) that when the network within the brain determines that the reward from an ongoing task does not meet expectations dopamine levels reduce resulting in fatigue and a reduction in blink rate. Kołodziej *et al.* (2020) found that blink duration was increased when in a state of fatigue while engaging with office work. The change in pupil diameter is also another common eye tracking measurement that has been used to measure visual fatigue (Fang *et al.*, 2022; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022). As visual fatigue sets in, the pupil diameter will continuously decrease as a user is exposed to a specific visual stimulus over time. It was also found that viewing time and the pupil diameter have a negative relationship (Koo *et al.*, 2018). These metrics quantify the effort done by the visual system to process stimuli. From the above literature the following hypotheses were drawn:

H1: There is a statistically significant association between Visual Fatigue and Usability of an e-commerce mobile app.

H1a: Visual fatigue as measured by the pupil diameter over time, is inversely related to efficiency as measured by the productive period.

H1b: Visual fatigue as measured by fixation dispersion is directly related to effectiveness as measured by the number of touches.

H1c: Visual fatigue is directly related to user satisfaction.

This section of the literature review has detailed and outlined the consumer neuroscience techniques generally utilised with a specific focus on the eye-tracking methods and the prior studies combining visual fatigue and eye-tracking phenomena. This unique method within marketing research seeks to understand how the consumers understand visual stimuli. It is important for the marketers to understand how consumers react to visual stimuli so as to understand how to best deliver the brand objectives. The next section sought to grasp the current knowledge about visual complexity. The next section specifically looks at how stimuli and information are processed by people, which is an explanation of visual complexity. The GMUIs and how visual complexity and the GMUIs interact are also explored.

2.7. VISUAL COMPLEXITY OF MOBILE INTERFACE DESIGN

Visual complexity is another important term in the world of user interface design and HCI. It is especially important in the world of interface design because it pertains to how visual stimuli is presented in the scenario of a software interface (Wang & Hsu, 2020). This section of the literature unpacks the processing of visual stimuli, visual complexity, interface design, GMUI and the visual complexity within the GMUI.

2.7.1. Processing Stimuli and Information

Everyday humans process information around them to better understand and comprehend the world around them. How people process information has been of particular interest to many researchers so as to better understand the cognitive function and the decision-making processes, people utilise on a daily basis (Niechwiej, 2004; Stone, 1971; Villena-Gonzalez *et al.*, 2016; Van der Meer *et al.*, 2012; Van Rullen & Thorpe, 2001; Adaval *et al.*, 2019; Wickens & Carswell, 2021).

Attention has been the main focus in regard to information processing as it can be easily quantified and it is considered as being important in understanding what leads to decisions making. Experience is often another factor that influences how decisions are made, and it is based on prior knowledge or events (Niechwiej, 2004; Villena-Gonzalez *et al.*, 2016; Sheikhi *et al.*, 2021; Bowins, 2022). Marketers create advertisements that grab attention through visual communication strategies and thus they make consumers visually process and interact with them. Within the online context, a well-functioning and satisfactory user experience can encourage consumer loyalty and purchase intentions (Andronie *et al.*, 2021; Mishra *et al.*, 2020; La Źa Źoiu *et al.*, 2020; Barari & Surachartkumtonkun, 2020).

The information within the focus of attention is often processed more efficiently and quicker (Lee, 2018; Adaval *et al.*, 2019). Prior research also investigates the different types of attention when processing and interacting with marketing media, saliency of a visual stimuli and how that impacts attention all to improve the advertising data (Faggi *et al.*, 2023; Rumpf *et al.*, 2020). More recently, research has focused on how the consumers interact and understand a graphical user interface of a technology such as a website or mobile application. The visual stimuli of a software interface is of importance as it is one of the first things the users notice when entering a website and if it is too visually complex, this might negatively impact consumer behaviour (Lavie & Tractinsky, 2004; Harper *et al.*, 2009; Jylh  & Hamari, 2020; Deng & Poole, 2010).

2.7.2. Visual Complexity

Kumar *et al.* (2018) define visual complexity as the visually perceived richness stemming from the presence of various app visual features such as size, shape, colour, pattern, composition and type. One of the earliest definitions of visual complexity focused on the number of individual elements in an image, thus implying that more complicated images would have more constituent elements (Huhmann, 2003). Visual complexity is a characteristic of stimulus appearance that is determined by the number and variety of visually distinguishable elements. High levels of complexity were found to be associated

with increased reading effort (Miniukovich *et al.*, 2018). Moderately complex stimuli are often preferred over simple or overly complicated ones (Wang *et al.*, 2020; Riegler & Holzmann, 2018; Wang & Hsu, 2020).

Wang *et al.* (2020) investigated the impact of website background complexity on the consumers' visual processing and concluded that the two are inseparable. They also discovered that the consumers are helped the most in their understanding and processing of product information when the images of those products have a moderate background complexity (Wang *et al.*, 2020:275-279). Applying imaginative storytelling has been shown to enhance the user experience of online shops and boost their allure in terms of explicit and implicit information processing. This suggests that the way data is presented is crucial and should be taken into account when developing an e-commerce system (Karampournioti & Wiedmann, 2022; Teufel & Nanay, 2017).

M-commerce relies on aesthetically pleasing design elements and components to preserve usability (Ahmad & Ibrahim, 2017:70; Molinillo *et al.*, 2022:8; Tang, 2019). The majority of the retail apps have succeeded with interfaces that possess a minimalistic, simple and straightforward graphical user interface. Mobile webpages are also known for their pragmatic, goal-oriented nature (Raphaeli *et al.*, 2017; Barari & Surachartkumtonkun, 2020). Young adults have come to rely on social media for their daily dose of news and purchase recommendations. Since smartphones require instantaneous decisions, it is thus crucial that the apps present information in an appealing and easy to understand manner (Jiang & Song, 2022:10; Molinillo *et al.*, 2022:8). Visual elements are used for marketing campaigns through the available interface to grab consumer attention and convey offerings (Jain, 2018:5; Correia, 2017:2).

2.7.3. Graphical Mobile User Interface (GMUI)

The term "graphical user interface" or "GUI" is used to describe the visual layout and the style of a software program, website, or operating system. Especially as technology evolves and develops over time, usability and interface complexity are crucial concepts in HCI (Qi & Xue, 2020; Jansen, 1998; Alemerien & Magel, 2015). Soui *et al.* (2022a) have recently developed a system to automatically assess GMUI. The researcher determined that the aesthetically flawed GMUIs contributed to the overall poor usability and persisted even after troubleshooting issues were resolved. The arrangement of a system's visual elements needs to be presented in a way that facilitates the easy execution of commands by the users (Soui *et al.*, 2022a; Soui *et al.*, 2022b). The elements of a GUI may include, but are not limited to text, colour, buttons, icons, menus, widgets, windows, input fields, choosers, and the computer mouse. Each of these elements contributes to the final, usable product's optimisation and quality (Oulasvirta *et al.*, 2020).

2.7.4. Visual Complexity in GMUI

The GMUI refers to the GUI of a mobile software. The GMUI elements such as windows, menus and the icons aid users in performing actions. When created attractively, the user interface should adapt to the users, as well as process information and facilitate interaction (Jylhä & Hamari, 2020). The visual elements play a key role in mobile applications to aid usability, fulfil consumer needs, provide

functionalities and engage user satisfaction. Visual complexity is linked to aesthetics, and it has a strong impact on the users in terms of initial impressions, comprehension and user productivity (Dubois *et al.*, 2022; Deng & Poole, 2012). When the optimal level of visual complexity is present, user pleasure will greatly increase, and a moderate level of visual complexity is preferred. These two concepts also have an inverted relationship (Gou *et al.*, 2022).

Visual complexity is often quantified by the number of elements that are present in a graphical user interface. A study by Corral *et al.* (2021) found that even the user interfaces with many elements and deep hierarchy could still appear simple and easy to use for the users but they are dependent on the easy to maintain development framework, used to create a user interface composition. The most common visual hierarchy is a horizontal layout whereby the screen is split through horizontal lines and the main elements are aligned from the top to the bottom of the whole screen (Jiang *et al.*, 2019; Corral *et al.*, 2021).

Visual cohesion refers to the level of interrelatedness of the components of a user interface within the visual layout. This combines the semantic, the structural and the aesthetic aspects of a user interface and how they are assorted (Alemerien & Magel, 2015; Soui *et al.*, 2022a). Visual cohesion is important when designing the GMUI of an app through the organisation of the app elements. The three levels of visual cohesion are low, medium and high (Soui *et al.*, 2022a; Soui *et al.*, 2020).

Understanding the visual complexity of a GMUI is crucial since visually appealing design elements and functionality are essential to the viability of m-commerce systems. It is crucial to comprehend how the quantity and kind of features and aspects employed in an interface design might influence the users' perceptions and motivate various behaviours (Minukovich *et al.*, 2018). The effective user interface design is always crucial since it has the ability to enhance system performance as a whole (Punchoojit & Hongwarittorn, 2017). For the study, the number of visual design elements were manipulated to achieve the three different levels of visual complexity. A further discussion of visual complexity in relation to the quantity of visual elements on a mobile webpage follows in the following paragraphs.

2.8. VISUAL DESIGN ELEMENTS

A great visual graphical user interface design has more focus on the design itself whereby they utilise a neat and elegant approach with a unified user interface design to achieve better harmony (Jiang *et al.*, 2019; King *et al.*, 2020; Kim & Lee, 2020:801-803). In simplifying the rote operations such as browsing and completing purchases, the mobile apps can enhance their user experience and display features accurately.

The design of a mobile app and the accurate displaying of essential features was found to have an effect on user behaviour (Wut *et al.*, 2020; Alshaykha, 2022). To better comprehend and enhance a mobile app usability with a focus on tourism, Tak and Gupta (2021) explored a wide range of app characteristics. The aforementioned research highlights visual design, which include an application's aesthetics, attractiveness, and consistency of appearance (Tak & Gupta, 2021:299). Another study by Guo *et al.*, (2022) found that the relationship between user satisfaction and the visual complexity of a mobile website resulted in an inverted U-shape. It was also discovered that an increase in complexity decreased the efficiency of the visual search activities of the respondents (Guo *et al.*, 2022).

2.8.1. GMUI Elements

The visual components of an app are useful because they convey information about the app's features and how they can be used. The colour scheme, visuals, typefaces, texts, animations, and the overall structure of a mobile app all contribute to its visual design (Tak & Gupta, 2021). Specific GMUI elements are used to translate and organise different information and direct consumers to the desired outcomes. Visual cohesion utilises the organisation of the GMUI elements to quantify visual complexity (Soui *et al.*, 2022a; Soui *et al.*, 2020; Soui *et al.*, 2022b). While previous studies focused on desktop interfaces and how visual elements impact user experience, the present study will address mobile-specific app elements. For this study, only colour, text and typography, as well as shapes and icons were changed to keep the consistency within the study and through that, the layout was indirectly changed. The visual aspects of advertisements utilise colour, messaging, layout and pictorial references to emphasise the design intention, communication and to catch the attention of the potential consumers (Jain, 2018:5; Correia, 2017:2).

2.8.1.1. Layout

An interface's layout describes the arrangement of its various components such as the images, text, icons, headers, and graphics. It also addresses how well the components are laid out to guarantee usability and effective navigation (Harris & Goode, 2010; Moran *et al.*, 2018). Mobile app design is unique from website design and thus, there is less room to incorporate the necessary components to achieve particular user goals. The common mobile screen layouts separate the menu, the navigation bar, and the content area (Alqahtani *et al.*, 2015). The visual design and the layout of a user interface should work together to improve consumer behaviour.

The consumers' impressions of an app's quality are heavily influenced by the GUI's visual appeal. Some common layout styles for the GMUI design include the horizontal and the non-horizontal layout. The most common GMUI layout among popular mobile apps is horizontal (Jiang *et al.*, 2019). Calculating the Number Of Layouts (NOL) event is also important to understand the size and complexity of the user interfaces in a mobile app. The NOLs are defined as the number of structural elements to organise the views in a screen (Corral *et al.*, 2021). In some cases, the layout is considered to be the same as the aesthetic.

There are two types of aesthetics, the classical and the expressive. Aesthetic value is used to understand the visual techniques that are used in the arrangement of the layout components. The classical aesthetic is defined as the "ordered" and clear design aesthetics while the expressive aesthetic is defined as the creative or original design aesthetics (Bhandari *et al.*, 2017:527; Jylhä & Hamari, 2020; Welhausen, 2018). The classical is perceived as having an even distribution of elements by the users and the expressive is perceived as being more dispersive and being dependent on contextual stimuli. All the elements, namely the text, images, colour and layout must thus work cohesively together to aid in establishing a mobile app's visual style. Dividing up the hierarchy facilitates a more detailed user interface (Qi & Xue, 2020; Bhandari *et al.*, 2017:527; Jylhä & Hamari, 2020; Gretalita *et al.*, 2017).

2.8.1.2. Colour

The impact a brand's colour has on consumer decisions has been investigated in many studies and particular focus has been on the hue, value and the chroma to establish a more specific answer to how different colours impact consumer purchases and decisions. Colour has been found as one of the main attributes of marketing visual communication leading to a high majority of purchase decisions (Batra, 2016:40; Anwar *et al.*, 2020; Martinez *et al.*, 2021; Won & Westland, 2018). The colour of a brand in terms of name, product and packaging can be used harmoniously to successfully gain a strong position in the markets (Kauppinen-Räsänen & Jauffret, 2018; Hajdú, 2021). The basic principles of colour are hue, saturation and value. The hue is the wavelength that each colour represents. Saturation describes the intensity/ pigmentation amount of the colour. Value refers to the brightness of a colour, that is, whether it is dim or bright. Various studies have explored how these basic principles impact people's perceptions and thus, consumer decision making (Batra, 2016; Kumar, 2017; Kovač *et al.*, 2019; Martinez *et al.*, 2021).

There was a correlation found between the colour of a website's background, user's perception of the site and their level of satisfaction with it (Lindgaard, 2007; Hall & Hanna, 2004; Bhandari *et al.*, 2019). The biases and associations attached to certain colours have been developed over time to become intrinsic thoughts and consumer preferences based on associations within one's subconscious mind (de Sousa & Macêdo, 2020:416; Noémi, 2021). Silvennoinen (2014) found that the use of colour can enhance the hedonic and pragmatic qualities of both productivity and leisure-focused mobile apps. Similarly Lupanda and van Rensburg (2021) state that the mobile user interface (UI) element readability depends on colour choice.

To improve the readability for low-vision users, an app should use primary, secondary, and accent colours with enough colour contrast while the font legibility was dependent on the font-background contrast (Lupanda & van Rensburg, 2021; White *et al.*, 2021). Colour information is typically sparse on the mobile interfaces. When making a purchase or being hesitant about a purchase, knowing how a product or service appears can be a deciding factor (Won & Westland, 2018; Anwar *et al.*, 2020; Atria & Singh, 2021). To enhance usability, colour must cooperate with the other GMUI components to create a unified design.

2.8.1.3. Text and Typography

To improve the appeal rate and the visual communication effect of a mobile app, the text design should be considered carefully. Processing information and text is often done in combination with the other visual elements, i.e., graphics and colour (Fan & Li, 2020). As stated by Séguinot (1994: 253). Rettenmaier *et al.* (2020) and Smith (2008:54), found that the goal of cleverly arranged typographical characteristics (i.e., text, colour, and white space) is to impose a path of reading to leave a clear message. The typeface of a website refers to the specific style and font that are used for the site's textual content. Certain typefaces can draw in customers and help unify a brand's visual identity. Using larger font sizes in the UI design of a mobile app creates the illusion of depth and emphasises the importance of text and other page elements (Qi & Xue, 2020:92). Despite its significance to the user experience, it is often overlooked as an element of a successful mobile branding strategy.

The impact of typeface on consumer responses and visual communication highlights the significance of maintaining cohesion between text, fonts and the brand's personality (Magrath & McCormick, 2013:105). A study investigated how visually salient information effected the reading process. The researchers found that using boldface to highlight key concept terms aided the participants in identifying and remembering the incorrect key textual concepts accurately (Wut *et al.*, 2021:152-155). Although boldface was focused on in this study, it demonstrates the impact that other typographies could have if used to mark visually salient information. This also shows how visual salience impacts advanced cognitive processing such as reading text (Wut *et al.*, 2021:152-155).

2.8.1.4. Shapes and Icons

Icons and other graphical elements are typically utilised for aesthetic purposes or to facilitate usability and navigation. Web pages with more of these visuals were found to be more appealing to the eye, simplified navigation, impact purchase intention and required more mental effort from visitors (Michailidou *et al.*, 2021; Michailidou *et al.*, 2008; Hung & Wang, 2021; Patel *et al.*, 2020; Hwang 2020). Iconic shapes and graphics reinforce a brand persona and encourage customers to have a positive attitude toward the business. Graphical controls such as buttons, menus, checkboxes, and the tab bar are all examples of shapes. The term "icons" is used to describe the mouse pointer, the company logo, and the other graphical symbols and buttons such as the "home" button (Magrath & McCormick, 2013:106). Another name for icons is pictographs.

The ten most important aspects of icon design in the GMUI were identified in a separate study to be; recognition, colour, simplicity, semantics, familiarity, shape, aesthetic, uniformity, individuality, and concreteness. All were discovered to enhance the user experience and they are crucial in providing the users with accurate information (Kamarulzaman *et al.*, 2020). Liu *et al.* (2021) implemented eye tracking techniques to investigate the effect of app icon design on the users' visual search efficiency. To improve search efficiency and to promote a positive user experience, it was determined that well-designed shapes and icons were necessary. The app icons that used a limited palette were also rated lower for perceived usability and happiness (Liu *et al.*, 2021).

2.8.1.5. Imagery

Creative, unique, symbolic and relevant visuals are able to encourage behaviour change, incite reactions and emotions, as well as create mental imagery, therefore they may influence consumer decision making behaviour (Jain, 2018:8-11; Irani & Frankel, 2020:317). The emotional connections that consumers develop from powerful visual imagery lead to increased positive attitudes or positive behavioural intentions towards the advertised products/services (Seo, 2020:177-179; Escalas, 2004; Gil-Pérez *et al.*, 2020; Wodehouse & Abba, 2016). Visual imagery in an advertisement is also able to enhance the memorability of a message through the picture superiority effect (Nelson, Reed & Walling, 1976). MacInnis and Price (1987) found that through the picture superiority effect, visual information processing contributed to the holistic evaluation of a subject, thus proving the link between the presence of visual images and the message recall (Seo, 2020:178; Lee *et al.*, 2020).

Research has showed a strong relationship between the eye movement in visual imaging and the ocular motor behaviour in actual visual perception (Laeng & Teodorescu, 2002; Hostetter & Alibali, 2019). According to Argyriou (2012), a website's iconic tabs provide little effect on the vividness of the

imagery, even for customers who are more likely to use imagistic processing (based on experiential reasoning) to make a choice. The images' persuasive effects can be affected by their stylistic qualities when recipients are forced to engage in the systematic processing of messages (Seo, 2020:179; Peracchio & Myer-Levy, 2005, Farace *et al.*, 2020; Pizzi *et al.*, 2020).

Imagery can also refer to the combination of text and visuals that is used in a mobile interface to convey all of the necessary information in a way that is straightforward and user-friendly. Authenticity is bolstered and user satisfaction is maximised through the use of relevant, consistent, and up-to-date visuals in a mobile interface (Magrath & McCormick, 2013; Stocchi *et al.*, 2022; Martinez *et al.*, 2023; Parker & Kuo, 2022; Spears & Singh, 2004; Lou *et al.*, 2023). Although used within the current study's application whereby multiple visual elements were changed, the images remained consistent.

2.8.2. Usability and Design

There are a number of different studies that sought to understand how design elements interact in a user interface to optimise usability, similarly to this study. The visual complexity of a mobile interface is measured by the number and the variety of visual elements it contains. Multiple design elements used together can give the impression of clutter and reduce the app's usability (Bashirzadeh *et al.*, 2022; Ramezani & Shokouhyar, 2020; Boardman & McCormick, 2022). Visual usability is a term created by Schlatter and Levinson (2013) and it refers to an app's capacity to be both aesthetically pleasing and highly functional. The main issue these researchers found was that there was a lack of a standard set of practices and a common visual language for designing applications (Schlatter & Levinson, 2013:12-14).

Another study investigated how older adults navigate their various user interfaces. It was found that in general, older adults were more effective with their navigation of a user interface when menus and buttons were present (Li & Luximon, 2020). The users often prefer more graphics than text-heavy apps. In general, users also appreciate a consistent aesthetic that has a coherent presentation of colour, pictures and themes throughout to aid in the usage of the app. Both the search and the menu bar help to facilitate usage and to reduce the time spent on searching (Wei *et al.*, 2020; Gou *et al.*, 2022). Wang and Huang's (2015) research explored the interactive interfaces of the mobile e-books to better comprehend their usability and design. The researchers concluded that consumers place a high value on aesthetics, accomplishment, and friendliness when evaluating an interface's usability.

Furthermore, they discovered that a user's memory and experience are tied to an interface's additional features, thereby emphasising the need for a standardised interface design (Wang & Huang, 2015; Kamaruddin & Sulaiman, 2018). website aesthetics have been found to improve usability and user satisfaction, according to Jongmans *et al.* (2022). In addition, usability and pleasure were found to affect user satisfaction. Later research applied this concept of visual usability to create an intuitive mobile UI. The research concentrated on the layout, colour, typography, imagery, controls, and affordance as specific visual usability tools. These techniques and how they have been incorporated into an interface's design were analysed with the help of the designer experts' comments (Andersson, 2021). Other research also found that usability has a significant impact on visual appeal (Winckler *et al.*, 2016; Jongmans *et al.*, 2022:2100; Liu *et al.*; 2021). Therefore through investigating, the impact of different visual design element of a mobile app on usability and user evaluation, prior research can be strengthened.

2.8.3. Visual Design in UX and UI

Branded applications aim to enhance the consumer perspectives of a brand through their application. Although not the only purpose of the application, a seamless User Experience (UX) is key for a brand to ensure positive consumer perceptions to be formed and the target consumer is satisfied by their experience (Jongmans *et al.*, 2022; Parker & Kuo, 2022; Al-Shamaileh & Sutcliffe, 2023). The visual design of an application plays a key part in the enhancement of a user's engagement with the app. Any system that is easy to navigate, visually appealing and allows easy access to important information has done research to create a high-end user experience for consumers (Lewis & Sauro., 2021).

User experience is the subjective feelings that result from the use of any product or service. The term was first coined by Don Norman many years ago and it is still relevant when designing systems, products and services (Still *et al.*, 2020; Dirin *et al.*, 2023). Since the introduction of the iPhone in 2007, little novelty has been added in the realm of the UX design of m-commerce systems. Most aim to showcase the products of a brand instead of exploring the potential for an experiential marketing platform (Parker & Kuo, 2022; Al-Shamaileh & Sutcliffe, 2023). This is mainly due to the limited growth that is seen from this industry thus brands prefer to focus their time and effort into simply creating m-commerce systems as other touchpoints for the consumer to buy products. There are a number of different mobile application types based on how a brand wants consumers to interact with the brand, the most popular being the sales focus applications which mainly serve to sell items from the app (Parker & Kuo, 2022; Tang, 2019; Blake *et al.*, 2021; Al-Shamaileh & Sutcliffe, 2023).

Understanding UX in the mobile application context has been explored before through the lens of the product life cycles (i.e. the Temporality of Experience (ToE) model and the Path to Long-Term User Experience (PLUX) model) (Dirin *et al.*, 2023; Karahanoğlu & Bakırlioğlu, 2022). It is important to understand how a consumer experiences a system so as to figure out the best way to improve a system and enhance how the users perceive the system and the overall brand that created the system. When done correctly, UX can improve sales, customer retention, market share and other company gains (Mufti & Aprianingsih, 2022; Gulfraz *et al.*, 2022; Barari & Surachartkumtonkun, 2020).

When overwhelmed with visual stimuli and information, the consumers tend to interact less with what is overloading them (i.e. the product, service, system, etc.). Thus, marketers and app developers have to consider the interaction costs and the benefits that certain amounts of interactive user interface (UI) elements have on a user and their attitude towards a brand (Neate *et al.*, 2016; Rosário & Raimundo, 2021; Fu *et al.*, 2020). Ensuring a high-quality UX means engaging the end-users from the early development stages when the UI elements are in the prototype phase. The interface elements are the visual design elements that are tied to a feature which allow user interactions and aid in providing a communication channel between the user and the system (Firth, 2019; de Andrade Cardieri *et al.*, 2018; Gulfraz *et al.*, 2022; Barari & Surachartkumtonkun, 2020).

Thus, from the above literature the following hypotheses were developed:

H2: The visual complexity of a m-commerce app interface has a direct relationship with the usability of that m-commerce app.

H3: The visual complexity of a m-commerce interface directly influences the visual fatigue experienced by the user.

This section of the literature review detailed the visual complexity of a system with specific focus on the mobile graphical user interfaces. It is crucial to make improvements to an excessively complex or simple UI as it may have a negative effect on user engagement or promote it. To effectively fulfil the brand objectives, marketers must comprehend how the consumers respond to visual information and interact with the graphical user interfaces. The next section sought to grasp current knowledge about how consumers behave online. Online and in-person behaviour frequently diverges, thus it is critical to recognise these behavioural differences and further explore online behaviour to gain a deeper understanding of the motivations behind people's activities. The next section specifically looks at information search behaviour, task-orientated behaviour and other online behaviours.

2.9. Behaviour Online

When engaging with systems and software, online consumers tend to exhibit a variety of actions and behaviours. It is important to understand how certain behaviours impact purchase behaviour, usage, adoption and other behaviours that are important for businesses and marketers to consider (Liu *et al.*, 2019). It has been shown that the consumers often act differently than expected as seen in the theories such as the Theory of Planned Behaviour (TPB). The TPB is an extension of the theory of reasoned action due to the limitations of understanding individuals with incomplete actions due to a specific decision. The theory states that a person behaves as intended, and this intention is informed by the attitudes and subjective norms that are experienced by the person (Redda, 2019; Ajzen & Fishbein, 1980; Azjen, 2011; Barth & De Jong, 2017).

With reference to generic online activities and consumer behaviour research theories (namely the privacy paradoxes), the goal is to comprehend specific activities (e.g., social networking and e-commerce) when the behaviour that actually occurs does not meet the theory's expectations. Due to the aforementioned fact that intentions and behaviour do not always match up, understanding specifically measured behaviour in different circumstances is important (Barth & De Jong, 2017; Azjen, 2011). Conducting internet-based experimentation requires the understanding of how people generally behave when processing online stimuli and prior experiments aid in this understanding. Ordinarily, these experimentations can be within a lab setting or through a participant's own device. For this experiment, a lab setting was used and there were two simple tasks to test each participant's experience with the application (Anwyl-Irvine *et al.*, 2021). This section of the literature review investigated prior research on specific online behaviour namely information search behaviour and task-orientated behaviour.

2.9.1. Information Search Behaviour

The consumer decision making process is key in understanding how consumers interact with a brand at different touchpoints. The first step of this decision-making process is the information search. This search can be done online or offline and it is done to aid the consumers in making a more informed decision when making a purchase (Haridasan *et al.*, 2021; Anesbury *et al.*, 2016). When using a retail

website or application, consumers search for basic information to inform their purchases such as but not limited to the price, dimensions, and the available colour, consumers often want to align with the brands and products that represent their personal values (Azzopardi & Van Der Sluis, 2024; Tang, 2019). When searching for potential online purchases, consumers on average visit one to two websites in a month. Online search and comparison behaviour are unlikely to differ compared to the behaviour in-store, thus indicating that consumers make quick decisions when searching online (Anesbury *et al.*, 2016).

Mobile app adoption behaviour often impacts other behaviours such as information search behaviour. The mobile channel adopters search more products, and often focus more on products when compared to the personal computer (PC) channel users. With the availability of information on one's mobile device, searching and considering alternatives occurs more than when using one's PC (Park *et al.*, 2020a). Customers search less, purchase earlier and select options with less discount after app adoption. The reduced search intensity is more pronounced for the price-sensitive customers after app adoption (Ba *et al.*, 2022).

Online consumer reviews often aid one's shopping experience by providing haptic cues and Customer-to-Customer (CTC) interaction thus providing unique information to the consumers (Wang *et al.*, 2023). The reviews and other forms of electronic-word-of-mouth (social media posts, messages, Influencer promotions etc.) information are a form of customer experience sharing whereby a recount of a customer's response and reaction to product interactions occur. Understanding consumer pre-purchase information needs is important for the marketers to improve the customer journey and encourage purchase while adding value (Wang *et al.*, 2023; Mudambi & Schuff, 2010; Fu *et al.*, 2020; Shah *et al.*, 2023).

The overwhelming amount of information online can frustrate and confuse consumers searching for important brand information that is needed to make a decision (Rosário & Raimundo, 2021). The common sources where consumers search for product and brand information include brand websites, social relationship sources (friends, and family), third-part print services, advertisement, social media and the internet. Consumers use mobile channels most often and find the highest level of satisfaction from mobile channels compared to the offline or the computer search channels (Singh & Jang, 2022; Rosário & Raimundo, 2021; Shang *et al.*, 2023). The mobile channel offers the most convenience and satisfaction as an addition to the computer and offline search channels. Enhancing the mobile device experience through shoppable videos and other marketing activities focused on the mobile channel could potentially lead to the generation of satisfaction and brand loyalty (Singh & Jang, 2022; Liu *et al.*, 2019).

2.9.2. Task-orientated Behaviour

The online grocery shoppers have been characterised to be mainly young female consumers with higher incomes. The younger consumers tend to have grown up with the internet and they are thus more familiar with the risks associated with interacting online, thereby resulting in a positive attitude towards shopping online (Anesbury *et al.*, 2016; Dharmesti *et al.*, 2021). Consumers often seek pleasure and functional goals through shopping and that can be achieved through hedonic qualities or the pragmatic

qualities of the product, service or the online environment itself. Pragmatic or utilitarian attributes refer to more task-orientated qualities related to behavioural goals while hedonic attributes refer to self-orientated qualities related to improving psychological well-being (Diefenbach *et al.*, 2014; Tang, 2019; Japutra & Song, 2020).

If an app was found to perform expectantly and was deemed useful in daily life, the consumers would be influenced to continue using the application. At times, one's satisfaction which is felt while engaging with an app can be related to an app's functionality and quality (Tang, 2019; Liu *et al.*, 2019; Andronie *et al.*, 2021). Mobile apps need to provide and enhance value-in-use experience through system functionality to increase customer engagement and usage especially with younger consumers (Zou *et al.*, 2023). Task-orientated behaviour refers to the interaction style the users have with an application and their intention. It specifically looks at the short-term practical goals consumers are motivated by when using a system, product, or service (Tang, 2019; De Cicco *et al.*, 2021).

The most common task that consumers engage with when interacting with a mobile website or mobile application is the purchase of a product or service, product selection and product evaluation which are all relevant for the consumer decision making process (Mishra *et al.*, 2020; Andronie *et al.*, 2021; Klein & Sharma, 2022). Research has shown that the consumers are able to select a brand within about nine to 17 seconds on average within an in-store environment. This suggests that the consumers often make quick decisions online (Anesbury *et al.*, 2016).

The product selection stage is often combined with the other stages such as information search or product purchase in regard to the consumer decision making process and it is often simply considered the pre-purchase stage (Mishra *et al.*, 2020; Lăzăroiu *et al.*, 2020). Product selection can be impacted largely by competitors and product differentiation, especially within an online environment. The consumers have a range of online options and thus the businesses often struggle to incentivise purchase or customer loyalty unless they offer a better price or better differentiation than the competitors (Etro, 2021; Shen *et al.*, 2016; Saini & Singh, 2020). Consumers select products that are most suitable to their needs and wants. Some important factors that are considered when making a selection or purchase include price, quality, perceived value, online trust, other utilitarian and hedonic values (Blake *et al.*, 2021; Lăzăroiu *et al.*, 2020).

2.9.3. Other Online Behaviours

Mobile apps have created a new avenue by which the consumers can be entertained, or can share opinions, obtain information, and make purchase decisions (Tang, 2019). A number of behavioural theories aim to quantify certain decisions that are made by the consumers. The motivation theory stipulates that both cognitive and affective motives assist in explaining shopper behaviour. Other important motivations include pragmatic, hedonic and utilitarian motives, as well as the cognitive-affective-conative theory (Dharmesti *et al.*, 2021; Tang, 2019). The cognitive-affective-conative model uses three dimensions to divulge the concerned processes with the reason behind certain behaviour, in specific ways. Cognition (thinking process), affection (emotional responses) and conation (behavioural action or purchase choice) are the three main perspectives in understanding motivations (Tang, 2019; Mishra *et al.*, 2021).

Impulse buying is another important behaviour to consider when understanding online behaviour. A study found that due to the belief in consistency, consumers desire to seek hedonic pleasure which is greatly associated with habitual buying (Japutra & Song, 2020; Ba *et al.*, 2022). An impulse purchase is one that is done with little thought, as well as spontaneously and it is triggered by some irresistible temptation or urge. Through a positive online consumer shopping experience, it is possible to trigger a flow state in consumers whereby they become so intensely engaged by the online site that all other matters fade (Barari & Surachartkumtonkun, 2020; Gulfraz *et al.*, 2022). In this state, impulsive buying decisions can increase. It is, however, quite unethical for e-commerce platforms to target this impulsive shopping behaviour of consumers, and rather a focus should be on genuine transactions and other marketing communication activities (Gulfraz *et al.*, 2022; Chopdar *et al.*, 2022).

From the above literature, the following hypotheses were drawn:

H4: The time that participants have spent on their mobile device before the experiment moderates the effect of visual complexity of the app on visual fatigue.

H5: The context of use (free exploration vs task-orientated) participants have with the application mediates the effect of visual complexity of the app on visual fatigue

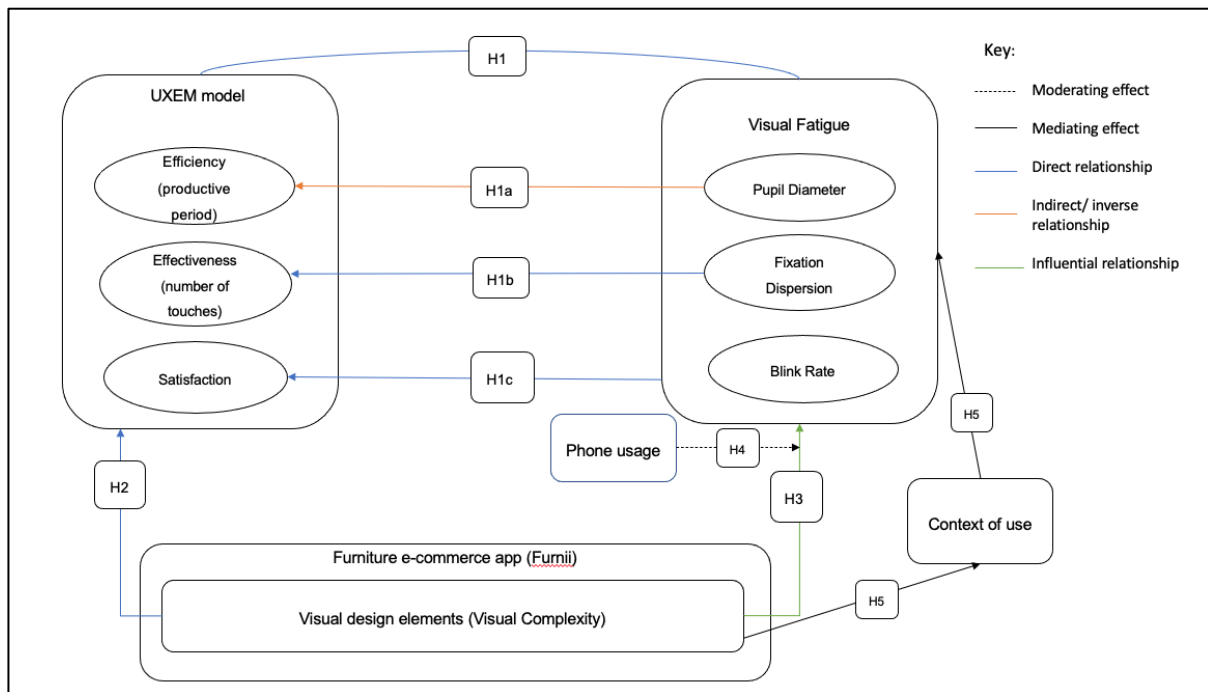
This section of the literature review detailed the current knowledge about how consumers behave online. The decision-making processes are impacted by how an individual operates in various online contexts. Marketers need to understand how people react and respond to online content to target and leverage these behaviours to increase brand reach and effectively achieve their marketing and corporate goals. The next section sought to tie in all the above literature to create a holistic picture of the purpose of this study through the conceptual model that was developed.

2.10. CONCEPTUAL MODEL

From the above literature review and from the theoretical model that was presented at the beginning of this chapter, the study's conceptual model was developed to understand how the various hypotheses and concepts interact. The main concepts that were investigated include mobile application usability, visual fatigue, visual complexity, context of use and the time spent on a mobile device. The model encompasses the original ISO 9241-11 definition of usability whereby efficiency, effectiveness and satisfaction are outlined, and each is quantified through the measures established by Saleh *et al.* (2020), from the UXEMs model.

Visual fatigue was quantified by a multitude of relevant studies and builds upon the research done by Fang *et al.* (2022), Cheng (2011), Wang *et al.* (2018a), and Wang *et al.*, (2018b) whereby fixation dispersion, pupil diameter and blinks per minute were used to measure visual fatigue over time, through eye tracking technology. Finally, the visual design elements (background colour, font style, button colour, etc.) of a mobile application were used to understand the visual complexity of an interface and how that impacts both visual fatigue and usability in accordance with the industry of interest. Below is a conceptual model depicting the hypotheses outlined for the study.

Figure 1: Conceptual Model



According to the literature review, the visual fatigue (explained through eye tracking metrics) that the users may experience when interacting with a mobile commerce application could potentially influence the usability in terms of efficiency, effectiveness, and the satisfaction of the said application. Furthermore, there is the implication that the visual complexity of an app in terms of the richness of the visual design elements may have an impact on both user visual fatigue and application usability. This all highlights the pertinence of the current study. This chapter's last section summarises the key ideas that were covered in the chapter while compiling the key takeaways.

2.11. CONCLUSION

The present chapter provided a comprehensive literature review on the concepts and theory grounding the current research study to develop the conceptual model and hypotheses. The chapter started with an outline of the relevant theoretical works underpinning the study, which is followed with a review of the relevant literature pertaining to the e-commerce and the m-commerce landscape in South Africa, m-commerce usability, visual complexity, visual design elements, visual fatigue, consumer neuroscience and eye tracking. The current literature presented gaps pertaining to mobile shopping application usability and the visual fatigue that is experienced by users, thus, indicating a need to investigate how the visual complexity of a mobile application impacts usability and the visual fatigue experienced by users.

How consumers process visual stimuli is important to understand how the consumers understand media and thus an app. The more visually complex a system is, the more difficult it is for the consumers to easily interact with. Shopping applications have been on the rise recently and thus, understanding how visual stimuli within an application affects consumers is important. Visual fatigue although it is a

relatively new concept has been shown to affect nearly all those who regularly interact with intense visual stimuli. Thus, highlighting the importance of the study as it investigates how the usability of a visually complex mobile shopping application is impacted by the visual fatigue experienced by users. From the literature and the theoretical model, a conceptual model was developed to understand how the relevant and important concepts interact and should be measured.

This chapter discussed the various phenomena used to understand consumer behaviour when interacting with m-commerce applications. The study's hypotheses, objectives, aims, and research questions were also outlined. The next chapter outlines the utilised methodology conducted for this study with a specific focus on the qualitative, the quantitative and the eye tracking methods that were used to collect the relevant data.

3. CHAPTER 3: THE RESEARCH METHODOLOGY

3.1. INTRODUCTION

This section outlines the specific methodology and the procedures that were followed to conduct this research study. It also includes the justification for the used methods. The research methodology includes the research philosophy, the research strategy and design, the target population and the sampling technique and frame, the data collection methods, the stimulus treatment, the measurement instruments, scaling, data analysis and the ethical considerations which are all drawn together with the conclusion.

3.2. RESEARCH PHILOSOPHY

Researchers hold a number of basic beliefs that assist, guide and collectively form the foundation of their activities and methods which ultimately lead them to conducting either a qualitative, quantitative or a mixed methodology. The research philosophy is the underlying understanding and belief that is used by a researcher to create a research design and implement the research study and underlying problem (Gannon *et al.*, 2022; Saliya, 2023). The best paradigm which will accurately answer the research problem and achieve research aims involves a combination of both a positivism and an interpretivism approach, thus a mixed methods approach. Ontology and epistemology are fundamental to research philosophy because they shape the underlying assumptions about the nature of reality and knowledge, guiding the choice of research methods and influencing the interpretation of findings in a study.

The positivism approach is whereby a researcher tries to discover theory and the research problems through hypotheses testing using deductive reasoning and statistical tests. A positivism researcher aims to explore the casual relationships between data so as to draw conclusions and generalisations through reducing complexity to simplicity and assumptions (Park *et al.*, 2020b; Saliya, 2023; Gannon *et al.*, 2022; Kirongo, & Odoyo, 2020; Alharahsheh & Pius, 2020; Harrison & Reilly, 2011). Positivism explores the testing and the identification of the cause-and-effect relationships (Park *et al.*, 2020b; Hasan, 2016).

Positivism research often consists of quantitative methodology, and it can involve questionnaires, surveys, and statistical models (Hasan, 2016). This study used a mixed method approach to understand how visual fatigue, visual complexity and usability interact. Mixed methods research is defined as the research by which a researcher combines the elements of quantitative and qualitative research approaches to solve specific research questions and problems (Harrison & Reilly, 2011; Dawadi *et al.*, 2021; Baškarada & Koronios, 2018). In a mixed methods approach, understanding epistemology and ontology is essential for integrating qualitative and quantitative research within a coherent philosophical framework. Ontology, which concerns the nature of reality, and epistemology, which addresses the nature and scope of knowledge, influence how researchers perceive and investigate the world and more specifically they problem they are attempting to address (Al-Ababneh, 2020; Mbanaso *et al.*, 2023).

Mixed methods research is often seen as a synthesis of qualitative (interpretivism) and quantitative (positivism) approaches. The main underlying philosophical approach for the mixed methods research

is pragmatism (Shan, 2022; Liu, 2022). The pragmatism approach uses the discovery of patterns, the testing of theories and hypotheses as well as discerning the best explanation for the interpretation of the found results. It thus makes use of abduction reasoning with a complement of the induction and the deduction approaches (Saliya, 2023; Harrison & Reilly, 2011). This logic of enquiry allows a uniform inquisition based on theory generation and hypotheses testing for the researchers. This particular study is dominated by the positivism paradigm more than the interpretivism paradigm which is more commonly used by social/ behavioural science journals (Bashir *et al.*, 2017; Baškarada & Koronios, 2018; Harrison & Reilly, 2011). Pragmatism aids in creating a more coherent and meaningful answer when comprehending the relationship between values and action (Zyphur & Pierides, 2020).

3.3. RESEARCH STRATEGY

The research utilised a mixed-method approach with quantitative research methods to measure the response to stimuli and the qualitative methods, to gather a deeper understanding of the investigated topics (Dawadi *et al.*, 2021; Baskarada & Koronios, 2018). Qualitative research is defined as an investigation that aims to provide a deep understanding of the specific phenomenon through interviews or focus groups which cannot be generalised. Quantitative research measures specific occurrences of the associations between entities through reducing phenomena to numerical values to carry out statistical analysis (Gelo *et al.*, 2008; Basias & Pollalis, 2018; Shan, 2022). Specifically, a confirmatory experimental research design was followed. A confirmatory experimental design will be used to test the specific hypotheses outlined by the study, through the verification of predetermined assumptions through a controlled experiment (Creswell & Creswell, 2017; Bethke & Rohlfing, 2023). The study aimed to understand the link between visual fatigue and usability in m-commerce applications of varying visual complexity.

The concurrent triangular mixed-method approach was achieved through conventional techniques, self-reporting and non-conventional techniques, namely eye tracking, methods to better understand the impact of visual complexity, mobile application usability and the visual fatigue on m-commerce app users (Adhikari, 2023; Harrison *et al.*, 2020). The mixed methods research integrates multiple research types to answer complex questions. It also aids in improving data accuracy through creating a more complete answer to research phenomena and the reduction of the risk of single-method biases (Almeida, 2018; Baskarada & Koronios, 2018). The triangulation design is most common, and it is a well-known mixed methods approach. It employs the use of both quantitative and qualitative research types to collect diverse but complimentary data on specific topics and interprets results (Almeida, 2018). A concurrent triangulation employs a combination of qualitative and quantitative data collection and a comparison of the two collected data types (Kroll & Neri, 2009; Creswell & Creswell, 2017).

For the qualitative portion for the study, participants were interviewed to gather a deeper understanding of their overall opinion of the application, the visual fatigue experienced, and to find out which specific visual stimuli elements could be improved on (Dawadi *et al.*, 2021; Basias & Pollalis, 2018). An interview is defined as a method of asking questions with the aim of obtaining an interviewee's descriptions of a specific topic in a natural and comfortable environment. This type of data collection allows for a more in-depth and detailed understanding of respondent answers (Taherdoost, 2022; Kallio *et al.*, 2016).

A general interview guide style was used to conduct the interviews whereby three questions were posed after a pre-experimental questionnaire and the eye-tracking experiment were conducted. This aided in learning more details about the user experience of the participants when interacting with the application and it also allowed specific information about which visual elements could lead to an improved experience (Turner & Hagstrom-Schmidt, 2022; Turner, 2010). This interview style also allows for the opportunity to pose follow up questions and enquire further about the given answers.

Neuromarketing research falls under qualitative research as it examines the consumers' cognitive response to marketing stimuli (Malhotra, 2018). For the eye tracking portion of this study, a causal experimental research design was applied, specifically a post-test control group design to understand the visual fatigue within the users. A true experimental design allows for strong causal-inferential claims and theory-driven hypothesis testing (Godfroid & Hui, 2020: 284).

The quantitative portion of the study used a confirmatory experimental methodology with the aim of understanding the relationships between visual fatigue, usability, and visual complexity (Willson & Miller, 2014:16; Halcomb & Hickman, 2015; Johnson *et al.*, 2007). It consists of self-reporting questionnaires similar to that done by the previous studies to measure visual fatigue prior to and after the experiment and user satisfaction (Koo *et al.*, 2018; González-Perez *et al.*, 2017; González-Perez *et al.*, 2014; Benedetto *et al.*, 2013; Zheng *et al.*, 2021; Habibi *et al.*, 2011; Jahangiri *et al.*, 2022).

3.4. RESEARCH DESIGN

This study followed a true experimental design and employed an experimental design whereby, the post-test control group design was used. The post-test control group design explained by Malholtra *et al.* (2017) involves the symbolic representation of the different processes with the experiment such as the Experimental Group (represented as EG), Control Group (represented as CG), Randomisation (represented as R), Observation (represented as O) and the treatment (represented as X). The proposed experiment is depicted below:

CG: R X1 O1

EG1: R X2 O2

EG2: R X3 O3

The CG symbol represents the simple visual design of the mobile application interface, or the first application that was used in the experiment (X1, Appendix B: Figure 9), The control group application (CG), which is the first application in the experimentation consisted of a white background, simple text to explain the product and one picture. The O symbol refers to the level of user satisfaction, visual fatigue and the usability observed during the experiments by the participants. Each subsequential design adds one layer of visual complexity to the application.

More specifically, X2 (EG1) the second mobile application (Appendix A: Figure 2) is a mobile application with the background colour and button colour changed and altered stylised font style of long text. X2 (Appendix A: Figure 3) is a mobile application with the background colour, button colour changed, different stylised font style of long text, different stylised font of numbers, altered shapes of

specific buttons (“add to basket”, “sign in” and “proceed to cart”) and container area colour change for categories and products on both product and category pages.

The participants were presented with stimuli to emulate a m-commerce app on a mobile device. Throughout the experiment, various visual design stimuli were added and visual fatigue, user satisfaction and usability were tested throughout. A total of about 30 participants were utilised in each app iteration. To measure satisfaction, the addition of post-test self-reporting through questionnaires was used to collect data. The application was developed through the Flutter Flow website (FlutterFlow, 2023) for the purpose of this experiment the Android Application Package (APK) was developed and downloaded. The experiment was conducted at the University of Cape Town to allow for convenience for participants as most were from the university.

3.5. SAMPLING

The following sections detail the sampling techniques and the procedures that were used in this study. Included is a description of the target population including the specific sampling technique and frame used in this study.

3.5.1. The Target Population

The target population is defined as a group of individuals that a study intends to conduct research on and draw conclusions from (Zhao *et al.*, 2013). For the purpose of this study, the target population was South African (Cape Town) residents within the 18 to 35 age range. This specific group of consumers make up the majority of South African consumers that own smartphones, at about 96% penetration for the young adult consumers cohort (Deloitte, 2020:8-9). Prior research has showed that most South African adults use their mobile phones for entertainment, transactions and daily work tasks (Kreutzer, 2009; Duffett, 2020).

Most eye tracking studies utilise those between the ages of 18 to 35 as the older eyes have the potential to become hooded, or they may droop and the individuals may develop eye problems, thus making it more difficult to measure the changes in the visual system such as the pupil diameter change (Koo *et al.*, 2018; Lin *et al.*, 2021; Guillon *et al.*, 2016). Some studies have also found that the consumers aged between 18 to 35 years old had a more obvious perception of colour, shape and layout as well as good feedback on the calibration of the eye tracker system (i.e. the iMotions software calibration with the Tobii Nano). The older adults were also known to have a processing bias towards positive versus negative information, which is something the younger consumers do not possess (Liu *et al.*, 2023; Cypryńska *et al.*, 2014).

3.5.2. The Sampling Technique

For the purpose of this study, the sample size of similar studies was used to determine the sample size of the current study. Other literature that studied visual fatigue when interacting with a digital medium through a consumer neuroscientific method have maintained a relatively small sample size of between 30 to 60 (Torrice *et al.*, 2018 (sample size of 40); Lin *et al.*, 2022 (sample size of 33); Xie *et al.*, 2021 (sample size of 60); Kim *et al.*, 2017 (sample size of 59)). The selected sample size of 90, whereby 30

participants who have used an e-commerce application prior to the experience was allocated to each iteration of the application.

The sample is thus in range with the prior studies, and it was recruited to obtain internal validity. The sampling technique adapted in this study was a non-probability sampling technique. Non-probability sampling is a type of sampling whereby each member of the target population is not required to participate, rather the participants are self-selected to participate in a study (Berndt, 2020; Stratton, 2021). This study used convenience and snowball sampling mainly due to the specific parameters that the study aimed to investigate (Malhotra *et al.*, 2017; Etikan *et al.*, 2016). These sampling methods were chosen due to their cost effectiveness, accessibility, easiness to measure and co-operation within the study.

Convenience sampling is defined as a non-probability sampling method that selects the participants for research that are available around a specific location, within a database (UCT DSA email list) and contacted through social media. The participants hear about the research through an announcement by which the participants self-select if they wish to participate (Stratton, 2021). The benefits of convenience sampling include simplicity, as it does not take extensive time to complete, and it is cost effective (Stratton, 2021). There was limited usage of the snowball sampling technique. For the snowballing sampling technique, the initial respondents were asked to refer other potential participants that belonged to the target population (Berndt, 2020; Stratton, 2021).

3.5.3. The Sampling Frame

The sampling frame for this study included a number of requirements so as to ensure that the correct respondents that fall within the target population were selected (Malhotra *et al.*, 2017; Malhotra, 2018; Malhotra *et al.*, 2020). The study parameters required the participants to be between 18 to 34 years old, live in Cape Town and must have previously interacted with an m-commerce application to be eligible for the study. The participants were initially asked a screening question, “Do you use mobile shopping applications (like Superbalist, Takelot, etc.)?”, to streamline the sample group. Therefore, the respondents who participated in this study were within the target audience parameters.

3.6. DATA COLLECTION

The data collection process involved a combination of the qualitative and the quantitative methods to compile the mixed methods data that was needed for this study. The respondents were asked a combination of Likert-type scale questions and other type of questions in both a pre-experimental and post-experimental questionnaire. The study started with participants completing pre-experimental self-reporting questionnaire, they were then spent about ten minutes interacting with the mobile application. Finally, an interview was conducted to understand the participants’ deeper thoughts and feelings, as well as to collect the qualitative data. Neuroscientific methods were also utilised within the experiment to understand the visual fatigue experienced by the participants when engaging with the mobile application. The data collection was therefore conducted with the use of two approaches which are self-reporting and interviews, as well as the consumer neuroscience collection methods.

3.6.1. Self-Reporting and Interview Methods

There have been extensive studies which have utilised consumer feedback after their experience, which often is less accurate than real time data, but allows for personal responses from the participants (Stein & Ramaseshan, 2020). This study used a specific method of data collection which encompassed a combination of self-reporting and consumer neuroscience methods, similar to that of Zunckel (2021), Monteiro *et al.* (2020), Abbott (2022), and Ren *et al.* (2022). The self-reporting and interview methods used allowed for a deeper understanding of the experienced visual fatigue, the time spent on one's mobile device, user satisfaction, user experience, opinions and thoughts about visual stimuli as well as the demographic statistics.

The quantitative data was then collected through self-reporting techniques and observational methods. A total of two questionnaires were posed to all the participants at the start before the experiment, and at the end, after the experiment. The pre-experimental questionnaire was used to gauge the visual fatigue that was experienced by participants in general and prior to the experiment. The post-experimental questionnaire gauged through the inquiry of participants; the level of visual fatigue experienced during the usage of the mobile application as well as the level of satisfaction experienced during the interaction with the mobile application. Likert scale questions were utilised to understand the experienced pre- and post-experimental visual fatigue. Semantic differential scale questions in accordance with those created by Schrepp *et al.* (2017) were used to measure overall satisfaction and the satisfaction derived from the visual elements within each app.

The interviews occurred after the participants completed the eye-tracking experiment. The interviews consisted of three questions to gather a deeper understanding of user interactions with the applications and how they relate to the different phenomena under investigation within the study. Open ended questions were posed to uncover the necessary responses that were needed for the qualitative portion of the study. A general interview guide style was followed (Turner & Hagstrom-Schmidt, 2022; Turner, 2010; Malhotra *et al.*, 2020).

3.6.2. Consumer Neuroscience Methods

When understanding the amount of fatigue experienced by a digital device, self-reporting metrics were often utilised. Visual fatigue can also be measured through eye-tracking metrics. This study investigated visual fatigue through the basis of a number of other prior studies (Lin *et al.*, 2022; Feng *et al.*, 2019; Li *et al.*, 2021; Fang *et al.*, 2022). Consumer neuroscience methodologies are often used in research studies to understand the unconscious responses to stimuli and to gather insights into the neural mechanisms that are central to consumer behaviour and decision making (Karmarkar & Plassmann, 2019; He *et al.*, 2021; Haidinger & Koller, 2023).

The consumer neuroscientific methods also allow for accurate results and novel results compared to just the simple self-reporting techniques. The specific application of neuroscientific methods has been useful in the field of product evaluation, as with this study (Karmarkar & Plassmann, 2019; He *et al.*, 2021; Haidinger & Koller, 2023). Eye-tracking is a physiological measure of eye movement that can understand blink rate, pupil diameter and fixation dispersion. For this study, only eye-tracking was utilised to understand the impact of visual fatigue on mobile application users (Lin *et al.*, 2022; Feng *et al.*, 2019; Li *et al.*, 2021; Fang *et al.*, 2022).

This research consists of three eye-tracking experiments for each mobile app iteration. Each participant engaged with two tasks, a browse-orientated task and the task-orientated assignment, which the participants got two minutes for each to complete (5 minutes in total). The eye-tracking data was collected using the Tobii Pro Nano 60 Hz and it was recorded using the iMotions software. The experiment was set up in accordance with Appendix B Figure 1. For this set-up, a Mobi stand was used to hold up the Galaxy 9 phone by which participants interacted with the mobile application. The Mobi stand was also used to prop the eye-tracker, by which the blink rate, the pupil diameter and the fixation dispersion were measured.

The iMotions software was used to collect and store the physiological data needed to understand the experienced visual fatigue. The stimuli were displayed on a Galaxy s9 Samsung touchscreen phone with a screen that is measured as 147.7 mm × 68.7 mm × 8.5 mm with a 1440 x 2960 pixels resolution (Wikipedia, 2024; Dimensions & Drawings, 2018). Objective reporting for usability used task time (reported as productive period) to complete the tasks to measure efficiency, and the number of touches to measure the effectiveness obtained from the analytical data from the app. The satisfaction usability metric was measured through a subjective self-reporting questionnaire that was posed as the end of the experimental process under the post-questionnaire form title.

3.6.2.1. Eye Tracking

Eye-tracking uses eye and pupillary movement to understand the neurological responses to stimuli. It is considered as non-invasive, as well as cost-effective and it aims to understand consumer attention when interacting with information in a specific environment (Graham *et al.*, 2022; Carter & Luke, 2020; Li *et al.*, 2024; Klaib *et al.*, 2021; Valtakari *et al.*, 2021). The screen-based eye trackers or the video oculography techniques, such as the one used for this study help researchers to understand how consumers process visual information, compare participants and measure the effects of stimuli on eye movement and fixations. It can also aid to improve the usability, the accessibility, and the engagement with various systems through testing and refining user interfaces, navigation, content and functionality (iMotions, 2024; Tobi, 2024; Klaib *et al.*, 2021).

The analysis of eye movements was done through the iMotions software which tracked the blink rate, fixation dispersion and the pupil diameter change. To avoid the unwanted flexibility of data analysis, the pre-registration of processing steps and the metrics needed to be done. It is also important that the hypotheses and the predicted outcomes generated from the theory are complete prior to the start of the experimentation (Motoki *et al.*, 2021; Babin *et al.*, 2020; Bridges, 2021). Most eye trackers are equipped with one or two cameras and one or two infrared light sources to recreate the corneal reflection and to illuminate the eyes. The camera films the eyes and the face to capture eye and pupillary movement (Valtakari *et al.*, 2021; iMotions, 2024).

The eye-tracking methodologies are dependent on the aim of the study and the researcher's available equipment. The current research and the prior research by which the study is based used a single eye-tracking set-up (Valtakari *et al.*, 2021; Klaib *et al.*, 2021). The overall combination of the eye tracker and the participant placement is referred to as the eye tracking setup which can be found in Appendix D, Figure 8. For the duration of this experiment, the Mobi stand was used to hold both the Galaxy 9 phone and the Tobii eye-tracker in place (Valtakari *et al.*, 2021).

3.7. STIMULUS TREATMENT

The stimulus treatment for the current study aimed to comprehend consumer behaviour when interacting with a m-commerce application, to understand how visual complexity impacts the visual fatigue that is experienced by the consumers and the usability of the app. Although prior studies have investigated the impact that different web, tablet or user interfaces have had on the visual fatigue experienced by consumers, there is little research to understand the visual fatigue that is experienced when interacting with a mobile device or application (Feng & Chen, 2021; Souchet *et al.*, 2022; Tang *et al.*, 2024; Peker *et al.*, 2021; Hirota *et al.*, 2019; Fang *et al.*, 2022). Visual fatigue has also been reported to impact performance and productivity when experienced by individuals. Thus, understanding if certain levels of visual complexity cause visual fatigue is important to aid businesses in ensuring that their applications do not cause the consumers harm and negatively impact their daily lives (Ren *et al.*, 2022; Wang *et al.*, 2018a; Lambooij *et al.*, 2009; Li *et al.*, 2021; Kim *et al.*, 2017). For this experiment, three applications were built with varying levels of visual complexity. All the applications were made through Flutterflow and named Furnii.

Furnii is a furniture retail application that was created by the researcher and each iteration was adjusted through the addition of visual elements. The app was tested prior to experimentation and the SDK was downloaded to run the app on the device. Android studio was used to test and debug the built app (Seymour *et al.*, 2014; Lashin & Helmy, 2021). The app was consistent in terms of format and layout to ensure the accuracy of the results when comparisons were made to understand the different phenomena tested within this study. The First Application (App 1) which the first 34 participants were exposed to employed a simple visual design. This consisted of a white background, black text, with a simple Montserrat as the primary font style and 'Raleway' as the secondary font style throughout, the containers had a simple brown outline, and the buttons were grey and had rounded edges.

The Second Application (App 2) iteration had 30 participants exposed to a moderate level of visual complexity. This consisted of a light green background, black text (with descriptive text as the Roboto Mono font style, while the other text style remained the same as the one used within the first application). The buttons were also changed as they were brown and remained rounded and the containers remained the same as within App 1. The third and final application iteration (App 3), is whereby 32 participants were exposed to a high level of visual complexity. This consisted of a light green background, black text (with descriptive text as the same font style as App 2), the number text was changed to the Playfair Display font style and all the other text was the same as App 1. The figures, displaying each application iteration can all be seen in Appendix D, Figure 9 to Figure 11.

3.8. MEASUREMENT INSTRUMENTS

A number of measurement instruments were used in this study. These included structured questionnaires to understand the perceived experienced visual fatigue and satisfaction and a personal interview to obtain a deeper understandings to the phenomena in question. Eye-tracking technology was also used to gather the consumer neuroscience measures of users' experienced visual fatigue and effectiveness operating a m-commerce app. To measure efficiency, the time taken to complete each task was used and tracked through the iMotions software. To measure effectiveness playback videos were obtained from the iMotions software and the number of touches were counted.

3.8.1. Eye Tracking

A Tobii Pro Nano 60Hz eye tracker (Appendix B: Figure 1) was used to record all the eye-tracking data. The eye tracking technology aided in measuring visual fatigue, thus, aided in understanding the user experience and comfort, from a consumer neuroscience perspective (Bercea, 2012; Zunckel, 2021). The study looked at the fixation count, frequency and dispersion, pupil diameter and the blink rate to measure visual fatigue and compare that to the objective usability metrics. The usability metrics that the study utilised are the time spent to complete the task, the number of fixation points, and the self-reporting satisfaction questionnaire. This was all in accordance with the prior studies that tested similar phenomena (Fang *et al.*, 2022; Li, *et al.*, 2021; Marandi, *et al.*, 2018; Shi, *et al.*, 2011; Feng, *et al.*, 2019; Souchet, *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022)

At the beginning of each eye tracking session with the respondents, a calibration was required to calibrate the respondent's eyes with the eye tracker. Here a researcher has the most control over the quality of eye tracking data and needs to ensure that the calibrations achieve acceptable levels of accuracy and precisions (Carter & Luke, 2020). Once recorded, the eye tracking data outputs a series of samples whereby each sample possesses the point of gaze estimate for both eyes as an x and y screen position in pixels. In accordance with the current study's experimental design, the blink frequency, fixation dispersion and the pupil diameter metrics were included to quantify visual fatigue (Valtakari *et al.*, 2021; iMotions 2024; Carter & Luke, 2020).

3.8.2. Online Questionnaires

The structured questionnaires adapted from Schrepp *et al.* (2017) were used to better understand the satisfaction that is experienced by the consumers pertaining from the visual design stimuli and the overall satisfaction experienced through the apps on the mobile app usability. The Likert rating scale and the semantic differential scale were used to measure the perceived visual fatigue that is experienced by the consumers when using the app and the satisfaction that is derived from the visual design elements and overall, respectfully (Malhotra *et al.*, 2020; Malhotra, 2018; Malhotra, 2010). Pre-experimental and post-experimental data were collected immediately before and after participants interacted with the mobile application, within the controlled environment of the experiment venue, to ensure data integrity and to account for potential non-completion of the post-experiment questionnaire by participants.

3.8.3. Personal Interviews

The interview consisted of three questions which were posed to the participants at the end of the experiment process. The first question was "How would you explain the mobile application you experienced?". This aimed to understand if the participants viewed the applications as simple, complex or somewhere in between, and to see how the consumers would explain the application in their own term. The second question was "How are your eyes feeling after interacting with the mobile application?". This question aimed to gauge the perceived amount of any visual fatigue, or any eye strain experienced by the participants. The third question was "How would you improve the visual stimuli on the mobile application to enhance a user's experience?". This question aimed to understand which specific visual design elements impacted the participants' experience with the mobile app, whether that be positive or negative.

3.9. SCALING

Measurement is defined as assigning numbers or symbols to characteristics of objects according to certain specified rules. Scaling is an extension of measurement and it is about creating a continuum by which the measured objects are located (Malhotra *et al.*, 2020). The current study employed a number of different scaling techniques namely the itemised rating scales falling under the non-comparative scaling techniques. The non-comparative scales are one or two types of scaling techniques by which each phenomena under investigation are scaled individually of the other phenomenon within the study. For this study, the focus was on non-comparative itemised rating scales namely the Likert and semantic differential scale (Malhotra *et al.*, 2020).

A non-comparative scale is a type of scaling technique in which each stimulus object is scaled independently of other objects within the stimulus set. To conduct the analysis portion of each state of an itemised rating scale, it is assigned a numerical scope ranging from either -3 to +3 or 1 to 7 (Malhotra *et al.*, 2020). The semantic differential scale is a seven-point rating scale by which the endpoints have bipolar labels with semantic meaning. This rating scale was applied to measure satisfaction for the visual design elements within the application and the satisfaction overall within the post-experiment questionnaire (Malhotra *et al.*, 2020; Stoklasa *et al.*, 2019; Malhotra, 2018). The individual items on the semantic differential scale may be either a -3 or +3 or a 1 to 7 scale.

The Likert rating scale developed by Rensis Likert requires the respondents to signify a degree of agreement or disagreement in accord with a number of statements about the phenomenon in question. Within this study, the Likert scale collected quantitative data on the perceived visual fatigue experienced when interacting with the mobile application that was utilised by this study (Jebb *et al.*, 2021; Malhotra *et al.*, 2020). For the data analysis with non-comparative scales, t-tests, ANOVA, regression and the factor analysis techniques are often used. The non-comparative scales are easy to construct and administer which is why they were utilised for this study (Malhotra *et al.*, 2020; Malhotra, 2018).

3.10. DATA ANALYSIS

Once the data had been obtained, it was prepared and analysed through the Statistical Package of Social Science (SPSS) using descriptive statistics, hypothesis testing and the available analysis tools from the Tobii Pro Nano 60Hz eye-tracking device. The iMotions software was then used to integrate the eye-tracking data which was exported into SPSS for processing. iMotions and Tobii allow for simplified, accurate mixed methods research (Tobii, 2024; iMotions, 2023). All statistical data was presented in the APA official format to ensure consistency and allows for a fair and concise investigation of the current research. The latest APA reporting style was followed, i.e. the 7th edition (American Psychological Association, 2024; Nicholson *et al.*, 2017; Watts *et al.*, 2023). The eye-tracking metrics, Fixation Dispersion (FD), Pupil Diameter (PD), and the Blink Rate (BR) were analysed through inferential statistics. To test for any significant difference in the visual fatigue experienced during the various versions of the application, statistical tests were conducted.

The eye tracking data was extracted from iMotions, and the data was cleaned. A low pass filter with a cut-off frequency of 1Hz was applied to isolate the tonic signal of the data. The eye-tracking data was analysed using descriptive and inferential statistics through identifying similarities and differences between the eye-tracking data, the objective data and the self-reporting data relating to the stimuli. Both Jeffrey's Amazing Statistics Program (JASP version 0.16) and the SPSS Version 4.2 were used to conduct the statistical tests to examine the hypotheses. Throughout the hypothesis testing, a number of statistical techniques were used including ANOVA (for within and between groups comparison), regression, correlation (to test association and the relationships between variables) and the Hayes mediation/moderation analysis method.

For the qualitative data, an interpretative phenomenological analysis was done to understand the phenomena of the study through each respondent's personal experience (Eatough & Smith, 2017; Malhotra *et al.*, 2020; Smith *et al.*, 1999). Themes were extracted for user experience as well as the initial impressions of each application iteration, perceived visual fatigue and improvements to the visual elements on the app. Heatmaps were also extracted from the iMotions software to understand the most salient elements on each app page (home, cart, product details, profile and product view) in each application level (app 1 = visual complexity level 1, app 2 = visual complexity level 2, app 3 = visual complexity level 3). The depth interviews are unstructured, as well as direct and a single respondent is probed by a researcher to discover underlying motivations, beliefs, attitudes and feelings about a specific topic (Malhotra *et al.*, 2020).

3.10.1. Descriptive Statistics

The descriptive statistics allowed the researcher to summarise the data in terms of location (mean, mode and median), the measures of variability or dispersion (range, interquartile range, standard deviation and coefficient of variation) and the measures of shape or normality (skewness and kurtosis). The measure of location or central tendency explains central distribution of the statistics (Malhotra *et al.*, 2020; Goss-Sampson, 2024; Mishra *et al.*, 2019). The measure of variability is applied to interval or ratio data, and it includes the range, the interquartile range, the variance or the stand deviation and the coefficient of variation (Malhotra *et al.*, 2020).

For this study, the mean, median, standard deviation, maximum and minimum values were used to explain both location and variability. Item reliability was also used to check the validity through the Cronbach Alpha of the individual items of satisfaction and the visual fatigue related constructs. Frequency distribution was also reported to better understand the number of responses associated with different values of the variable. A table was used to present this data by which the frequency counts and the valid percentages for all values associated with the particular variable in question, which can all be found in Appendix E (Malhotra *et al.*, 2020; Mishra *et al.*, 2019).

To understand the shape and the normality of the data skewness, kurtosis and the Kolmogorov-Smirnov tests were conducted. Understanding the shape and the normality of data is important as a number of statistical analysis techniques assume normality, including correlation regression, t-tests and the Analysis Of Variance (ANOVA). Understanding normality also establishes if the mean is applicable as the representative value of the data (Malhotra *et al.*, 2020; Khatun, 2021; Mishra *et al.*, 2019). The Kolmogorov-Smirnov test is used for studies that possess a sample size higher than 50. When the p-value is over 0.05, the null hypothesis is accepted and the data is considered as normal (Mishra *et al.*, 2019).

Skewness is used to assess the symmetry of the distribution, while kurtosis explains the heaviness or the lightness of the tails, that is, the peakedness of the distribution. For both the kurtosis and the skewness tests, the z value or the critical ratio was calculated through dividing the test value by their standard of errors (Mishra *et al.*, 2019; Malhotra *et al.*, 2020; Khatun, 2021). When the z value is between -1.96 to 1.96 for skewness and kurtosis, it can be concluded that the data is normally distributed.

3.10.2. Inferential Statistics

Hypothesis testing involves a number of steps to infer a statistical decision as to whether to reject or not to reject the relevant hypothesis. The hypotheses of this study were tested through the inferential statistical methods. The inferential statistics refer to all the methods and the techniques that enable the researchers to explore the in-depth relationships between variables (Barnes & Lewin, 2005; Turner *et al.*, 2020). A number of statistics tests were applied to the data to draw accurate conclusions and to understand the relationships between variables. The following inferential tests were applied to the hypotheses:

Table 2: Statistical Techniques for Hypothesis Testing

Hypothesis	Data Distribution	Statistical Technique
H1a; H1b	Non-normal distribution	Bivariate Correlation Analysis: Spearman rho Correlation, Linear Regression Analysis,
H1c	Non-normal distribution	Regression Analysis, Multivariate tests, Bivariate Correlation Analysis: Spearman rho Correlation,
H2	Non-normal distribution	Independent Sample t-test: Kruskal-Wallis Test, Post Hoc Tests: Bonferroni correction, Bivariate Correlation Analysis: Spearman rho Correlation
H3	Non-normal distribution	Multivariate tests included Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, General Linear Model, Post Hoc Tests: Bonferroni correction
H4	Non-normal & normal distribution	Hayes Process Analysis for Mediation and Moderation
H5	Non-normal & normal distribution	Hayes Process Analysis for Mediation and Moderation,

The technique of understanding the link between one or more independent variables that predict a dependent variable is known as linear regression (Malhotra *et al.*, 2020; James *et al.*, 2023). The differences in the sample means of the two groups were compared using the independent sample t-tests (Malhotra *et al.*, 2020). To determine if the influence of an independent variable on the dependent variable may be indirectly explained through a mediating variable, the logical regression analysis for moderation and mediation (Hayes Process) study was employed. The moderating effects of one variable on the connection between two other factors were also studied using the same methodology (Hayes, 2018; Igarua *et al.*, 2021). To determine the strength and the direction of a significant association between two variables, a bivariate correlation study was performed (Malhotra, *et al.*, 2020).

A General Linear Model was employed as a crucial statistical strategy to comprehend between-subjects effects and investigate the impact of a single variable on many variables (Dobson & Barnett, 2018). To find the combination of variants that perform best in comparison to all the other possible combinations, several multivariate tests were conducted on the research variables (Ferreira *et al.*, 2009). To determine the areas in which particular groups differ from one another, the Post Hoc Tests were run in tandem

with an ANOVA. To measure the differences between more than two groups, an analysis of variance test is frequently utilized (Malhotra *et al.*, 2020; Kucuk *et al.*, 2016).

3.11. ETHICAL CONSIDERATIONS

With regards to consumer neuroscience, it is important to ensure that the subjects and the obtained information are obtained ethically (Spence, 2020). While the validity of traditional marketing research methods has often been questioned for inadequate validity, consumer neuroscientific methods have been questioned for ethical responsibility for the human respondents. All the data is considered to be more sensitive as it pertains to the participants' intrinsic thoughts, feelings and movements (Kim & Waldman, 2020). For this study, the data was adequately stored and protected to ensure that the identities were concealed. A researcher also has an ethical responsibility to ensure that the used scales have reasonable reliability, validity and generalisability. Thus, the scales should not be biased, and must not slant findings in a specific direction (Malhotra *et al.*, 2020; Malhotra, 2018). The adequate measures were put in place to ensure that all the data was not biased, and it was obtained in a just manner. During the study, those taking part were properly informed of the purpose of the study, as well as their voluntary and anonymous right in participating in the study.

3.12. CONCLUSION

Chapter 3 presented the mixed (quantitative and qualitative) methodologies that guided and were utilised for this study. The chapter detailed the explanations and the understandings of the methods that were used to conduct the research study and it justified the most suitable methods which aligned with the objectives of the study. Chapter 3 began by detailing the research philosophy, the research strategy, the research design, the sampling target populations, the frame and technique, the data collection methods, the stimulus treatments, the measurement instruments, scaling, the data collection procedure as well as the data analysis technique and finally the ethical considerations.

This study aimed to target young adult m-commerce users to improve user experience when interacting with a retail application, which could potentially render consumer visually fatigued if over taxed with visually complex and usability issues. From this, a number of strategies can be utilised to improve the consumers' long-term usage of a retail application. The research used methodologies include self-reporting techniques, personal interviews, and eye tracking methods to allow for more accurate and intricate data collection and processing. The data analysis encompassed a number of statistical techniques to adequately test the hypotheses and compare the descriptive statistics in relation to the quantitative data thus allowing the researcher to draw accurate conclusions. The next chapter divulges deeper into the data analysis of the collected data from the study through a number of statistical models to test the quantitative, the qualitative and the eye-tracking data that was collected from the study participants.

4. CHAPTER 4: PRESENTATION OF RESULTS

4.1. INTRODUCTION

This chapter presents the results that were obtained from the mixed methods analysis which incorporated both quantitative and qualitative data analysis. Firstly, this chapter showcases the descriptive statistics; whereby, the reliability and normality tests were obtained and are presented below. Thereafter, the hypothesis tests are presented for each hypothesis, using inferential statistics and the qualitative analysis. The results were generated through the iMotions software, Microsoft excel, SPSS and JASP.

4.2. DESCRIPTIVE STATISTICS

This section provides an explanation of the self-report, the eye-tracking, and the descriptive statistics for the sample population. By examining the statistics that describe the demographics and the split of the target group and respondents, the descriptive statistics help to understand the fundamental makeup of the sample (Mishra *et al.*, 2019).

4.2.1. Sample Composition

The respondents completed a questionnaire before (pre) and after (post) the collection of the eye-tracking data to identify demographic data such as age, gender and the level of visual fatigue that is experienced generally before and after the use of the applications. The respondents were required to have normal or corrected vision, and they had to be between the ages of 18 and 35 and must have interacted with a mobile shopping application. Demographics are explored to give an overall picture of the sample profile. All the participants understood the purpose of the study, and they consented to participate in the study and they met all the criteria for the study.

A total of 96 people completed the study, and of these 38.54% (37) were men, 59.38% (57) were women and 2.08% (2) identified as non-binary. Of the participants, 66.67% (64) were between the ages of 18 and 23, while 31.25% (30) of the participants were between the ages of 24 and 29 and 2.08% (2) were between the ages of 30 and 35. This means that most of the participants were female and were between the age of 18 and 23. A table indicating the respondent ages and the gender can be found below in Tables 3 and 4. Furthermore, all the respondents indicated prior use of a m-commerce application. From the 96 participants, 35.42% (34 participants) used application iteration 1, 31.25% (30 participants) used application iteration 2, while 33.33% (32 participants) used application iteration 3. These statistics can also be found below in Table 3. The study met the minimum acceptable sample size in accordance with similar prior studies and the objectives of the study were addressed with the data that was gathered from the participants.

Table 3: Age & Gender Distribution Across the Experimental Groups

#	Answer	%	Count	Mean	Standard Deviation
1	18-23	66.67	64	1.4	0.5
2	24-39	31.25	30		
3	30-35	2.08	2		
	Total	100	96		
#	Answer	%	Count	Mean	Standard Deviation
1	Male	38.54	37	1.6	0.5
2	Female	59.38	57		
3	Non-binary	2.08	2		
	Total	100	96		

4.2.2. Descriptive Statistics of the Interval Data

The descriptive statistics are used to describe and to summarise the data but do not test any hypotheses. This section specifically looks at the descriptive scale data to measure visual fatigue, usability and visual complexity data. The mean and the standard deviation of each construct, hypothesis and all the data used to run statistical analyses and to draw conclusions are presented in Appendix E. All the means are reported prior to reverse coding to allow for the direct interpretation of items from the questionnaire. The means were interpreted in accordance with the questions used in the questionnaires.

All the mean differences between the perceived visual fatigue pre- and post-experiment were negative meaning that less visual fatigue was reported after the experiment in comparison to when the experiment started. For all the paired t-tests conducted the null hypothesis and alternative hypothesis was; H_0 : There is no difference in the mean of the paired scores. H_1 : There is a difference in the mean of the paired scores (could be in either direction). The results from the paired t-test for perceived visual fatigue post and pre experiment revealed that the p-value is less than the standard significance level of 0.05, and therefore the null hypothesis can be rejected. The results are therefore statistically significant, and it can be concluded that the average paired difference does not equal zero. It is interesting to note that the largest change in the mean perceived visual fatigue between the pre- and post-experiment data was for item 8: *'my eyes feel watery after'* and item 1: *'I have difficulty focusing'* with a difference of -0.7 and -0.6 respectively.

The smallest difference was reported for item 2: *'my eyes are tired'* where a -0.4 difference was reported. For item 8, on average the responses changed from somewhat disagree to disagree after their experience with the application. For item 1, on average the responses stayed at somewhat disagree. For item 2, on average the responses changed from neutral and somewhat disagree after their experience with the application. Thus, for feelings related to visual fatigue (mainly watery eyes, and difficulty focusing) participants felt it to a less degree after experience with the m-commerce application. Below is a table summarising these changes (Table 5).

Table 4: Item Means, and Standard Deviations Perceived Visual Fatigue Pre- & Post-experiment

Item	Question	Pre-exposure		Post-exposure		Mean VF change	Paired t-test	
		Mean	SD	Mean	SD		correlation	p-value
Please indicate how strongly you agree or disagree with each of the following statements after using your mobile phone								
1	I have difficulty focusing	3.2	1.6	2.6	1.5	-0.7	.4	<.001
2	My eyes are tired	3.4	1.8	3.1	1.9	-0.4	.48	<.001
3	My eyes feel sore/aching	3	1.6	2.6	1.6	-0.4	.54	<.001
4	I feel dizzy looking at the screen	2.6	1.5	2	1.2	-0.6	.30	<.001
5	My eyes feel irritated	2.9	1.6	2.4	1.6	-0.5	.48	<.001
6	I experience eye strain	3.5	1.8	3	1.8	-0.5	.45	<.001
7	I feel visual discomfort	3	1.6	2.6	1.5	-0.4	.52	<.001
8	My eyes feel watery after	2.8	1.6	2.2	1.4	-0.7	.42	<.001
9	I experience blurred vision	2.8	1.6	2.2	1.4	-0.6	.60	<.001
Overall statistic for pre- vs post experimental visual fatigue							.59	<.001

The mean change for perceived visual fatigue prior to the experience with each application iteration to the perceived post experimental visual fatigue differed significantly between the three different apps. Overall, the highest change was for item 5: ‘*my eyes are irritated*’ in regard to app 1 with a difference of -1 followed by item 1: ‘*I have difficulty focusing*’ in regard to app 3 with a difference of -1. The smallest differences were reported for two items in app 2. Item 3: ‘*my eyes feel sore/aching*’ with a difference of -0.1, item 7: ‘*I feel visual discomfort*’ with a difference of -0.1 and item 5: ‘*my eyes feel irritated*’ with a difference of 0.1 for app 2 and it was the only the positive difference that was reported. This indicates that only within app 2 did perceived visual fatigue increase after interacting with the application (see Appendix E Table 31).

For the overall perceived visual fatigue post experiment, the mean was 2.4 and the standard deviation was 1.2, median was 2, the minimum was 1, the maximum was 5.6 in regard to app 1. For the overall perceived visual fatigue prior to the experiment for app 1 the mean was 3, the standard deviation was 1.4, the median was 2.7, the minimum was 1.1, and the maximum was 6.4. Concerning the second visual complexity level (app 2) overall perceived visual fatigue post experiment had a mean of 2.7, standard deviation of 1.4, median of 2.7, minimum of 1, and a maximum of 5.9. Overall perceived visual fatigue prior to the experiment had a mean of 3, standard deviation of 1.3, median of 3.1, minimum of 1, and a maximum of 5.9 in regard to app 2. For the final visual complexity level (app 3) perceived prior visual fatigue had a mean of 3.1, a standard deviation of 1.2, median of 3.2, minimum of 1, and a maximum of 5.8. For app 3, the overall post experimental visual fatigue had a mean of 2.5, standard deviation of 1.1, median of 2.3, minimum of 1, and a maximum of 4.4 (see Appendix E Table 43).

For the prior time spent (TMPh) on the phone, the mean was 2.9 and with a standard deviation of 0.8, overall for the three apps. This indicates that on average, the users spent between two to four hours or four to six hours on their phone prior to the experiment (see Appendix E Table 43). From the frequency data, it is clear that 36.5% of the respondents (the majority) spent four to six hours on their phone prior to the experiment (see Appendix E Figure 35). For the prior time spent (TMApp) on an app, the mean was 2 with a standard deviation of 1, thereby indicating that most of the users spent two to four hours on an app on average. This matches the frequency data whereby 42.7% of the respondents indicated that they spent two to four hours on a mobile app on average (see Appendix E Figure 36).

For app 1 (visual complexity level 1), TMPh had a mean of 2.8, standard deviation of 0.9, median of 3, minimum of 1, and a maximum of 4. For app 1, TMApp had a mean of 1.9, standard deviation of 0.9,

median of 2, minimum of 1, and a maximum of 4. For app 2, (visual complexity level 2) TMPH had a mean of 3, standard deviation of 0.8, median of 3, minimum of 2, and a maximum of 4. TMAApp had a mean of 2.2, standard deviation of 1, median of 2, minimum of 1, and a maximum of 4 in regard to app 2. For app 3 (visual complexity level 3), TMPH had a mean of 2.8, standard deviation of 0.8, median of 3, minimum of 1, and a maximum of 4. For app 3, TMAApp had a mean of 2, standard deviation of 1, median of 2, minimum of 1, and a maximum of 4 (see Appendix E Table 43).

The usability metrics were obtained through objective measures (efficiency and effectiveness) and self-reporting metrics (satisfaction) (see Appendix E Table 41). Efficiency was measured through a productive period whereby the time taken to complete a task was taken into account. This was recorded in HH:MM:SS duration formatting for each task that was completed by a respondent. This was then transformed into decimal format on excel. The first task of the experiment consisted of a free browse task whereby the individuals got two minutes to explore the m-commerce application. For the initial visual complexity level (app 1), the mean efficiency for the initial free browse task (task 1) was 0.04 hours (2.4 minutes), with a standard deviation of 0.004 (14.4 seconds), thus indicating relatively consistent efficiency times. The effectiveness from app 2 of the initial free browse task (task 1) measured by the number of touches, averaged 80 (79.5) with a higher variability (SD = 17.1). The satisfaction scores averaged 4.9, with a standard deviation of 1.01 for app 1. Similar patterns were observed across the visual complexity levels 2 (app 2) and 3 (app 3), with slight variations in the means and standard deviations, thereby reflecting the different usability experiences of each version.

The second task involved a task orientated objective whereby the users had to add an item from each product category to their cart. Efficiency for the second task-orientated assignment in app 1 (visual complexity level 1) had a mean of 0.02 (1.2 minutes), and a standard deviation of 0.008 (28.8 seconds). The efficiency of the task 2 app 2 reported a mean of 0.03 (1.8 minutes), and a standard deviation of 0.01 (36 seconds). The efficiency for task 2 app 3 reported a mean of 0.02 (1.2 minutes), and a standard deviation of 0.01 (36 seconds). The effectiveness of task 2 app 1 had a mean of 53.1, as well as a standard deviation of 22.4. The effectiveness task 2 app 2 (visual complexity level 2) had a mean of 60, with a standard deviation of 23.6. The effectiveness of task 2 app 3 (visual complexity level 3) had a mean of 54.3, and a standard deviation of 23.4 (see Appendix E Table 41).

The final metric to measure usability was the self-reported measures of satisfaction overall and satisfaction for the visual elements on the apps based on the UEQ-S scale by Schrepp *et al.* (2017). Satisfaction is described as the perceived joy or the displeasure from a specific system. For transformed satisfaction overall items 1: '*obstructive vs supportive*' had a mean 1.5 and a standard deviation of 1.2, item 2: '*complicated vs easy to use*' had a mean of 2.3 and a standard deviation of 1, while item 3: '*ineffective vs effective*' had a mean of 1.6 and a standard deviation of 1.1. Item 4: '*confused vs clear*' had a mean of 2.1 and a standard deviation of 1.1, item 5: '*does not meet expectation vs meets expectations*' had a mean of 1.2 and a standard deviation of 1.4, while item 10: '*annoying vs enjoyable*' had a mean of 1.2 and a standard deviation of 1.4 but they all reported positive mean scores (see Appendix E Table 24).

This indicated that on average, the participants felt that the overall the app was supportive, easy to use, effective, clear, meets expectations and enjoyable. For item 6: '*not interesting vs interesting*' a mean of 0.5 and a standard deviation of 1.5 was reported, item 7: '*conventional vs inventive*' had a mean of 0.2 and a standard deviation of 1.7, while item 8: '*usual vs unique*' had a mean of 0.1 and a standard deviation of 1.7. Item 9: '*boring vs exciting*' had a mean of 0.3 and a standard deviation of 1.6. These means are all

below 1 thus indicating that the items skewed towards the negative constructs and the users felt that the apps are not interesting, conventional, usual and boring (see Appendix E Table 24).

From the untransformed satisfaction overall data for visual complexity level 1 (app 1), the mean was reported at 4.9 with a standard deviation of 1, a median of 4.8, a minimum of 1.7 and a maximum of 6.6. For visual complexity level 2 (app 2), the mean for satisfaction overall was 5, the standard deviation was 1, the median was 5, the minimum was 2.9, while the maximum was 7. For the third visual complexity level 3 (app 3), the mean was 5.2, the standard deviation was 1.2, the median was 5.3, the minimum was 2.3 and the maximum was 7 (see Appendix E Table 41 or the table below).

Table 5: Usability Descriptive Data

		Mean	SD	Median	Minimum	Maximum
App 1	Efficiency T1	0	0	0	0.02	0
	Effectiveness T1	79.5	17.1	80	37	117
	Efficiency T2	0	0	0	0	0
	Effectiveness T2	53.1	22.4	46.5	27	105
	Satisfaction	4.9	1	4.8	1.7	6.6
App 2	Efficiency T1	0	0	0	0	0.1
	Effectiveness T1	83.1	17.5	85	45	116
	Efficiency T2	0	0	0	0	0
	Effectiveness T2	60	23.6	52.5	29	107
	Satisfaction	5.1	1	5	2.9	7
App 3	Efficiency T1	0	0	0	0	0
	Effectiveness T1	87.6	16	84	58	130
	Efficiency T2	0	0	0	0	0.1
	Effectiveness T2	54.3	23.4	47	30	110
	Satisfaction	5.2	1.2	5.3	2.3	7

Visual fatigue was measured through the physiological indicators, that is, the eye tracking metrics, specifically the pupil diameter change over time, fixation dispersion, and the blink rate. These were measured on a continuous metric data scale in milliseconds per minute. The pupil diameter is identified by the iMotions software whereby an algorithm measures the changes in pupil diameter, and it can be used to assess the strain on the eye. The basic logic is that when visual fatigue occurs, the pupils decrease in an attempt to maintain focus and counter visual tiredness (Fang *et al.*, 2022; Koo *et al.*, 2018; Wang *et al.*, 2018a; Partala & Surakka, 2003; Tian *et al.*, 2022). The visual system uses the blinks to lubricate the eyes when they are hyper focused.

A lower blink rate over time indicates that visual fatigue has occurred (Li *et al.*, 2021; Marandi *et al.*, 2018; Shi *et al.*, 2011; Feng *et al.*, 2019; Souchet *et al.*, 2022; Haq & Hasan, 2016; Maffei & Angrilli, 2018, Kaur *et al.*, 2022). The dispersion of fixations (often calculated by fixation count over time) was found to increase and the gaze dispersion increases when fatigue sets in (Llanes-Juado *et al.*, 2020; Fang *et al.*, 2022; Wang *et al.*, 2019; Urruty *et al.*, 2007; Zhang *et al.*, 2024; Jiang *et al.*, 2017; Lin *et al.*, 2022). The overall combined pupil diameter had a mean of $-9.28E-05$, a standard deviation of $6.37E-04$, a median of $-4.05E-05$, a minimum of $-7.54E-03$, and a maximum of $2.41E-03$. The overall fixation dispersion had a mean of $2.86E-05$, standard deviation of $2.38E-04$, median of $4.80E-06$, minimum of $-1.14E-03$ and a maximum of $1.37E-03$. The overall blinks per minute had a mean of $6.19E-03$, a standard deviation of $2.38E-04$, a median of $5.23E-03$, a minimum of 0, and a maximum of $2.19E-02$ (see Appendix E Table 37

and the table below). For a more detailed breakdown of the descriptive statistics for each hypothesis please refer to Appendix E Table 38, Table 39, Table 40, Table 41, Table 42, Table 43 and Table 44:

Table 6: Eye Tracking Descriptive Statistics

Descriptive Statistics					
	Mean	SD	Median	Min	Max
Combined pupil diameter	-9.28E-05	6.37E-04	-4.05E-05	-7.54E-03	2.41E-03
Fixation dispersion	2.86E-05	2.38E-04	4.80E-06	-1.14E-03	1.37E-03
Blinks per minute	6.19E-03	2.38E-04	5.23E-03	0	2.19E-02

4.3. THE RELIABILITY OF THE SCALES

The reliability of the scales shows whether the scales were reliable indicators of the constructs and if they were valid.

4.3.1. Item Reliability

To evaluate the internal consistency reliability of the satisfaction and perceived visual fatigue pre- and post-experiment items used in the questionnaires, the Cronbach's alpha was used as an indicator. The Alpha-Coefficient (Cronbach, 1951) is a measure for the consistence of a scale. There is no generally accepted rule on how big the value of the coefficient should be. Many authors assume that a scale should show an alpha value > 0.7 to be considered as sufficiently consistent. Appendix E Table 29, and Table 26 show the Cronbach alpha score for the satisfaction data. From this, the satisfaction felt from the overall experience with the mobile shopping app was at 0.8 Cronbach alpha for the pragmatic items and 0.9 Cronbach alpha for the hedonic items. For the satisfaction received from the visual elements on the app, a Cronbach alpha score of 0.8 was found for the pragmatic items and 0.9 for the hedonic items. All alpha values are above 0.7 and are thus considered as sufficiently consistent.

For the pre-experimental visual fatigue, the data can be found in Appendix E Table 32, whereby the Cronbach alpha was reported at 0.9, with the 95% confidence interval lower bound at an alpha of 0.9 and the upper bound with an alpha of 0.9. For the post-experimental visual fatigue, the data can be found in Appendix E Table 33, whereby the Cronbach alpha was reported at 0.9, with the 95% confidence interval lower bound at an alpha of 0.9 and the upper bound with an alpha of 0.9. The individual item reliability statistics also show that if any of the nine items from both the pre- and post-experimental data is removed, the Cronbach alpha will be decreased and thus all items should stay (see Appendix E Table 32 and Table 33). No items needed to be reverse scored.

4.4. TESTS FOR NORMALITY

A number of statistical analyses were done for the data to understand the distribution of the data and to test the normality of the data. These methods included hypothesis testing by using the Kolmogorov-Smirnov statistic (since the sample size was larger than 50), as well as the skewness and kurtosis measures. The

results of the normality tests are summarized in the tables within Appendix F. The following hypotheses were used to test normality: H_0 : *The data is normally distributed*, H_1 : *The data is not normally distributed*.

The p-value for the pre-experimental Visual Fatigue (VFQ) self-reporting data from the Kolmogorov-Smirnov statistic was above .05, thus the null hypothesis cannot be rejected at the 5% significance level with a p-value of .2 and a statistic of 0.07. The small test statistic and high p-value substantiate this as well as the results from the skewness and the kurtosis z scores. Both the skewness and the kurtosis values for the pre-experimental visual fatigue were also between -1.96 to 1.96. Therefore, it could be concluded that the data was normally distributed (see Appendix F Table 45).

The p-value for the post-experimental visual fatigue (VFQ2) self-reporting data from the Kolmogorov-Smirnov statistic shows that the null hypothesis could be rejected at the 5% significance level with a p-value of .005 and a statistic of 0.11. The skewness values were not between -1.96 to 1.96, while the kurtosis z score was reported at -1.11 which would indicate a normal distribution. However, due to the fact that the Kolmogorov-Smirnov test and the skewness score both indicate that the null hypothesis could be rejected, the data is not normally distributed (see Appendix F Table 45).

The blink rate, the fixation dispersion, and the pupil diameter had a Kolmogorov-Smirnov p-value of < .001 and a test statistic of 0.11, 0.28, and 0.32, respectively. For the blink rate, the skewness was above the -1.96 and 1.96 range, thereby indicating that the data was not normal, while the kurtosis was between this range indicating normality. For fixation dispersion, both the skewness and the kurtosis z scores were reported above the -1.96 and the 1.96 range. For the combined pupil diameter metric, both the skewness and the kurtosis z scores were reported above the -1.96 and 1.96 range. Therefore, the null hypothesis could be rejected at the 5% significance level, and it can be concluded that all the eye tracking visual fatigue data is not normally distributed (see Appendix F Table 48).

The usability metrics follow different distribution shapes. efficiency task 1, efficiency task 2, and effectiveness task 2 have a p-value of < .001 and a test statistic of 0.23, 0.13, 0.18 respectively from the Kolmogorov-Smirnov test. Thus, the null hypothesis could be rejected at the 5% significance level, and it can be concluded that the data is not normally distributed. The skewness and kurtosis for efficiency task 1 is above -1.96 and 1.96 thus indicating a non-normal distribution, substantiating this. The skewness and the kurtosis for efficiency task 2 is, however, between this range, thereby indicating normality. For effectiveness task 2, the skewness does not lie between this range thus indicating a non-normal distribution and the kurtosis z score is between this range thereby indicating a normal distribution (see Appendix F Table 49).

For effectiveness task 1, the Kolmogorov-Smirnov test revealed a test statistic of .09 and a p-value of .09. Both the skewness and the kurtosis z scores are between -1.96 and 1.96 also indicating a normal distribution of the data. Thus, the null hypothesis cannot be rejected at the 5% level, and it can be concluded that the data is normally distributed. Satisfaction had a Kolmogorov-Smirnov p-value of .2 and a test statistic of 0.08. Both the skewness and the kurtosis z scores lay between -1.96 and 1.96 thus indicating a normal distribution of the data. Therefore, the null hypothesis cannot be rejected at the 5% level, and it can be concluded that the data is normally distributed (see Appendix F Table 49).

The normality tests for the prior time spent on the phone and the apps reveal that a normal distribution does not apply to these variables. For the prior time spent on an app, the Kolmogorov-Smirnov test statistic was 0.22 and there was a p-value of < .001. The skewness z score was above the -1.96 and the 1.96 range

and this indicates a non-normal distribution of the data. The kurtosis z score was, however, between this range and thus indicated a normal distribution. Therefore, the Kolmogorov-Smirnov test and the skewness z score substantiate that the null hypothesis could be rejected at the 5% significance level, and it can be concluded that the data is not normally distributed (see Appendix F Table 50).

For the prior time spent on the phone, the Kolmogorov-Smirnov test statistic was 0.26 and there was a p-value of $< .001$. The kurtosis z score was above the -1.96 and the 1.96 range and this indicates a non-normal distribution of the data. The skewness z score was, however, between this range and thus indicates a normal distribution. Therefore, the Kolmogorov-Smirnov test and the kurtosis z score substantiate that the null hypothesis could be rejected at the 5% significance level, and it can be concluded that the data is not normally distributed (see Appendix F Table 50).

The normality tests for the hypotheses of H1a, H1b, H1c, and H3 were conducted in regard to the visual fatigue data. For H1a, the Kolmogorov-Smirnov test statistic was reported at 0.23, 0.13, 0.26, 0.35 and there was a p-value of $< .001$ or less for efficiency task 1, efficiency task 2, combined pupil diameter for task 1 and for the combined pupil diameter for task 2 respectfully. This therefore indicates a non-normal distribution of the data, and the null hypothesis can be rejected at the 5% significance level. For H1b, the Kolmogorov-Smirnov test statistic was reported at 0.09, 0.18, 0.30, and 0.26 for effectiveness for task 1, effectiveness for task 2, fixation dispersion for task 1 and fixation dispersion for task 2, respectfully with a p-value of .09 for effectiveness for task 1 and a p-value of $< .001$ for the other variables. This therefore indicates a non-normal distribution of the data, and the null hypothesis can be rejected at the 5% significance level. This also indicates that for effectiveness task 1, the data cannot be rejected at the 5% significance level, thus concluding that this data is normally distributed, which is contradictory to the other variables tested for H1b (see Appendix F Table 51 and Table 52).

For H1c, the Kolmogorov-Smirnov test statistic was reported at 0.08, 0.11, 0.17 and p-values of .2, .009 and $< .001$ for overall satisfaction, blink rate for task 1 and blink rate for task 2 respectfully. This indicates that for satisfaction, there is not enough evidence to reject the null hypothesis at the 5% level as the test statistic is small and the p-value is high concluding that this data is normally distributed. The blink rate for task 1 and task 2 show enough evidence to reject the null hypothesis at the 5% level and conclude that the data is not normally distributed. For H3, the Kolmogorov-Smirnov test statistic was reported at 0.26, 0.30, 0.35, 0.26, 0.17 with a p-value of $< .001$ for the combined pupil diameter task 1, fixation dispersion task 1, combined pupil diameter task 2, fixation dispersion task 2 and for the blink rate task 2, respectfully while blink rate for task 1 had a p-value of .009 and a test statistic of 0.11. This therefore indicates a non-normal distribution of the data, and the null hypothesis can be rejected at the 5% significance level (see Appendix F Table 53 and Table 54).

4.5. INFERENCE STATISTICS: QUANTITATIVE DATA ANALYSIS (HYPOTHESIS TESTING)

For this section of the results, hypothesis testing was done for each hypothesis that was discussed in the literature review. Inferential statistics were used to better understand, infer and extrapolate conclusions about the hypotheses through analysis. A number of data types including self-reporting, fixation data, blink rate data, and other metrics were used to measure the constructs. The specific eye tracking metrics used to measure visual fatigue include Fixation Dispersion (FD), Pupil Diameter (PD) and Blink Rate (BR). In

this section, the hypotheses from the literature review were tested and thereafter the findings were presented.

4.5.1. H1a

H1a: Visual fatigue as measured by pupil diameter over time, is directly related to efficiency as measured by the productive period.

The first hypothesis was split into three separate hypotheses, namely H1a, H1b and H1c. Each hypothesis tested one metric of visual fatigue (pupil diameter, blink rate, and fixation dispersion) with a metric of usability (efficiency quantified by productive period, effectiveness quantified by number of touches and the satisfaction quantified by a self-reporting questionnaire). This hypothesis (H1a) stated that the visual fatigue, as measured by pupil diameter, and experienced by users when interacting with a mobile shopping application has a direct relationship with the efficiency measured by the productive period.

Specifically, it was proposed that the metrics of visual fatigue increased as the efficiency of a m-commerce interface increased. This section used a number of specific statistical tests to better understand if a relationship does exist between these variables. The basic logic is that the pupil diameter over time decreases as fatigue is experienced. For the productive period, the shorter time it took to finish a task, the more efficient a user was. Thus, as the pupil diameter trend decreases, the productive period should decrease as well.

The analysis involved calculating the Spearman rank correlation between efficiency (measured by Efficiency_T1 dec for Task 1 and Efficiency_T2 dec for Task 2) and visual fatigue (measured by Combined Pupil Diameter TF for Task 1 and Combined Pupil Diameter TF for Task 2). Given the non-normal distribution of the data, the Spearman rho correlation was used to assess the relationship. For the initial free browse task (task 1), the Spearman correlation coefficient was $-.001$ with a p-value of $.994$, thus indicating no significant correlation between efficiency and pupil diameter. Similarly, for the second task-orientated assignment (task 2), the Spearman correlation coefficient was $.03$ with a p-value of $.743$, also showing no significant correlation between the two variables. This data can be seen in the tables below. Also note that the Pearson correlations are also available in Appendix G Table 55 and Table 57, and they yield similar results to the Spearman rho correlation.

Table 7: Spearman's rho Correlation Between Efficiency and Combined Pupil Diameter for Task 1 and 2

Spearman's rho (Task 1) Correlations (N = 96)				
	Efficiency T1dec		Combined Pupil Diameter TF T1	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Efficiency T1dec	--		-.00	.994
Combined Pupil Diameter TF T1			--	
Spearman's rho (Task 2) Correlations (N = 96)				
	Efficiency T2dec		Combined Pupil Diameter TF T2	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Efficiency T2dec	--		.03	.743
Combined Pupil Diameter TF T2			--	

The results from both the initial free browse and the task-orientated tasks suggest that there is no significant relationship between visual fatigue and efficiency. The correlation coefficients for both tasks were very close to zero, and the p-values were considerably higher than the typical threshold for significance (.05), thus indicating a lack of statistical evidence to support the hypothesis. The above shows that the hypothesis was rejected and there was no evidence to support the existence of a relationship between efficiency and pupil diameter.

Comparison of Correlations Between the Initial Free Browse Task (T1) and Second Task-Orientated Assignment (T2)

To formally test the relationship between the correlations observed in the initial free browse task (T1) and the second task-orientated assignment (T2), one can compare the correlation coefficients using the statistical methods designed for comparing the dependent correlations. One common method for this purpose is the Fisher's z-transformation. The process by which to calculate this value can be seen in more detail in Appendix G Figure 16.

The results for the Fisher's z-transformation show that the Fisher's z-score for the initial task was -.001 while the Fisher's z-score for the second task was .03. The Standard Error (SE) equation was used to calculate the difference between the two z-scores that were found for the initial and the second task. The z-score of the difference between the initial and the second task yielded a value of -.24. This difference indicates a very small difference in the correlation coefficients when considering the Fisher transformation. The p-value for the difference between the correlations was .81, which is far above the significance threshold of .05. Thus, the two tasks do not possess a significant relationship. The high p-value (.81) indicates that there is no significant difference between the correlations for Task 1 and Task 2. This means that the relationship between visual fatigue (measured by pupil diameter) and efficiency (measured by productive period) is statistically similar across both tasks. The results suggest that the negligible correlations observed in both tasks are consistent, thereby reinforcing the conclusion that visual fatigue, as measured in this study, does not significantly impact efficiency in either context.

To conclude, the direct comparison between the correlation coefficients for the initial free browse task (Task 1) and the second task-oriented assignment (Task 2) shows no significant difference, as indicated by the Fisher's z-transformation and the high p-value. Both tasks exhibit similar, negligible correlations between visual fatigue and efficiency, thus suggesting a consistent lack of evidence to suggest a significant relationship between these variables across the different contexts. The hypothesis can therefore not be supported at the 5% significance level, therefore visual fatigue as measured by pupil diameter over time does not have a relationship with efficiency as a measure by productive period.

4.5.2. H1b

H1b: Visual fatigue as measured by fixation dispersion is directly related to effectiveness as measured by the number of touches.

This hypothesis posits that visual fatigue and effectiveness have a direct relationship. Specifically, it suggests that there is a significant relationship between the level of visual fatigue experienced by the individuals and their performance in terms of the number of touches. The basic idea is that fixation

dispersion expands when visual fatigue sets in while the number of touches also increases when a system is ineffective. A number of statistical tests and analyses were conducted to better understand and conceptualise the relationship between these variables.

For the initial free browse task (Task 1), the correlation between visual fatigue (as measured by fixation dispersion) and effectiveness (as measured by the number of touches) was very weak and positive (.01). The p-value (.91) was significantly higher than the typical alpha level of .05, thus indicating that this correlation is not statistically significant. This suggests that there is no meaningful relationship between the visual fatigue users experienced and the effectiveness of the mobile application for the initial free browse task (Task 1). This can be seen in the table below whereby the Spearman rho correlation was conducted due to the non-normal distribution of the data. A Pearson correlations for task 1 was also conducted, and it can be found in Appendix G Table 59.

Table 8: Spearman’s rho Correlation Between Effectiveness and Fixation Dispersion for Task 1

Spearman's rho Correlations (N = 96)				
	Effectiveness T1		Fixation Dispersion TF T1	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Effectiveness T1	--		.01	.906
Fixation Dispersion TF T1			--	

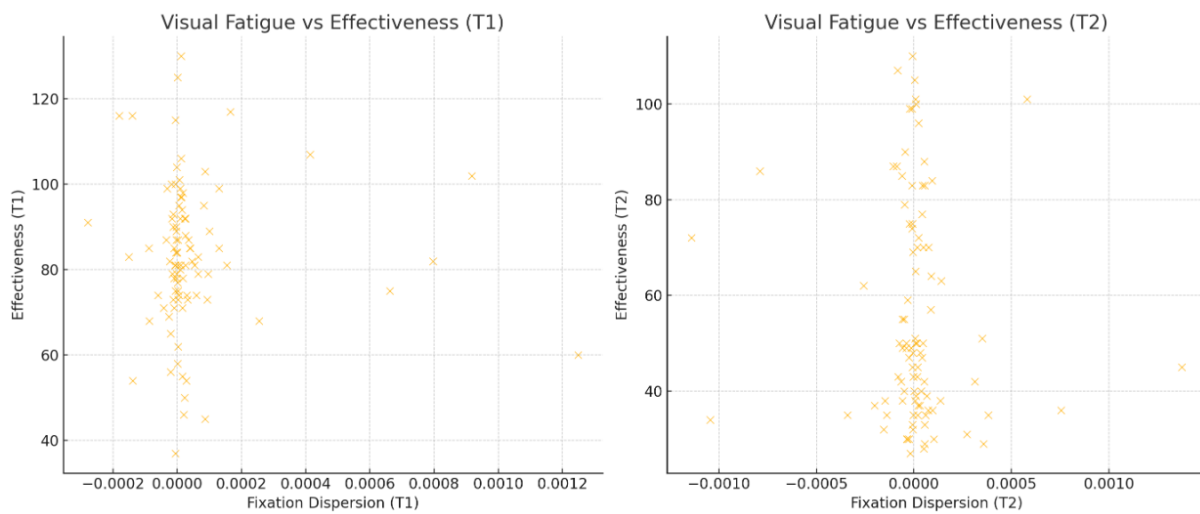
For the second task-orientated assignment that the users had to complete (Task 2), the correlation between visual fatigue and effectiveness was also weak but slightly negative (-.11). The p-value (.280) was again higher than .05, thus indicating that this correlation is not statistically significant either. This implies that visual fatigue does not have a significant impact on effectiveness for the second task-orientated assignment completed by the users (Task 2). The results by which this data originates is shown in the table below. A Pearson correlation was also conducted, and it can be found in Appendix G Table 61.

Table 9: Spearman’s rho Correlation Between Efficiency and Combined Pupil Diameter for Task 2

Spearman's rho Correlations (N = 96)				
	Effectiveness T2		Fixation Dispersion TF T2	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Effectiveness T2	--		-.11	.280
Fixation Dispersion TF T2			--	

The above analyses indicate a number of implications for the two variables for the initial and the second task. The negligible correlation and the high p-value indicate that visual fatigue as measured by fixation dispersion, does not significantly affect the effectiveness of operating the mobile application. Therefore, other factors might be more critical in influencing the number of touches in the initial free browse task. Although there is a slight negative correlation, it is not significant. This suggests that while there might be a minor trend indicating that increased visual fatigue could lead to an increase in the number of touches, it is not strong enough to be considered reliable. The two figures below also visually represent the insignificant relationship between the two metrics for each task.

Figure 2: Representation of the Relationship Between Visual Fatigue and Effectiveness



Fisher's z-transformation results

To formally compare the correlations observed in the initial free browse task (T1) and the second task-orientated assignment (T2), the researchers performed Fisher's z-transformation similarly to what was done in H1a (see the method to calculate this value in Appendix G Figure 18). The Z-score for the difference in correlations was .85, and the p-value was .398. Since the p-value was much higher than the typical alpha level of .05, the researchers thus failed to reject the null hypothesis that the correlations between visual fatigue and effectiveness in the initial free browse task (Task 1) and the final task-orientated assignment (Task 2) are significantly different.

The results thus indicate that there is no statistically significant difference between the correlations of visual fatigue and effectiveness in the initial free browse task (Task 1) and the final task-orientated assignment (Task 2). This implies that the relationship between visual fatigue and effectiveness does not differ substantially across the two tasks. From the above statistical analyses, it is clear that there is no evidence to support the hypothesis that visual fatigue as measured by fixation dispersion has a direct relationship with effectiveness as measured by a user's number of touches. The hypothesis can therefore be rejected at the 5% significance level.

4.5.3. H1c

H1c: Visual fatigue, as measured by the blinks per minute, is directly related to user satisfaction

This hypothesis posits that there is a significant relationship between the level of visual fatigue that is experienced by the individuals and their overall satisfaction with the task, thereby suggesting that higher levels of visual fatigue may lead to lower user satisfaction. Visual fatigue is quantified by the blink rate (i.e., blinks per minute) which uses the basic logic that a lower blink rate indicates that visual fatigue is present. User satisfaction is measured by self-reporting metrics by which the users were asked about their overall experience with the specific m-commerce application they were exposed to.

The Spearman rho correlation was again calculated due to the non-normal distribution of the data. For the initial free browse task, the relationship between visual fatigue and user satisfaction was explored. The correlation between visual fatigue (as measured by blinks per minute) and user satisfaction was weakly negative (-.10). The p-value (.312) was significantly higher than the typical alpha level of .05, thus indicating that this correlation is not statistically significant. This suggests that there is no meaningful relationship between visual fatigue and user satisfaction for the initial free browse task (Task 1). The below table shows the explained results. A Pearson correlation was also conducted, and it can be found in Appendix G Table 63.

Table 10: Spearman’s rho Correlation Between Satisfaction and Blink Rate for the Task 1

Spearman's rho Correlations (N = 96)				
	Satisfaction		Blinks Per Minute TF T1	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Satisfaction	--		-.10	.31
Blinks Per Minute TF T1			--	

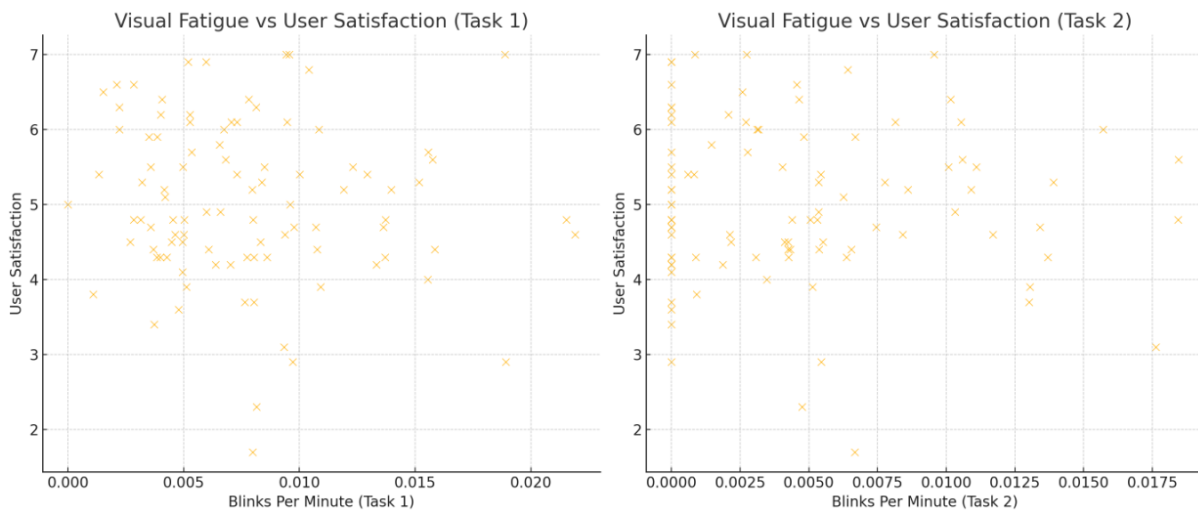
In relation to the second task-orientated assignment, the second task-orientated assignment showed similar results to the initial task correlation test for visual fatigue and satisfaction. The correlation between visual fatigue and user satisfaction was almost zero (-.007). The p-value (.95) was much higher than .05, thus indicating that this correlation was also not statistically significant. This implies that visual fatigue does not have a significant impact on user satisfaction for the final task-orientated assignment (Task 2) the users completed. The below tables show the results that are explained above. A Pearson correlation was also conducted, and it can be found in Appendix G Table 65.

Table 11: Spearman’s rho Correlation Between Satisfaction and Blink Rate for the Task 2

Spearman's rho Correlations (N = 96)				
	Satisfaction		Blinks Per Minute TF T2	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Satisfaction	--		-.01	.95
Blinks Per Minute TF T2			--	

These results indicate that there is no statistically significant indirect relationship between visual fatigue and user satisfaction for both tasks. The weak negative correlations and the high p-values suggest that user satisfaction is not significantly influenced by the level of experienced visual fatigue, as measured by the blinks per minute users experience. Below are the scatterplots of the correlation that indicate the insignificant relationship between the two variables. This visually represents the insignificant and the uncorrelated relationship between the blink rate and user satisfaction.

Figure 3: Representation of the Relationship Between Visual Fatigue and User Satisfaction



Fisher's z-transformation Comparison Results

To formally compare the correlations observed in the initial free browse task (Task 1) and the final task-orientated assignment (Task 2), the researchers performed Fisher's z-transformation similarly to what was done in H1a and H1b (see the method to calculate this value can be seen in more detail in Appendix G Figure 19). The Z-score for the difference in correlations is -0.67 , and the p-value was $.504$. Since the p-value was much higher than the typical alpha level of $.05$, the researchers therefore fail to reject the null hypothesis that the correlations between visual fatigue and user satisfaction in the initial free browse task (Task 1) and the final task-orientated assignment (Task 2) are significantly different.

The results indicate that there is no statistically significant difference between the correlations of visual fatigue and user satisfaction in both the initial free-browse task (Task 1) and the final task-orientated assignment (Task 2). This implies that the relationship between visual fatigue and user satisfaction does not differ substantially across the two tasks. It can therefore be concluded that the hypothesis is rejected at the 5% significance level and that visual fatigue as measured by the blink rate does not have a relationship with user satisfaction. From all the three hypotheses for H1 (H1a, H1b, and H1c), it is clear that no evidence exists that proves that there is a significant relationship between visual fatigue and usability in relation to a mobile application experience. It, however, is important to mention that although a relationship was not present it is clear that the visual fatigue experienced was significant.

4.5.4. H2

H2: The visual complexity of an e-commerce app interface has a direct relationship with the usability of a m-commerce app

This hypothesis posits that the visual complexity of a m-commerce app interface has a significant relationship with the usability of a m-commerce app. To explore this hypothesis, various metrics related to efficiency, effectiveness, and user satisfaction across different versions of the app were analysed. This

analysis included descriptive statistics, hypothesis testing, and correlation analyses to determine the nature and the strength of these relationships. A summary of the hypothesis's tests can be seen in Table 13 below:

Table 12: H2 Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of efficiency (productive period in hours) Task 1 is the same across categories of App Version.	Independent-Samples Kruskal-Wallis Test	.022	Reject the null hypothesis.
2	The distribution of effectiveness (number of touches) Task 1 is the same across categories of App Version.	Independent-Samples Kruskal-Wallis Test	.270	Retain the null hypothesis.
3	The distribution of efficiency (productive period in hours) Task 2 is the same across categories of App Version.	Independent-Samples Kruskal-Wallis Test	.106	Retain the null hypothesis.
4	The distribution of effectiveness (number of touches) Task 2 is the same across categories of App Version.	Independent-Samples Kruskal-Wallis Test	.414	Retain the null hypothesis.
5	The distribution of satisfaction is the same across categories of App Version.	Independent-Samples Kruskal-Wallis Test	.699	Retain the null hypothesis.
a. The significance level is .05				
b. Asymptotic significance is displayed.				

The hypothesis testing utilised the Independent-Samples Kruskal-Wallis Test to compare the distributions of the different metrics across the app versions. The results showed a significant difference in the distribution of efficiency (productive period in hours) for Task 1 ($p = .022$), thus leading to the rejection of the null hypothesis. However, no significant differences were found for the distributions of effectiveness (number of touches) for Task 1 ($p = .270$), efficiency for Task 2 ($p = .106$), effectiveness for Task 2 ($p = .414$), and Satisfaction ($p = .699$), thus resulting in the retention of the null hypotheses for these metrics. Therefore, it can be concluded that the distribution of efficiency for the free browse task differs across the visual complexity levels while for effectiveness (free browse and task orientation), satisfaction overall, and efficiency for the task orientated assignment the distributions are the same across the different visual complexity levels.

Pairwise Comparison of App Levels

Table 13: Pairwise Comparison of App Levels (Efficiency Task 1)

Pairwise Comparisons of App Version					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
1-3	-14.81	6.85	-2.16	.003	.009
1-2	-17.75	6.97	-2.55	.001	.003
3-2	2.94	7.07	.42	.068	1.000
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

The **pairwise** comparisons of the app levels provide a detailed look at how the different levels differ in terms of the usability metrics. These comparisons were performed using the Independent-Samples Kruskal-Wallis Test results, followed by the pairwise comparisons to identify specific differences between the visual complexity levels.

For the efficiency of the free browse task, (and thus the initial impression of the apps) visual complexity level 1 vs visual complexity level 3 revealed a significant difference between the two levels. The test statistic was -14.81 with a standard error of 6.85, thus resulting in a significant test statistic of -2.16 ($p = .003$). After applying the Bonferroni correction, the adjusted significance level was .009 thereby confirming the significant relationship between the first and the last level of visual complexity in regard to the efficiency of the free browse task. The comparison of visual complexity level 1 and visual complexity level 2 revealed a test statistic of -17.75 with a standard error of 6.97, thus leading to a significant test statistic of -2.55 ($p = .001$). The adjusted significance level was .003, highlighting a significant difference between Levels 1 and 2 for the efficiency in Task 1. The comparison of visual complexity level 3 and visual complexity level 2 revealed the test statistic was 2.94 with a standard error of 7.07, resulting in a non-significant test statistic of .42 ($p = .068$). The adjusted significance level was 1.000, indicating no significant difference between Levels 3 and 2 for efficiency in Task 1.

The other usability metrics yielded the same results across all the levels, that is the effectiveness (number of touches) of the free browse task, the efficiency (productive period in hours) of the task orientated assignment, the effectiveness (number of touches) of the task orientated assignment, and satisfaction overall. For these metrics, the pairwise comparisons did not reveal any significant differences between the visual complexity levels. The adjusted significance levels for all the comparisons exceeded the threshold of 0.05, thus indicating that the distributions of these metrics were similar across different visual complexity levels (see Table 67, Table 68, Table 69 and Table 70, in Appendix G).

The pairwise comparisons indicate that significant differences exist primarily in the efficiency for Task 1 between Levels 1 and both Levels 2 and 3. Specifically, Level 1 is significantly different in efficiency compared to Levels 2 and 3, thereby suggesting that Level 1 may have been less efficient for Task 1. However, no significant differences were found between Levels 2 and 3 for this metric, and the effectiveness and satisfaction metrics did not show significant differences across any levels. These findings suggest that while some usability aspects such as the efficiency in specific tasks vary between app levels, other aspects such as effectiveness and overall satisfaction remain consistent. This information can guide further improvements in app design focusing on enhancing efficiency without negatively impacting other usability factors.

Correlation across all App Iterations

Understanding the correlations between various usability metrics across all app levels is essential for comprehending how different aspects of an app’s interface influence user experience. In this study, the relationships between efficiency, effectiveness, and the satisfaction metrics across different visual complexity levels of the app were examined to identify any significant patterns or interactions.

Table 14: Correlations Across all Apps

	Efficiency Task 1	Effectiveness Task 1		Efficiency Task 2		Effectiveness Task 2		Satisfaction	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Efficiency Task 1	--	.33**	<.001	.13	.20	.11	.273	-.04	.669
Effectiveness Task 1		--		-.11	.31	.2	.051	.04	.73
Efficiency Task 2				--		.82**	<.001	-.04	.722
Effectiveness Task 2						--		-.04	.727
Satisfaction								--	

** . Correlation is significant at the 0.01 level (2-tailed).

The correlation analysis revealed significant relationships between several usability metrics across all app levels. For efficiency (productive period in hours) and effectiveness (number of touches) in the free browse task (Task 1), there was a significant positive correlation ($r = .33, p < .001$) found, thereby indicating that as the efficiency of the free browse task increases, the number of touches required also tends to increase. This suggests that a greater productive period might lead to a greater number of interactions, thus the two are closely linked for the initial free browse task. For efficiency and effectiveness with regard to the task - orientated task (Task 2) a strong correlation ($r = .82, p < .001$) exists, thus showing that a higher efficiency in Task 2 is associated with a higher number of touches.

For the effectiveness in the free browse task and for the effectiveness in the task-orientated assignment, a positive correlation ($r = .2, p = .051$) exists, thus suggesting a tendency for the users who interact more in Task 1 to also interact more in Task 2. Thus, an increased interaction with the initial impression should indicate an increase in interaction with a task focused task. The relationship between efficiency for task 1 and task 2 was found to be positive ($r = .13, p = .195$), though not statistically significant, thereby indicating a slight tendency for efficient performance in an initial free browse experience to correspond with efficient performance in the next task focused experience.

Satisfaction had an insignificant relationship with both efficiency and effectiveness for both tasks. The satisfaction with efficiency task 1, efficiency task 1 and effectiveness task 2 both revealed a negative correlation ($r = -.04, p = .669$, and $r = -.04, p = .722$, and $r = -.04$ and $p = .727$ respectively), though not statistically significant, indicating a tendency for satisfaction to decrease when users efficiently and effectively interacting with the app. Satisfaction with effectiveness task 1 had a positive insignificant relationship ($r = .04, p = .730$). Therefore, satisfaction had no significant relationship with the other usability metrics.

Interpretation of Correlation Analysis per App Level

The correlation analysis per app level provides a detailed examination of how different usability metrics interact within each specific app level. This analysis helps to identify the unique patterns and relationships that may not be evident when looking at the overall data across all the levels.

Firstly, the visual complexity level 1 (see Appendix G Table 71) yielded a number of results. For **efficiency (productive period in hours)** and **effectiveness (number of touches)** in regard to the free browse initial task (task 1), a significant positive correlation ($r = .49, p = .004$) indicated that the higher efficiency in the initial free browse task (task 1) is associated with an increased number of touches. This suggests that for the first visual complexity level (App 1), a more productive period corresponds with more user interactions, potentially reflecting a more engaging or complex task.

For **efficiency (productive period – hours)** and **effectiveness (number of touches)** in regard to the second task-orientated assignment (task 2), the strong positive correlation ($r = .88, p < .001$) shows a robust relationship, indicating that the users who are more efficient in the second task-orientated assignment tend to have a higher number of interactions. This significant correlation highlights the close link between efficiency and effectiveness for the second task in the initial visual complexity level. Finally, the correlations with **satisfaction** were generally weak and they were not statistically significant, thus

suggesting that other factors beyond efficiency and effectiveness are likely influencing user satisfaction at this level.

Secondly, visual complexity level 2 (see Appendix G Table 72) yielded a number of results. For **efficiency (productive period in hours)** and **effectiveness (number of touches)** in regard to the initial free-browse task (task 1), a positive correlation ($r = .24$, $p = .203$) was observed, though not statistically significant, indicating a mild tendency for efficient users to interact with the moderate visual complexity app more. For **efficiency (productive period in hours)** and **effectiveness (number of touches)** in regard to the second task-orientated assignment, a significant positive correlation ($r = .72$, $p < .001$) indicated a strong relationship between efficiency and effectiveness for the second task-orientated assignment (task 2), similar to visual complexity app 1. This consistency suggests that the nature of the task-orientated assignment (task 2) promotes a close link between these metrics across the different levels. The correlations with **satisfaction** were weak and not significant, thereby mirroring the findings in visual complexity level 1 and suggesting that user satisfaction may depend on additional factors that are not measured by efficiency and effectiveness alone.

Finally, the visual complexity level 3 (see Appendix G Table 73) also yielded a number of results. For the **efficiency (productive period in hours)** and **effectiveness (number of touches)** metrics for the initial free-browse task (task 1), a weak positive correlation ($r = .05$, $p = .795$) indicated no significant relationship, thus suggesting that efficiency and effectiveness for the first free browse task (task 1) are not closely related at this visual complexity level. For the **efficiency (productive period in hours)** and **effectiveness (number of touches)** metrics in regard to the second task-oriented assignment (task 2) a strong positive correlation ($r = .86$, $p < .001$) confirmed a consistent relationship between these metrics, reinforcing the trend observed in the previous levels. The correlations with **satisfaction** remained weak and non-significant, which is consistent with the findings across all the levels.

The correlation analysis per app level reveals that the relationship between efficiency and effectiveness is strong for the second task-orientated assignment (task 2) across all the levels, thus indicating a robust interaction between these metrics regardless of the app version/ visual complexity level. However, for the initial free browse task (task 1), the correlations vary, with significant relationships in visual complexity level 1 but weaker or non-significant correlations in visual complexity levels 2 and 3. User satisfaction did not show significant correlations with the other metrics at any visual complexity level, thereby suggesting that it may be influenced by additional factors that are not captured in this analysis.

Evaluation of the Hypothesis

The hypothesis postulates that the visual complexity of a m-commerce app interface (defined as the three different app levels) has an indirect relationship with the usability of a m-commerce app, where usability is defined by the metrics of efficiency, effectiveness, and satisfaction. To evaluate this hypothesis, the findings related to these three-usability metrics across different app levels were analysed.

Efficiency is measured as the productive period in hours, and it was evaluated for both Task 1 and Task 2. For the initial free browse task, the Independent-Samples Kruskal-Wallis Test revealed significant differences in efficiency between the app levels, thus leading to the rejection of the null hypothesis. The pairwise comparisons showed significant differences between Levels 1 and both Levels 2 and 3. These results indicate that positive visual complexity may indeed negatively affect the efficiency for Task 1, with different levels of complexity leading to varying efficiency outcomes. For the second task focused

assignment, there were no significant differences between the three different visual complexity levels, indicating that visual complexity may not have a significant impact on efficiency for this task.

Effectiveness is measured by the number of touches, and it was also evaluated for both tasks. The initial free browse task found from the hypothesis test and the Independent-Samples Kruskal-Wallis Test did not find significant differences in the effectiveness between the visual complexity app levels. This suggests that visual complexity may not significantly impact the effectiveness of the initial free browse task. Similarly, no significant differences were found in effectiveness for the task-orientated assignment (task 2) between the visual complexity levels, indicating visual complexity lacks impact on this metric. Thus overall, it is revealed that effectiveness does not have an impact on visual complexity.

Satisfaction as a subjective measure of user experience, did not show significant differences between the app levels in the hypothesis tests. This indicates that visual complexity may not have a direct or strong indirect relationship with user satisfaction as measured in this study.

Correlation Analysis

The correlation analysis provides additional insights (see Appendix G Table 71, Table 72, and Table 73). Across all the levels of visual complexity, it was found that a significant positive correlation was found between efficiency and effectiveness for both tasks, and it was particularly strong for Task 2. However, satisfaction did not correlate significantly with the other metrics. Additionally, within each individual level of visual complexity, the correlation analysis revealed a number of insights. For visual complexity level 1, efficiency in relation to the free browse task showed a significant positive correlation with effectiveness. Strong correlations between efficiency and effectiveness were also revealed for the second task-orientated assignment consistently across all the levels. Satisfaction remained uncorrelated with efficiency and effectiveness within each level.

To determine if the hypothesis was met, the indirect relationship between visual complexity and the three-usability metrics was assessed. For **efficiency**, there was partial support for the hypothesis, as significant differences in efficiency for the initial free browse task (task 1) were observed across the visual complexity levels, thus suggesting a negative impact of visual complexity. However, no significant impact was found for the second task-focused assignment (task 2) between efficiency and visual complexity. For **effectiveness**, the hypothesis was not supported, as no significant differences were observed between the visual complexity levels for either task. The hypothesis was not supported for **satisfaction**, as no significant differences or correlations were observed, thus implying that satisfaction and visual complexity have no relationship.

The hypothesis that visual complexity indirectly affects usability was partially supported. Visual complexity appears to influence efficiency, particularly for the free browse task, but it does not have a significant impact on effectiveness or satisfaction. Further research could investigate the additional factors that may influence these usability metrics and explore other dimensions of visual complexity to provide a more comprehensive understanding of its relationship with the mobile app usability.

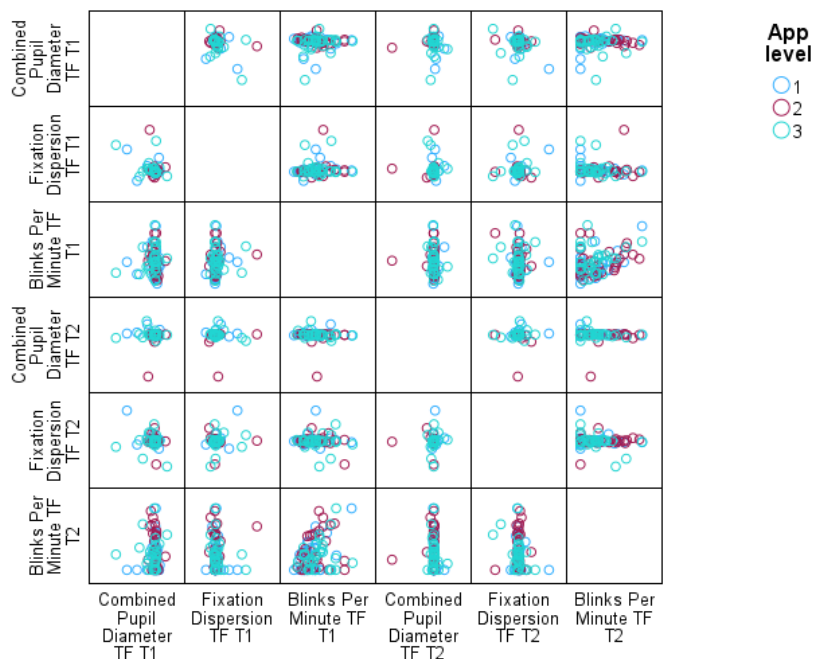
4.5.5. H3

H3: The visual complexity of a m-commerce interface directly influences the visual fatigue experienced by the user

This hypothesis stated that the visual complexity of a mobile shopping interface has a direct impact on the visual fatigue that is experienced by a user. Specifically, it is proposed that the metrics of visual fatigue, that is the blink rate, fixation dispersion, and the pupil diameter over time are directly influenced by the visual complexity level (app level 1 to 3) of a m-commerce interface. This section used a number of specific statistical tests to better understand if a relationship does exist between these variables.

In this study, the General Linear Model (GLM) was employed to investigate the impact of visual complexity on visual fatigue. The GLM is a flexible statistical technique that allows for the analysis of multiple dependent variables simultaneously, thus accommodating both continuous and categorical independent variables. This makes it an ideal tool for examining the multifaceted nature of user interactions with the different m-commerce interfaces (App level 1, App level 2, App level 3). The figures in Appendix G, (Figure 20, Figure 21, Figure 22 and Figure 4 below) visually display the GLM to understand the relationship between the models for each visual complexity level and for all visual fatigue metrics for both the initial free browse and the task-orientated assignment.

Figure 4: Scatterplot for the Two Tasks for the Relationships Between Visual Fatigue Metrics and Visual Complexity Levels



The scatterplots show that the visual fatigue metrics have a similar relationship across all the visual complexity levels. For the first initial free browse task (task 1), there was a very slightly negative linear relationship between the combined pupil diameter and the blinks per minute, as well as fixation dispersion and the blinks per minute across the different application iterations. A very slight negative relationship was observed between the blinks per minute and the combined pupil diameter across all the visual complexity

levels. The relationships between fixation dispersion and the combined pupil diameter showed no correlation between these visual fatigue metrics across all visual complexity levels.

The primary objective of this study was to determine whether visual complexity measured as different app levels (1, 2 and 3), directly influences visual fatigue. Visual fatigue is measured using three key indicators: combined pupil diameter, fixation dispersion, and the blinks per minute (or blink rate), each reflecting different aspects of the visual strain that is experienced by users. By employing the GLM, this study aimed to provide an analysis of how varying levels of visual complexity affect these indicators of visual fatigue. The results are shown below in the following tables, but more figures and statistics are in Appendix G:

Table 15: Task 1 Multivariate Tests from the GLM Model Visual Complexity and Visual Fatigue

Multivariate Tests ^a						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.77	98.86 ^b	3	91	<.001
	Wilks' Lambda	.24	98.86 ^b	3	91	<.001
	Hotelling's Trace	3.26	98.86 ^b	3	91	<.001
	Roy's Largest Root	3.26	98.86 ^b	3	91	<.001
App level	Pillai's Trace	.06	.88	6	184	.508
	Wilks' Lambda	.95	.88 ^b	6	182	.513
	Hotelling's Trace	.06	.87	6	180	.518
	Roy's Largest Root	.04	1.35 ^c	3	92	.264
a. Design: Intercept + App level						
b. Exact statistic						
c. The statistic is an upper bound on F that yields a lower bound on the significance level.						

Table 16: Multiple Comparisons for Visual Fatigue Metrics Between Visual Complexity Levels Task 1¹

Dependent Variable		Sig.	95% Confidence Interval		
			Lower Bound	Upper Bound	
Combined Pupil Diameter TF T1	1	2	1.000	-1.76E-04	1.10E-04
		3	1.000	-8.56E-05	1.95E-04
	2	1	1.000	-1.10E-04	1.76E-04
		3	.431	-5.72E-05	2.32E-04
	3	1	1.000	-1.95E-04	8.56E-05
		2	.431	-2.32E-04	5.72E-05
Fixation Dispersion TF T1	1	2	1.000	-1.28E-04	1.20E-04
		3	1.000	-1.50E-04	9.37E-05
	2	1	1.000	-1.20E-04	1.28E-04
		3	1.000	-1.50E-04	1.01E-04
	3	1	1.000	-9.37E-05	1.50E-04
		2	1.000	-1.01E-04	1.50E-04
Blinks Per Minute TF T1	1	2	.833	-4.01E-03	1.53E-03
		3	.268	-4.65E-03	8.06E-04
	2	1	.833	-1.53E-03	4.01E-03
		3	1.000	-3.49E-03	2.13E-03
	3	1	.268	-8.06E-04	4.65E-03
		2	1.000	-2.13E-03	3.49E-03

¹ Task 1 = free-browse task; Task 2 = task-orientated assignment

Table 17: Task 2 Multivariate Tests for Visual Complexity and Visual Fatigue

Multivariate Tests ^a						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.51	31.15 ^b	3	90	<.001
	Wilks' Lambda	.49	31.15 ^b	3	90	<.001
	Hotelling's Trace	1.04	31.15 ^b	3	90	<.001
	Roy's Largest Root	1.04	31.15 ^b	3	90	<.001
App level	Pillai's Trace	.08	1.26	6	182	.279
	Wilks' Lambda	.92	1.26 ^b	6	180	.279
	Hotelling's Trace	.09	1.26	6	178	.279
	Roy's Largest Root	.07	2.24 ^c	3	91	.089
a. Design: Intercept + App level						
b. Exact statistic						
c. The statistic is an upper bound on F that yields a lower bound on the significance level.						

Table 18: Multiple Comparisons for Visual Fatigue Metrics Between Visual Complexity Levels Task 2

Dependent Variable			Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Combined Pupil Diameter TF T2	1	2	.219	-1.36E-04	9.25E-04
		3	1.000	-4.70E-04	5.81E-04
	2	1	.219	-9.25E-04	1.36E-04
		3	.393	-8.81E-04	2.03E-04
	3	1	1.000	-5.81E-04	4.70E-04
		2	.393	-2.03E-04	8.81E-04
Fixation Dispersion TF T2	1	2	1.000	-1.28E-04	2.03E-04
		3	.926	-9.55E-05	2.34E-04
	2	1	1.000	-2.03E-04	1.28E-04
		3	1.000	-1.38E-04	2.01E-04
	3	1	.926	-2.34E-04	9.55E-05
		2	1.000	-2.01E-04	1.38E-04
Blinks Per Minute TF T2	1	2	.290	-4.96E-03	9.15E-04
		3	1.000	-3.30E-03	2.52E-03
	2	1	.290	-9.15E-04	4.96E-03
		3	.564	-1.37E-03	4.64E-03
	3	1	1.000	-2.52E-03	3.30E-03
		2	.564	-4.64E-03	1.37E-03

For both Tasks 1 and 2, the next trends were observed in relation to all the visual complexity levels and the visual fatigue metrics. All four multivariate tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) had intercept p-values < .001. This indicates that the intercept is highly significant, thereby meaning that the overall model explained a significant amount of the variance in the dependent variables. A similar trend is seen in Appendix G Table 75 whereby the intercept for the test of between-subjects effects for the initial free browse task all yielded a p-value < 0.01, thus showing some significance between the visual fatigue metrics and the visual complexity app levels at the 5% significance level. As seen for Table 78 (in Appendix G), the p-values for the intercept in regard to the test of between-subject effects for the second task-orientated assignment did not yield values below the 5% significance level. The interaction between App level and the visual fatigue metrics in regard to both task 1 and task 2 revealed non-significant results in terms of the p-value and the F statistic.

In regard to the multivariate tests across all the four tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) all the p-values for the visual complexity effect were greater than the 5% significance level, thus indicating that visual complexity (App level) does not have a statistically significant effect on the combined dependent variables related to visual fatigue. This could indicate that the visual fatigue metrics have a relationship with each other, but they are not impacted by the visual complexity of a m-commerce application. This can be seen in Appendix G Table 74 for task 1 and Table 77 task 2.

The multiple comparisons indicate the pairwise differences between the levels of visual complexity (App level) for each dependent variable (combined pupil diameter, fixation dispersion, blinks per minute). For both tasks, the multiple comparisons indicated that none of the pairwise differences between the levels of visual complexity (App level) for each dependent variable (Combined Pupil Diameter, Fixation Dispersion, Blinks Per Minute) for the initial free browse (T1) and for the task-orientated (T2) assignments were significant (seen in Appendix G Table 76 and Table 79).

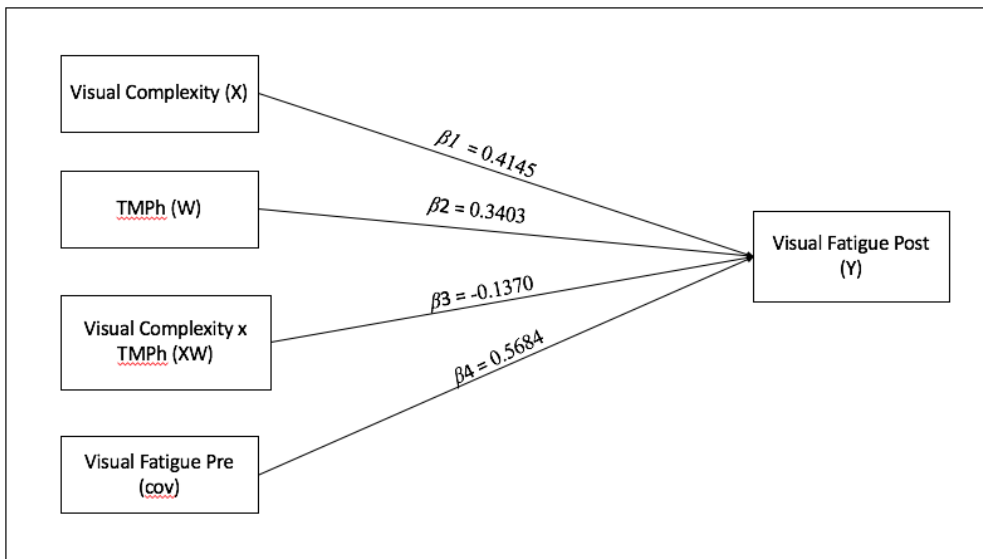
To conclude, the results of both the multivariate tests and the multiple comparisons suggest that the visual complexity of the m-commerce interface does not significantly influence visual fatigue as measured by the combined pupil diameter, fixation dispersion, and the blinks per minute for both the initial free browse (task 1) and for the second task-orientated assignment (task 2). Despite the overall model being significant, the specific effect of visual complexity (App level within the statistical tests) was not statistically significant, and there were no significant pairwise differences between the levels of visual complexity. This indicates that although visual fatigue is experienced by the users, and is considered significant across the three measures of visual fatigue at the different app levels, there is no evidence to suggest that visual fatigue is influenced by the different levels of visual complexity. This hypothesis can therefore be rejected, and it can be concluded that at the 5% significance, visual fatigue as measured by these metrics (combined pupil diameter, fixation dispersion and blinks per minute) is not significantly impacted by the level visual complexity of a mobile application interface, thus visual complexity does not directly impact visual fatigue.

4.5.6. H4

H4: The time the participants have spent on their mobile device before the experiment moderates the effect of the visual complexity of the app on visual fatigue

The hypothesis states that the amount of time the participants spent on their mobile devices before the experiment moderates the effect of the visual complexity of the app on visual fatigue. Specifically, it proposed that the visual complexity of the app would have varying impacts on visual fatigue based on the prior mobile device usage by the participants. Moderation was tested using Hayes (2022) PROCESS macro on SPSS for logistic regression analysis. The moderation model for H4 shows the path of time spent on the mobile device (TMPH) as a moderator and visual fatigue prior to the experiment (Vfpre) as a covariate (see Figure 4 below).

Figure 5: H7 Moderation Model



The results indicate that the model is significant, and it explains approximately 36.46% (R-squared value) of the variance in the post visual fatigue experienced (Vfpost). The model is statistically significant overall at the 5% significance level with p-value < .001 and F-statistic = 12.92, thus indicating that at least one predictor is significantly associated with visual fatigue post experience (Vfpost). From the individual variable statistics, it is clear that the visual fatigue experienced before (Vfpre) is the only statistically significant variable of post visual fatigue (Vfpost) with a p-value = < .001 and $\beta = .57$. The 95% upper and lower confidence interval (BOOTLLCI: 0.43, and BOOTULCI: 1.18) does not include 0, thereby supporting this conclusion that the visual fatigue prior to the experiment significantly predicts the visual fatigue experienced after the experiment. Thus, for each unit increase in visual fatigue prior to the experiment (Vfpre), the visual fatigue after the experience (Vfpost) increases by approximately 0.5684 units, holding other variables constant.

All other variables were insignificant at the 5% level. The constant was not statistically significant with a p-value = .806, and $\beta = -.234$. The 95% upper and lower confidence interval (BOOTLLCI: -2.120, and BOOTULCI: 1.652) also includes 0, supporting that it is not significantly significant. Visual complexity (App Level) is also not statistically significant with a p-value = .352 and $\beta = .415$. The 95% upper and lower confidence interval (BOOTLLCI: -0.465, and BOOTULCI: 1.294) also include 0 supporting that it is not significantly significant. Thus, visual complexity (App level) does not have a significant main effect on visual fatigue after the experience (Vfpost).

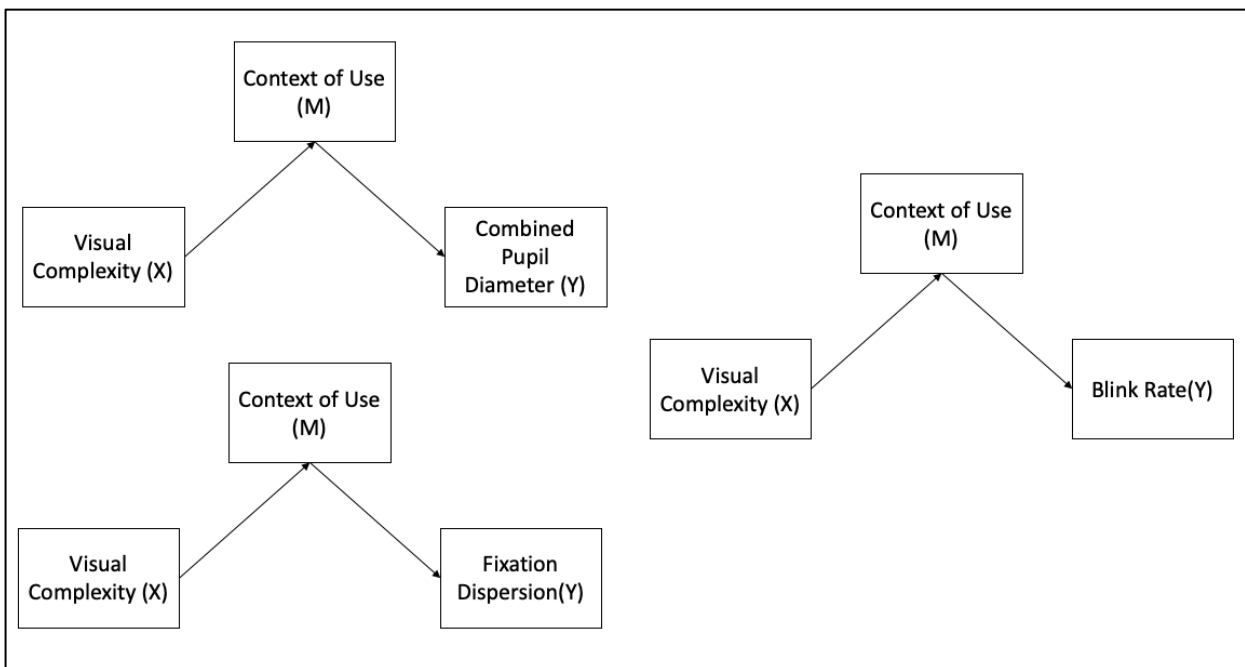
The interaction term (App level and TMPH) was also not significant at the 5% level, with a p-value = .361 and $\beta = -.137$. The 95% upper and lower confidence interval (BOOTLLCI: -0.433, and BOOTULCI: 0.159) also includes 0 supporting that it is not significantly significant. It can thus be concluded that the interaction between the time spent on the phone prior (TMPH) and visual complexity (app level) is not significant, indicating that the effect of visual complexity (App level) on visual fatigue (Vfpost) is not moderated by the time spent on the phone prior (TMPH). The time spent on the phone does not have a significant effect on Vfpost with a p-value = .277 and $\beta = .340$. The 95% upper and lower confidence interval (BOOTLLCI: -0.277, and BOOTULCI: 0.958) also includes 0 supporting that it is not significantly significant.

From the test of the highest order unconditional interaction, the interaction between visual complexity (app level) and the time spent on the phone prior (TMPh) does not significantly improve the model ($p = 0.3608$). Thus, there is no evidence to support the hypothesis that the time spent on the phone prior to the experiment (TMPh) moderates the effect of visual complexity (app level) on the visual fatigue after the experiment (VF post). Therefore, the hypothesis is not supported: the time spent on a mobile device before the experiment does not moderate the effect of visual complexity on visual fatigue. The PROCESS macro-output for H7 is presented in Appendix H, Figure 23.

4.5.7. H5

H5: The context of use (free exploration vs task-orientated) participants have with the application mediates the effect of visual complexity of the app on visual fatigue

Figure 6: Context of use (Task type) as a mediator



This hypothesis suggests that the context of use mediates the effect of visual complexity of the app on visual fatigue. Specifically, the context of use, that is, the task done by a user explains the observed relationship between visual fatigue and visual complexity. To test this hypothesis, a mediation analysis was conducted with three dependent variables: combined pupil diameter, fixation dispersion, and the blinks per minute. The independent variable was the visual complexity of the app (App level), and the moderator was the task type (free exploration vs task-oriented). Mediation was tested using Hayes (2022) PROCESS macro on SPSS for logistic regression analysis. The analysis aimed to estimate the direct and the indirect effects of visual complexity on visual fatigue, with the task type serving as the mediator.

The hypothesis H5 was tested to determine if the context of use (free exploration vs task-oriented) mediates the effect of visual complexity on visual fatigue. The analysis revealed a number of key findings. For the combined pupil diameter mediation analysis, the direct effect of visual complexity on visual fatigue was

not significant. The indirect effect mediated by the task type was also negligible. For fixation dispersion, the direct effect of visual complexity on visual fatigue was not significant. Similarly, the indirect effect mediated by the task type was negligible. For the blinks per minute, the task type had a significant effect on visual fatigue. However, the direct effect of visual complexity was not significant, and the indirect effect was negligible.

The results from the mediation analysis in relation to the combined pupil diameter indicated that the model was insignificant (p -value = .062) with a p -value above the 5% significance level. All individual variables were insignificant at the 5% level. The constant was not statistically significant with a p -value = .752, and β = $-5.7965e-05$. The 95% upper and lower confidence interval (BOOTLLCI: $-4.1874e-04$, and BOOTULCI: $3.0281e-04$) also included 0 supporting that it is not significantly significant. The visual complexity (App level) was also not statistically significant with a p -value = .603, and β = $-2.9005e-05$. The 95% upper and lower confidence interval (BOOTLLCI: $-1.3885e-04$, and BOOTULCI: $8.0839e-05$) also included 0 supporting that it is not significantly significant. The context of use (task type) was also not statistically significant with a p -value = .871, and β = $1.5034e-05$. The 95% upper and lower confidence interval (BOOTLLCI: $-1.6706e-04$, and BOOTULCI: $1.9713e-04$) also included 0 therefore it is not significantly significant. Thus, the task type does not mediate the relationship between visual fatigue (measured by combined pupil diameter) and visual complexity (see Figure 24 in Appendix H).

The results from the mediation analysis in relation to the fixation dispersion indicate that the model is insignificant (p -value = .428) with a p -value above the 5% significance level. All the individual variables were insignificant at the 5% level. The constant was not statistically significant with a p -value = .106, and β = $1.1046e-04$. The 95% upper and lower confidence interval (BOOTLLCI: $-2.3727e-05$, and BOOTULCI: $2.4464e-04$) also included 0 thus it is not significantly significant. The visual complexity (App level) was also not statistically significant with a p -value = .641, and β = $-9.6669e-06$. The 95% upper and lower confidence interval (BOOTLLCI: $-5.0520e-05$, and BOOTULCI: $3.1187e-05$) also included 0 supporting that it is not significantly significant. The context of use (task type) was also not statistically significant with a p -value = .225, and β = $-4.1841e-05$. The 95% upper and lower confidence interval (BOOTLLCI: $-1.0957e-04$, and BOOTULCI: $2.5886e-05$) also included 0 therefore it is not significantly significant. Thus, the task type does not mediate the relationship between visual fatigue (measured by fixation dispersion) and visual complexity (see Figure 25 in Appendix H).

The results from the mediation analysis in relation to the blink rate indicate that the model was significant (p -value = $< .001$) with a p -value below the 5% significance level. One individual variable was also significant at the 5% level, and the constant. The constant is statistically significant with a p -value $< .001$, and β = $9.7320e-03$. The 95% upper and lower confidence interval (BOOTLLCI: $7.0857e-03$, and BOOTULCI: $1.2378e-02$) also did not include 0 thus it is significantly significant. The visual complexity (App level) was not statistically significant with a p -value = .177, and β = $5.5389e-04$. The 95% upper and lower confidence interval (BOOTLLCI: $-2.5179e-04$, and BOOTULCI: $1.3596e-03$) also included 0 supporting that it is not significantly significant. The context of use (task type) was, however, statistically significant with a p -value $< .001$, and β = $-3.0952e-03$ for this visual fatigue metric. The 95% upper and lower confidence interval (BOOTLLCI: $-4.4309e-03$, and BOOTULCI: $-1.7596e-03$) also did not include 0 thus it is significantly significant. Thus, the task type did mediate the relationship between visual fatigue (measured by blink rate) and visual complexity (see Figure 26 in Appendix H).

The results indicate that the context of use (free exploration vs task-oriented) does not significantly mediate the effect of visual complexity on visual fatigue. The task type had a significant effect only on the blinks

per minute measure, but the mediation effect was not supported across all the other measures of visual fatigue.

4.6. THE RESULTS OF THE QUALITATIVE DATA ANALYSIS

For this section of the data analysis, the interviews that occurred after the eye-tracking experiment and the post- and pre-questionnaire are analysed to understand the key themes from the personal user experiences. An Interpretive Phenomenological Analysis (IPA) was done to identify and understand the themes originating from the interviews. The IPA stipulates a qualitative method to provide an in-depth account of each participant's personal experience before investigating the patterning of convergence and divergence within the different scenarios (Eatough *et al.*, 2017; Nizza *et al.*, 2021). The IPA analysis aimed to understand consumer's initial impressions and user experience with the mobile app, the visual fatigue experienced from the application and how the visual elements were experienced by the users.

4.6.1. Self-reported User Experience

For the first application which employed a simple visual design, consumers explained the initial impressions of the application through common themes such as the simplicity of the layout and the app in general, intuitiveness of the app, product limitations of the app, the blandness of the app, coordination of choices, the flexible interactive nature of the app, issues regarding item pricing, modern design and operational issues. The second application employed a slightly more complex design which was described by the users as intuitive, simple, to provide adequate information, enjoyable text, colours and design, operational errors, as well as other comments and issues experienced with the app. The third application employed the most complex visual design, and the common themes found from user responses include but are not limited to opinions on; intuitiveness, minimalism, design, functionality, text and information, pictures and visuals of the app.

4.6.1.1. Simplicity and Blandness

The layout and the navigation of the first app was described as simple or unrefined, thus in accordance with the ordinary m-commerce application layout and design. The participants stated the simpleness of the visual aesthetics of the application, "visually like it's quite simplistic in a very positive manner". The application features minimal colour in the user interface with black/ grey or white utilised the most within the buttons, text, background colour, and comments like "simple aesthetic" and "nothing too flashy," which showcased this simple design. The participants found this design choice helpful in terms of alleviating visual fatigue, thus allowing the use of the system without distraction, difficulty or confusion, the quotes include: "it was quite simple, it wasn't too much, like distracting you, which was quite cool," and "it wasn't anything, to catch the eye or to like, make my eyes really tired because sometimes when you have a mobile app, especially the shopping apps, when all the ads pop up and the widgets so it can get very tiring".

For the first app, about half of the users explained that the app as bland, boring or basic, thus limiting the desire to stay on the application for any prolonged time. The participants reported that the design was not innovative, "(it) follows the kind of average e-commerce app that you would see with the profile homepage with the little kind of same icons that you would see normally". Quotes such as, "I think the lack of colour

is slightly boring,” and “it wasn’t very gripping in the sense of like the icons and things like that,” show that the lack of colour was an issue for some users and the simple nature of the icons, and the other elements make it unmemorable or left an impression that the app was decent at best. A number of participants explained the app as adjectives of nice, implying that the app had minimal impact on them.

For the second application, not as many people explained the app as simple and minimalistic compared to app one. In total, about only eight users explained the app as simple and minimalistic. One user stated, “I think you know the usability and user interface, it’s seems straight to the point, there you can easily find what you want”, meaning that the layout was thought to be straightforward thus contributing to the usability of the app. Other people stated similar sentiments in regard to the simplicity of the app, “the site is very plain” and “visually, everything was quite like simple”. There was also one participant who described the app as being bland in comparison to what is expected from a m-commerce app, they stated, “It was rather bland from what I’m used to, it kind of felt boring in a sense”.

The third application was also described as being simple by most users (about 19 users). The participants did not feel overwhelmed by the app features and found the layout and the overall user interface to be simple and straightforward. The users stated, “I didn’t feel overwhelmed because sometimes mobile applications can feel like they’re bombarding you every second with like another product or an ad or something,” and “simple layout, it’s not like complicated or anything,” and “I would say that it had a simple interface”. These comments show that there was a common consensus that the application was simple but not in a bland or boring manner. The simplicity also made it easier to use the app, as per the user quote, “it’s very minimalist so it makes the user interface is very easy to navigate”. Overall all three apps were considered ordinary and with a minimal design aesthetic which aided in the usability of the app and users did not feel overwhelmed by the features. App three was the only application which was not described as boring.

4.6.1.2. Intuitive and Interactive nature of the app

Approximately 62% of the participants considered the first application iteration easy to use, easy to navigate, intuitive, accessible and user-friendly. The simplicity of the colours and interface allowed a user to achieve the intended shopping goals easily. One participants said, “it was usable, like it didn’t freeze or anything like it gave me access to like the things that I wanted to, see and everything”, “it’s very easy to use, it’s not problematic and simple for the user, no problems whatsoever”. Participants also provided comments such as, “pretty user-friendly, could use it quite well” and “I would say it was quite seamless and user-friendly”, which gives context for the above insights about the user experience. The overall user experience of the app was intuitive in general, and it received mostly positive feedback.

From the second iteration, a number of users also described the app as easy to use, intuitive and easy to navigate. The participants stated, “it is easy to use, and it’s allowed me to access the things that I needed to easily,” and “I don’t feel like I’m struggling to look for (items)” thus emphasising the ease of use of the app in terms of navigation and operating the app. The simplicity of the app also made it easy to navigate, self-explanative and user-friendly as stated by the users, “the site is very plain and easy to get through and look through” and “It was quite easy to use quite self-explanative”. Although most found the second app easy to navigate, one person found it difficult to use, “I found it difficult to navigate and when I entered each item”, while others had operational issues using the app due to the buttons used and other technical bugs, “it(‘s) hard to click some of the buttons but it’s fine” and “I quite liked it, but there are a couple of bugs like little things that were annoying,” show these sentiments.

The third iteration had about 60% of the respondents compliment the ease of use of the app. Most found the experience enjoyable due to the navigable nature of the app, “not too distracting and I think it got all the points across that it needed to quite effectively,” was stated by one user, and shows that the addition of more visual stimuli did not negatively impact user experience. The other users stated, “it was easy to navigate”, “I think it’s quite easy to use, simple to navigate through the different options” , “like easy to follow” and “pretty simple and intuitive” all showing this common opinion that the app was easy to use and navigate. There was one user who did not think the app was as easy to use, they stated “It was quite difficult to navigate because the scroll bars are only accessible (at) specific points”. This quote shows that they found the functionality of the application, specifically the scrolling function difficult to utilise, thus hindering the user’s experience. Overall, the simple, minimalistic user interface allowed for easy use and navigation of the app, “It’s very minimalist so it makes the user interface is very easy to navigate”, as stated by a user. Overall most users found all three apps easy to use but one or two users had issues with functionality on all three apps.

4.6.1.3. Design (colour)

The consumers who interacted with the first iteration highlighted that their interaction was guided by the coordination of a space or of a certain colour. Specifically, the users chose or browsed items that aligned with certain colours or a particular space in mind. This could be a colour pallet that matched their personal preference or that made sense within their current living spaces. Often products were chosen in coordination with other items chosen from the app or a space in their current home in mind. The users also imagined the items in a specific space to understand if the choice was correct for them. The participants said, “I was just choosing things that go well with each other, like the colours” and “I looked at the lamp, I found one that maybe I could use for things like studying that could also be good for like an office space” in relation to this choice based on coordination.

Many of the participants that experienced the second app iteration enjoyed the design in terms of colour and text. Many participants also stated that they enjoyed the design and the user interface, stating that it was aesthetically pleasing, laid out well, and distinct. This showcases the general positive impression the users felt from the second app iteration. The quotes, “It was also very aesthetically pleasing”, “the user interface is great”, “this mobile application I would say it’s nicely laid out” and “fairly craft or indie” were sourced from participants pertaining to app two. About 23% of the users had something to say about the colours that were used and how that impacted their user experience. Some participants found that the colours used within the second app aided in the overall pleasant and calming design of the app, “I like the colours and the neatness of it, and I like the items, that’s all” , “I like the colours quite calming, green and browns” and “I feel like maybe even this green colour, it’s like calming almost, I don’t know, like really, It gives off like (a) peaceful kind of energy” shows this. These participants found the colour pallet that was used evoked a calming, peaceful atmosphere. One participant even stated that the mellow colours of green and brown relieve eye strain compared to brighter colours, “I feel the green helps with the eyes versus having like a brighter warm tone colour”. There was also one respondent who liked the colours but felt that more colours should be added, “I like the colours, think you should add more colours on the like the main page”.

A small number of users that utilised the third app iteration also made comments about the design, pictures and visuals used throughout the app. Some felt the use of limited visuals aided the experience as it did not distract the users, “the visuals were the same, so it wasn’t like I wasn’t getting distracted” and “it was very, visually appealing because it was to the point for me” which show this enjoyment of the sparse visuals

present. Another explained how accessibility to the picture and information was presented in a manner that allowed good decision making, “I think I look at pictures first and really like reading the details, so, I liked how that was quite visible”. Another respondent explained how both the product pictures and the icons and buttons within the app aided their use of the app. Overall users enjoyed the limited colour pallet used in both app one and two while colour was always in the back of consumer minds when engaging with the products for app one.

4.6.1.4. Design (text)

Most people from the first app iteration did not comment much on the text and information presentation in regard to user experience. One participant did state that, “I don’t think I even saw like dimensions and stuff”, indicating that there was not enough information for them to make an informed decision. This indicates that due to the high involvement nature of furniture products as much information needs to be presented for some users, to make better informed decisions. For the third iteration, there was one comment made in regard to text and information, “didn’t overwhelm me with too much information”, thus the app was not text-heavy and taxing on the user.

Another common theme was in regard to text, and information presentation, especially for the second app iteration. Information presentation was done in a manner that was not overwhelming and distracting for the viewers, “all the information it wasn’t an overwhelming amount of information where you have to click and look for small infographic like things”. The text was thought to be visible, and the descriptions were adequate enough for some and not enough for others, and the fonts were enjoyed for the most part. One participant said, “it wasn’t really maybe picture heavy maybe or like text heavy”, this indicates that the design was balanced well. Another participant said, “the descriptions, there’s no like dimensions, so I don’t know how big my hypothetical coffee table is going to be” indicating that more information was needed for them to make their purchase decision. “I like the fonts that were chosen, it(‘s) like some of them pop, which is cool” was also stated by a participant, indicating the enjoyment of the fonts used.

4.6.1.5. Limited options

Another theme that arose from the personal interviews from three users who engaged with the first app iteration pertained to product limitation options. The consumers felt that there were not enough options; “Not a lot of options” was reported by one respondent. Due to the fact that the term ‘options’ is a fairly broad term, this could refer to the categories, products, icons, and widgets. This was, however, only reported by about three users, who felt their choices were limited. For this experiment, limiting product choices was done on purpose to aid in limiting the time spent choosing items. Although these participants felt that there was not enough choices, the other participants did not feel this and felt the application was perfect in helping them to achieve their shopping objectives.

For the second app iteration about five users commented on the limiting options available to choose from. The users stated, “you only have three options” , “limited options... there’s not a lot to choose from”, indicating that the number of options was not enough for some participants, but this was done purposefully to ensure control for the study. One participant stated, “I think they’ve done the limited selection, high quality sort of trade off”, implying that the limited selection could be done on purpose by brands to imply the high quality of the items available. Some had issues with the lack of variety due to the limited options, “they all felt like they’re in the same kind of like range” and “there wasn’t like, much options, but just still good variety”. For the third app iteration, only one participant had an issue with the limited options, “I’m

just disappointed about the lack of couches”. This means that it was not as big of an issue for users of the third app, this could be due to the fact that they were more interested in the visual stimuli present on the app.

4.6.1.6. Other Themes

The following themes and observations were not considered common as it was only experienced by a maximum of three participants. For the first app iteration, a user considered the items on display as expensive, “very pricey”. This indicates that perhaps because the group of participants were within the young adult cohort, that brand new furniture items are not often explored or considered affordable. Another user indicated that they felt the navigation bar should not have been placed at the bottom of the screen, but rather on the left, stating that, “(the home tab) it’s weird, it’s fine, in the centre (but) like it could have been on the left”.

The placement of the navigation bar, although ordinarily in the middle bottom of the screen for a mobile application, for a website, it is often on the side. Either placement aids navigation or makes the app easier to use. Two participants also indicated that they had issues operating the application, “there was a lot of bugs and issues with it”. Although only a few users experienced these issues, it is important to ensure that all the users have a seamless experience that does not bring forth feelings of frustration, due to the efficiency of the system. The users of the first app iteration would have preferred to see the prices for the items on the home page, stating that, “I think (it) would be a drawback for some people is that the price isn’t displayed when you’re browsing over it like it’s only displayed when you click on it, which I guess is also enforcing people to click on the product,” states how the lack of an immediate price display hinders convenience for users of the platform, but also drives engagement to other pages of the application. This suggests that if displayed earlier, the users would not have to view the application further within the details page.

The participants of the second iteration stated that they needed more pictures and visuals to improve the user experience, “it would be nice to have more pictures than just one”, this might be aligned with other apps experienced by the user that allow users to view at least four pictures of an item from different angles, but this would’ve added another layer of complexity within the study. Another participant expected a more technologically advanced application, “with technology, technological advancements, you know, expecting maybe more stuff on the back end, yeah”, this could mean that the individual is very experienced with apps and potentially building apps.

A total of five users from the third app iteration also found some operation issues with the app that obstructed the usability of the app. There were two participants who described the app as having operational issues, “basic, glitchy,” and “just interesting a little glitchy”. Others had issues with buttons, icons and the navigation of the app in general. Other comments about the third app include, that the app did not overwhelm the user with too much information, “didn’t overwhelm me with too much information” and that users also found the app to be similar to other conventional m-commerce apps. The users stated, “I actually do enjoy this because it’s easy to use, It’s like a normal like, Superbalist you know?” and “I think it goes along with how most of the applications work these days, yeah”. All the comments within this section could also indicate the personal preferences of the particular user interviewed, due to the fact that only a few individuals expressed these views.

4.6.2. Self-reported Visual Fatigue experienced

For the first application which employed a simple visual design, the consumers explained their initial impressions of the application in regard to visual fatigue below. The second app iteration employed a slightly more visually complex design than the first iteration. The third iteration employed the most visually complex design. The common themes that arose across all three apps included the minimal strain felt, no change felt, brightness impact, slight strain felt, and adjustment due to prolonged focusing. Overall, the users felt little to no strain from their experience with all the three application iterations.

4.6.2.1. No Strain

Most participants felt, fine, no strain or normal. This means that the simple visual design interface from the first iteration allowed the perception of little to no strain. The participants stated, “I didn’t feel any effects on my eyes”, “it feels fine, doesn’t feel like really strained.”, “my eyes feel normal”, and “I didn’t feel any effects on my eyes”. This could be due to the fact that the participants were exposure to the screen for too long as indicated by this user, “I didn’t have to stare at the screen for too long”. The consumers thus perceived app one as incurring little to no visual fatigue. One user even stated feelings of energisation, “I actually feel like I’m a little energized, you know, if it’s just easy to go through it all”. This indicates that the ease of use of the application helped to relieve feelings of visual fatigue and could encourage a lengthy time spent on an app in theory, but was only expressed by one user.

In regard to the second app iteration, half of the participants reported a normal to zero amount of perceived visual strain. Quotes showing this sentiment include, “normal, still fine”, “not too strange or anything, feels alright”, “they are still in great shape”, and “I don’t feel any different”. Some users felt a little fatigued, but this was dependent on whether they had their glasses on. It was stated, “a normal amount without glasses I think” and “my normal glasses have a blue light filter”, indicating that with the adequate glasses less visual strain would have been felt. One user also felt that if they had prolonged their stay on the app they would have experienced some discomfort or visual fatigue, “they don’t feel strained, it’s just the difficulty of knowing what to focus on, I think after a longer while it may become difficult to see”.

The third app iteration had 63% of the users who explained the none to a little visual fatigue felt. This was the most number of users who reported feeling no strain. The users stated, “everything is fine”, “they feel alright, ... they don’t really strain”, “my eyes actually feeling ok”, “they feel fine”, “same as before, normal”, and “neutral” and a number of others who felt the same and had no discomfort, pain and visual strain. One user stated that due to their regular use of their mobile phone and mobile apps their eyes are used to the experimental app, “I think it’s because I’m always on mobile apps and I feel like my eyes have been accustomed to it”. Other users described the colour scheme and minimalism as why no strain was felt by users, “(my) eyes are actually fine because it’s like this light green colour“, “not too bad because it wasn’t over stimulating” and “I didn’t feel like I was straining my eyes to figure things out”. Thus, the app was not too overwhelming and distracting for the users and a calm colour scheme eased any discomfort felt on their eyes.

4.6.2.2. Some reasons for strain felt (Brightness, Colour, and Font size, work prior, focusing)

There were a few participants who felt that certain visual elements and external factors encouraged visual fatigue. The respondents felt that brightness was an issue in relation to visual fatigue. Users felt that the phone brightness was quite intense and not something their eyes were used to; “the phone is a bit bright, I like to keep my phone’s brightness really low,” and another commented on the adjustment of the brightness depending on the specific room they occupy; “sometimes when I use apps I would adjust the light depending on what kind of room I’m in”. The white background was especially straining to users; “the white back drop will always make my eyes a little bit tired” and “I usually have everything set to dark mode because it was a very bright, very white design I do feel like you know my eyes had to strain a little bit”.

A participant also commented that the colour scheme used for the first app iteration was not straining on the eyes. This contradicts other complaints of brightness and shows that the personal preferences when using one’s personal mobile device will impact personal opinion and feelings on what strains one’s eyes. Another user found that the small font increased the strain felt. They said; “they’re fine (in relation to their eyes), just that the font was a little bit small”. This indicates that the user had to focus a lot more and thus their eyes had to do a lot of work to read information causing visual fatigue.

The users of app two felt that the brightness was a bit much, even though the colours utilised were calming and relaxing on the eyes. The users stated, “also on my phone I enable the blue light filter and generally turn the brightest brightness down” and “these colours were quite mellow, and they’re fine, but the screen brightness was actually not too bad”. This showcases contradictory opinions in regard to the brightness of app two, but it was only reported by two users. There were two users who also stated that the colours were not too bright and thus did not add to the visual fatigue felt, “because the colours weren’t that bright, it was not so bad”.

Some participants that used app iteration three felt some strain due to the prior work done either the day before or earlier in the day. Quotes include, “Quite strained looking at it for quite a while, but they were a bit strained before since looking at my computer” , “To be honest I’ve been working the entire morning, so my eyes are a little like (tired)” and “I think I was on my laptop for last three hours, so yeah”. Others felt some strain from the intense focus while interacting with the app. Quotes to support this include, “I was straining them quite a lot just to try to stay on the screen”, “I think ... a bit more from the trying to focus”, and “my focus, went blurry at some points, but that was the constant moving across the screen, which can be solved by the back button and the scrolling function”. The last quote, speaks about the buttons and icons which hindered the functionality and contributed to the visual fatigue felt due to focus while using the app. There was also one user who actually felt more focused and aware after using the application, “I think actually, (I am) more aware ... more focused than when I began”.

4.6.2.3. Slight strain

A number of participants also felt slight strain when experiencing the first application. Comments such as, “like I can feel the eye strain”, “I think it is average for me though, but overall, the only thing I can feel is the strain, there’s no kind of aching or anything like that, yeah”, and “slightly irritated”, indicated that some strain was felt, and this could have originated from the screen brightness, visual elements or other factors. A number of participants also felt that this strain was due to having to focus on the mobile device and looking at something else which meant some adjustment had to occur. The respondents stated; “I don’t

feel eye strain, but..., I felt like I had to readjust ... so it was less uncomfortable” and “they feel ... like it’s kind of difficult to look at other things like, to like, focus on other things”.

From application iteration two, about seven users felt slight strain from interacting with the mobile application. The quotes include, “a little bit strenuous” , “to be honest, slightly strained” and “actually a little bit itchy, I would say fatigued” which show the slight strain felt by the users. Some attributed the strain felt to the external influences such as not enough sleep while others felt that interacting with the app caused excess work for the eyes. The users stated, “I didn’t sleep a lot, so my eyes are feeling tired, but then engaging with it in terms of like the focusing my eyes feel a little bit weird ... like just a little bit strained, tired”, “just a lot going on like with the scrolling up and down, but I think that’s, usual”, and “not like before, when I came in here, it’s like, I feel like the by the end of this, they’re probably going to be watery or as soon as I get out of the of this place”.

The third application iteration also received similar feedback that some visual strain was felt while interacting with the app. The quotes from the participants showcase the slight strain that was felt, “a bit strained” , “I think maybe like slightly strained” , “it’s just a little bit hazy” , “not too strained, but my eyes do get a bit strained” and “there was a bit of discomfort, yeah, and a little bit blurry”. Overall, 31.25% of the users felt a bit of discomfort when viewing the app. One user attributed other activities and experiences prior to the experience as the reason behind the slight strain felt, they stated; “but I think they were feeling dry beforehand, so I wouldn’t say that that’s the right... thing, I think they feel fine”. Another participant stated that ordinarily their eyes do get strained but during this experience the strain was minimal, “not too strained, but my eyes do get a bit strained”. One user actually felt better concentration and more fixated due to their experience with the interaction with the app. They stated; “I think actually, more aware than ... more focused than when I began”.

4.6.2.4. Lots of strain felt

A total of three users of application iteration one felt tired after their interaction with the first application, while two felt their eyes were teary and or watery after their experience. The users stated that “they’re a little tired, but it’s been a long day” and “they’re quite tired, but I think that’s ... because it’s like the end of the day and my eyes have been busy the whole day”. This shows that the tiredness of their eyes could also be due to prior activities and experiences which caused strain. From the two that stated that their eyes were watery, it is clear this was not due to other experiences, “they were a bit teary in the like in the first one when I was like scrolling”. This indicates that the functionality of the app was causing strain for these specific users. There was one user from application iteration two that reported that a lot of strain was felt, “I did have a late night yesterday, so it was quite strenuous”. This shows that the perceived visual strain was a lot due to prior activities done by that participant, similar to the user from app one. From the third iteration of the application, only one user felt exhausted after their interaction with the app, they stated to have felt “very tired” in regard to the visual fatigue felt.

4.6.3. Self-reported Visual Elements

The users were also asked to report a number of visual stimuli changes that would improve the application. The first application iteration had a number of suggestions including; changes to the colours, pictures, font, brightness, and functionality. From the second iteration, the themes included but were not limited to;

changes to pictures, layout, colours, information and text, as well as functionality. The third app iteration themes such as; changes to design and colour, functionality, layout, information and text, as well as pictures. Other suggestions were also included.

4.6.3.1. Design and Colour

A large portion (41,18%) of the respondents that used app iteration one reported that they found the application to be boring and the addition of colour would help to improve the overall design blandness. The respondents said that “maybe add more colour” and “add a bit of colour to it, ...it’s just more bland”. The participants specifically suggested adding colour to certain aspects such as the search bar or the cart section to highlight the symbolism of money and to improve on the greyscale design, “I think that maybe instead of using grayscale for the search bar, use a lighter colour and then a darker colour for the rest of the application and maybe a checkout in green that symbolizes cash”. The others indicated that such a bland colour pallet would discourage a prolonged stay and repeat usage of the application. Comments such as; “I think some more colour would help a lot (with) branding and stuff like (that),” and “I think the one thing that jumped out at me was the colour, the contrast is very nice, but having no colour makes me want to leave and not spend like lots of time (on the app)” show this sentiment.

One respondent even suggested that maybe the lack of colour leaves less distractions and the users are then able to focus on their shopping goals and tasks, “a little bit more colour, but other than that, yeah, it’s quite nice the non-distractions”. While another made a comment about the addition of colour to make it a bit more interesting which could be exactly what the other user was suggesting would be distracting. The comment was that “maybe add a little bit more colour through it, make it ... like make things pop out, you know, like sale items, etcetera, ... just make it more in your face” This showcases that users’ opinions differ on what is considered too distracting and what is considered just the right amount of visual stimuli to enable engagement and promote a prolonged stay on an app.

In regard to app two which implored a bit more colour to the design, about 30% of the users had a variety of opinions as well. Some users enjoyed the colours that were used, while others did not. The users that enjoyed the colours stated, “the colours are calm and neutral” and “I like the colours, I think they’re like very warm, ... I like warm colours”. While the others commented about the dullness, blandness, and white background. Users felt more colour should have been added, “maybe add like a bit more colour to it (the app)”, “maybe go for more vibrant colours, bold things,” , “I like to have more colours, ... but that’s just my preference” and “maybe more colours cause it’s mainly just white”. Some respondents thus prefer more colours and one even stated that although the use of green and brown was complementary, it also did not stand out to them, meaning a mediocre impression was left on the users. There were also comments about the white background that was used, many found it to cause some strain and suggested the addition of other colours. These comments were, “the white background, it’s a bit glaring,” and “other than that I would say like maybe the background could be a bit more, like less plain”.

The respondents from the third app iteration also made various comments about the colour and design that were used. About six users had negative comments regarding the app colour and design. They suggested, “maybe more than one accent colour, because right now it’s just green, so maybe different colours can like draw attention to different places” , “maybe make it a darker colour and ... not green” , “I don’t know, make it like black and white, maybe not a colour“ , “brighter colours, because the green is a bit bland” and “a lot of green, lot of green, I don’t know, I feel like that’s just stupid thing to say, but yeah, maybe like a

different colour”. It is clear from these comments that these users did not enjoy the use of green throughout the app and would have preferred a different colour or no colour at all.

About nine users had positive comments about their experience with the third app’s colour and design. These comments include; “I think the colours are not too bright and distracting and that helps quite a bit to maintain my attention” , “the nice light green is good” , “I like the colour personally the sage and the brown, I like the aesthetic” , “I think the colours are quite attractive, It’s easy on the eye,” , “the colours and lighting is great” and “I also like the colour, I think it’s calming, I don’t think it necessarily makes you squint, It’s not harsh”. One user also stated that they thought the prices and other important information should have been highlighted in a different colour such as red. The users liked the simplicity and tasteful design and even stated, “I really liked that, it was simple, that there wasn’t too much to look at, I really thought that was good”. Overall, the third app iteration’s used colours and the colour scheme were considered the least dull, straining to the eyes and entertaining. It is important to note that less users had issues with the colours used in app two than in app one, and that only two users found app two to be boring.

4.6.3.2. Images

Another common suggestion was the addition and the change to the type of pictures used for the items. The pictures used to display items were generic, with a white or see-through background. A number of the users of app iteration one suggested to have items in the context of living spaces and real-life settings, which help those who prefer to view items in real-life contexts to better understand how the item might look in their particular space (i.e., the living room, bedroom, kitchen and bathroom), “I think just adding more pictures of each of the items, maybe from different angles or, for example, in real life settings, so like when you have like real estate (for) example they have staging’s to use some of the products and show how would be used” and “if you could figure out how to make it so that the furniture could be seen in somebody’s house like they could take a picture and see what it looks like in their house, that would be really cool”. One user also suggested to use real images instead of icons, which might confuse users who are familiar with the common icons used for functionality. They stated, “I think it will be more catchy if (the app) use(d) like proper images, not just like icons.”.

Other users of app one suggested that more images be added of the items from different angles, to create a fuller image in the consumer’s minds so as to make a more informed decision., “more photos could have been nice as well” and “providing me more pictures on different angles”. Another user suggested the addition of animation and other graphics to help add a more interactive visual layer. They stated that, “possibly upon clicking a button, maybe getting like a cute animation or a cute graphic or something just makes it more fun”. This addition would potentially add more interactivity but could also lead to a more visually taxing experience for the users.

Those that experienced app iteration two had similar comments to that of the users of app one. The first was regarding the usage of images of the items in real-life contexts, “I would say just the pictures ..., just like seeing them in the actual like maybe setting”. Another comment was regarding the images from different angles, “maybe different like angles of the picture or maybe like close-ups or something like that and I quite like when ... if you click a picture then instead of like zooming in, you just like scroll through different magnifications of the picture”. For app two, someone did also suggest that better items and images should be used, “and the pictures are not so good maybe better items”. Users also found the overall design enjoyable; they considered it functional and relished in the modern, clean design, “I like the smoothness of everything ... it’s very welcoming and like I said clean”.

The respondents that used app iteration three had less comments about the images. This could be due to the other visual elements which entertained the users enough that they preferred the minimal amount of pictures. Two users suggested more images for each item, “more pictures for each thing” and “more pictures of the product so that people get a better sense of what they’re actually buying”. Another suggested the addition of animations when a button was pressed, “maybe like animation wise you want to like ... you know when you press something (a button) it goes tudalu (sound) And then it makes the sound effects and it does the thank you for buying (animation)”. Another preferred the images to possess a see-through background (app background colour was the image background colour) rather than a white background, as the image with a white background was found to be straining to the eyes, “I kind of like the picture of the colour background, I think the colour in comparison to white is also less harsh in your eyes”.

4.6.3.3. Type, Typeface and information

The participants also made a few suggestions in regard to the font, text and information used within the app. The users of app iteration one suggested that more information was needed within the description to aid the users in making their decisions. A participant stated; “I think in terms of each product, maybe like within it could have been a little bit more descriptive” and another stated “I don’t know, like some descriptions, it’s very basic, like you don’t really know what you’re getting out of it”. This suggests that the minimal information provided was not enough for some consumers and that longer more explanatory descriptions are needed.

Another concern for application one was that the font was very small, thus making it more taxing for the viewers and contributing to the visual fatigue felt. The participants reported that the small text size meant they had to squint, and that the information could not be seen properly. The following statements show this, “obviously, make the front a little bigger so you can see and don’t have to squint”, “the font is a little small, so making the font bigger as well” , “the text could also be larger” and “you can’t see all the information, but even when you have to scroll, the information was written quite small”. Font size 12 was utilised, which is quite standard, as one participant noticed, but still it caused trouble for some users. Contradictory to the comments made by other users, one participant stated that they found the font to be big, “ I mean the font is pretty big, which is nice”.

The comments about the information, text and font in regard to application iteration two were mainly negative. The users stated that the information needed to stand out more, that there was not adequate enough information for their eyes to be drawn to and that descriptions were sufficient. They stated, “but maybe just having some things like important information stand out more so that my eye is more drawn to the important things first and then I know exactly where to focus”, “categories could jump out a bit more” , “I think the home screen can be a little bit more like catchy, yeah” and “it’s like a description of the product was like, ok”. The users of application iteration two found that the font style was not consistent (which one preferred), and the text needed to be larger. They stated, “I would have all the font to be the same, because some of the descriptions were different from the font, should all be the same” , “maybe the font could be a little bit bigger”, “I think maybe the text could be a little bit larger, especially in the descriptions” and “maybe some different fonts and maybe slightly bigger fonts”. The least number of comments about font, text and information was found in app two compared to app one and three.

For application iteration three, the users found the text to be small. The users stated, “the writing which is small”, “I mean, for me personally, I always make my font very big”, “I don’t want to say the front could be bigger cause then that’s giving me like old man vibes”, “maybe make some of the writing a bit bigger

in terms of like the product names” and “if I wasn’t looking at the pictures on the sides, then I would have to look at the writing which is small” in regard to the size of the text. Other users suggested to make important information such as the price bold so as to attract user attention, “I think maybe some of the text could be a little bolder” and “for the price make it also a bit more bold”. Another user suggested that the colour of the text be changed so that the information is more easily accessible and salient, “I’d like change grey information on a coloured background”. One user also felt that further specifications are needed for descriptions, “maybe more description about the products”.

4.6.3.4. Brightness

Participants from all three apps also suggested a dark mode or the ability to adjust the brightness of the app. This aligns with the comments about the app user experience whereby brightness was an issue, and it impacted the visual fatigue that was experienced by the users. From application iteration one, there were comments pertaining to adding a dark mode to aid with the fatigue felt with brightness, “having the option to enter dark mode so that there’s less strain, especially if you’re like, if there’s maybe like a night mode for example, or like a low lighting mode perhaps”. Other comments also highlighted the need to add a dark mode option, “I would maybe have an option for a dark mode” and “maybe if the app is in dark mode?”

In general, the brightness emanating from the overall greyscale pallet of application one was overall not too concerning for some users. The participants stated, “because it wasn’t like bright lights that sometimes the apps have, like really bright things that hurt your eyes ... it was like more neutral tone(s),” and “I didn’t find any challenges or anything because the brightness level I think it was at a reasonable level for me as well because even though it wasn’t quite bad”. The white background had increased the brightness levels on the phone, and the respondents even suggested using different colour tones for the app overall to decrease the harshness of the brightness. The discomfort felt from the prolonged intense exposure to the white light could deter the consumers and the brand users from further interaction with the brand products and systems, although not many consumers noticed this discomfort.

For app iteration two, similarly to app iteration one, the users suggested the addition of a dark mode switch to compensate for the brightness of the white background. In regard to the addition of a dark/ light mode switch, the users commented, “to have a dark mode and the light mode” , “if it’s like a dark mode and a light mode like sometimes they can help them choose like what kind of visual experience they want” , “maybe if we put it in dark mode it will be much better” and “I would create an option to like decrease the brightness (through) like a darker colour because I’m quite sensitive to bright colours like this”. The respondents felt that this would allow the users to customise their visual experience with the app, therefore those who prefer the light mode can use the app in the light mode and vice versa. The users also made comments in regard to the bright white background which caused the strain on their eyes, “I mean probably maybe just a little bit bright would say not really much else” , “maybe add like a bit more colour to it like yeah, it’s just not like very white, which makes it very bright” and “I think that you go with darker colours as your background or on the bits that were white”. The users did thus not enjoy the bright white background and felt it made the experience unpleasant.

Regarding application iteration three, the users also suggested the addition of a dark/ light mode button to allow for a customisable experience and to decrease the impact of a white backgrounds. Only five users commented on the brightness, it is important to note that this may be due to the minimal use of the white background throughout the app. Those that advocated for the addition of a dark/light mode button stated, “I would maybe do a darker, dark mode” , “white background’s nice, during nights there will need to be

like a dark mode just to decrease the amount of light shooting in my eyes” and “I think I could choose the brightness”. One user also found the usage of the colour white throughout the app to be displeasing, “dimming the white a bit down because it is a bit bright, but yeah, other than that I think it’s pretty nice”.

4.6.3.5. Functionality and Operational issues

Two users of application iteration one also reported issues operating the app and one stated that they needed to spend more time on the application. The main operational issues pertained to tapping buttons, whereby the indicators or the selection buttons needed to be bigger or different to alleviate frustration from slow or no function. The participants said, “just the arrows are a bit too small,” and “I struggled with the tapping a little” pertaining to this issue. It is important to ensure there are little to no functionality issues for the users and that all buttons are big enough to be effective and usable.

A lot more operational issues were reported by the users of application iteration two. The main issue was the size of the buttons, the load time of the pictures, unfamiliarity with the operating system and other bugs. The buttons and icons used throughout the app were sometimes thought of as being too small thus affecting the functionality, and causing frustration for the users of the app. Two users stated, “I feel like the arrows and way like (you) click on (it), the accessibility that could have been better” and “I think you should be able to press on things like pressing the arrow if you just pressed on the bar”. One user felt that the pictures were loading slowly, also causing frustration when using the app, “I don’t know (if) the pictures can be loaded a bit faster when you go into it”. The other users just had issues with the functionality in general and stated, “I don’t know if this is just me, but the errors were not erroring” and “but also every time you go into a category and the text box pops up, I think like minimizing it all the time increased like the fatigue of using the app”. Another user noted that due to their unfamiliarity with the operating system (Android), interacting with the application was not always intuitive, “I think it’s more of a touch screen problem that maybe some people have, and I like some people will zoom”.

Notably, the most number of users had issues with functionality in regard to using the third app iteration. Most users had issues operating the buttons on the application, it either was not something that was intuitive to them, or the buttons were too small to click on. They commented, “I think the buttons it just requires some familiarity with how they normally work”, “My focus, went blurry at some points but that was (due to) the constant moving across the screen, which can be solved by the back button and the scrolling function”, “The arrows maybe like a little bit larger”, “the icons are like (a) little small” and “just some of the buttons that don’t really seem to be like (accessible) if I could click that (area) and then open (the page instead of) actually having to click the arrow”.

A few users also had an issue with scrolling on the app, they stated, “would change the scrolling, the scrolling feature”, “you could rather introduce a scrolling function (and) make it more friendly in that the eye can have continuous movement rather than discrete movement”, “sometimes it’s difficult, I don’t know, I really, I don’t really like the fact that you have to scroll up like this” and “I think I would first of all have an actual scrollbar ... to help scroll up and down”. “it’s easy to use” was stated by one user which contradicts the other comments in regard to the functionality of app three. It is important to note that although many users had issues with all three applications, considerably more users stated that the apps were intuitive and easy to use when explaining their experience with an app.

4.6.3.6. Other Suggestions

There were a number of other suggestions only stated by one or two respondents that explain their individual issues or suggested changes associated with the application or their experience therewith. A few users found the first app to be perfect and thought there were no changes needed. “I think it’s already fine” and “so far I don’t think there’s anything that you could enhance” show these feelings.

Other comments made by one or two users of application iteration two were in regard to the layout, reviews, the number of items available and the prices. Two respondents found the layout to be straight-forward and the other user found the layout to be difficult to operate. They stated, “I don’t know the layout is a bit, like, it’s straightforward, but it doesn’t really catch your eye” and “if for example the items were like next to each other and (you did) not have to scroll because there it’s only three items and I still have to like scroll to see if it was just like next to each other that would be easier”. Two users made comments about the prices, they stated, “you know, like when you have the items listed under like couches or whatever, if you could have like the prices there” and “so it’s like quick and easy to like compare the prices” and another user stated, “the price is small”. The main thing to notice here is that the users are searching for this important information and the size and location makes it difficult to find, thereby prolonging their search and increasing user frustration.

Remarks of the users of application iteration three, include comments about the layout, reviews, and prices. In regard to the layout of application iteration three, one user felt that a grid format could have been used, another felt that everything was clearly laid out. They stated, “maybe like instead of having the images or like the products in like a straight list, kind of like fashion, maybe making more of like a, gallery kind of thing” and “everything is clearly laid out ..., you can see exactly what you’re getting type of thing”. Another comment was made about the reviews of products, explaining the usefulness it would bring to potential buyers of the products, “then obviously easily readable reviews of products... because people want to know what other people think”. Although only one user commented about this, it might be an important factor to consider by brands. “Maybe including the prices in the main category like section where the lamps were split out for example, but besides that it’s pretty good thing” was noted by another user, in regard to displaying the prices to allow for better comparison of items and thus a more informed decision. A respondent also found the app to lack brand identity, stating, “I guess ... maybe this is specific to the branding of like (the company)”. Finally, a participant thought more visual elements could have been bolded to ensure essential items are salient, stating, “more things like bolded, because I usually gravitate towards things that like stand out”.

4.6.4. Heatmaps results

The heatmaps are often used in eye-tracking data to understand the concentrated attention of the respondents in regard to different visual stimuli. This section presents a qualitative analysis of the different app pages, (i.e., for the cart, product details, home, products and profile pages) across the different visual complexity levels (app one, app two, app three) in regard to attention. Please refer to Appendix J Figure 27 to Figure 31 for app one, Figure 32 to Figure 36 for app two, and Figure 37 to Figure 41 for app three to see the heatmap pages’ images.

The heat map results indicate that for the **cart** page app three the back button, the information about the cart, the price breakdown and the total label were the most concentrated on, while for app one the remove button, the total price and the total label were the most concentrated on, indicated by the red area on the figure. For app two, the total more information button, the product name, the remove button and the order summary information received the most concentrated attention. Thus, across all three apps, the total text was important to viewers as it was the most focused on visual element. The remove button for both app two and app one received a lot of attention. This could indicate that the users were unsure about the items they add to their basket and often contemplated removing the items throughout their initial exploration of the app.

The heat map results indicate that for the **product details** page, app one and app two the back button, the product image, and the add to cart button had the most concentrated attention, while for app three, only the product image was the most concentrated visual element. This is seen through the red area on the heatmap images. This indicates that across all three visual complexity levels, the product image was the most concentrated on, this could mean the image of a product is of high importance no matter the level of visual complexity present. The reason that the back button and the add to cart elements were the most concentrated on for app one and two but not for app three could be because there were less elements for the viewer to focus on and no distractions for the viewer so the buttons that were used the most were focused on.

The heat map results for the **home** page on all apps show that the lamps category name was focused on, while for app two the chair category name and the lamp icon were focused on slightly indicated by the red and yellow areas. For app three, the chair category name was focused on. Thus, across all three app iterations, similar behaviours of users were observed in regard to the home page. This could indicate that often the first category of a list of categories is focused on by the users when browsing a mobile shopping app for the first time.

The heat map results for the **products** page show that for app one, only the first two item names were focused on, while for app two, all three item names and the first two item images were focused on. Finally for app three, all three item names and the first item image were focused on, while the first two item names were focused on the most (indicated by the red area on the heatmap). This indicates that the first item name or information is always focused on no matter the visual complexity level. The initial impression for the viewers of a m-commerce application does not change much when looking at an items list. Those who used app two and app three could have been more focused on gathering information about the items than the images, especially for app two. It could also indicate that a moderate level of visual complexity could render consumer attention to important information better than a highly or minimally visually complex app.

The heat map results for app one's **profile** page show that the activate button label and the edit profile information received the most attention. While for app two's profile page, the same area was concentrated on the most between the activate button label and the edit profile information. Finally for app three, the activate button label, the edit profile label, the account settings label and the profile email address received the most attention. This could indicate that people place importance on editing their profile and personal information across all app levels. Users might place high importance on customisation that allows personalisation, thus they care about their own information even on a mobile shopping app.

4.7. CONCLUSION

This chapter was compiled to present the results from the quantitative and qualitative analyses conducted for the current study. The chapter initially explored the descriptive statistics to understand the composition of the sample, thereafter the descriptive statistics for the self-reporting data, eye-tracking data, usability metrics (efficiency for each task, effectiveness for each task, and satisfaction overall and satisfaction for the visual elements) and other variables (time spent on the app and phone before the experiment) were obtained. After this, the results for the normality and the reliability tests were presented to understand the distribution of the current data and to help establish the correct tests needed to conduct the various hypothesis tests. The results of the hypothesis testing were then presented. Finally, the results for the qualitative data analysis were presented, including the heatmap results.

The results of the first hypothesis test to determine the nature of the relationship between usability and visual fatigue revealed a number of conclusions. For all three of the mini hypotheses for the first hypothesis, there was no evidence to support that a relationship exists between visual fatigue and usability. For the second hypothesis, partial support was found, and it was established that visual complexity only appears to influence efficiency, particularly for the free browse task, but does not have a significant impact on effectiveness or satisfaction. The third hypothesis found that no significant correlation was found between visual complexity and the visual fatigue metrics. The qualitative data show that the more visually complex application was reportedly seen as less mundane due to fewer reports of boredom. Thus, suggesting that although visual fatigue was significant among all apps it did not impact users. The visual fatigue metrics were found to be significant, thus the three eye-tracking metrics could be used in further studies to quantify the visual fatigue experienced with interacting with a mobile device. The qualitative data support these findings, as survey responses show a significant difference in visual fatigue before and after the experiment, despite most users reporting no strain during it.

The fourth hypothesis found no evidence to support the moderation by time spent on a mobile device before the experiment impacts the effect of visual complexity on visual fatigue. This is further supported by the qualitative data that shows that most users felt no to little strain on their eyes during the experiment. Prior- and post-experimental visual fatigue were found to have a significant relationship with each other. The final hypothesis concluded that task type (context of use) does not mediate the relationship between visual complexity and visual fatigue for combined pupil diameter and fixation dispersion, but does for blink rate.

The qualitative analysis also showcased a number of insights relevant to the study. Specifically, initial user experience, visual fatigue and the visual elements that impact the overall user experience were all probed to the users of each visual complexity iteration. The results found a number of themes such as functionality overall and in terms of buttons, no to little eye-strain, control of the brightness, as well as design in terms of colour and text. In addition to this, the heatmaps for each application iteration and each app page were investigated. It was found that the most focused on elements were generally similar between each visual complexity iteration on each app page, except for the product details page. These themes are able to contribute to better understanding the quantitative data found through hypotheses testing.

In the next section, an in-depth exploration of the results is discussed to better understand how the results impact the researchers, marketers, brand owners and application developers. The discussion is split into the findings of the study which will be explained through each objective, then the managerial implications are explained. The future recommendations and limitations of the study are also discussed in the final chapter of this dissertation.

5. CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

Previous studies revealed an absence in the literature regarding the visual fatigue that the users from developing nations such as South Africa experience while interacting with visually complex m-commerce applications. Due to the lack of research, academics and marketing managers lack the necessary knowledge to effectively explain the offerings to consumers in the m-commerce sector. This research sought to gain a better understanding of how users interact with various visually complex programs and how this may affect their comfort when experiencing visual fatigue. The degree of visual fatigue that the consumers experienced while using several visually complicated applications was measured using consumer neuroscience techniques, specifically eye-tracking.

Along with interviews and heatmaps to determine which visual elements affected the user experience, the users' opinions on the visual fatigue when interacting with the application, and the initial overall impression on the user's journey through the application, were used in conjunction with objective and self-reporting measures to understand the usability of each application by the users. The discussions based on the objectives of the current research are presented in this chapter. The chapter provides an overview of the conclusions drawn from the collected data in the previous results chapter. The recommendations and the given implications for marketing managers in the e-commerce and m-commerce sector are reviewed upon the findings' conclusions. After outlining the theoretical advances made by this study for the marketing field, the paper's limitations are discussed and additional research suggestions are made. The chapter ends with a summary of the entire paper.

5.2. THE FINDINGS OF THIS STUDY

This section answers the research question: *How does a mobile application's visual complexity impact its usability and the users' visual fatigue?* By presenting the study's findings in relation to the research objectives a number of insights can be drawn and applied to future studies and management practises. The study's conclusions are evaluated in light of their overarching goals and assumptions, and they are contrasted with those of other research projects that have been carried out in the same field of study. While some discoveries provide fresh perspectives on the subject of study, the others corroborate earlier findings.

5.2.1. Primary Objective

The findings of this research assisted in reaching the primary objective of the study which was: *To determine the relationship between usability and visual fatigue in regard to m-commerce applications and Cape Town 18 – 35 consumers/users.*

The quantitative results show that for this study, there was no significant relationship between usability and any of the visual fatigue metrics. For H1a, visual fatigue as measured through pupil diameter over

time and efficiency (a metric of usability) was measured through the productive period and no significant relationship was found. For H1b, the relationship between visual fatigue as a measure through fixation dispersion and effectiveness (another metric of usability) measured through the number of touches of the user was also found to be non-significant. Finally, for H1c the relationship between visual fatigue as measured through the blink rate (blinks per minute) and user satisfaction was also found to be insignificant. The qualitative results showed a support for the quantitative results, as even though visual fatigue and the symptoms thereof were experienced by users it did not hinder their ability to complete the given tasks. Other issues stemming from the actual app had some impact on usability, like the sizing of buttons and text for a small number of users. Highlighting that visual elements may have more of an impact on usability, potentially even visual complexity, then visual fatigue rendered.

Many prior studies have also found no significant evidence to support the relationship between visual fatigue and usability in a number of different contexts (Robertson & Kortum, 2017; Köpper *et al.*, 2016; Jaiswal *et al.*, 2019). Other studies found that the visual discomfort experienced by the users impacted the time taken to complete tasks, but they also observed that there were significant differences with low vision participants compared to the normal vision participants (Chan, 2017; Calabrèse *et al.*, 2018). This could indicate that the vision condition of a user impacts the relationship between usability and visual fatigue. Thus, as all the users had normal to corrected vision, those without pre-existing conditions do not experience enough visual fatigue to impact their usability of a m-commerce application, in the period of the time tested through this study.

Other studies that found a significant relationship between usability and visual fatigue either used a personal computer or measured visual fatigue through subjective ratings, through CFFF or after a prolonged period of time (Lin *et al.*, 2019; Wang *et al.*, 2017; Glimne *et al.*, 2020; Kaneko & Sakamoto, 2001). It is also important to note that only after a prolonged period of time (6/8 hours of work) were moderate measures of visual fatigue reported to have impacted the way a system was used for studies done by Wang *et al.*, (2017) as well as Kaneko and Sakamoto (2001). Another study by Szpak *et al.* (2020) indicated that the tasks that are less than ten minutes do not impact the visual system. This could indicate that even on other interfaces such as a computer, significant enough visual fatigue is experienced to impact concepts like usability.

The current study's results therefore contradict these studies due to the shorter task time and type of visual stimuli that was presented. Since this experiment was not advocating to render users visually fatigue but rather investigated how much visual fatigue was felt when an ordinary type of interaction with a mobile application occurred, it achieved this objective. Thus, even though the current study found no evidence to suggest that a significant relationship exists between visual fatigue and the usability of the m-commerce users at different levels of visual complexity, it is important to note that no matter the level of visual complexity, there was still high levels of visual fatigue that were felt by the users. This could mean that although visual fatigue is felt when using an m-commerce application and can be quantified by the eye-tracking methods used, it is not impacted by the number of present visual items and does not impact usability when using a m-commerce app or any mobile application.

5.2.2. 1st Secondary Objective

The findings discussed in this section show the quantitative and the qualitative results that were obtained from the first secondary objective of this study: *To understand the relationship between the usability metrics of an m-commerce application and the eye tracking visual fatigue metrics to establish a neuroscientific method in which to measure the usability of an e-commerce app*, which is similar to the first objective.

This poses the question as to whether the adoption or the continued usage of an online system (mobile app for this study) has the potential to impact the well-being (in terms of visual strain) of a consumer. The quantitative data from H1a, H1b and H1c revealed that there is no significant correlation between the visual fatigue metrics (pupil diameter over time, fixation dispersion, and blinks per minute) and usability (efficiency, effectiveness and satisfaction). Therefore, from these eye tracking metrics that were utilised to measure visual fatigue, a relationship between the usability of a m-commerce application and the visual fatigue experienced by the user cannot be established due to insignificant evidence. Within the findings for the primary objective, it is shown why this relationship might be insignificant in the current context (i.e., experiment time was too short, those who have a normal vision do not experience obvious eye strain in accordance with the current visual fatigue metrics, visual fatigue experienced on a mobile device is not as extreme as that experienced on other devices). It is also important to note that even though the variables do not influence the visual fatigue metrics, they were found to be significant. These results therefore contradict the prior studies which explored similar constructs.

The perceived ease of use has been investigated within the m-commerce context. One study by Sharma & Madan (2022) found that the perceived ease of use positively impacted m-commerce adoption. The authors also found that both convenience and website quality were key determinants of perceived ease of use, that is, the efficiency and the effectiveness of an application. The users considered that all the apps are highly easy to use and user-friendly, thus implicating the quality of each app. The apps that are considered as easy to use utilise innovative features to enable quick decisions in regard to product selection and purchase (Wasiq *et al.*, 2022; Sharma & Madan 2022).

A system should always be designed to deliver functional benefits and enhance the well-being of the users through satisfaction. The marketers that aim to increase users' continued intention to use an application need to focus on making a distinct value proposition that will improve the life of the users (Purohit *et al.*, 2022; Hilty *et al.*, 2022). Ensuring that an application is able to facilitate tasks seamlessly to enable satisfaction while considering the well-being of users is important. Since, this study has shown that when free browsing an application for about two minutes the visual fatigue that is experienced is not significant enough to render a user's ability to use a system effectively, it is clear that the developers can utilise visual elements in a similar manner by creating a simple aesthetically pleasing application that is able to functionally deliver a seamless experience for users. This will aid in encouraging the intention for the continued usage of the system by consumers.

From the qualitative data, it was found that in regard to the first app, the layout, words and the images used were found to be clear and easy to understand, thus allowing simple navigation and easy access to the essential systems to operate the app. The second app was found to be simplistic, minimalistic and modern thereby allowing for easy navigation while the design elements and the user interface were thought to be aesthetically pleasing, well laid out, and helped users to achieve desired goals. The third

app received similar comments about the user interface and the used design elements. The user interface was described as being straightforward as well as simple and it was stated that the design element choices such as the limited visuals, the icons and the buttons aided in their navigation of the application. The overall comments related to the usability of the m-commerce applications did not differ much between the visual complexity levels while users perceived visual fatigue did differ between the apps.

From the qualitative data, mainly no perceived visual fatigue was felt by the users of all the three apps. This is the optimal result that an application developer would want as the more visual strain felt, the less likely a participant will stay on the application for long periods of time, thereby decreasing the likelihood of purchase. This could also indicate that users do not know when they have experienced a significant amount of visual fatigue and thus, the visual fatigue due to a mobile screen does not discourage the usage of an application. From the quantitative data, it is clear that a high level of visual fatigue was felt by users, even if self-reporting data does not show this. This corresponds with other studies that found inconsistencies between the self-reporting data and the physiological measures (Vanneste *et al.*, 2021; Xu *et al.*, 2023; Shi *et al.*, 2020; Alvino *et al.*, 2020).

Even though for these applications most participants experienced minimal functionality issues, some did, and none should encounter this. At times, even one bad experience could deter further usage of a system, product or service from that brand, it also could lead to the spreading of negative word-of-mouth. The functionality issues of an application refer to the usability issues in terms of the ease of use, that is, the efficiency and the effectiveness. Companies should aim to please all customers, but this is not always possible. The bigger risk is the negative reviews that could deter future clients from using a product or service from the brand. The brands should always aim for positive reviews, and they can do this through a good quality product, experience or system. The systems that work effectively to aid users in completing tasks (i.e., product search and purchase in the m-commerce space), might want to avoid the risk of encountering a poor system through exploring the experiences of other users of that systems (i.e., reviews) (Shi *et al.*, 2020).

This, however, could also account for the insignificant relationship between visual fatigue and usability as reported in the quantitative data. Users felt that there was no strong impact from the visual elements to render visual fatigue and they found the application iterations easy to use at all the visual complexity levels. There also exists mixed comments in regard to visual fatigue, and consistent comments about usability. Mainly, low levels of visual fatigue were experienced by the users while usability remained consistent in terms of user feedback. The perceived pre- and post- visual fatigue results revealed that a significant relationship does exist between the two and that they are potential predictors for each other. This is supported by other quantitative data that revealed that significant visual fatigue was experienced by the users as measured by the eye-tracking metrics. This could mean that the amount of visual fatigue that is experienced by users, although significant, does not impact how users interact with a system. This thereby suggests that users' usability is not impacted by the visual fatigue that is rendered from a mobile device. The visual fatigue that was felt did not render the user's capacity or functioning of a mobile system meaning and with rest this could diminish (Solomon & Manea, 2022).

Most people utilise their smartphones as a means of taking a break during work, but this usage could cause another type of fatigue (visual fatigue) while combating the boredom or the fatigue experienced during task disengagement. This form of a break would not impact the usage of a mobile device but might have consequences for the usage of other devices (Dora *et al.*, 2021; Urus *et al.*, 2023). The current study revealed that although visual fatigue does not impact a person ability to effectively,

efficiently and satisfactorily use a mobile shopping application, it has the potential to impact the usage of other systems such as a desktop computer based on prior studies that investigated similar phenomena. A few studies investigated the impact of smartphone usage to escape boredom or fatigue at work (whereby mental labour is experienced from work) and it was found to reveal more fatigue and boredom rather than less (Dora *et al.*, 2021; Urus *et al.*, 2023). Other studies have found that prolonged exposure to a desktop computer renders the users as fatigued and it affects productivity (Li *et al.*, 2021; Fang *et al.*, 2022; Lin *et al.*, 2019; Wang *et al.*, 2017). Thus, when combining the results from all these studies, it is clear that although visual fatigue might not impact the usability of a mobile device, it could impact other tasks and productivity, and future studies could investigate this further.

It does need to be noted that although user feedback remained consistent among the applications, the objective data revealed that efficiency was impacted by visual complexity while the other metrics were not. This could therefore mean that visual fatigue is experienced regardless of the nature of the usability metrics. This also means that the mixed data regarding the usability metrics could indicate that other metrics related to usability might need to be investigated along with the current metrics to create a more holistic picture of how other usability other factors impact visual fatigue. It is also important to note that satisfaction, showed contradictory results to the other metrics and this could be due to the subjective nature of the metric, and thus the individual preconceived biases the consumers could have possessed.

5.2.3. 2nd Secondary Objective

Both the quantitative and the qualitative results of the current research assisted in better understanding and in drawing the insights and conclusions of the second objective of the study: *To investigate how the visual complexity of an m-commerce app interface effects the visual fatigue of the users.*

The data from the qualitative analysis is corroborated by the results from the quantitative analysis. More specifically, the third hypothesis which aimed to understand the relationship between visual fatigue and visual complexity, found no evidence to support a relationship between the two variables. The H3 quantitative results suggest that although across the visual complexity levels, there is no significance in terms of visual fatigue, it is suggested that the model which combines these metrics is significant. Thus, fatigue is observed no matter the amount of visual complexity that is present. The present visual complexity levels may not be significantly different in terms of visual fatigue. This could thus indicate that for this specific application, the amount of visual complexity was not enough to render the users of all applications a high enough level of visual fatigue. A number of other explanations could also explain this insignificant relationship such as the age group tested which might be used to the level of visual complexity due to excessive phone usage.

Prior studies have found similar results whereby visual fatigue and visual complexity do not possess a significant relationship (Köpper *et al.*, 2016; Li *et al.*, 2021). While there are other studies whereby this relationship was found to be significant, these studies utilised other screen types such as personal computers or head mounted devices, dark and light mode were utilised, and visual fatigue was measured differently (Kadner *et al.*, 2021; Wang *et al.*, 2017; Glimne *et al.*, 2020; Lin *et al.*, 2019; Kim *et al.*, 2019; Hsiao *et al.*, 2018; Orduna-Hospital *et al.*, 2023). Other studies have been based on the visual fatigue that is felt when engaging with more intense stimuli such as that found on a personal computer, thereby meaning that visual fatigue is easier and potentially more significant on these type of devices

compared to a m-commerce application. The current results therefore does not contradict these prior studies as the inclusion of dark and light mode was not included and a mobile device was utilised, which might be considered a less intense stimuli, resulting in less extreme visual fatigue symptoms.

A number of users also reported that the app was not distracting in terms of the pop-up advertisements from the qualitative analysis. It might be interesting for future researchers to use pop-up advertising as well as more visually complex elements on the application to see if this changes the visual fatigue that is experienced by the users on a mobile app. This is supported by the heatmap analysis whereby the most concentrated attention went towards functional buttons, icons and the important information needed to navigate the application for most app pages. A large number of the users also experienced little to some strain, for all the three app iterations. The third app mainly reported a normal amount of strain by the most number of users, but also reported the most number of slight strain perceived by the users.

Users reported more strain for app one and app two in comparison to app three. This could suggest that a higher level of visual complexity impacts the perceived visual fatigue that is felt by the users. The quantitative data suggests something different, that the visual complexity levels and visual fatigue do not present a significant relationship to each other. From the qualitative data one user even stated that due to their regular usage of m-commerce apps they did not feel any visual eye strain after their interaction, this could explain the none, significant relationship. Thus implying that users that regularly engage with their mobile device and m-commerce systems have acclimatised their eyes to adjust to user interfaces similar to the three apps tested.

Prior studies have also found that when the consumers are overloaded with information and marketing communication, emotional fatigue can occur, which could give rise to feelings such as the apathy towards a brand which would hinder the users' continued intention to use an application. Brands need to avoid this through simple communication and a simple user interface which optimises functionality (Huang *et al.*, 2023; Pang, & Ruan, 2023). Young adults currently exist in a contemporary mobile-media saturated world, whereby marketing communications and media are constantly adding to the experienced information overload. Marketers could allow the users to control pop-up advertisements through explicitly recommending "advertisement management" functions to the users when they first enter the application (Huang *et al.*, 2023; Pang, & Ruan, 2023).

Within the qualitative analysis, a number of users suggested the addition of a dark and light mode. This finding and prior research indicate that this type of contrast (between light and dark mode) yields more significant results as it could impact the users' experience and levels of visual fatigue more than changes to the visual elements would (Kim *et al.*, 2019). An inclusion of the button for the selection of a white or dark mode, or a scrolling brightness bar would allow the users to control for brightness and reduce the experienced visual fatigue. This was consistently suggested by the users of all the three apps. Research has found that having a dark or black background is better for the eyes as less visual fatigue is experienced (Xie *et al.*, 2021; Tao *et al.*, 2024).

A small number of users also felt that they were focusing hard while interacting with all the app iterations. This could indicate that once engrossed in a mobile application, consumers can experience a sort of escapism whereby focusing on other things is not easy after an experience with the app. This further implies that if an application can capture a user's interest, it will also capture their focus and potentially influence the amount of time spent on the application. The data also indicates that when

some visual fatigue was felt, other activities such as working on the laptop or watching television also occurred. This could also impact the amount of effort and work that has already been done by the eyes prior to the use of a mobile application, hence the visual fatigue felt. However, from the quantitative results, it is clear that the visual fatigue that was experienced was not significantly impacted by the application's level of visual complexity but there was a significant relationship observed between the visual fatigue that was experienced before the experiment and the visual fatigue that was experienced after the experiment, from the fourth hypothesis.

5.2.4. 3rd Secondary Objective

Both the quantitative and the qualitative results of the current research assisted in better understanding and drawing the insights and conclusions of the third objective of the study: *To understand how the three usability metrics of a m-commerce app relates to the visual complexity of the app's interface.*

From the quantitative analysis, specifically from H2, a number of statistical models were run to quantify and understand the relationship between visual complexity (app levels) and usability. These findings suggest that while some usability aspects such as the efficiency in specific tasks, vary between the visual complexity levels, other aspects such as the effectiveness and the overall satisfaction remain consistent. This information can guide further improvements in app design, by focusing on enhancing efficiency without negatively impacting other usability factors.

Interestingly, user satisfaction did not show significant correlations with other metrics, thus implying that satisfaction might be influenced by factors beyond those captured by the efficiency and effectiveness measures. The satisfaction items revealed mainly positive attributes for explaining a user's experience in regard to the m-commerce application. The satisfaction of the visual elements was revealed to be described as supportive, easy to use, effective, clear, meets expectations, interesting, conventional, usual, boring, and enjoyable. The lack of significant correlation suggests that other qualitative factors such as the user interface design aesthetics or user expectations, could play a critical role in determining overall satisfaction. Prior studies also revealed that the visual element changes (which is how visual complexity was measured in this experiment) impact the time taken to complete tasks (which is how efficiency was measured in this study) (Hsiao *et al.*, 2018; Kim *et al.*, 2019; Lin *et al.*, 2019). Thus, the partial support of this hypothesis is supported by these prior studies.

The correlation analysis across all the visual complexity levels provides valuable insights into how the different usability metrics are interrelated. The significant relationships between the efficiency and the effectiveness metrics highlight the areas where improvements could enhance overall user experience, particularly by focusing on streamlining interactions to improve efficiency without compromising the effectiveness of the tasks. These insights highlight the importance of considering specific tasks and levels when evaluating app usability, as the relationships between the metrics can vary significantly. The strong and consistent correlation between efficiency and effectiveness for the second task-orientated task (task 2) suggests the potential areas for further investigation and improvement in app design to enhance user performance and experience. The third objective was thus partially achieved through the quantitative data analysis that revealed the partial relationship between usability and visual complexity, whereby only the efficiency for the initial free browse task was found to be indirectly impacted by the visual complexity levels.

The qualitative data revealed a number of insights about the user thoughts in relation to their user experience with an application visual complexity iteration. Ordinarily, applications employ a complex design with too many interactive pop-up advertisements, widgets, icons, buttons and text which limit consumer focus and distract the users from their intended purpose. The simplicity of the first app iteration enabled consumers to easily access all the necessary features to complete the action of product search, selection or the buying of items. Simple applications often become more navigation objective and fluid. The other application iterations rendered less comments about the visual appeal of the application, but they had other functionality issues. This is supported by the quantitative data that revealed the only the usability metric efficiency was found to have a correlation with the different visual complexity levels. More specifically, there was an association between efficiency and the first and last visual complexity levels as well as between level one and two in regard to the initial impressions of the applications, highlighting the importance of a simple user interface design for efficiently using a system.

Understanding how the visual cues are analysed by the users is important as consumption decisions are often based on the visual sensory details available in an e-commerce platform. A mobile app interface also impacts continued intention to shop on an app and the overall perceived website quality (Chi & Sullivan, 2018; Xiao *et al.*, 2020; Pelet & Taieb, 2022). It is also clear from the qualitative data that the simply designed application (app one) was seen as bland and simple. The second iteration was seen as simple but not as boring or bland and the third iteration was seen as simple as well by more people in comparison to the other two iterations, it was not, however, seen as bland or boring. Clearly users found the third app more unique but the first app was used more efficiently.

User boredom can deter further use of the application or positive word of mouth from the users to increase the adoption of the application. The users of a mobile device make decisions based on the perceived psychological costs (i.e., visual complexity and satisfaction), thus the simpler an application is, the less impact there is on the perceived psychological costs (Lucas *et al.*, 2023; Petel & Taieb, 2022). This could imply that the app developers have a trade-off between efficiency to allow the users to complete actions and visual complexity through the visual appeal of an app. The significant relationship between efficiency and visual complexity and user interview data supports this.

5.2.5. 4th Secondary Objective

The findings summarised in this section show the results obtained from the quantitative analysis to understand the fourth objective: *To determine if the context of use within the experiment mediated the effect of the visual complexity of the interface on the visual fatigue of the user.*

The results of H5 showed that the context of use within the mobile commerce application was only found to mediate the relationship between visual complexity and visual fatigue when the blink rate was used to measure visual fatigue. For the mediation model that used pupil diameter to measure visual fatigue, no significance was found for the context of use (task type) in mediating the relationship between visual fatigue and visual complexity. Additionally, for the mediation model that used fixation dispersion to measure visual fatigue, no significance was found for the task type in mediating the relationship between visual fatigue and visual complexity. This might indicate that the blink rate is more sensitive when measuring visual fatigue, to the context of use by which a participant uses a mobile device.

A prior study found that the eye gaze measure is more suited to the visually complex tasks while pupil dilation and the blink rate are more suited for simple visual tasks that employ a minimum number of visual elements to minimise sources of artifacts (e.g. eye movements and large luminance contrast) (Eckstein *et al.*, 2017). The current study did not employ different visually complex tasks, which could be why the pupil diameter and the fixation dispersion task type did not mediate the results. The variable context of use rather assesses if the user motivations impact the relationship between visual fatigue and visual complexity of an app. The other studies that employed blink rate support the results of this study whereby the motivation of a user impacts the fatigue felt (Herlambang *et al.*, 2019; Chao *et al.*, 2019). Some other studies showed that the motivation and or the task of the users does not impact the amount of visual fatigue felt (Herlambang *et al.*, 2021; Choi *et al.*, 2019; Li *et al.*, 2021; Hsiao *et al.*, 2023; Hu & Lodewijks, 2021).

There was little data from the qualitative analysis to better understand if the motivations for usage impacted the relationship between the visual fatigue that was felt and the visual complexity of the system. The users did, however, suggest that the least visually complex application allowed a focus on their goals and tasks, while the others suggested their motivation for purchases. Users completed both tasks with the motivation to decorate their space or to coordinate item colours. Users were also less concerned about the specific motivation behind their purchase when more visual elements like colour were introduced (app two and app three). There were, however, little comments about the two separate tasks, and this could suggest that the users considered the one a continuation from the other and thus only saw each as one task all together.

5.2.6. 5th Secondary Objective

The findings summarised in this section explain the results obtained in the quantitative and qualitative analysis by which the final objective is explained: *To determine if the time spent on the mobile device before the experiment moderates the effect of the visual complexity of the interface on the visual fatigue of the user.*

From the results of H4, it was found that the moderation model that explored the amount of time the participants spend on their mobile devices before the experiment moderates the effect of the visual complexity of the app on visual fatigue was statistic significant. However the interaction effect and thus the time spent on the mobile device prior to the experiment was not significant and thus did not moderate the effect of visual complexity on the visual fatigue experienced. The moderation analysis did show that the primary predictor of post-experiment (Vfpost) visual fatigue was pre-experiment visual fatigue (Vfpre), which is statistically significant. This means that the initial levels of visual fatigue have the potential to predict the levels of post-experiment visual fatigue.

The time spent on a mobile device prior to the experiment did not moderate the effect of visual complexity on the visual fatigue after the experiment. These results therefore contradict prior studies that have suggested that the excessive levels of mobile device usage impacts visual fatigue and suggest that only the prior visual fatigue experienced by users is able to impact the visual fatigue that is experienced after the usage of a mobile commerce application (Kim *et al.*, 2017).

There was some data from the qualitative analysis to better understand if the motivations for usage impacted the relationship between the visual fatigue that was felt and the visual complexity of the system. The users suggested that the prior usage of other devices and focusing on other tasks could have impacted the experienced visual fatigue. This further supports the significant relationship between perceived prior- and post-experimental visual fatigue, as the activities done before the experiment could potentially impact visual fatigue experienced from the experiment.

5.2.7. Additional Findings

The qualitative data used self-reported data to better comprehend the reason behind the motivations and the feelings of users when engaging with each application iteration. This section outlines the data from the qualitative analysis that does not align with the objectives but does provide interesting and important data about the users, their habits and their preferences which could impact how the brand systems are perceived and how managers chose to design their applications and marketing messages.

The qualitative data from the first iteration found that the users employed a coordination of choices based on colour, a space the items might occupy and what the user already owns. Prior usage of a mobile app has thus influenced the selection and the purchase decisions of consumers. It was found that a reduction in functional and aesthetic signs would enhance product choices for items, thus the simple design of this app aided the product selection process (Wallner *et al.*, 2022). It might be important for marketers to consider the type of images that are put forth on applications when presenting products as using a combination of aesthetically pleasing items together might encourage more purchases. The heatmap data also showed that both product information and images were focused on conjunctively and thus marketers need to ensure that these align and make sense to consumers. These results also show how important imagination and creative thinking are for consumers when purchasing a product, thus the design of a user interface and marketing communication should encourage and aid this (Elder & Krishna, 2022).

Another suggestion in regard to the least visually complex application was to have a navigation bar on the side instead of at the bottom of the app. Although, it is important to account for all the comments, it is important to note that most m-commerce applications position the navigation bar at the bottom of the app screen for easy accessibility. The designers use the navigation bars to provide clues and to ease the searching process from a top-down perspective (Still *et al.*, 2020). Retailers have to therefore, utilise the layout that best suits their target market and ensure that it is user-friendly and that consumers are familiar with the layout. This personal preference also indicates that the users might enjoy the ability for personification and customisation.

From the heatmap data, a number of insights were also found that could align with some of the in-depth interview results that indicated some of the buttons and icons were not helpful and actually impacted the functionality of the mobile application. These comments were only made by very few respondents in regard to all three apps. On all pages, the users mainly focused on the buttons, icons and text that allowed them to either personalise their profile (profile page), reveal important information about price, total and product name, or achieve certain goals such as buying an item or adding to the basket (products page and cart page). This highlights the importance of buttons, icons and the text of a graphical user interface for a user's experience. This also could showcase the difficulty experienced by users which

lead to intense focus on these elements. These heatmaps might indicate that the mobile interface was able to help users to successfully find relevant entry points and information. The symbols and icons on an application need to facilitate intuitive interaction to aid the customer experience and improve the usability of the system (Magrath & McCormick, 2012). The consumers value brands that are able to effectively communicate and educate them so that they are able to independently use a system. A support system to aid consumers is thus valuable for the consumer who might struggle to access important information when operating an application (Purohit *et al.*, 2022).

The concentrated attention on personalisation features within the heatmaps of the profile page of all app iterations presents an interesting result. Although no participants from the in-depth interviews suggested the need for the personalisation of their profiles within the experience, all the users who did engage with this page profile page had a great attention to the edit profile buttons. The users also placed a great deal of concentration on the profile name and email address, for the experiment a dummy address was used and 'your name'. This could also indicate that the inclusion of self-reference interactive dialogues such as directly greeting individuals with their name might improve a user's experience as users were seeking out those features (Cavdar Aksoy *et al.*, 2021).

This also aligns with users' comments to include reviews and to coordinate the choices mentioned above. The inclusion of the reviews could allow for the users to share their own opinions and make more informed decisions based on the experience of other users. This personalisation is called the social-level personalisation, and it is based on the information presented, such as recommendations, likes and the other elements based on the behaviour within a social environment (Cavdar Aksoy, *et al.*, 2021). In this instance, the ability to add a review and browse previous reviews allows the users to engage with others and add value to the world through sharing their opinion.

The comments from the qualitative data about the visual elements that were used revealed that the brand identity is important to consumers as it creates an impression in their minds that allows and enables curiosity and engagement with the brand products and systems. A user comment also indicated that there is a lack of branding colour, which could leave the consumer with a poor impression of the company and thus impacts the brand memorability. This was based on the fact that a large number of users of the first 'simple' app design suggested more, or different colours to be used to improve the app. It is important to note that, however, a large majority of the users found the colour scheme in app one to be bland, boring and thus uninviting, the addition of colour would thus encourage repeat visits and more enjoyment while enforcing brand identity. This builds on a prior studies that more salient colours elicit faster decision responses from consumers and higher likelihood for adoption due to habit and saliency (Reeck *et al.*, 2023).

5.3. THEORETICAL CONTRIBUTION TO KNOWLEDGE

The e-commerce and m-commerce marketing managers are challenged to promote interactions, facilitate communications between brands and consumers, and encourage purchases through the understanding of consumer preferences and motivations (Ashraf *et al.*, 2021; Xiao *et al.*, 2020). Currently, there is not much available research about the standard of a mobile graphical user interface in terms of the visual complexity levels and usability to not render users visually fatigued. The available research is only pertaining to the usage of a computer when exploring online retail.

The current study differs as it has investigated the visual fatigue experienced by users and the usability of an app through a comparison of a number of visually complex mobile shopping apps. The users' experience and opinions were also observed in addition to the objective measures to better understand how to adequately cater to users and communicate offerings in the most effective and efficient manner. The study is also able to showcase the robust use of eye-tracking techniques to measure visual fatigue, most notable blink rate and efficiency to understand the correlation between visual fatigue and usability. This indicates an important contribution in terms of a new methodology to understand user experience on a m-commerce application. Future studies can use this key finding to further investigate m-commerce applications and their impact on user wellbeing in the form of visual fatigue and how people use these systems.

5.4. PRACTICAL IMPLICATIONS AND RECOMMENDATIONS

The present investigation's outcomes and conclusions have demonstrated several pragmatic ramifications that managers and marketers can implement in their company to effectively connect with their target audience and convey their offerings, all the while fostering an atmosphere that encourages sustained engagement and transactions through m-commerce applications. The findings showed that there were no significant correlations between visual fatigue and the three levels of visual complexity (minimum, moderate, and maximal) or visual fatigue and the usability indicators (efficiency, effectiveness and satisfaction). This suggests that, in this particular situation, visual fatigue was insufficient to cause functional problems for the m-commerce app users, regardless of the level of visual complexity. For the managers, it implies that a system's usability problems might not make users tired, that is, a malfunctioning operating system might not cause the users to feel uncomfortable in terms of their vision. For instance, a brand's m-commerce app's low adoption rate might not be caused by the app's visual richness in terms of the quantity of the visual elements. It is also possible that the system's poor usability is to blame for this low adoption rate, but it cannot be assumed that the users experience visual discomfort as well.

Thus, the number of elements, or at least the number tested in this scenario, does not need to concern the user interface designers or the user experience designers. This suggests that the visually sophisticated designs on a mobile interface do not cause the users to become visually impaired, which could make the user experience uncomfortable or deter users from using the application continuously. It should be mentioned, nonetheless, that some users claimed that an excessive number of pop-ups would cause a great deal more problems for consumers. The user interface and user experience designers of m-commerce apps need to ensure that the visual elements are entertaining enough to render user interest and do not necessarily have to be concerned that these elements are creating an environment for users that causes digital eye strain. For example, the applications that utilise many pop-ups might cause frustration with the users while the apps with many colours, buttons and icons within an app might intrigue the users and encourage sustained usage of the app but users will not be visually uncomfortable after usage of the system.

Efficiency, the only usability metric, was discovered to be correlated with the various degrees of visual complexity. Specifically, efficiency was found to be correlated with both level one and level two visual complexity as well as the first and third levels. This demonstrates that, in comparison to more moderate or extreme levels of visual complexity, a user interface's minimal level of visual complexity has the

greatest impact on efficiency. This means that system designers must provide user-friendly platforms, and a straightforward user interface may be ideal for facilitating effective app use. With this knowledge, the marketers may create advertisement stimuli that are appropriately designed and presented on a mobile interface without negatively affecting the users.

While visual fatigue was experienced by the users, the degree of visual richness on a mobile application did not contribute to it. The data from the heatmap of the product list page suggests that the users focus their attention on items in the beginning of a list and do not look past the first few items. For instance, marketers can convey things that are on sale by simply arranging visual cues, particularly in the very beginning of a product list. The items that are on special can be shown at the front of a list, and their status can be signified by colour, such as by a red label. This is consistent with the user interviews indicating that colour is necessary to draw attention to essential information and heatmap data demonstrating that the users focus on the first item on a list.

The other usability measures did not find any meaningful relationships with visual complexity, thus suggesting that the quantity of visual elements on an m-commerce user interface has little bearing on user pleasure or effectiveness while engaging with a mobile app. Effectiveness was not substantially connected across the entire experience, despite the fact that the effectiveness and visual complexity within the second task, which required users to add an item from each category, were found to be significant. The positive attitudes toward all the degrees of visual complexity as well as the employed visual elements were primarily evident in the satisfaction survey.

This implies that the number of visual components in an m-commerce application has no bearing on the users' positive perceptions of it. With this knowledge, marketers and managers can create an m-commerce interface for a company that incorporates as many visual cues as necessary to convey the brand's offerings while also ensuring that the customers will not become overly visually exhausted after a brief exposure. Fashion brands, for instance, can use a variety of visual components to promote new products or categories while maintaining a subtle aesthetic and brand-coordinated colour scheme. Too much flash and intensity in an advertisement could make users uncomfortable.

Many users suggested that adding a brightness button with a dark or light option would be a significant help in reducing the symptoms of eye strain. As many responders have pointed out, having a brightness button and the ability to switch between a dark and light mode are crucial for the consumers to reduce eye strain. Furthermore, this emphasises the need for user customisation to further personalise their experience, which is consistent with the profile page heatmaps that show the users concentrated on personalised features that can be customised. Given that the users are obviously interested in customising their accounts and the user interface, designers should permit them to do so even on m-commerce applications. The marketers and managers must also build promotional stimuli that may be viewed in dark mode, giving viewers the opportunity to choose.

Additionally, when a user enters an application, makes a purchase, or add an item to their cart, self-reference interactive dialogue incorporating the user's name can be used by application developers. When interacting with visual elements to highlight the distinctive character of the application's user, the app developers should utilise phrases such as "Welcome back, Alex!" and "Your item has been added, Alex". A study by Huang *et al.* (2023) found that factors like enabling mechanism, perceived usefulness and social influence increase satisfaction which increases their intention for continued usage of a mobile application. The data from the heatmap of each application iteration's page shows the users

attention to social engagement and individuality. Marketers should thus consider the addition of social engagement and personalisation when developing an application.

According to user interviews, the developers and marketers need to consider all of the possibilities and choose whether adding more visual elements is worth the potential discomfort that the users may experience. It is also crucial to remember that in the context of a m-commerce application, the visual complexity of the visual elements present cannot be held responsible for the visual fatigue experienced; instead, other factors may be having a greater influence. On other user interfaces, however, it may be more crucial to take this into account. Managers must evaluate the impact of colour, layout, text, font, and buttons on a mobile user interface when building a mobile app, but there is no need to limit the elements used provided they do not jeopardise brand identification or prospective user engagement. The visual elements also need to provide users with important information and functional benefits of using the application to allow for new users to easily adapt to the application.

The relationship between visual complexity and visual fatigue was discovered to be influenced by the reasons and methods by which the users explore an app. The underlying motives of consumers typically govern their behaviour. It is imperative for marketers and managers to understand the purpose of the customers' use of applications. If the users are merely perusing the content rather than purchasing anything specific, the richness of the visual aspects may not have the same impact on them and could potentially lead to visual fatigue. While it may be challenging to comprehend the underlying causes of consumer behaviour, programs such as loyalty cards or incentive systems can assist in identifying and targeting these behaviours so that the right messages are delivered to the right customers.

The two different tasks that the users completed on the m-commerce application were also used to assess a user's priming to a system. The non-primed task was the first free browse task, while the primed task was the second task. It is apparent that the previous experience with a mobile application influences usability in terms of how efficiently an application is utilised. An individual's past usage of an m-commerce application influences their interaction with other graphically complicated applications. It is crucial to remember that every participant admitted to using an m-commerce app before the experiment. It is imperative for retailers to have in mind that a significant portion of m-commerce application users possess past experience, particularly in this age group where curiosity and technical adoption are crucial.

A number of users expressed the want to view item prices prior to accessing the details page. This is an intriguing result that requires developers and marketers to weigh the trade-off between pricing display's ability to make users' lives easier and its ability to entice the customers to use the app longer. Through the focused attention observed on the cart and the detail pages displayed on the heatmaps, the current study has demonstrated the significance of price. As a result, when producing advertisements and stimuli for the consumers to engage with, the presentation of product and item prices is critical to the consumers' decision-making processes. When it comes to m-commerce applications, developers and brand managers need to make sure that the price is easily visible to the customers. This may be achieved by making the price bold or using a larger font size than other elements to draw their attention.

It is crucial for the marketers to comprehend how information is presented in stimulus, particularly when it is exhibited on a small screen such as a mobile device. Although one consumer recommended a grid arrangement, the stimuli were presented in a list format. While the grid format might provide consumers with a more engaging sensory experience, it might also cause problems with functionality

and functioning. Additionally, the users felt that several of the buttons and icons were excessively small which interfered with functionality. This could refer to the efficiency of the visual aspects in facilitating user interactions with the products. To maintain the overall efficiency of the app, retailers need to support digital content and make sure that the page load times, and the transition speeds are sufficient (Bleier, *et al.*, 2019). The presentation of visual elements is critical to how the users use an application.

Overall, the degree of visual complexity of an app had no discernible effect on the impact of the visual fatigue brought on by the usage of the m-commerce application. It was also discovered that users' visual fatigue had no effect on how usable the app was. This result makes it possible to draw several conclusions about the ramifications for managers, marketers, and user experience designers. The study's limitations are described in the next section and that information is then used in the following section to provide possible directions for future study topics.

5.5. LIMITATIONS OF THE STUDY

This section describes the limitations found in this research study in terms of sample size, treatment stimuli, data collection processes, and the investigated constructs. While the study observed visual fatigue across all levels of visual complexity in the m-commerce applications, the relationship between visual fatigue and usability did not reach statistical significance. This outcome does not undermine the validity of the research; rather, it highlights the complexity of human-computer interaction research and the multifactorial nature of the key constructs to this research study (Raizen *et al.*, 2023; Ren *et al.*, 2019). It is possible that while users experienced fatigue, it did not directly impact their perceived usability of the application, especially if they were still able to complete tasks efficiently or found the interface familiar. Other potentially influential factors such as individual user differences, limitations in measurement sensitivity, sample size, and the temporal disconnect between fatigue accumulation and usability perception may have contributed to the non-significant findings. These results underscore the importance of using multi-dimensional evaluation methods and suggest that visual fatigue while present, may not directly influence perceived usability in a linear or immediate way.

Firstly, the study's sample population distribution was geographically restricted because it only included the residents of Cape Town, South Africa. Due to the experimental in-person nature of the study and the time constraints imposed by the need for the respondents to be reachable by the researcher, this was the outcome. Due to limited room availability and respondent accommodations, the data collection for the study took place on the University of Cape Town campus between 9 a.m. and 6 p.m. the findings may not be easily generalised to wider demographic groups. Additionally, the sample size had to be restricted to ensure proper data collection and to be consistent with earlier studies of a similar kind. Small sample sizes are frequently used in consumer neuroscience research and other usability studies to guarantee consistency and reliable results (Torricco *et al.*, 2018; Lin *et al.*, 2022; Xie *et al.*, 2021; Kim *et al.*, 2017). Only a limited number of people were able to be tested within the time period and specific room (to keep with consistency in terms of lighting) since consumer neuroscience research is typically time-consuming due to the biometric data involved.

Additionally, the majority of the participants were in the 18–35 age range. The participants with impaired vision were also removed from the study, meaning only individuals with normal vision participated. Previous research has demonstrated that while using a digital system, visual fatigue affects

the respondents who are older and/or have low vision more severely (Chan, 2017; Calabrèse *et al.*, 2018; Guillon *et al.*, 2016; Koo *et al.*, 2018). The purpose of this study was to determine how the constructs affected this particular group of users because of their increased accuracy regarding the eye tracker and objective measures and due to their prior experience and propensity to engage with m-commerce apps, as well as the influence of age on the visual system (Koo *et al.*, 2018; Lin *et al.*, 2021; Guillon *et al.*, 2016; Deloitte, 2020; Li & Luximon, 2020).

The findings' generalisability was also restricted due to the fact that the respondents were only exposed to one iteration of the stimulus treatment, either the minimum, the moderate, or the highest degree of visual complexity app, with only roughly 30 participants experiencing each iteration. In addition, the participants were only allowed to use the application for about five minutes at a time, and they were given 30 seconds in between tasks to read the instructions. Given that earlier studies on visual fatigue used considerably longer exposure times (up to 6 hours), this limited exposure may be the reason for the low correlations between the visual fatigue measurements and the other constructs (Wang *et al.*, 2017; Kaneko & Sakamoto, 2001).

A study by Szpak *et al.* (2020) found that the trials lasting less than ten minutes did not cause the users to experience significant visual tiredness; and the study's overall task duration was five minutes. To fully understand the impact on the consumers, it is important to note that the consumers typically use the mobile commerce applications for no more than five minutes in real-world scenarios, which are replicated in this experiment. Previous studies on usability also limited the users' time on mobile sites to five minutes, during which they could use the application or perform tasks related to it (Kim *et al.*, 2017; Venkatesh & Agarwal, 2006; Ahmad & Hussaini, 2021).

Furthermore, the sole consumer neuroscience method employed to gauge the physiological reactions to the stimuli was eye-tracking. Eye tracking has been used in a number of earlier studies to quantify visual fatigue, but they have also combined it with other methods like CFFF and self-reporting metrics to provide a more comprehensive picture of the visual fatigue that users experience (Lin *et al.*, 2022; Song *et al.*, 2020; Singh *et al.*, 2023). Similarly, to gain a deeper understanding of the available data, this study employed self-reporting questionnaires, interviews, and eye tracking techniques to measure visual fatigue.

The tools and metrics used to assess VF and usability may have had limitations in sensitivity or granularity, eye-tracking for example was able to capture the physiological indicators of fatigue but may not align perfectly with subjective perceptions of usability, influenced by individual experiences or task success. The researchers can learn more about the user attention-related cognitive processes and behaviour by examining the correlations between the eye movements and visual information processing. To learn more about how the consumers respond to m-commerce applications in terms of usability, visual complexity, and visual fatigue, more neuroscientific approaches can be employed. Additional metrics, such as heart rate monitoring, fMRI, GSR, and EEG, may help to provide more information about the users' emotional states and degrees of visual fatigue (Wang *et al.*, 2017; Wang *et al.*, 2018a; Wang *et al.*, 2018b; Fang *et al.*, 2022).

The current study was able to explore the research objectives and discover helpful recommendations and a deeper understanding of the effects that various visually complex applications have on the experience of visual fatigue and the usability of a mobile application, despite the aforementioned limitations. Additionally, the limitations provide guidance for potential future research avenues that

scholars could pursue to expand on the current study and offer additional insights into the components under discussion.

5.6. FUTURE RESEARCH RECOMMENDATIONS

As a result of the limitations and the findings of the current study, this section outlines future research opportunities and recommendations for future studies that attempt to understand the visual fatigue experienced through the usability of and the level of visual complexity that impacts users of a m-commerce application. The participants in this study were restricted to those who, at the time of the experiment, were residing in the Cape Town metropolitan area of South Africa and were between the ages of 18 and 35. For the younger generations (X and Y), deductions might be made based on this age range. Age, gender, and the past use of a m-commerce app were the only demographic data collected for this study. Marketing managers that wish to explicitly target users from these groups to further engage with m-commerce applications can benefit from future research studies that concentrate on specific demographic aspects such as age, gender, race, and geography. These studies can offer cross-sectional evaluation along with additional insights specific to each of these groups. The comparison of the effects of visual fatigue, usability, and visual complexity on the users of m-commerce applications could be based on factors such as gender, race, or age in these studies. It is also advised that, given the limitations of this study, a greater number of participants be used in a subsequent investigation.

The participants from the current study were streamlined to ensure that all were familiar with a m-commerce application. To have a better understanding of how people use these platforms, future research might compare people whom are and whom are not familiar with a m-commerce application. Additionally, the current study developed a m-commerce application on an Android operating system by which the variables were tested. Future studies could compare two different operating systems to learn how the customers of the two operating systems (e.g. Apple vs Android or Google vs Apple) differ while using the m-commerce applications. To gain a better understanding of how consumers engage with visually complex systems and how this affects usability and visual fatigue, various mobile applications from various industries could also be employed.

To guarantee the study's validity, reliability, and control, the operating system and the mobile application remained constant. Diverse operator system users may exhibit distinct behaviours, consequently offering marketers a potentially valuable and innovative research route. Due to the fact that banking mobile applications are less visually sophisticated than fashion m-commerce apps, users may experience a different degree of visual fatigue. As a result, engaging these consumers requires various forms of communication and incentives. Due to brand loyalty and habitual purchasing, the users of various operating systems, brands, and industries may behave differently, which emphasises the significance of future research into these sectors.

To assess the fundamental user experience when interacting with a m-commerce application, a simple m-commerce application was used in this study. There were only five pages in the application. Subsequent research endeavours may uncover more potentially important m-commerce pages, which could result in distinct customer interactions and behavioural patterns. To gain a deeper understanding of the impression of visual fatigue, the study might make use of a more varied age range. Low vision users might also be employed, and their outcomes could be contrasted with the current study's findings

to expand the body of knowledge on people with various eye conditions and how these may influence perceived and objective visual fatigue experienced by users.

Future research might build on the findings from this investigation and compare them with the findings from another investigation that only included individuals with low vision or older individuals to provide a more thorough examination of the ways in which usability, visual complexity, and visual fatigue affect different categories of users. The current experiment's task duration was limited to five minutes. To further understand usability, visual fatigue, and visual complexity, longer tasks may be used in future research. This would contribute to the body of knowledge on the potential effects of task duration on the various experiment constructs.

Furthermore, a combination of other neuroscientific instruments may be employed in a later investigation to gauge and comprehend the effect that a visually complicated program has on system usability and user visual fatigue. fMRI, EEG, facial coding, heart rate monitors, GSR, and other techniques may help future research to assess customer responses and emotions in relation to visually sophisticated apps in a comprehensive way. This may enable the collection of fresh data regarding the participants characteristics and the physiological reactions related to a user's experience with a m-commerce application. The current study combined self-reporting, objective, and eye tracking methodologies to better understand how the various constructs interact. This combination, along with CFFF, could potentially be used in future studies to quantify visual fatigue and its effects on the users of m-commerce more holistically.

Another avenue for future research could investigate a combination of digital systems (e.g. personal computer or desktop vs a mobile device) and how visual fatigue and user performance are impacted. The results from this study show that visual fatigue does not impact how users interact with a m-commerce system, but prior studies suggest that the users that utilise their mobile devices as a means to relax from boredom or fatigue experienced from work-related activities only induce more fatigue. This can be investigated further with the results from the current study to see if when interrupted by smartphone usage, the work-related digital system usability is impacted and thus if job performance is impacted. The researchers can also compare how different digital systems impact users in terms of visual fatigue and usability differently. It might also be interesting to investigate how different context of use for applications (i.e. Zoom for meeting vs Zoom with peer) on different devices impact the usability of participants. This research will aid the managers in better understanding how the usage of different devices impact productivity and job performance.

In conclusion, future research might examine the visual complexity of a mobile application, the level of visual fatigue experienced, and the usefulness of the system in a more naturalistic setting. This study was conducted in an experimental laboratory setting. To assess the scientific validity of the current work, replication in a naturalistic setting could be helpful.

5.7. SUMMARY

Within this study, the effects of various visually sophisticated m-commerce applications on users' eye strain and overall system usability were examined. The findings of this research suggest that there is no significant correlation between the degree of visual fatigue experienced in a m-commerce application

and its usability. It was also determined that there was no significant correlation between visual fatigue and the visual complexity of a m-commerce system. This has several ramifications for brand marketers and the developers of m-commerce applications, which were covered in this thesis chapter.

The efficiency of a user when interacting with a m-commerce system was impacted by the visual complexity of the system. However, the degree of visual complexity in a system did not significantly affect other usability indicators. Marketers may only need to take into account a system's visual richness in relation to how well the customers use it, as visual fatigue was found to be insignificant overall in the context of the m-commerce applications when compared to the constructs currently being tested (usability and visual complexity). It is, however, important to note that visual fatigue was significant across all the three app levels, but it was just not significantly impacted by visual complexity and did not impact how the users interact with a system. This presents a number of implications for marketers, managers and developers of m-commerce systems.

The marketers can assume that visual element (specifically font style, colour and button shape) changes that are present on a m-commerce app do not cause visual fatigue and thus it does not impact the users' well-being in a negative manner. This does not, however, negate the visual elements such as pop-up advertisements which may still negatively impact users. Marketers can also assume that if users are struggling to use the m-commerce application effectively, efficiently and satisfactory, it is not due to the visual fatigue that is experienced by the application. Thus, even if visual fatigue is experienced, it will not impact the usability of a m-commerce system and further investigation should occur to understand what is causing the user discomfort or omitting continued usage.

A number of limitations from the study were presented. These show that factors such as location, age group, and experimental exposure might have impacted the insignificant relationships that were found but were controlled out of necessity. These limitations do make the findings difficult to apply to those over the age of 35, who are not residing in Cape Town South Africa and who spend longer than 10 minutes on an m-commerce application in general. These limitations can be applied to future research so as to strengthen the results from this study and to find novel insights about the phenomena investigated herein. Future research can include a larger sample size, a more diverse sample group to better understand how specific users might be impacted by visual complexity and how this impacts the usability of the system and the visual fatigue that is experienced by the users.

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Appendix A: Ethics Approval & Department of Student Affairs (DSA) Approval, Language Editing Certificate, Statistical Editing Certificate, Turnitin Score, Cover Letter & Questionnaire

Department of Student Affairs (DSA) Approval

	RESEARCH ACCESS TO STUDENTS	DSA100
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NOTES

- This form must be **FULLY** completed by all applicants who want to access UCT students for the purpose of research or surveys.
- Return the fully completed (a) **DSA 100** application form by email, in the same word format, together with your: (b) **research proposal inclusive of your survey**, (c) **copy of your ethics approval letter / proof** (d) **informed consent letter** to: Nadierah.Pienaar@uct.ac.za. Your application will be attended to by the Executive Director, Department of Student Affairs (DSA), UCT.
- The turnaround time for a reply is **approximately 10 working days**.
- NB: It is the responsibility of the researcher/s to apply for and to obtain **ethics approval and to comply with amendments that may be requested**; as well as to **obtain** approval to access UCT staff and/or UCT students, from the following, at UCT, respectively: (a) **Ethics**: Chairperson, Faculty Research Ethics Committee (FREC) for ethics approval, (b) **Staff access**: Executive Director: HR for approval to access UCT staff, and (c) **Student access**: Executive Director: Student Affairs for approval to access UCT students.
- Note**: UCT Senate Research Protocols requires compliance to the above, **even if prior approval has been obtained from any other institution/agency**. UCT's research protocol requirements applies to **all persons, institutions and agencies from UCT and external to UCT** who want to conduct research on human subjects for academic, marketing or service related reasons at UCT.
- Should approval be granted to access UCT students for this research study, such approval is effective for a period of one year from the date of approval (as stated in Section D of this form), and the approval expires automatically on the last day.
- The approving authority reserves the right to revoke an approval based on reasonable grounds and/or new information.

SECTION A: RESEARCH APPLICANT/S DETAILS

Position	Staff / Student No	Title and Full Name	Contact Details (Email & Cell / Land line)
A.1 Student Number	JHNALE015	Ms Alexandra Shelley Johnson	JHNALE015@myuct.ac.za / alexandrajohnson205@gmail.com / 0824973145
A.2 Academic / PASS Staff No.			
A.3 Visitor/ Researcher ID No.			
A.4 University at which a student or employee	University of Cape Town	Address if <u>not</u> UCT:	
A.5 Faculty & Department/School	Faculty of Commerce, School of Management Studies		
A.6 APPLICANTS DETAILS	Title and Name		Tel.
If different from above	Alexandra Shelley Johnson		0824173145
			alexandrajohnson205


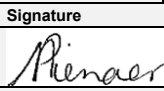

SECTION B: RESEARCHER/S SUPERVISOR/S DETAILS

Position	Title and Name	Tel.	Email
B.1 Supervisor	Dr Pragasen Pillay	0216505909	p.pillay@uct.ac.za
B.2 Co-Supervisor/s	Mr Mark Drummond Mr Ashraf Vahed Jean-Paul Fouche	0785112786	mark.drummond@neuralsense.com ashraf.vahed@neuralsense.com jpfouche123@gmail.com

SECTION C: APPLICANT'S RESEARCH STUDY FIELD AND APPROVAL STATUS

C.1 Degree – if applicable	Master of Business Science
C.2 Research Project Title	The impact of visual complexity on visual fatigue within the context of e-commerce mobile application usability: from a consumer neuroscience perspective
C.3 Research Proposal	Attached: Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>
C.4 Target population	UCT students 18 – 35-year-olds who have used a mobile e-commerce application
C.5 Lead Researcher details	If different from applicant:
C.6. Will use research assistant/s	Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> If yes- provide a list of names, contact details :
C.7 Research Methodology and Informed consent	Research methodology: Quantitative eye tracking and questionnaire Informed consent: Yes, advised o participants
C.8 Ethics clearance status from UCT's Faculty Ethics in Research Committee /Chair (EIRC)	Approved by the UCT EIRC: Yes <input checked="" type="checkbox"/> With amendments: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> (a) Attach copy of your UCT ethics approval. Attached: Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> (b) State date / Ref. No / Faculty of your UCT ethics approval: 24/01/2024 Ref. / Faculty: COM/00564/2024

SECTION D: APPLICANT/S APPROVAL STATUS FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE (To be completed by the ED, DSA or NOMINEE)

	Approved / With Terms / Not	* Conditional approval with terms	Applicant/s Ref. No.:
D.1 APPROVAL STATUS	(i) Approved  (ii) With terms (iii) Not approved	a) Access to students for this research study must only be undertaken <u>after</u> written ethics approval has been obtained. b) In event any ethics conditions are attached, these must be complied with <u>before</u> access to students.	JHNALE015 / Ms Alexandra Shelley Johnson
D.2 PREPARED BY:	Designation Personal Assistant	Name Nadierah Pienaar	Signature  Date of Approval 8/02/2024
D.3 APPROVED BY:	Designation Executive Director / Nominee Department of Student Affairs	Name Mr Pura Mgolombane	Signature  Date of Approval 9/02/2024

Ethics Approval



RE: Research Ethics Committee Project Approval Letter

Dear Alexandra Johnson,

Your application for ethics review of your project titled

The impact of visual complexity on visual fatigue within the context of e-commerce mobile application usability: from a consumer neuroscience perspective

has been reviewed and evaluated by the Commerce Research Ethics Committee.

You may proceed with your research project titled:

The impact of visual complexity on visual fatigue within the context of e-commerce mobile application usability: from a consumer neuroscience perspective

Please note that should:

1. (i) any serious or adverse effects to participants occur and/or,
2. (ii) aspect(s) of your current project change and/or
3. (iii) any unforeseen events that might affect continued ethical acceptability of the project occur then you should immediately report this to the approving REC. You may be required to submit an amendment to this application, in order to determine whether the changed aspects increase the ethical risks of your project.

Based on the information supplied your application has been successful and is approved. Please note the following additional conditions associated with this approval:

(i)

Regards,
Commerce Research Ethics Committee.

Language Editing Certificate



You Write. **We Edit.** You Love it.

28 August 2024

TO WHOM IT MAY CONCERN

RE: CONFIRMATION OF LANGUAGE EDITING SERVICES: ALEXANDRA SHELLEY JOHNSON

I confirm that I have done language editing for Alexandra Shelley Johnson's research report titled:



**THE IMPACT OF VISUAL COMPLEXITY ON VISUAL FATIGUE WITHIN THE CONTEXT OF E-COMMERCE
MOBILE APPLICATION USABILITY: FROM A CONSUMER NEUROSCIENCE PERSPECTIVE**

The research report now conforms to the University of Cape Town's expected academic language editing standards.



Yours sincerely

Lynn N. Sibanda Moyo

Tel: 011 050 0376

Mobile: 071 989 0983

Email: lynn@lovetoedit.co.za



Member of the [Professional Editors Guild](#)



Address: 16 Countesses Ave, Randburg, South Africa, 2194 | **Telephone:** +27 11 050 0376 | **Email:** info@lovetoedit.co.za
Website: www.lovetoedit.co.za | **Registration Number:** 2016/ 425723/ 07

Statistical Editing Certificate

DEEPAK SINGH

Database and Statistical Analysis

P. O. Box 24002

(cell): 083-775-9239

Hillary

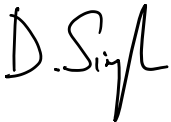
singhd@hotmail.co.za

4024

STATISTICIAN DECLARATION FOR CONSULTATION

This is to confirm that I have given appropriate recommendations relating to the student's research:

Student Name	Alexandra Johnson
Student number	JHNALE015
Title	The Impact of Visual Complexity On Visual Fatigue Within The Context Of E-Commerce Mobile Application Usability: From A Consumer Neuroscience Perspective.
Institution	The University of Cape Town
Faculty	Commerce
Department	School of Management Studies

	15 August 2024
Deepak Singh	Date

(M.Sc)

QUESTIONNAIRE



THE IMPACT OF VISUAL COMPLEXITY ON VISUAL FATIGUE WITHIN THE CONTEXT OF E-COMMERCE MOBILE APPLICATION USABILITY: FROM A CONSUMER NEUROSCIENCE PERSPECTIVE

Faculty:

Commerce

Department:

School of Management Studies (Marketing)

Researcher:

Name: Alexandra Shelley Johnson

Student Number: JHNALE015

Student Email Address: jhnale015@myuct.ac.za

Alternative Email Address: alexandrajohnson205@gmail.com

Contact Number: 0824973145

Questionnaire 1: Pre-Exposure Self-Report

Screening Questions

For each question identified below, mark with an 'X' in the relevant box to indicate your answer.

A	Are you between the ages of 18 and 35?	Yes	No
B	Do you reside in the Cape Town metropolitan area?	Yes	No
C	Do you have normal or corrected-to-normal vision?	Yes	No
D	Are you colour blind?	Yes	No
E	Do you regularly use mobile shopping applications (e.g. Takealot, Superbalist, Bash, Checker6060, MyRunway)?	Yes	No

If you answered “yes” in all four of the above questions, continue with the rest of the questionnaire and experiment. If you answered “no” in any of the questions, you do not have to complete the rest of the questionnaire or participate in the subsequential experiment.

For each question identified below, mark with an 'X' the number to the right that best fits your judgment of its quality. Use the rating scale to select the quality number. For example:

1	2	3	4	5	6	7
---	---	--------------	---	---	---	---

SECTION 1: Visual Fatigue baseline questionnaire (Source: Oner, M., 2018; Kim, D.J., Lim, C.Y., Gu, N. and Park, C.Y., 2017)

	Please indicate how strongly you agree or disagree with each of the following statements after the use of your mobile phone	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
1	I have difficulty focusing	1	2	3	4	5	6	7
2	My eyes are tired	1	2	3	4	5	6	7
3	My eyes feel sore/aching	1	2	3	4	5	6	7
4	I feel dizzy looking at the screen	1	2	3	4	5	6	7
5	My eyes feel irritated	1	2	3	4	5	6	7
6	I experience eye strain	1	2	3	4	5	6	7
7	I feel visual discomfort	1	2	3	4	5	6	7
8	My eyes feel watery after use	1	2	3	4	5	6	7
9	I experience blurred vision	1	2	3	4	5	6	7

SECTION 2: Visual Fatigue Pre-experimental questionnaire (Source: Oner, M., 2018; Kim, D.J., Lim, C.Y., Gu, N. and Park, C.Y., 2017)

	Please indicate how strongly you agree or disagree with each of the following statements after the use of a mobile e-commerce app	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
10	I have difficulty focusing	1	2	3	4	5	6	7
11	My eyes are tired	1	2	3	4	5	6	7
12	My eyes feel sore/aching	1	2	3	4	5	6	7
13	I feel dizzy looking at the screen	1	2	3	4	5	6	7
14	My eyes feel irritated	1	2	3	4	5	6	7
15	I experience eye strain	1	2	3	4	5	6	7
16	I feel visual discomfort	1	2	3	4	5	6	7
17	My eyes feel watery after use	1	2	3	4	5	6	7
18	I experience blurred vision	1	2	3	4	5	6	7

SECTION 3: Phone Usage

Participants were asked the following questions:

1. How long on average do you spend on your phone?
 - a. 1 hour or less
 - b. 2 – 4 hours
 - c. 4 – 6 hours
 - d. More than 6 hours
 - e. 0 hours

2. Before coming to this experiment how long did you spend on your phone
 - a. 1 hour or less
 - b. 2 – 4 hours
 - c. 4 – 6 hours
 - d. More than 6 hours
 - e. 0 hours

THANK YOU! YOU MAY CONTINUE WITH THE EXPERIMENT.

Questionnaire 2: Post-Exposure Self-Report

For each question identified below, mark with an 'X' the number to the right that best fits your judgment of its quality. Use the rating scale to select the quality number. For example:

1	2	3	4	5	6	7
---	---	---	--------------	---	---	---

SECTION 1: Visual Fatigue Post-exposure questionnaire (Source: Oner, M., 2018; Kim, D.J., Lim, C.Y., Gu, N. and Park, C.Y., 2017)

	Please indicate how strongly you agree or disagree with each of the following statements after the use of the mobile e-commerce app	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
1	I have difficulty focusing	1	2	3	4	5	6	7
2	My eyes are tired	1	2	3	4	5	6	7
3	My eyes feel sore/aching	1	2	3	4	5	6	7
4	I feel dizzy looking at the screen	1	2	3	4	5	6	7
5	My eyes feel irritated	1	2	3	4	5	6	7
6	I experience eye strain	1	2	3	4	5	6	7
7	I feel visual discomfort	1	2	3	4	5	6	7
8	My eyes feel watery after use	1	2	3	4	5	6	7
9	I experience blurred vision	1	2	3	4	5	6	7

SECTION 2: User Satisfaction (visual stimuli) Post-experiment questionnaire (Source: Schrepp, M., Hinderks, A. and Thomaschewski, J., 2017)

Please indicate how each of the following statements resonate with you (feel in common with).								
1	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Obstructive	1	2	3	4	5	6	7	Supportive
2	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Complicated	1	2	3	4	5	6	7	Easy to use
3	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Ineffective	1	2	3	4	5	6	7	Effective
4	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Clear	1	2	3	4	5	6	7	Confusing
5	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Meets Expectations	1	2	3	4	5	6	7	Does not meet Expectations
6	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Not Interesting	1	2	3	4	5	6	7	Interesting
7	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Conventional	1	2	3	4	5	6	7	Inventive
8	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Usual	1	2	3	4	5	6	7	Unique
9	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Boring	1	2	3	4	5	6	7	Exciting
10	For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as							
Annoying	1	2	3	4	5	6	7	Enjoyable

SECTION 3: User Satisfaction (overall) Post-experiment questionnaire (Source: Schrepp, M., Hinderks, A. and Thomaschewski, J., 2017.)

Please indicate how each of the following statements resonate with you (feel in common with).								
1	For me personally, the mobile shopping application can be described as							
Obstructive	1	2	3	4	5	6	7	Supportive
2	For me personally, the mobile shopping application can be described as							
Complicated	1	2	3	4	5	6	7	Easy to use
3	For me personally, the mobile shopping application can be described as							
Ineffective	1	2	3	4	5	6	7	Effective
4	For me personally, the mobile shopping application can be described as							
Clear	1	2	3	4	5	6	7	Confusing
5	For me personally, the mobile shopping application can be described as							
Meets Expectations	1	2	3	4	5	6	7	Does not meet Expectations
6	For me personally, the mobile shopping application can be described as							
Not Interesting	1	2	3	4	5	6	7	Interesting
7	For me personally, the mobile shopping application can be described as							
Conventional	1	2	3	4	5	6	7	Inventive
8	For me personally, the mobile shopping application can be described as							
Usual	1	2	3	4	5	6	7	Unique
9	For me personally, the mobile shopping application can be described as							
Boring	1	2	3	4	5	6	7	Exciting
10	For me personally, the mobile shopping application can be described as							
Annoying	1	2	3	4	5	6	7	Enjoyable

SECTION 4: Non-compulsory questions

The following questions are voluntary and are not compulsory to answer, but to provide useful information to the research in question.

7	What is your gender identity (Please mark 'X' in the appropriate box)			
Male	Female	Other	Prefer not to say	
8	Which age range do you fall within?			
18 – 23		24 – 29		30 – 35

THANK YOU FOR YOUR PARTICIPATION, YOUR RESPONSES ARE GREATLY APPRECIATED!

Respondent Number:

Personal Interview

1. Interviewer: How would you explain the mobile application you experienced?
2. Interviewer: How are your eyes feeling after interacting with the mobile app?
3. Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Cover Letter



Dear Respondent,

My name is Alexandra Johnson, and I am currently registered as a Master of Business Science student (specialising in Marketing) at the University of Cape Town (UCT). The research topic under investigation pertains to the impact of visual complexity on visual fatigue within the context of e-commerce mobile application usability: from a consumer neuroscience perspective. This research aims to determine the relationship between usability and visual fatigue in regard to e-commerce mobile applications and Cape Town 18 – 35 consumers/users. I therefore invite you to participate (voluntarily) in this research study by completing the questionnaires and experiment that follow.

Your participation in this research is **voluntary**. Your feedback is greatly appreciated and will be kept as strictly confidential. You will be kept anonymous throughout the experience as you will be referred to in all data as your participation number. You may further choose to withdraw from the study at any given time without any negative consequences and the researcher's contact details have been made available for any further queries, the contact details are supplied on the cover sheet of this questionnaire. By participating in this research, you will be entered into a lucky draw to potentially received a R250 Take-a-lot voucher. You will also gain insights on how much visual fatigue you experience when interacting with an e-commerce app for about 5 minutes.

Completing the questionnaires will indicated you have provided implicit consent to your responses being included within the researcher's data analysis, results presentation and potentially published online. Participation in this study requires you to answer a questionnaire that will take approximately **5 minutes** to complete, as well as a **25-minute** eye-tracking experiment. Both the questionnaire and experiment will take approximately **30 minutes** to complete. This research will take place at the Neural Sense offices in Claremont. The eye tracking experiment will use a Tobii screen-based eye-tracking device. This is non-invasive and records eye movements from a distance while you are experiencing the mobile application. Please note that this research will be excluding the participation of minors.

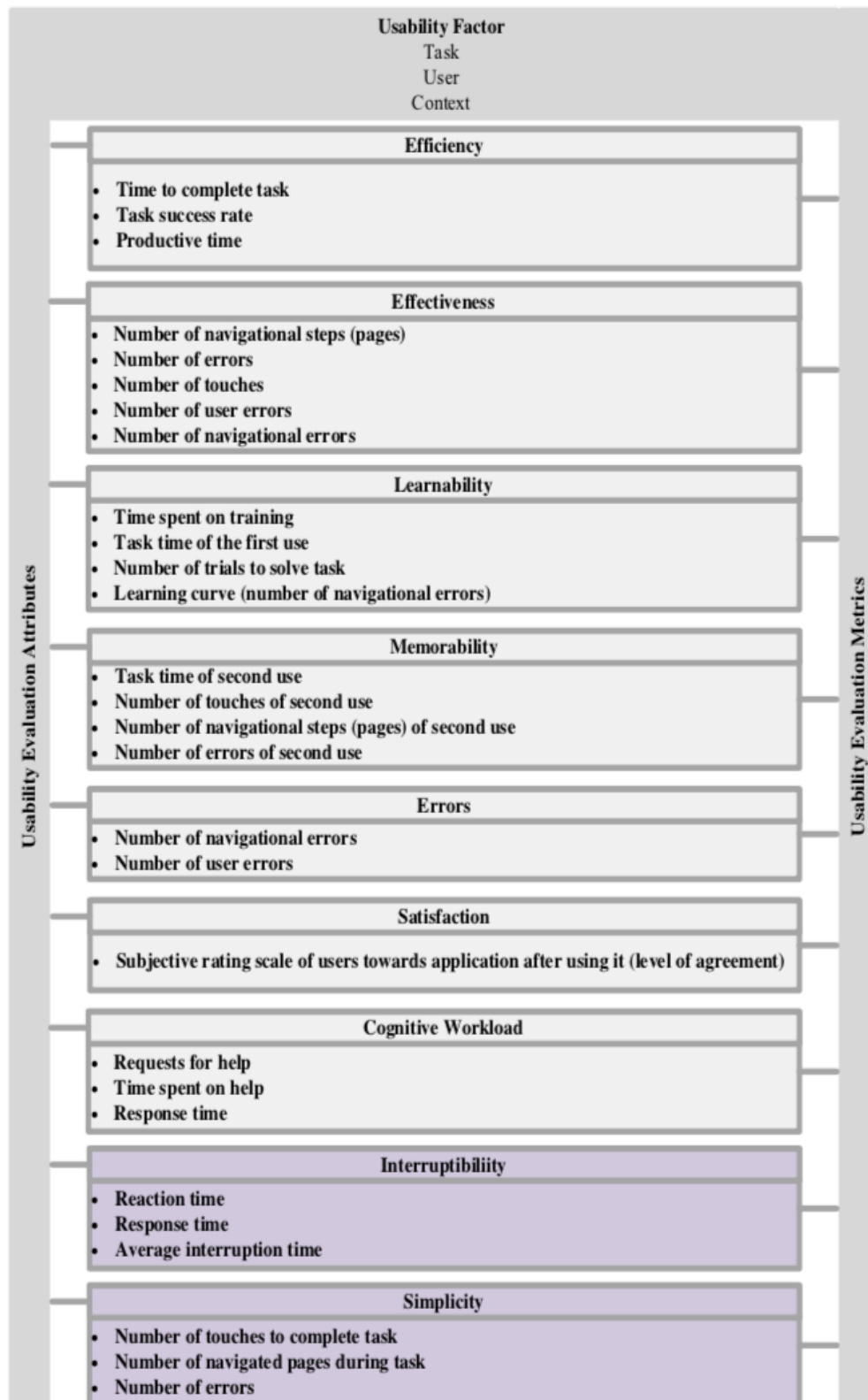
The entire process should take no longer than 15 minutes. Thank you in advance for your valuable contribution and participation in this investigation.

Researcher

A handwritten signature in black ink, appearing to be 'A. Johnson', is written over a horizontal line.

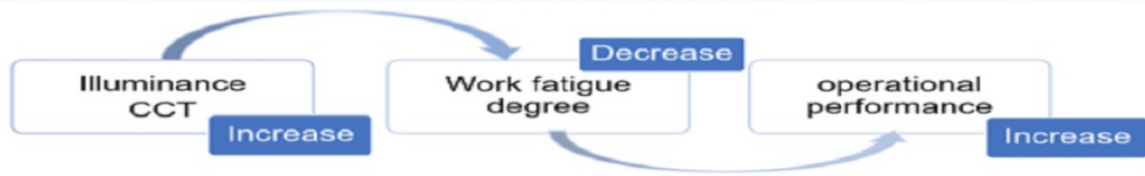
Appendix B: Theoretical Models

Figure 7: Mobile Application Usability Evaluation Metrics (MAUEM) Model (Saleh, et al., 2017)



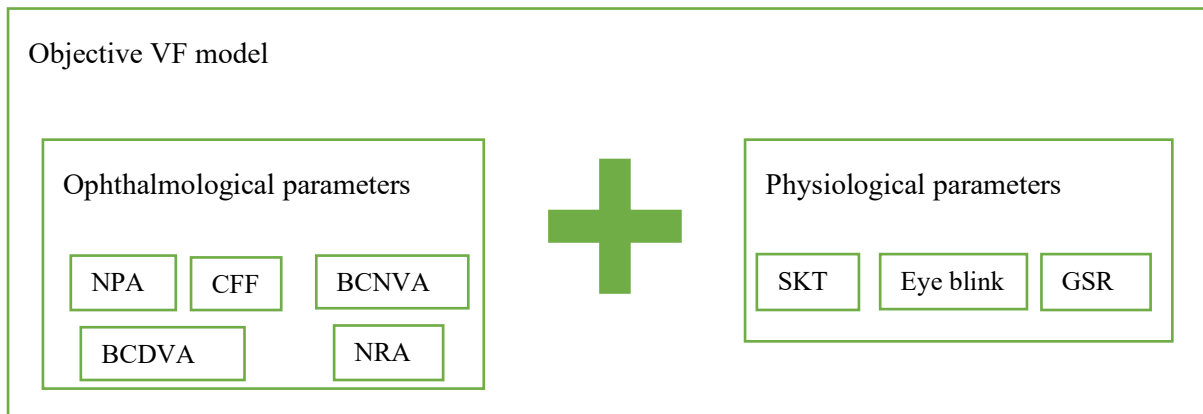
SOURCE: Saleh, et al., 2017

Figure 8: Abstract Model for Effect of Indoor Lighting on Visual Fatigue



SOURCE: Fang, *et al.*, 2022

Figure 9: Objective Visual Display Terminal (VDT) Visual Fatigue Model



SOURCE: Wang, *et al.*, 2018a

Appendix C: Data Collection Procedure

Step 1: Screening & Randomization

Prescreening of respondents for exclusion based on demographics (outside the age range of 18-35), prior experience with a mobile shopping application, eyesight that might not be picked up by the eye tracker (any serious eye conditions) and any health issues. Randomization occurred to match respondents with each application (differing visual complexity levels) to allow comparisons between each.



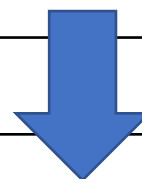
Step 2: Pre-experimental Questionnaire

Each respondent completed a pre-experimental questionnaire to assess prior visual experience, prior time spent on the phone and prior time spent on a mobile application before completing the eye-tracking experience with the mobile app visual complexity iteration.



Step 3: Treatment & Data Collection

During the exposure to the specific visual complexity application iteration. Consumer neuroscience techniques were utilized in collaboration with iMotions and Tobii eye tracking software to measure the autonomic responses in real-time. All respondents had to complete two separate tasks each and had a total of five minutes to complete each.



Step 4: Post-experimental questionnaire

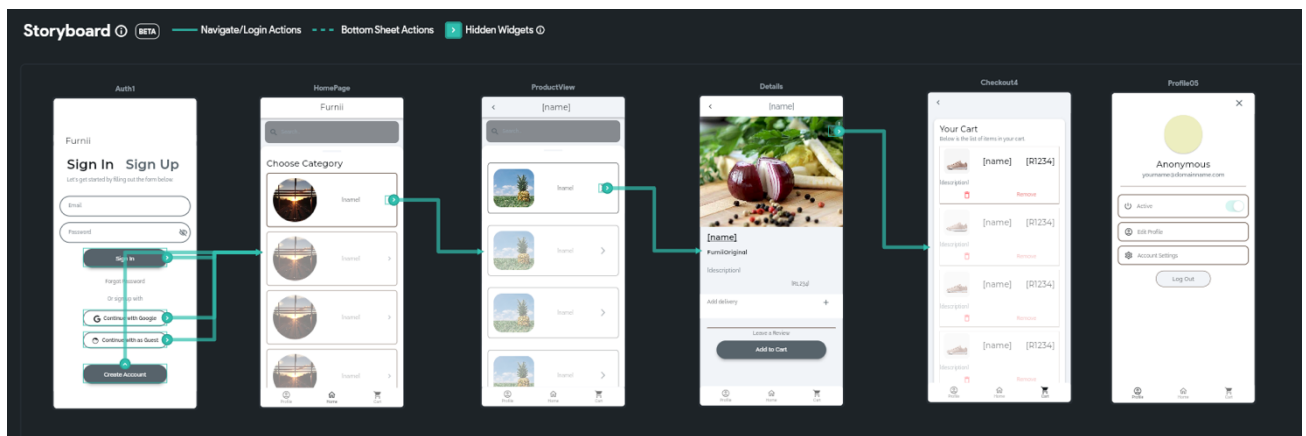
Finally, each respondent completed a final post-experimental questionnaire to answer self-reporting questions related to visual fatigue experienced in relation to each specific app, demographic questions about age and gender and satisfaction to the app overall.

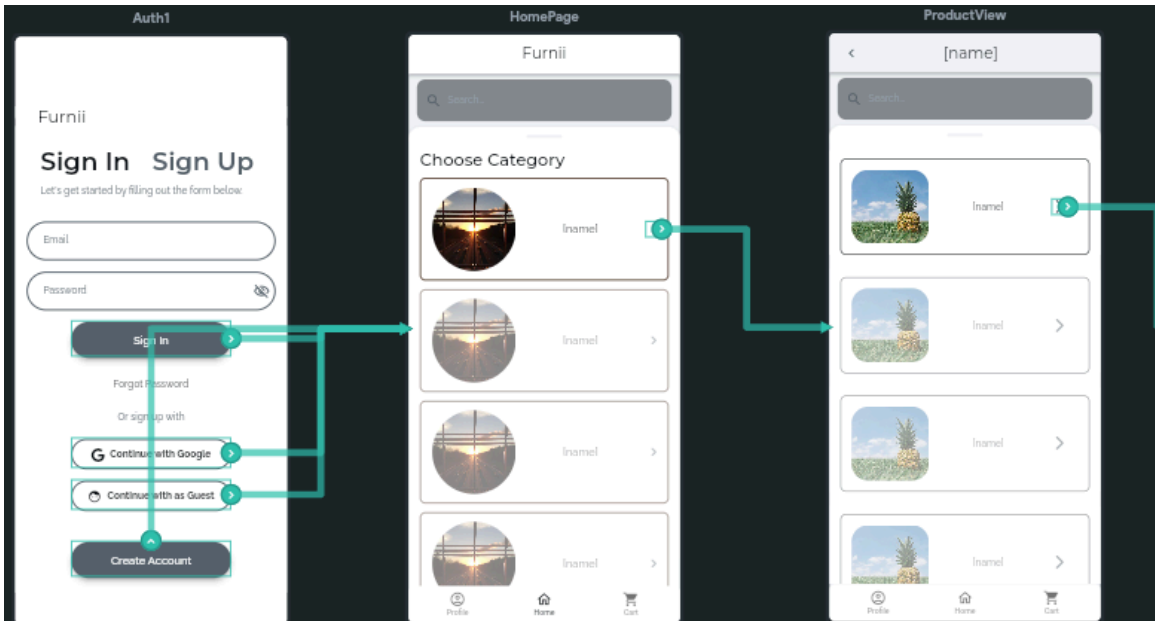
Appendix D: Stimuli

Figure 10: Experimental Eye-Tracking Set-up



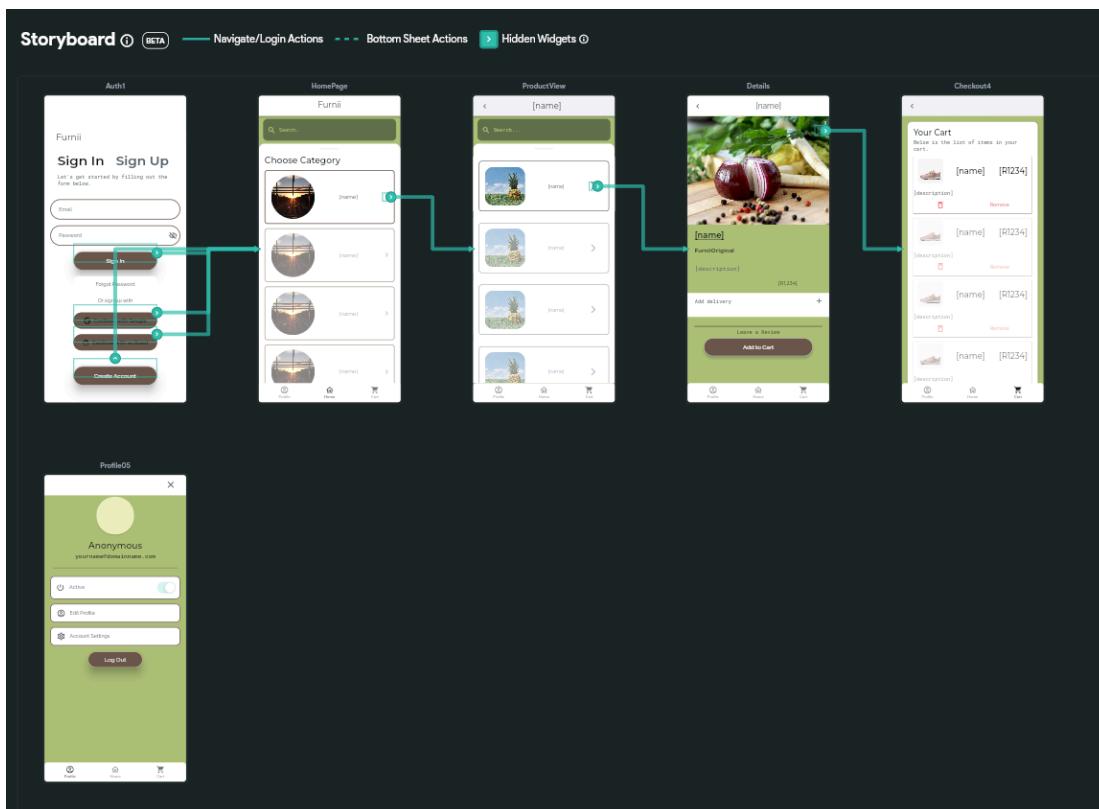
Figure 11: Furnii Application Iteration 1 (App 1 – basic level of visual complexity)

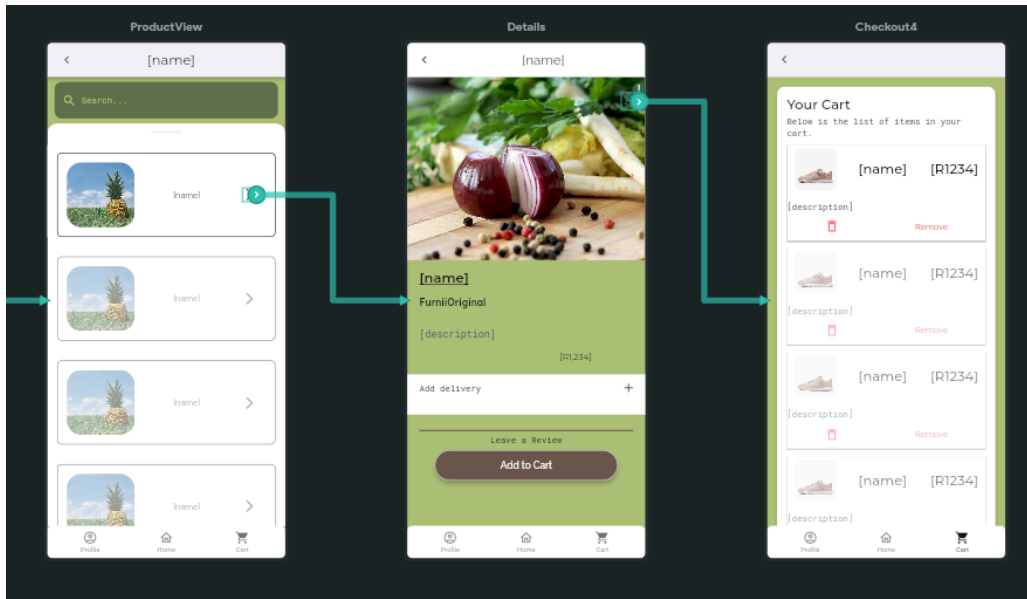




SOURCE: flutterflow.io

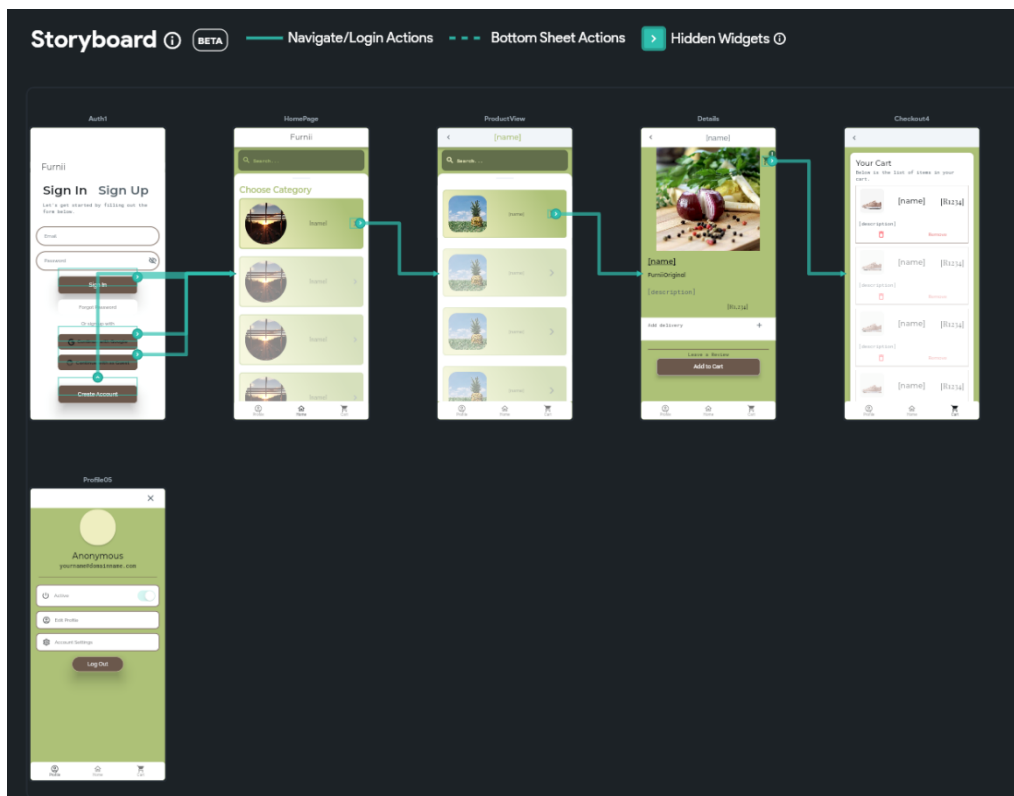
Figure 12: Furnii Application Iteration 2 (App 2 - moderate level visual complexity)

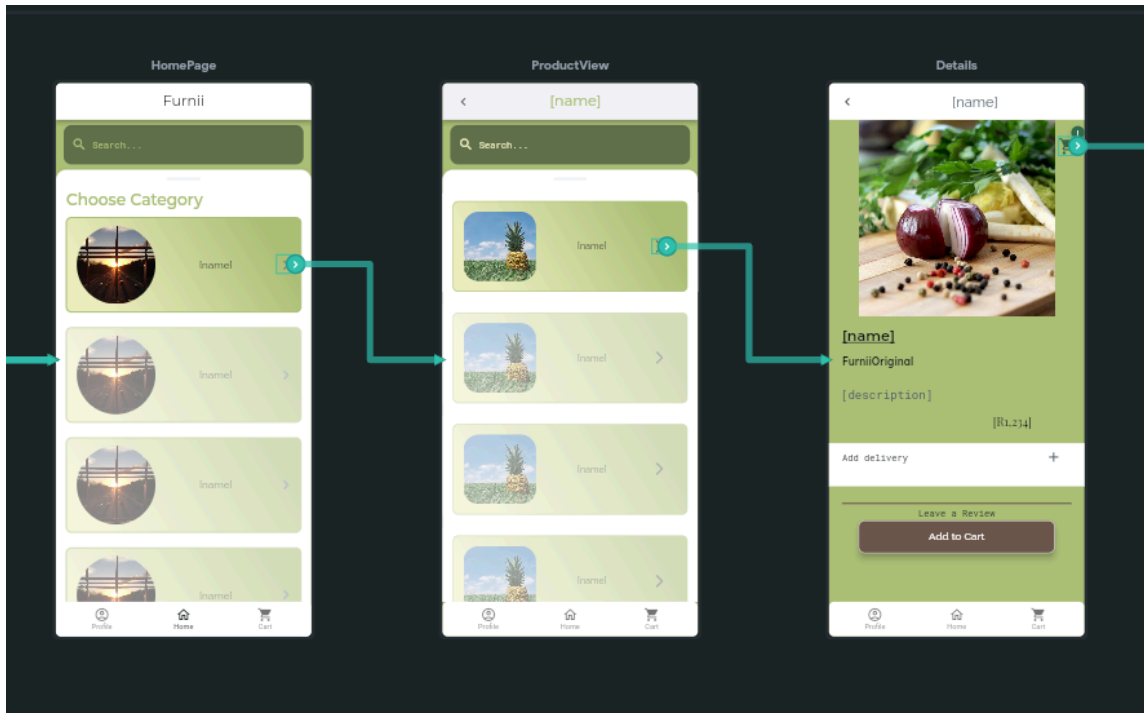




SOURCE: flutterflow.io

Figure 13: Furnii Application Iteration 3 (App 3 - high level visual complexity)





SOURCE: flutterflow.io

Appendix E: Descriptive Statistics & Item Reliability Scales

Table 19: Distribution of Respondents Between Experimental Groups

Experimental Group	Frequency	Valid Percent
App 1	34	35.42
App 2	30	31.25
App 3	32	33.33
Total	96	100

Table 20: Task Distribution Between Experimental Groups

Task Distribution between experimental groups								
Task	App 1		App 2		App 3		Total	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
Free-Browse	34	35.42	30	31.25	32	33.33	96	100
Task-Orientated	34	35.42	30	31.25	32	33.33	96	100

Table 21: Age Distribution Across Experimental Groups

#	Answer	%	Count	Mean	Standard Deviation
1	18-23	66.67	64	1.35	0.52
2	24-39	31.25	30		
3	30-35	2.08	2		
	Total	100	96		

Table 22: Gender Distribution Across Experimental Groups

#	Answer	%	Count	Mean	Standard Deviation
1	Male	38.54	37	1.64	0.53
2	Female	59.38	57		
3	Non-Binary	2.08	2		
	Total	100	96		

Table 23: Satisfaction Overall (transformed data)

Item	Negative	Positive	Mean	Standard deviation
For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as:				
1	Obstructive	Supportive	1.469	1.231
2	Complicated	Easy to use	2.302	0.964
3	Ineffective	Effective	1.583	1.139
4	Confused	Clear	2.125	1.059
5	Does not meet expectations	Meets expectations	1.156	1.431
6	Not interesting	Interesting	0.490	1.522
7	Conventional	Inventive	0.198	1.690
8	Usual	Unique	0.094	1.742
9	Boring	Exciting	0.313	1.551
10	Annoying	Enjoyable	1.167	1.427

Table 24: Short UEQ Scales for Satisfaction Overall

Short UEQ Scales	
Pragmatic Quality	1.870
Hedonic Quality	0.339
Overall	1.104

Table 25: Scale Consistency Satisfaction Overall: Cronbachs Alpha-Coefficient

Pragmatic Quality		Hedonic Quality	
Items	Correlation	Items	Correlation
1,2	0.580	6,7	0.718
1,3	0.734	6,8	0.748
1,4	0.577	6,9	0.826
2,3	0.547	6,10	0.583
2,4	0.695	7,8	0.795
3,4	0.585	7,9	0.743
2,5	0.301	7,10	0.533
3,5	0.634	8,9	0.747
4,5	0.494	8,10	0.544
1,5	0.585	9,10	0.718
Average	0.573	Average	0.696
Alpha	0.843	Alpha	0.901

Table 26: Satisfaction Visual Elements (transformed data)

Item	Negative	Positive	Mean	Standard deviation
For me personally, the mobile shopping application visual stimuli (images, colour and buttons) can be described as:				
1	Obstructive	Supportive	1.219	1.291
2	Complicated	Easy to use	2.021	1.265
3	Ineffective	Effective	1.240	1.390
4	Confused	Clear	2.146	1.124
5	Does not meet expectations	Meets expectations	1.375	1.300
6	Not interesting	Interesting	0.823	1.436
7	Conventional	Inventive	-0.292	1.666
8	Usual	Unique	-0.281	1.769
9	Boring	Exciting	0.146	1.576
10	Annoying	Enjoyable	1.1	1.4

Table 27: Short UEQ Scales Satisfaction for Visual Elements

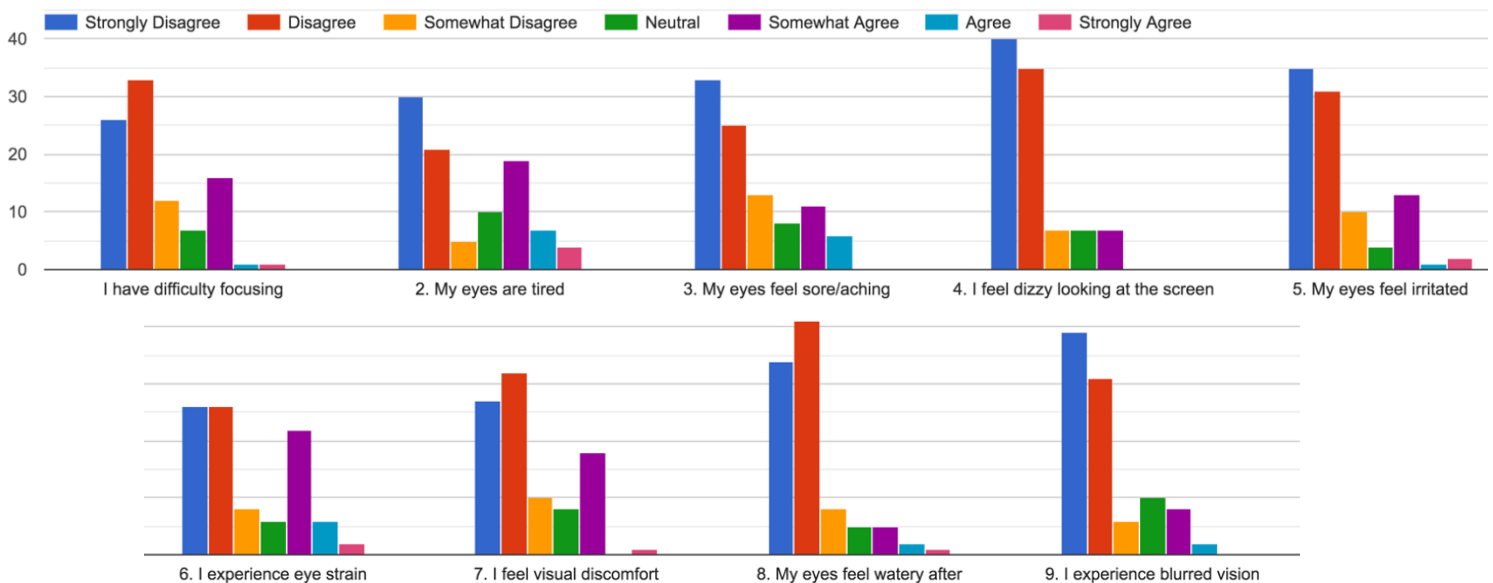
Short UEQ Scales	
Pragmatic Quality	1.656
Hedonic Quality	0.406
Overall	1.031

Table 28: Scale Consistency Satisfaction Visual Elements: Cronbachs Alpha-Coefficient

Pragmatic Quality		Hedonic Quality	
Items	Correlation	Items	Correlation
1,2	0.268	6,7	0.484
1,3	0.651	6,8	0.659
1,4	0.275	6,9	0.746
2,3	0.374	6,10	0.547
2,4	0.479	7,8	0.729
3,4	0.463	7,9	0.610
2,5	0.354	7,10	0.439
3,5	0.707	8,9	0.800
4,5	0.503	8,10	0.606
1,5	0.477	9,10	0.694
Average	0.455	Average	0.631
Alpha	0.770	Alpha	0.873

Figure 14: Distribution of Post-experimental Visual Fatigue Likert-scale Answers

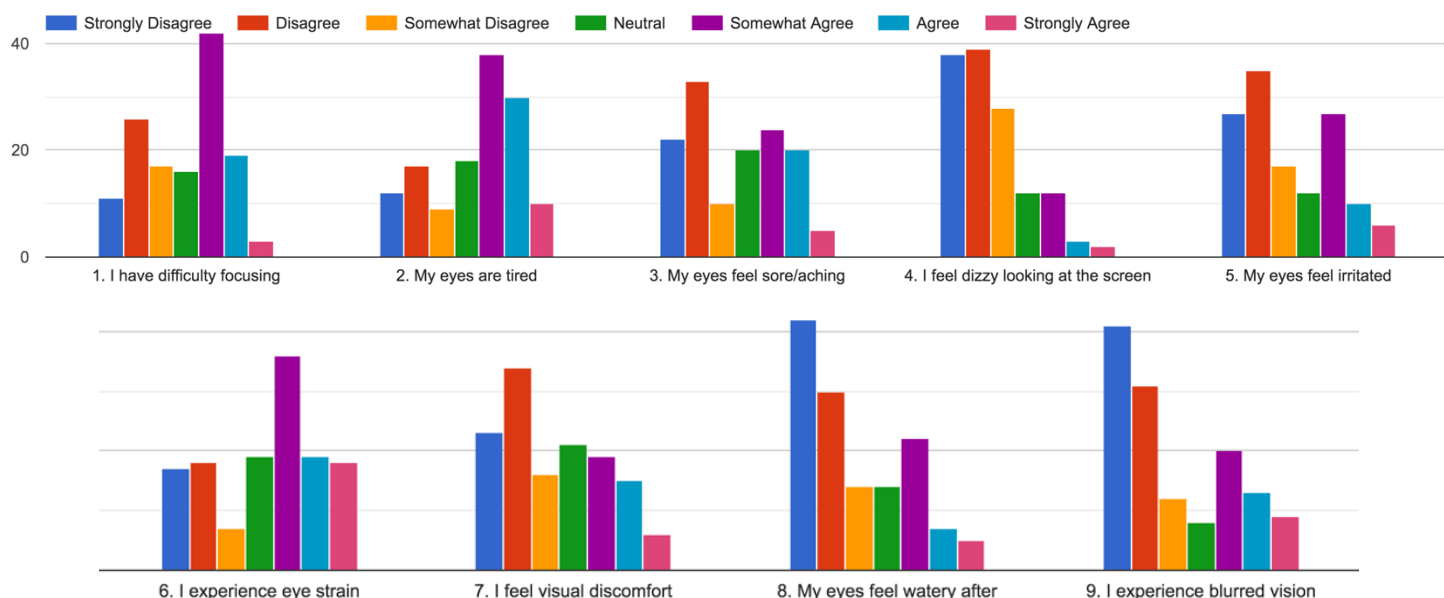
Please indicate how strongly you agree or disagree with each of the following statements after using the mobile e-commerce app



SOURCE: Google forms (2024)

Figure 15: Distribution of Pre-experimental Visual Fatigue Likert-scale Answers

Please indicate how strongly you agree or disagree with each of the following statements after using your mobile phone



SOURCE: Google forms (2024)

Table 29: Item Means and Standard Deviations Visual Fatigue Pre- & Post-experiment

Item	Question	Pre-exposure		Post-exposure		Mean VF change
		Mean	SD	Mean	SD	
Please indicate how strongly you agree or disagree with each of the following statements after using your mobile phone						
1	I have difficulty focusing	3.229	1.593	2.583	1.513	-0.646
2	My eyes are tired	3.427	1.752	3.052	1.943	-0.375
3	My eyes feel sore/aching	2.980	1.566	2.5625	1.621	-0.427
4	I feel dizzy looking at the screen	2.583	1.477	2.021	1.205	-0.5625
5	My eyes feel irritated	2.927	1.617	2.427	1.621	-0.5
6	I experience eye strain	3.490	1.789	2.990	1.821	-0.5
7	I feel visual discomfort	3	1.616	2.594	1.526	-0.407
8	My eyes feel watery after	2.823	1.654	2.156	1.364	-0.667
9	I experience blurred vision	2.792	1.635	2.198	1.396	-0.594

Table 30: Item Means and Standard Deviations Visual Fatigue Pre- & Post-experiment for Each App Iteration

	Item	Question	Pre-exposure		Post-exposure		Mean VF change
			Mean	SD	Mean	SD	
Please indicate how strongly you agree or disagree with each of the following statements after using your mobile phone							
App 1	1	I have difficulty focusing	3.235	1.478	2.529	1.581	-0.706
	2	My eyes are tired	3.324	1.770	2.8234	1.930	-0.500
	3	My eyes feel sore/aching	2.971	1.714	2.529	1.656	-0.441
	4	I feel dizzy looking at the screen	2.618	1.557	2.029	1.425	-0.588
	5	My eyes feel irritated	3.118	1.665	2.147	1.351	-0.971
	6	I experience eye strain	3.294	1.679	2.853	1.811	-0.441
	7	I feel visual discomfort	3.029	1.696	2.529	1.562	-0.500
	8	My eyes feel watery after	2.853	1.760	1.971	1.243	-0.882
	9	I experience blurred vision	2.647	1.686	1.912	1.264	-0.735
App 2	1	I have difficulty focusing	3.033	1.752	2.733	1.574	-0.300
	2	My eyes are tired	3.500	1.796	3.200	2.058	-0.300
	3	My eyes feel sore/aching	2.967	1.671	2.833	1.764	-0.133
	4	I feel dizzy looking at the screen	2.467	1.525	2.033	1.033	-0.433
	5	My eyes feel irritated	2.767	1.633	2.900	1.954	0.133
	6	I experience eye strain	3.867	1.871	3.433	1.977	-0.433
	7	I feel visual discomfort	2.867	1.634	2.733	1.639	-0.133
	8	My eyes feel watery after	2.800	1.769	2.333	1.626	-0.467
	9	I experience blurred vision	2.567	1.524	2.300	1.418	-0.267
App 3	1	I have difficulty focusing	3.406	1.583	2.500	1.414	-0.906
	2	My eyes are tired	3.469	1.741	3.157	1.886	-0.313
	3	My eyes feel sore/aching	3.031	1.332	2.344	1.450	-0.688
	4	I feel dizzy looking at the screen	2.656	1.382	2	1.136	-0.656
	5	My eyes feel irritated	2.875	1.581	2.281	1.486	-0.594
	6	I experience eye strain	3.344	1.825	2.719	1.651	-0.625
	7	I feel visual discomfort	3.094	1.553	2.531	1.414	-0.563
	8	My eyes feel watery after	2.813	1.469	2.188	1.230	-0.625
	9	I experience blurred vision	3.156	1.668	2.406	1.500	-0.750

Table 31: Cronbach's Alpha Pre-experimental Visual Fatigue (VFQ)

Frequentist Scale Reliability Statistics	
Estimate	Cronbach's α
Point estimate	0.923
95% CI lower bound	0.897
95% CI upper bound	0.944

Frequentist Individual Item Reliability Statistics		
	If item dropped	
Item	Cronbach's α	Item-rest correlation
VFQ1a [1. I have difficulty focusing]	0.927	0.517
VFQ1b [2. My eyes are tired]	0.912	0.749
VFQ1c [3. My eyes feel sore/aching]	0.908	0.816

VFQ1d [4. I feel dizzy looking at the screen]	0.922	0.584
VFQ1e [5. My eyes feel irritated]	0.908	0.809
VFQ1f [6. I experience eye strain]	0.911	0.764
VFQ1g [7. I feel visual discomfort]	0.905	0.858
VFQ1h [8. My eyes feel watery after]	0.914	0.723
VFQ1i [9. I experience blurred vision]	0.916	0.692

Table 32: Cronbach's Alpha VFQ2

Frequentist Scale Reliability Statistics	
Estimate	Cronbach's α
Point estimate	0.924
95% CI lower bound	0.900
95% CI upper bound	0.943

Frequentist Individual Item Reliability Statistics		
	If item dropped	
Item	Cronbach's α	Item-rest correlation
VFQ2a [I have difficulty focusing]	0.916	0.716
VFQ2b [2. My eyes are tired]	0.906	0.863
VFQ2c [3. My eyes feel sore/aching]	0.908	0.834
VFQ2d [4. I feel dizzy looking at the screen]	0.922	0.617
VFQ2e [5. My eyes feel irritated]	0.911	0.785
VFQ2f [6. I experience eye strain]	0.914	0.746
VFQ2g [7. I feel visual discomfort]	0.911	0.790
VFQ2h [8. My eyes feel watery after]	0.920	0.648
VFQ2i [9. I experience blurred vision]	0.926	0.543

Table 33: Survey Response: Visual Fatigue Phone (Pre-experiment)

Item	Question	Mean	Standard deviation
Please indicate how strongly you agree or disagree with each of the following statements after using your mobile phone			
1	I have difficulty focusing	3.885	1.666
2	My eyes are tired	4.240	1.697
3	My eyes feel sore/aching	3.531	1.789
4	I feel dizzy looking at the screen	2.573	1.375
5	My eyes feel irritated	3.208	1.788
6	I experience eye strain	4.219	1.882
7	I feel visual discomfort	3.302	1.842
8	My eyes feel watery after	2.917	1.822
9	I experience blurred vision	3.010	1.944

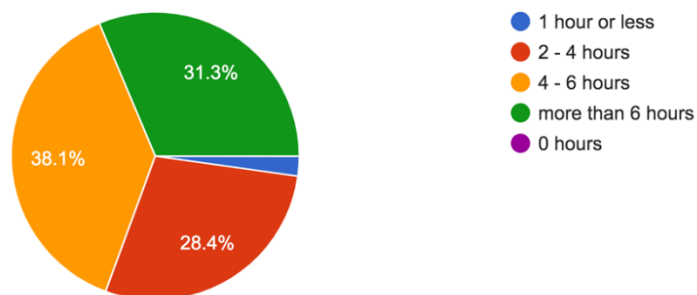
Table 34: Survey Response: Prior Time Spent on Phone

#	Answer	%	Count	Mean	Standard Deviation
1	1 hour or less	2.08	2	2.906	0.834
2	2-4 hours	33.33	32		
3	4-6 hours	36.46	35		
4	More than 6 hours	28.13	27		
	Total	100	96		

Figure 16: Prior Time Spent on Phone

How long, on average, do you spend on your phone?

134 responses



SOURCE: Google forms (2024)

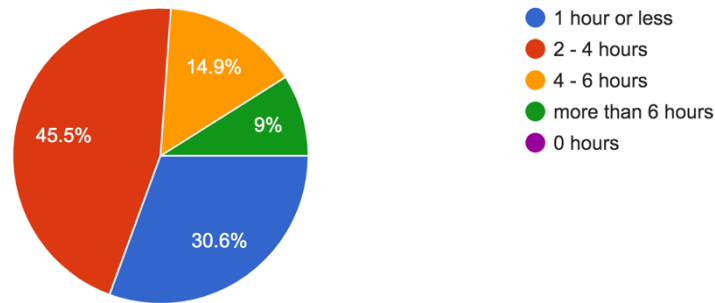
Table 35: Survey Response: Prior Time Spent on an App

#	Answer	%	Count	Mean	Standard Deviation
1	1 hour or less	32.29	31	2.031	0.945
2	2-4 hours	42.71	41		
3	4-6 hours	14.58	14		
4	More than 6 hours	10.42	10		
	Total	100	96		

Figure 17: Prior Time Spent on an App

How long, on average, do you spend on a mobile app?

134 responses



SOURCE: Google forms (2024)

Table 36: Eye Tracking Descriptive Statistics

Descriptive Statistics					
	Mean	SD	Median	Min	Max
Combined Pupil Diameter	-9.28E-05	6.37E-04	-4.05E-05	-7.54E-03	2.41E-03
Fixation Dispersion	2.86E-05	2.38E-04	4.80E-06	-1.14E-03	1.37E-03
Blinks Per Minute	6.19E-03	2.38E-04	5.23E-03	0	2.19E-02

Table 37: Descriptive Statistics H1a

H1a (n = 96)					
	Mean	SD	Median	Minimum	Maximum
Efficiency T1	0.036	0.003	0.036	0.017	0.047
Efficiency T2	0.024	0.008	0.023	0.011	0.045
Combined pupil diameter TF T1	0	0	0	-0.002	0
Combined pupil diameter TF T2	0	0.001	0	-0.008	0.002

Table 38: Descriptive Statistics H1b

H1b (n = 96)					
	Mean	SD	Median	Minimum	Maximum
EffectivenessT1	83	17	83	37	130
EffectivenessT2	56	23	49	27	110
Fixation Dispersion TF T1	4.95E-05	2.01E-04	4.80E-06	-2.79E-04	1.25E-03
Fixation Dispersion TF T2	7.64E-06	2.69E-04	4.08E-06	-1.14E-03	1.37E-03

Table 39: Descriptive Statistics H1c

H1c (n = 96)					
	Mean	SD	Median	Minimum	Maximum
Sat	5	1.1	4.9	7	1.7
Blinks Per Minute TF T1	7.73E-03	4.57E-03	7.03E-03	0	2.19E-02
Blinks Per Minute TF T2	4.64E-03	4.83E-03	4.08E-03	0	1.84E-02

Table 40: Descriptive Statistics H2

H2						
		Mean	SD	Median	Minimum	Maximum
App 1	Efficiency T1	0.035	0.004	0.035	0.017	0.040
	Effectiveness T1	79.471	17.056	80	37	117
	Efficiency T2	0.023	0.008	0.023	0.011	0.036
	Effectiveness T2	53.118	22.351	46.500	27	105
	Satisfaction	4.897	1.014	4.800	1.700	6.600
App 2	Efficiency T1	0.037	0.003	0.036	0.029	0.047
	Effectiveness T1	83.100	17.476	85	45	116
	Efficiency T2	0.027	0.008	0.028	0.012	0.044
	Effectiveness T2	59.967	23.567	52.500	29	107
	Satisfaction	5.047	0.954	5	2.900	7
App 3	Efficiency T1	0.036	0.001	0.036	0.033	0.038
	Effectiveness T1	87.563	15.962	84	58	130
	Efficiency T2	0.023	0.007	0.022	0.013	0.045
	Effectiveness T2	54.313	23.353	47	30	110
	Satisfaction	5.159	1.212	5.250	2.300	7

Table 41: Descriptive Statistics H3

H3						
		Mean	SD	Median	Minimum	Maximum
App 1	Combined Pupil Diameter TF T1	-9.23E-05	2.32E-04	-3.42E-05	-1.11E-03	1.19E-04
	Fixation Dispersion TF T1	3.90E-05	1.46E-04	1.01E-05	-2.79E-04	6.63E-04
	Blinks Per Minute TF T1	6.70E-03	4.32E-03	5.66E-03	0	2.15E-02
	Combined Pupil Diameter TF T2	5.64E-05	3.69E-04	-2.19E-05	-3.61E-04	1.84E-03
	Fixation Dispersion TF T2	4.15E-05	2.56E-04	-3.27E-07	-3.40E-04	1.37E-03
	Blinks Per Minute TF T2	3.92E-03	4.57E-03	3.70E-03	0	1.84E-02
App 2	Combined Pupil Diameter TF T1	-5.95E-05	1.13E-04	-3.83E-05	-3.14E-04	3.33E-04
	Fixation Dispersion TF T1	4.27E-05	2.36E-04	5.98E-07	-1.81E-04	1.25E-03

	Blinks Per Minute TF T1	7.95E-03	4.62E-03	7.05E-03	1.33E-03	1.89E-02
	Combined Pupil Diameter TF T2	-3.38E-04	1.39E-03	-2.89E-05	-7.54E-03	6.24E-05
	Fixation Dispersion TF T2	4.04E-06	2.38E-04	1.33E-05	-1.04E-03	5.81E-04
	Blinks Per Minute TF T2	5.94E-03	5.46E-03	4.26E-03	0	1.76E-02
App 3	Combined Pupil Diameter TF T1	-1.47E-04	3.08E-04	-5.63E-05	-1.52E-03	3.93E-04
	Fixation Dispersion TF T1	6.70E-05	2.20E-04	4.26E-06	-1.51E-04	9.18E-04
	Blinks Per Minute TF T1	8.63E-03	4.69E-03	8.09E-03	1.08E-03	2.19E-02
	Combined Pupil Diameter TF T2	8.87E-07	5.54E-04	-4.68E-05	-1.14E-03	2.41E-03
	Fixation Dispersion TF T2	-2.76E-05	3.15E-04	-7.35E-06	-1.14E-03	7.55E-04
	Blinks Per Minute TF T2	4.31E-03	4.36E-03	3.46E-03	0	1.84E-02

Table 42: Descriptive Statistics H4

		H4				
		Mean	SD	Median	Minimum	Maximum
	Overall Visual Fatigue Pre	3	1.3	3	1	6.4
	Overall Visual Fatigue Post	2.5	1.2	2.3	1	5.9
	Overall Time on phone	2.9	0.8	3	1	4
App 1	Visual Fatigue Pre	3	1.4	2.7	1.1	6.4
	Visual Fatigue Post	2.4	1.2	2	1	5.6
	Time on phone	2.9	1	3	1	4
	Time on App	1.9	0.9	2	1	4
App 2	Visual Fatigue Pre	3	1.3	3.1	1	5.9
	Visual Fatigue Post	2.7	1.4	2.7	1	5.9
	Time on phone	3	0.8	3	2	4
	Time on App	2.2	1	2	1	4
App 3	Visual Fatigue Pre	3.1	1.2	3.2	1	5.8
	Visual Fatigue Post	2.5	1.1	2.3	1	4.4
	Time on phone	2.9	0.8	3	1	4
	Time on App	1.7	1	2	1	4

Table 43: Descriptive Statistics H5

		H5					
		Mean	SD	Median	Minimum	Maximum	
Task 1	App 1	Combined Pupil Diameter TF	-9.23E-05	2.32E-04	-3.43E-05	-1.11E-03	1.19E-04
		Fixation Dispersion TF	3.90E-05	1.46E-04	1.01E-05	-2.79E-04	6.63E-04
		Blinks Per Minute TF	6.70E-03	4.32E-03	5.66E-03	0	2.15E-02
	App 2	Combined Pupil Diameter TF	-5.95E-05	1.13E-04	-3.83E-05	-3.14E-04	3.33E-04
		Fixation Dispersion TF	4.27E-05	2.36E-04	6.00E-07	-1.81E-04	1.25E-03
		Blinks Per Minute TF	7.95E-03	4.62E-03	7.05E-03	1.33E-03	1.89E-02
	App 3	Combined Pupil Diameter TF	-1.47E-04	3.08E-04	-5.64E-05	-1.52E-03	3.93E-04

		Fixation Dispersion TF	6.70E-05	2.20E-04	4.26E-06	-1.51E-04	9.18E-04
		Blinks Per Minute TF	8.63E-03	4.69E-03	8.09E-03	1.08E-03	2.19E-02
Task 2	App 1	Combined Pupil Diameter TF	5.64E-05	3.69E-04	-2.19E-05	-3.61E-04	1.84E-03
		Fixation Dispersion TF	4.15E-05	2.56E-04	-3.30E-07	-3.40E-04	1.37E-03
		Blinks Per Minute TF	3.92E-03	4.57E-03	3.70E-03	0	1.84E-02
	App 2	Combined Pupil Diameter TF	-3.38E-04	1.39E-03	-2.89E-05	-7.54E-03	6.24E-05
		Fixation Dispersion TF	4.04E-06	2.38E-04	1.33E-05	-1.04E-03	5.81E-04
		Blinks Per Minute TF	5.94E-03	5.46E-03	4.26E-03	0	1.76E-02
	App 3	Combined Pupil Diameter TF	1.01E-06	5.45E-04	-4.47E-05	-1.14E-03	2.41E-03
		Fixation Dispersion TF	-2.49E-05	3.10E-04	-7.11E-06	-1.14E-03	7.55E-04
		Blinks Per Minute TF	4.17E-03	4.36E-03	3.29E-03	0	1.84E-02

Appendix F: Tests for Normality

Tests for Normality

Table 44: Results of the Normality Test for Visual Fatigue Pre- and Post-experiment

Pre-experimental Visual Fatigue (VFQ)	Kolmogorov-Smirnov	p-value
	0.070	.2
	Skewness	Kurtosis
	1.333	0.838
Post-experimental Visual Fatigue (VFQ2)	Kolmogorov-Smirnov	p-value
	0.112	.005
	Skewness	Kurtosis
	2.179	-1.107

Table 45: Results of Normality Test Pre-experimental Visual Fatigue (VFQ)

Pre-experimental Visual Fatigue (VFQ)					
Item	Question	Skewness	Kurtosis	Kolmogorov-Smirnov	p-value
1	I have difficulty focusing	1.224	-2.039	0.176	<.001
2	My eyes are tired	0.943	-2.353	0.188	<.001
3	My eyes feel sore/aching	2.325	-1.162	0.195	<.001
4	I feel dizzy looking at the screen	4.203	0.803	0.258	<.001
5	My eyes feel irritated	2.472	-1.273	0.217	<.001
6	I experience eye strain	0.622	-2.385	0.163	<.001
7	I feel visual discomfort	1.866	-1.627	0.201	<.001
8	My eyes feel watery after	2.972	-0.715	0.201	<.001
9	I experience blurred vision	3.077	-0.734	0.238	<.001

Table 46: Results of Normality Test Post-experimental Visual Fatigue (VFQ2)

Post-experimental Visual Fatigue (VFQ2)					
Item	Question	Skewness	Kurtosis	Kolmogorov-Smirnov	p-value
1	I have difficulty focusing	3.468	-0.523	0.265	<.001
2	My eyes are tired	1.841	-2.478	0.237	<.001
3	My eyes feel sore/aching	3.321	-1.141	0.240	<.001
4	I feel dizzy looking at the screen	5.077	1.375	0.288	<.001
5	My eyes feel irritated	4.455	0.268	0.291	<.001
6	I experience eye strain	1.931	-2.430	0.248	<.001
7	I feel visual discomfort	3.138	-1.014	0.266	<.001
8	My eyes feel watery after	6.581	4.648	0.327	<.001
9	I experience blurred vision	4.500	0.297	0.286	<.001

Table 47: Results of the Normality Test for Eye Tracking Visual Fatigue Data

Blink Rate	Kolmogorov-Smirnov	p-value
	0.106	<.001
	Skewness	Kurtosis
	4.708	0.997
Fixation Dispersion	Kolmogorov-Smirnov	p-value
	0.276	<.001
	Skewness	Kurtosis
	6.480	43.412
Combined Pupil Diameter	Kolmogorov-Smirnov	p-value
	0.322	<.001
	Skewness	Kurtosis
	-46.366	287.404

Table 48: Results of the Normality Test for Usability Data

Efficiency T1 (Productive Period)	Kolmogorov-Smirnov	p-value
	0.226	<.001
	Skewness	Kurtosis
	-8	37.146
Effectiveness T1 (number of touches)	Kolmogorov-Smirnov	p-value
	0.085	.086
	Skewness	Kurtosis
	-0.012	1.359
Efficiency T2 (Productive Period)	Kolmogorov-Smirnov	p-value
	0.125	<.001
	Skewness	Kurtosis
	1.358	1.717
Effectiveness T2 (number of touches)	Kolmogorov-Smirnov	p-value
	0.184	<.001
	Skewness	Kurtosis
	3.126	-1.289
Satisfaction	Kolmogorov-Smirnov	p-value
	0.076	.2*
	Skewness	Kurtosis
	-1.220	0.631

Table 49: Results of Normality Test for Prior Phone Usage Data

TMPhone	Kolmogorov-Smirnov	p-value
	0.215	<.001
	Skewness	Kurtosis
	-0.1748	-2.2418
TMApp	Kolmogorov-Smirnov	p-value
	0.263	<.001
	Skewness	Kurtosis
	2.846	-0.662

Table 50: Normality Test for H1a Variables

One-Sample Kolmogorov-Smirnov Test (n = 96)										
	Normal Parameters ^{a,b}		Most Extreme Differences			Test Statistic	Asymp. Sig. (2-tailed) ^c	Monte Carlo Sig. (2-tailed) ^d		
	Mean	Std. Deviation	Absolute	Positive	Negative			Sig.	99% Confidence Interval	
									Lower Bound	Upper Bound
Efficiency_T1time	0:02:08.92	0:00:11.068	0.224	0.178	-0.224	0.224	<.001	<.001	0	0
Efficiency_T1dec	0.036	0.003	0.226	0.177	-0.226	0.226	<.001	<.001	0	0
Efficiency_T2time	0:01:27.14	0:00:29.016	0.125	0.084	-0.125	0.125	.001	.001	0	1.53E-03
Efficiency_T2dec	2.42E-02	8.07E-03	0.125	0.089	-0.125	0.125	.001	.001	0	1.53E-03
Pupil Left TF T1	-6.37E-05	1.30E-04	0.229	0.167	-0.229	0.229	<.001	<.001	0	0
Pupil Right TF T1	-9.74E-05	3.34E-04	0.329	0.283	-0.329	0.329	<.001	<.001	0	0
Combined Pupil Diameter TF T1	-1.00E-04	2.34E-04	0.258	0.197	-0.258	0.258	<.001	<.001	0	0
Pupil Left TF T2	-1,21E-05	3.33E-04	0.319	0.319	-0.252	0.319	<.001	<.001	0	0
Pupil Right TF T2	-3,81E-05	3.48E-04	0.315	0.315	-0.291	0.315	<.001	<.001	0	0
Combined Pupil Diameter TF T2	-8,53E-05	8.72E-04	0.353	0.334	-0.353	0.353	<.001	<.001	0	0
a. Test distribution is Normal.										
b. Calculated from data.										
c. Lilliefors Significance Correction.										
d. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 2000000.										

Table 51: Normality Test for H1b Variables

One-Sample Kolmogorov-Smirnov Test										
	Normal Parameters ^{a,b}		Most Extreme Differences			Test Statistic	Asymp. Sig. (2-tailed) ^c	Monte Carlo Sig. (2-tailed) ^d		
	Mean	Std. Deviation	Absolute	Positive	Negative			Sig.	99% Confidence Interval	
									Lower Bound	Upper Bound
EffectivenessT1	83.302	16.994	0.085	0.064	-0.085	0.085	.086	.084	0.077	0,091
EffectivenessT2	55.656	23.018	0.184	0.184	-0.107	0.184	<.001	<.001	0	0
Fixation Dispersion TF T1	0	0	0.302	0.302	-0.244	0.302	<.001	<.001	0	0
Fixation Dispersion TF T2	0	0	0.260	0.260	-0.258	0.260	<.001	<.001	0	0
a. Test distribution is Normal.										
b. Calculated from data.										
c. Lilliefors Significance Correction.										
d. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 2000000.										

Table 52: Normality Test for H1c Variables

One-Sample Kolmogorov-Smirnov Test										
	Normal Parameters ^{a,b}		Most Extreme Differences			Test Statistic	Asymp. Sig. (2-tailed) ^c	Monte Carlo Sig. (2-tailed) ^c		
	Mean	Std. Deviation	Absolute	Positive	Negative			Sig.	99% Confidence Interval	
									Lower Bound	Upper Bound
Sat	5.031	1.062	0.076	0.076	-0.071	0.076	.200 ^d	.187	0.177	0.197
Blinks Per Minute TF T1	7.73E-03	4.57E-03	0.107	0.107	-0.067	0.107	.009	.007	5.19E-03	9.61E-03
Blinks Per Minute TF T2	4.64E-03	4.83E-03	0.169	0.134	-0.169	0.169	4.18E-07	0	0	0
a. Test distribution is Normal.										
b. Calculated from data.										
c. Lilliefors Significance Correction.										
d. This is a lower bound of the true significance.										

Table 53: Normality Test for H3

One-Sample Kolmogorov-Smirnov Test										
	Normal Parameters ^{a,b}		Most Extreme Differences			Test Statistic	Asymp. Sig. (2-tailed) ^c	Monte Carlo Sig. (2-tailed) ^d		
	Mean	Std. Deviation	Absolute	Positive	Negative			Sig.	99% Confidence Interval	
									Lower Bound	Upper Bound
Combined Pupil Diameter TF T1	-1.00E-04	2.34E-04	0.258	0.197	-0.258	0.258	<.001	<.001	0	0
Fixation Dispersion TF T1	4.95E-05	2.01E-04	0.302	0.302	-0.244	0.302	<.001	<.001	0	0
Blinks Per Minute TF T1	7.73E-03	4.57E-03	0.107	0.107	-0.067	0.107	.009	.007	0.005	0.010
Combined Pupil Diameter TF T2	-8.63E-05	8.76E-04	0.352	0.333	-0.352	0.352	<.001	<.001	0	0
Fixation Dispersion TF T2	7.13E-06	2.70E-04	0.259	0.259	-0.259	0.259	<.001	<.001	0	0
Blinks Per Minute TF T2	4.69E-03	4.84E-03	0.166	0.130	-0.166	0.166	<.001	<.001	0	0
a. Test distribution is Normal.										
b. Calculated from data.										
c. Lilliefors Significance Correction.										
d. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 2000000.										

Appendix G: Inferential Statistics: H1a, H1b, H1c, H2, H3, H4, H5

H1a

Table 54: Pearson Correlation Between Efficiency and Combined Pupil Diameter for the Task 1

Correlations (N = 96)			
	Efficiency_T1dec	Combined Pupil Diameter TF T1	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)
Efficiency_T1dec	--	-.024	.815
Combined Pupil Diameter TF T1		--	

Table 55: Spearman's rho Correlation Between Efficiency and Combined Pupil Diameter for Task 1

Correlations (N = 96)				
Spearman's rho (Task 1)				
	Efficiency_T1dec		Combined Pupil Diameter TF T1	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Efficiency_T1dec	--		-.001	.994
Combined Pupil Diameter TF T1			--	

Table 56: Pearson Correlation Between Efficiency and Combined Pupil Diameter Task 2

Correlations (N = 96)			
	Efficiency_T2dec	Combined Pupil Diameter TF T2	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)
Efficiency_T2dec	--	-.149	.147
Combined Pupil Diameter TF T2		--	

Table 57: Spearman's rho Correlation Between Efficiency and Combined Pupil Diameter for Task 2

Correlations (N = 96)				
Spearman's rho (Task 2)				
	Efficiency_T2dec	Combined Pupil Diameter TF T2		
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Efficiency_T2dec	--		.034	.743
Combined Pupil Diameter TF T2			--	

Figure 18: Method for the Fisher Transformation H1a

H1a: Visual Fatigue as measured by pupil diameter over time, is inversely related to Efficiency as measured by productive period

1. Calculate Spearman Correlation Coefficients:

- Task 1: ``spearman_corr_T1_H1a``
- Task 2: ``spearman_corr_T2_H1a``

2. Convert Correlation Coefficients to Fisher's z-scores:

- $z1 = \operatorname{arctanh}(r1)$
- $z2 = \operatorname{arctanh}(r2)$

3. Calculate Standard Error of the Difference:

- $SE_{\text{diff}} = \sqrt{\frac{1}{n1-3} + \frac{1}{n2-3}}$

4. Calculate Z-score for the Difference:

- $z_{\text{diff}} = \frac{z1 - z2}{SE_{\text{diff}}}$

5. Calculate P-value:

- $p = 2 \times (1 - \text{norm.cdf}(|z_{\text{diff}}|))$

Figure 19: Fisher Z-transformation Results for H1a

Fisher's z-transformation Results:

1. Fisher's z-score for T1:

$$z1 = -0.0008$$

2. Fisher's z-score for T2:

$$z2 = 0.0339$$

3. Standard error (SE) of the difference:

$$SE = \sqrt{\frac{1}{N-3} + \frac{1}{N-3}}$$

4. z-score for the difference between T1 and T2:

$$z_{\text{diff}} = -0.2362$$

5. p-value for the difference:

p-value=0.8132

H1b

Table 58: Pearson Correlation Between Effectiveness and Fixation Dispersion for the Task 1

Correlations (N = 96)				
	EffectivenessT1		Fixation Dispersion TF T1	
	Pearson Correlation		Pearson Correlation	Sig. (2-tailed)
EffectivenessT1	--		-.045	.663
Fixation Dispersion TF T1			--	

Table 59: Spearman's rho Correlation Between Effectiveness and Fixation Dispersion for Task 1

Correlations (N = 96)					
Spearman's rho					
	EffectivenessT1			Fixation Dispersion TF T1	
	Correlation Coefficient			Sig. (2-tailed)	
EffectivenessT1	--			.012	.906
Fixation Dispersion TF T1				--	

Table 60: Pearson Correlation Between Effectiveness and Fixation Dispersion for the Task 2

Correlations (N = 96)				
	EffectivenessT2		Fixation Dispersion TF T2	
	Pearson Correlation		Pearson Correlation	Sig. (2-tailed)
EffectivenessT2	--		-.082	.425
Fixation Dispersion TF T2			--	

Table 61: Spearman's rho Correlation Between Effectiveness and Fixation Dispersion for Task 2

Correlations (N = 96)					
Spearman's rho					
	EffectivenessT2			Fixation Dispersion TF T2	
	Correlation Coefficient			Sig. (2-tailed)	
EffectivenessT2	--			-.111	.280
Fixation Dispersion TF T2				--	

Figure 20: Method for the Fisher Transformation H1b

H1b: Visual Fatigue as measured by fixation dispersion is directly related to Effectiveness as measured by number of navigational errors

1. Given Correlation Coefficients:

- Task 1: $\text{spearman_corr_T1_H1b} = 0.012$
- Task 2: $\text{spearman_corr_T2_H1b} = -0.111$

2. Convert Correlation Coefficients to Fisher's z-scores:

- $z_1 = \text{arctanh}(0.012)$
- $z_2 = \text{arctanh}(-0.111)$

3. Calculate Standard Error of the Difference:

- $$SE_{\text{diff}} = \sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}$$

4. Calculate Z-score for the Difference:

- $$z_{\text{diff}} = \frac{z_1 - z_2}{SE_{\text{diff}}}$$

5. Calculate P-value:

- $$p = 2 \times (1 - \text{norm.cdf}(|z_{\text{diff}}|))$$

H1c

Table 62: Pearson Correlation Between Satisfaction and Blink Rate for the Task 1

Correlations (N = 96)			
	Satisfaction	Blinks Per Minute TF T1	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)
Sat	--	-.105	.308
Blinks Per Minute TF T1		--	

Table 63: Spearman's rho Correlation Between Satisfaction and Blink Rate for the Task 1

Correlations (N = 96)				
Spearman's rho				
	Satisfaction		Blinks Per Minute TF T1	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Sat	--		-.104	.312
Blinks Per Minute TF T1			--	

Table 64: Pearson Correlation Between Satisfaction and Blink Rate for the Task 2

Correlations				
	Satisfaction		Blinks Per Minute TF T2	
	Pearson Correlation		Pearson Correlation	Sig. (2-tailed)
Sat	--		-.048	.640
Blinks Per Minute TF T2			--	

Table 65: Spearman's rho Correlation Between Satisfaction and Blink Rate for the Task 2

Correlations				
Spearman's rho				
	Satisfaction		Blinks Per Minute TF T2	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
Sat	--		-.007	.950
Blinks Per Minute TF T2			--	

Figure 21: Method for the Fisher Transformation H1c

H1c: Visual Fatigue is indirectly related to User Satisfaction

1. Calculate Spearman Correlation Coefficients:

- Task 1: `spearman_corr_T1_H1c`
- Task 2: `spearman_corr_T2_H1c`

2. Convert Correlation Coefficients to Fisher's z-scores:

- $z1 = \text{arctanh}(r1)$
- $z2 = \text{arctanh}(r2)$

3. Calculate Standard Error of the Difference:

- $SE_{diff} = \sqrt{\frac{1}{n1-3} + \frac{1}{n2-3}}$

4. Calculate Z-score for the Difference:

- $z_{diff} = \frac{z1 - z2}{SE_{diff}}$

5. Calculate P-value:

- $p = 2 \times (1 - \text{norm.cdf}(|z_{diff}|))$

Table 66: Pairwise Comparison of App Levels (Efficiency Task 2)

Pairwise Comparisons of App Version					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
3-1	0.246	6.858	0.036	.971	1.000
3-2	13.121	7.077	1.854	.064	.191
1-2	-12.875	6.975	-1.846	.065	.195
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 67: Pairwise Comparison of App Levels (Effectiveness Task 1)

Pairwise Comparisons of App Version					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
1-2	-7.621	6.974	-1.093	.275	.824
1-3	-10.767	6.857	-1.570	.116	.349
2-3	-3.147	7.075	-0.445	.656	1.000
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 68: Pairwise Comparison of App Levels (Effectiveness Task 2)

Pairwise Comparisons of App Version					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
1-3	-1.531	6.858	-.223	.823	1.000
1-2	-8.767	6.975	-1.257	.209	.626
3-2	7.235	7.076	1.022	.307	.920
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 69: Pairwise Comparison of App Levels (Satisfaction)

Pairwise Comparisons of App Version					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
1-2	-3.709	6.973	-0.532	.595	1.000
1-3	-5.699	6.856	-0.831	.406	1.000
2-3	-1.991	7.074	-0.281	.778	1.000
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 70: Correlations per Visual Complexity Level 1 – App 1

	Efficiency (productive period - hours) Task 1	Effectiveness (number of touches) Task 1		Efficiency (productive period - hours) Task 2		Effectiveness (number of touches) Task 2		Satisfaction	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Efficiency (productive period - hours) Task 1	--	.486**	.004	.144	.416	.165	.350	.019	.917
Effectiveness (number of touches) Task 1		--		-.210	.234	.007	.970	.059	.741
Efficiency (productive period - hours) Task 2				--		.875**	<.001	-.111	.531
Effectiveness (number of touches) Task 2						--		-.192	.278
Satisfaction								--	
**. Correlation is significant at the 0.01 level (2-tailed).									
a. App Version = 1									

Table 71: Correlations per Visual Complexity Level 2 – App 2

	Efficiency (productive period - hours) Task 1	Effectiveness (number of touches) Task 1		Efficiency (productive period - hours) Task 2		Effectiveness (number of touches) Task 2		Satisfaction	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Efficiency (productive period - hours) Task 1	--	.239	.203	.108	.568	.120	.529	-.236	.209
Effectiveness (number of touches) Task 1		--		-.207	.273	.321	.083	.030	.875
Efficiency (productive period - hours) Task 2				--		.718**	<.001	.078	.682
Effectiveness (number of touches) Task 2						--		.210	.265
Satisfaction								--	
**. Correlation is significant at the 0.01 level (2-tailed).									
a. App Version = 2									

Table 72: Correlations per Visual Complexity Level 3 – App 3

	Efficiency (productive period - hours) Task 1	Effectiveness (number of touches) Task 1		Efficiency (productive period - hours) Task 2		Effectiveness (number of touches) Task 2		Satisfaction	
	Pearson Correlation	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Efficiency (productive period - hours) Task 1	--	.048	.795	-.120	.514	-.195	.284	-.042	.818
Effectiveness (number of touches) Task 1		--		.121	.508	.293	.104	-.036	.843
Efficiency (productive period - hours) Task 2				--		.861**	<.001	-.067	.716
Effectiveness (number of touches) Task 2						--		-.097	.596
Satisfaction								--	

** . Correlation is significant at the 0.01 level (2-tailed).

a. App Version = 3

H3

Figure 22: Scatterplot for Task 1 for Relationship Between Visual Fatigue Metrics and Visual Complexity Levels

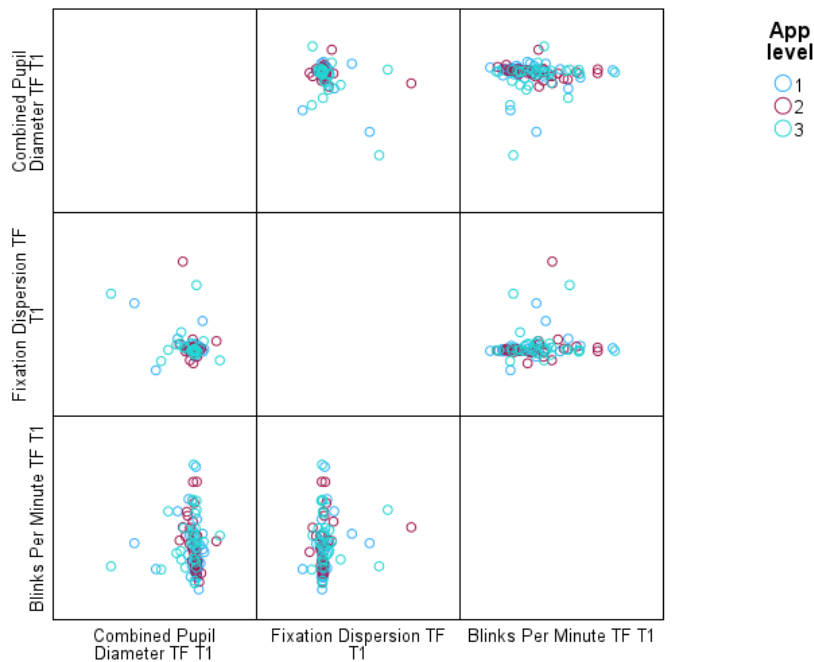


Figure 23: Scatterplot for Task 2 for Relationship Between Visual Fatigue Metrics and Visual Complexity Levels

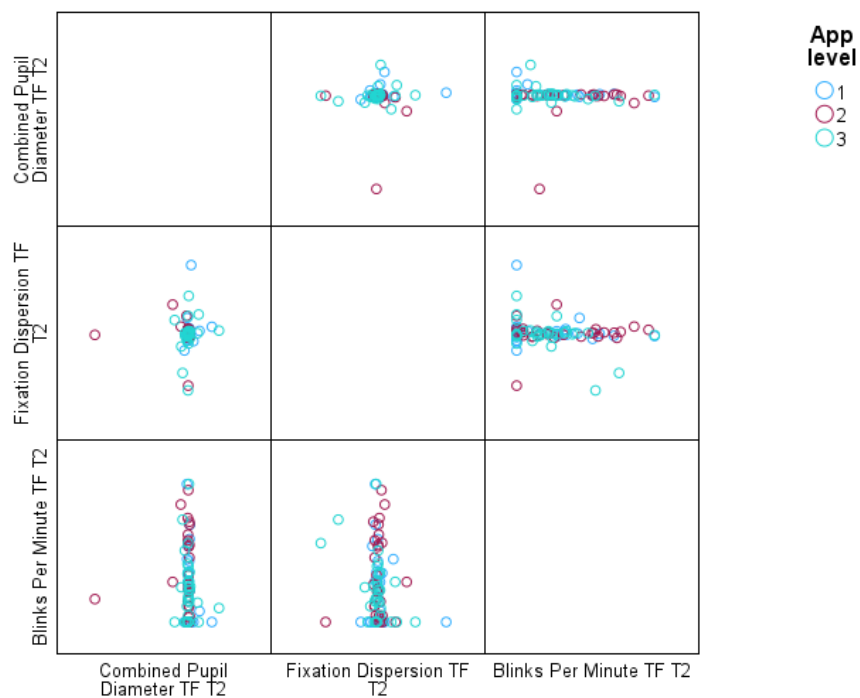


Figure 24: Scatterplot for a Combination for the Two Tasks for Relationship Between Visual Fatigue Metrics and Visual Complexity Levels

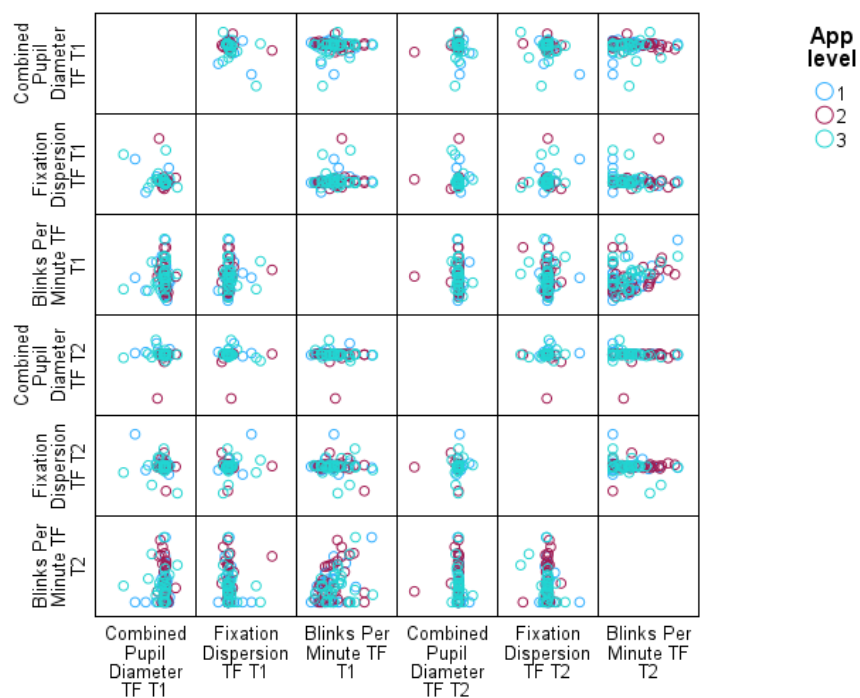


Table 73: Task 1 Multivariate Tests from the GLM Model Visual Complexity and Visual Fatigue

Multivariate Tests ^a						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.765	98.856 ^b	3	91	<.001
	Wilks' Lambda	0.235	98.856 ^b	3	91	<.001
	Hotelling's Trace	3.259	98.856 ^b	3	91	<.001
	Roy's Largest Root	3.259	98.856 ^b	3	91	<.001
App level	Pillai's Trace	0.056	0.883	6	184	.508
	Wilks' Lambda	0.945	0.877 ^b	6	182	.513
	Hotelling's Trace	0.058	0.870	6	180	.518
	Roy's Largest Root	0.044	1.348 ^c	3	92	.264
a. Design: Intercept + App level						
b. Exact statistic						
c. The statistic is an upper bound on F that yields a lower bound on the significance level.						

Table 74: Task 1 Test of Between-Subject Effects

Tests of Between-Subjects Effects						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Combined Pupil Diameter TF T1	1.222E-7 ^a	2	6.112E-08	1.119	.331
	Fixation Dispersion TF T1	1.495E-8 ^b	2	7.473E-09	0.182	.834
	Blinks Per Minute TF T1	6.282E-5 ^c	2	3.141E-05	1.524	.223
Intercept	Combined Pupil Diameter TF T1	9.509E-07	1	9.509E-07	17.407	<.001
	Fixation Dispersion TF T1	2.352E-07	1	2.352E-07	5.722	.019
	Blinks Per Minute TF T1	0.006	1	0.006	279.602	<.001
App level	Combined Pupil Diameter TF T1	1.222E-07	2	6.112E-08	1.119	.331
	Fixation Dispersion TF T1	1.495E-08	2	7.473E-09	0.182	.834
	Blinks Per Minute TF T1	6.282E-05	2	3.141E-05	1.524	.223
Error	Combined Pupil Diameter TF T1	5.080E-06	93	5.463E-08		
	Fixation Dispersion TF T1	3.822E-06	93	4.110E-08		
	Blinks Per Minute TF T1	0.002	93	2.062E-05		
Total	Combined Pupil Diameter TF T1	6.169E-06	96			
	Fixation Dispersion TF T1	4.072E-06	96			
	Blinks Per Minute TF T1	0.008	96			
Corrected Total	Combined Pupil Diameter TF T1	5.202E-06	95			
	Fixation Dispersion TF T1	3.837E-06	95			
	Blinks Per Minute TF T1	0.002	95			
a. R Squared = 0.023 (Adjusted R Squared = 0.002)						
b. R Squared = 0.004 (Adjusted R Squared = -0.018)						
c. R Squared = 0.032 (Adjusted R Squared = 0.011)						

Table 75: Post Hoc Tests for Visual Fatigue Metrics Between Visual Complexity Levels Task 1

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Combined Pupil Diameter TF T1	1	2	-3.28E-05	5.85E-05	1.000	-1.76E-04	1.10E-04
		3	5.48E-05	5.76E-05	1.000	-8.56E-05	1.95E-04
	2	1	3.28E-05	5.85E-05	1.000	-1.10E-04	1.76E-04
		3	8.76E-05	5.94E-05	.431	-5.72E-05	2.32E-04
	3	1	-5.48E-05	5.76E-05	1.000	-1.95E-04	8.56E-05
		2	-8.76E-05	5.94E-05	.431	-2.32E-04	5.72E-05
Fixation Dispersion TF T1	1	2	-3.74E-06	5.08E-05	1.000	-1.28E-04	1.20E-04
		3	-2.80E-05	4.99E-05	1.000	-1.50E-04	9.37E-05
	2	1	3.74E-06	5.08E-05	1.000	-1.20E-04	1.28E-04
		3	-2.43E-05	5.15E-05	1.000	-1.50E-04	1.01E-04
	3	1	2.80E-05	4.99E-05	1.000	-9.37E-05	1.50E-04
		2	2.43E-05	5.15E-05	1.000	-1.01E-04	1.50E-04
Blinks Per Minute TF T1	1	2	-1.24E-03	1.14E-03	.833	-4.01E-03	1.53E-03
		3	-1.92E-03	1.12E-03	.268	-4.65E-03	8.06E-04
	2	1	1.24E-03	1.14E-03	.833	-1.53E-03	4.01E-03
		3	-6.79E-04	1.15E-03	1.000	-3.49E-03	2.13E-03
	3	1	1.92E-03	1.12E-03	.268	-8.06E-04	4.65E-03
		2	6.79E-04	1.15E-03	1.000	-2.13E-03	3.49E-03

Table 76: Task 2 Multivariate Tests for Visual Complexity and Visual Fatigue

Multivariate Tests ^a						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.509	31.151 ^b	3	90	<.001
	Wilks' Lambda	0.491	31.151 ^b	3	90	<.001
	Hotelling's Trace	1.038	31.151 ^b	3	90	<.001
	Roy's Largest Root	1.038	31.151 ^b	3	90	<.001
App level	Pillai's Trace	0.080	1.258	6	182	.279
	Wilks' Lambda	0.921	1.258 ^b	6	180	.279
	Hotelling's Trace	0.085	1.258	6	178	.279
	Roy's Largest Root	0.074	2.239 ^c	3	91	.089
a. Design: Intercept + App level						
b. Exact statistic						
c. The statistic is an upper bound on F that yields a lower bound on the significance level.						

Table 77: Task 2 Test of Between-Subject Effects

Tests of Between-Subjects Effects						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Combined Pupil Diameter TF T2	2.829E-6 ^a	2	1.414E-06	1.876	.159
	Fixation Dispersion TF T2	7.770E-8 ^b	2	3.885E-08	0.526	.592
	Blinks Per Minute TF T2	7.168E-5 ^c	2	3.584E-05	1.551	.218
Intercept	Combined Pupil Diameter TF T2	8.293E-07	1	8.293E-07	1.100	.297
	Fixation Dispersion TF T2	3.397E-09	1	3.397E-09	0.046	.831
	Blinks Per Minute TF T2	0.002	1	0.002	91.504	<.001
App level	Combined Pupil Diameter TF T2	2.829E-06	2	1.414E-06	1.876	.159
	Fixation Dispersion TF T2	7.770E-08	2	3.885E-08	0.526	.592
	Blinks Per Minute TF T2	7.168E-05	2	3.584E-05	1.551	.218
Error	Combined Pupil Diameter TF T2	6.938E-05	92	7.541E-07		
	Fixation Dispersion TF T2	6.789E-06	92	7.379E-08		
	Blinks Per Minute TF T2	0.002	92	2.311E-05		
Total	Combined Pupil Diameter TF T2	7.292E-05	95			
	Fixation Dispersion TF T2	6.872E-06	95			
	Blinks Per Minute TF T2	0.004	95			
Corrected Total	Combined Pupil Diameter TF T2	7.221E-05	94			
	Fixation Dispersion TF T2	6.867E-06	94			
	Blinks Per Minute TF T2	0.002	94			
a. R Squared = 0.039 (Adjusted R Squared = 0.018)						
b. R Squared = 0.011 (Adjusted R Squared = -0.010)						
c. R Squared = 0.033 (Adjusted R Squared = 0.012)						

Table 78: Multiple Comparisons for Visual Fatigue Metrics Between Visual Complexity Levels Task

2

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Combined Pupil Diameter TF T2	1	2	3.94E-04	2.18E-04	.219	-1.36E-04	9.25E-04
		3	5.55E-05	2.16E-04	1.000	-4.70E-04	5.81E-04
	2	1	-3.94E-04	2.18E-04	.219	-9.25E-04	1.36E-04
		3	-3.39E-04	2.22E-04	.393	-8.81E-04	2.03E-04
	3	1	-5.55E-05	2.16E-04	1.000	-5.81E-04	4.70E-04
		2	3.39E-04	2.22E-04	.393	-2.03E-04	8.81E-04
Fixation Dispersion TF T2	1	2	3.74E-05	6.80E-05	1.000	-1.28E-04	2.03E-04
		3	6.90E-05	6.75E-05	.926	-9.55E-05	2.34E-04
	2	1	-3.74E-05	6.80E-05	1.000	-2.03E-04	1.28E-04
		3	3.16E-05	6.96E-05	1.000	-1.38E-04	2.01E-04
	3	1	-6.90E-05	6.75E-05	.926	-2.34E-04	9.55E-05
		2	-3.16E-05	6.96E-05	1.000	-2.01E-04	1.38E-04
Blinks Per Minute TF T2	1	2	-2.02E-03	1.20E-03	.290	-4.96E-03	9.15E-04
		3	-3.88E-04	1.19E-03	1.000	-3.30E-03	2.52E-03
	2	1	2.02E-03	1.20E-03	.290	-9.15E-04	4.96E-03
		3	1.63E-03	1.23E-03	.564	-1.37E-03	4.64E-03
	3	1	3.88E-04	1.19E-03	1.000	-2.52E-03	3.30E-03
		2	-1.63E-03	1.23E-03	.564	-4.64E-03	1.37E-03

Appendix H: Moderation and Mediation Analysis (H4 and H5)

Figure 25: Hayes (2022) PROCESS Moderation Analysis Output

H4: The time participants' have spent on their mobile device before the experiment moderates the effect of Visual Complexity of the app on Visual Fatigue

Run MATRIX procedure:

***** PROCESS Procedure for SPSS Version 4.2 *****

Written by Andrew F. Hayes, Ph.D. www.afhayes.com

Documentation available in Hayes (2022). www.guilford.com/p/hayes3

Model : 1

Y : VFpost

X : Applevel

W : TMPHHowl

Covariates:

VFpre

Sample

Size: 96

OUTCOME VARIABLE:

VFpost

Model Summary

R	R-sq	MSE	F	df1	df2	p
0.6018	0.3621	1.0218	12.9163	4.0000	91.0000	0.0000

Model

	coeff	se	t	p	LLCI	ULCI
constant	-0.2339	0.9493	-0.2464	0.8059	-2.1195	1.6517
Applevel	0.4145	0.4429	0.9359	0.3518	-0.4653	1.2943
TMPHHowl	0.3403	0.3109	1.0948	0.2765	-0.2771	0.9578
Int_1	-0.1370	0.1492	-.9185	0.3608	-0.4334	0.1593
VFpre	0.5684	0.0807	7.0410	0.0000	0.4081	0.7288

Product terms key:

Int_1 : Applevel x TMPHHowl

Test(s) of highest order unconditional interaction(s):

	R2-chng	F	df1	df2	p
X*W	0.0059	0.8436	1.0000	91.0000	0.3608

***** ANALYSIS NOTES AND ERRORS *****

Level of confidence for all confidence intervals in output:

95.0000

----- END MATRIX -----

Figure 26: Mediation Analysis H5 for Combined Pupil Diameter

Mediation Analysis Results

Outcome Variable: Combined Pupil Diameter

Model Summary

R: 0.0397

R-sq: 0.0016

MSE: 4.0905E-07

F: 0.1489

df1: 2

df2: 189

p: 0.8617

Model Coefficients

	coeff	se	t	p	LLCI	ULCI
constant	-5.7965E-05	1.8290E-04	-0.3169	0.7516	-4.1874E-04	3.0281E-04
App_level	-2.9005E-05	5.5685E-05	-0.5209	0.6031	-1.3885E-04	8.0839E-05
Task_Type	1.5034E-05	9.2314E-05	0.1629	0.8708	-1.6706E-04	1.9713E-04

Effects

Direct Effect: -2.9005E-05

Indirect Effect: -9.4931E-21

Total Effect: -2.9005E-05

Figure 27: Mediation Analysis H5 for Fixation Dispersion

Outcome Variable: Fixation Dispersion

Model Summary

R: 0.0945

R-sq: 0.0089

MSE: 5.6583E-08

F: 0.8515

df1: 2

df2: 189

p: 0.4284

Model Coefficients

	coeff	se	t	p	LLCI	ULCI
constant	1.1046E-04	6.8023E-05	1.6238	0.1061	-2.3727E-05	2.4464E-04
App_level	-9.6669E-06	2.0711E-05	-0.4668	0.6412	-5.0520E-05	3.1187E-05
Task_Type	-4.1841E-05	3.4334E-05	-1.2186	0.2245	-1.0957E-04	2.5886E-05

Effects

Direct Effect: -9.6669E-06

Indirect Effect: 2.6420E-20

Total Effect: -9.6669E-06

Figure 28: Mediation Analysis H5 for Blinks Per Minute

Outcome Variable: Blinks Per Minute

Model Summary

R: 0.3277

R-sq: 0.1074

MSE: 2.2006e-05

F: 11.3680

df1: 2

df2: 189

p: 0.0000

Model Coefficients

	coeff	se	t	p	LLCI	ULCI
constant	9.7320e-03	1.3415e-03	7.2546	0.0000	7.0857e-03	1.2378e-02
App_level	5.5389e-04	4.0844e-04	1.3561	0.1767	-2.5179e-04	1.3596e-03
Task_Type	-3.0952e-03	6.7710e-04	-4.5713	0.0000	-4.4309e-03	-1.7596e-03

Effects

Direct Effect: 5.5389e-04

Indirect Effect: 1.9545e-18

Total Effect: 5.5389e-04

Appendix I: Heatmaps for Each Application Iteration, App 1, App 2, App 3

App 1 Heatmaps

Figure 29: Heatmap App 1, Cart page

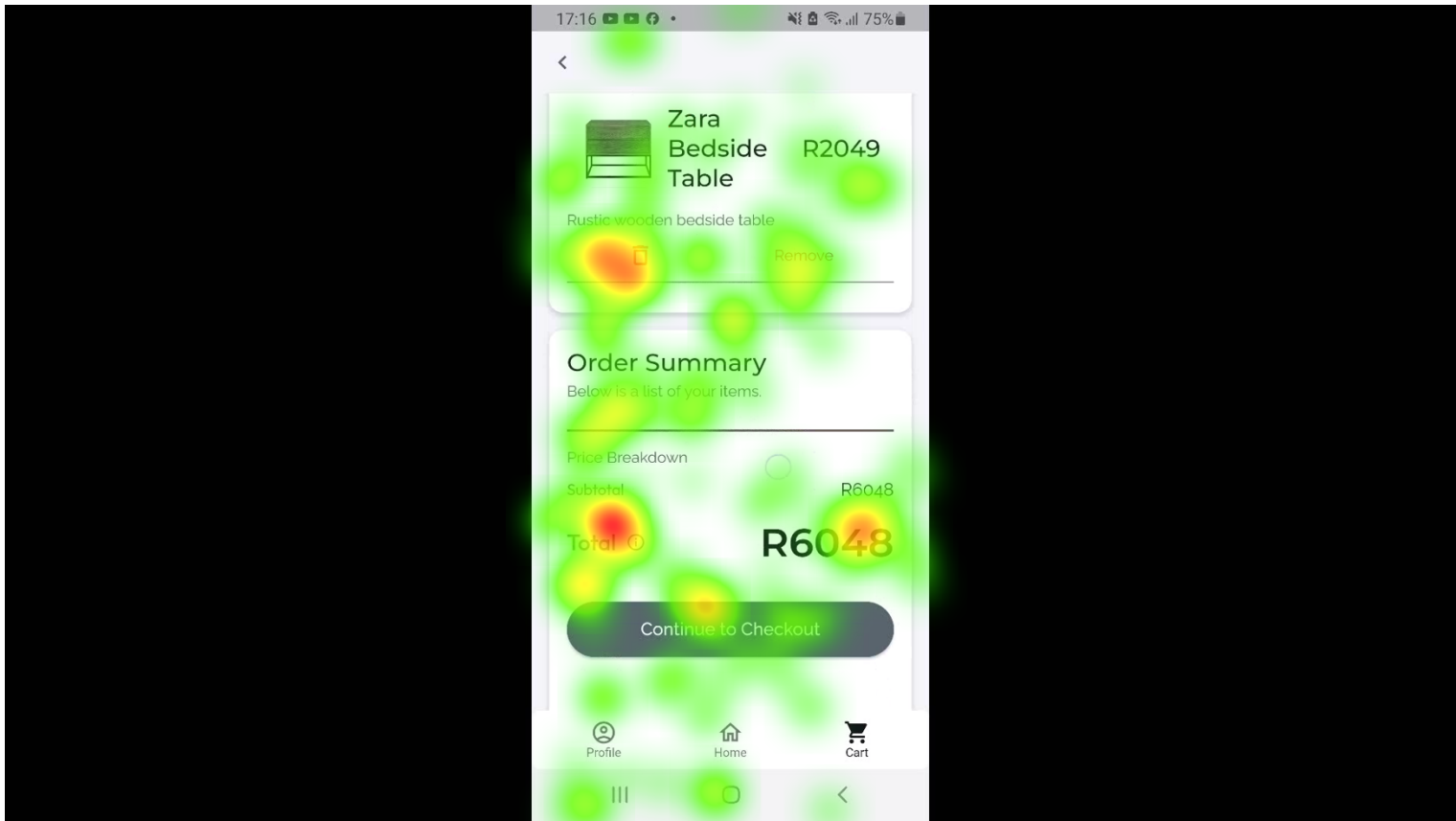


Figure 30: Heatmap App 1, Product Details page

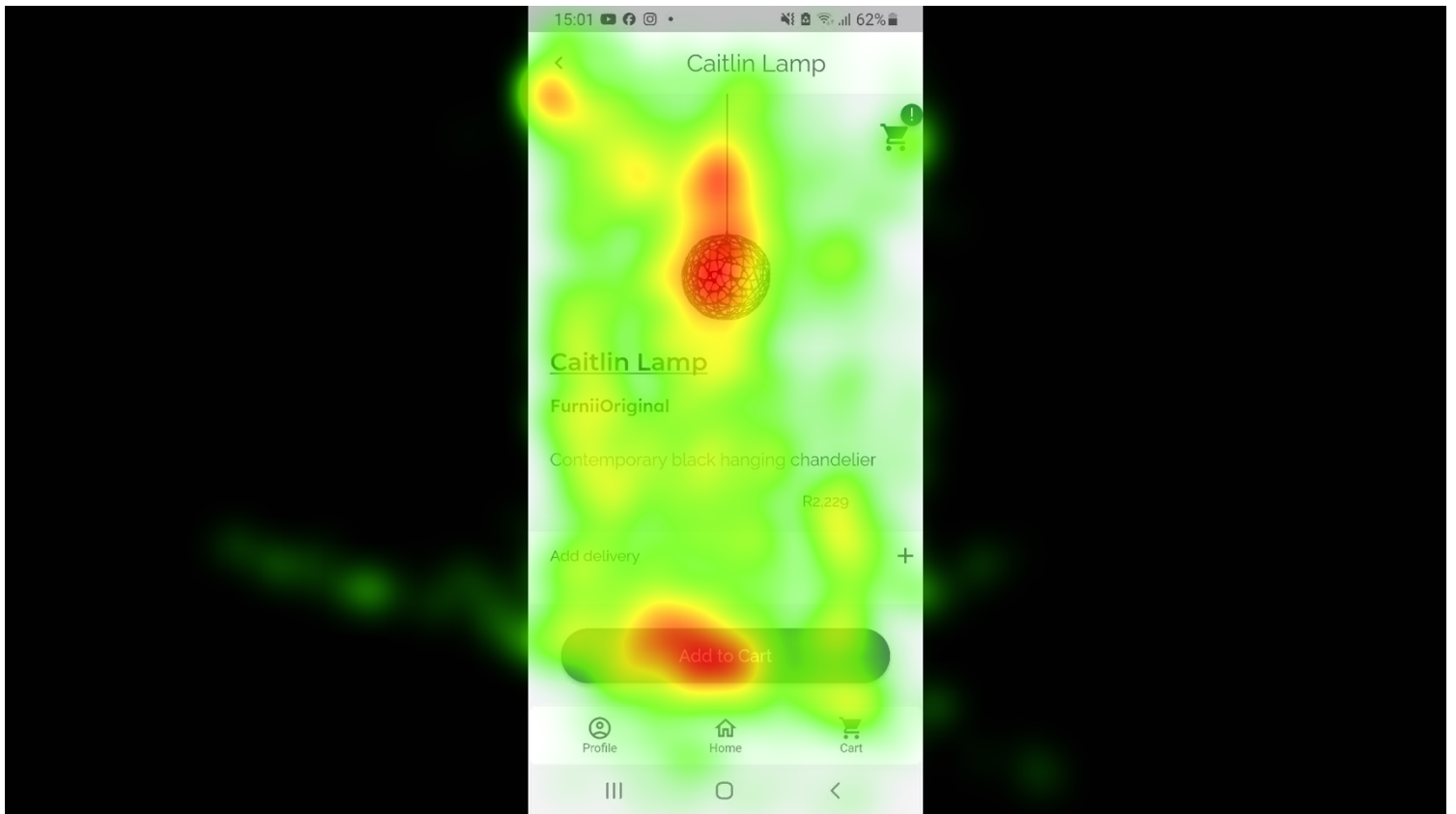


Figure 31: Heatmap App 1, Home page

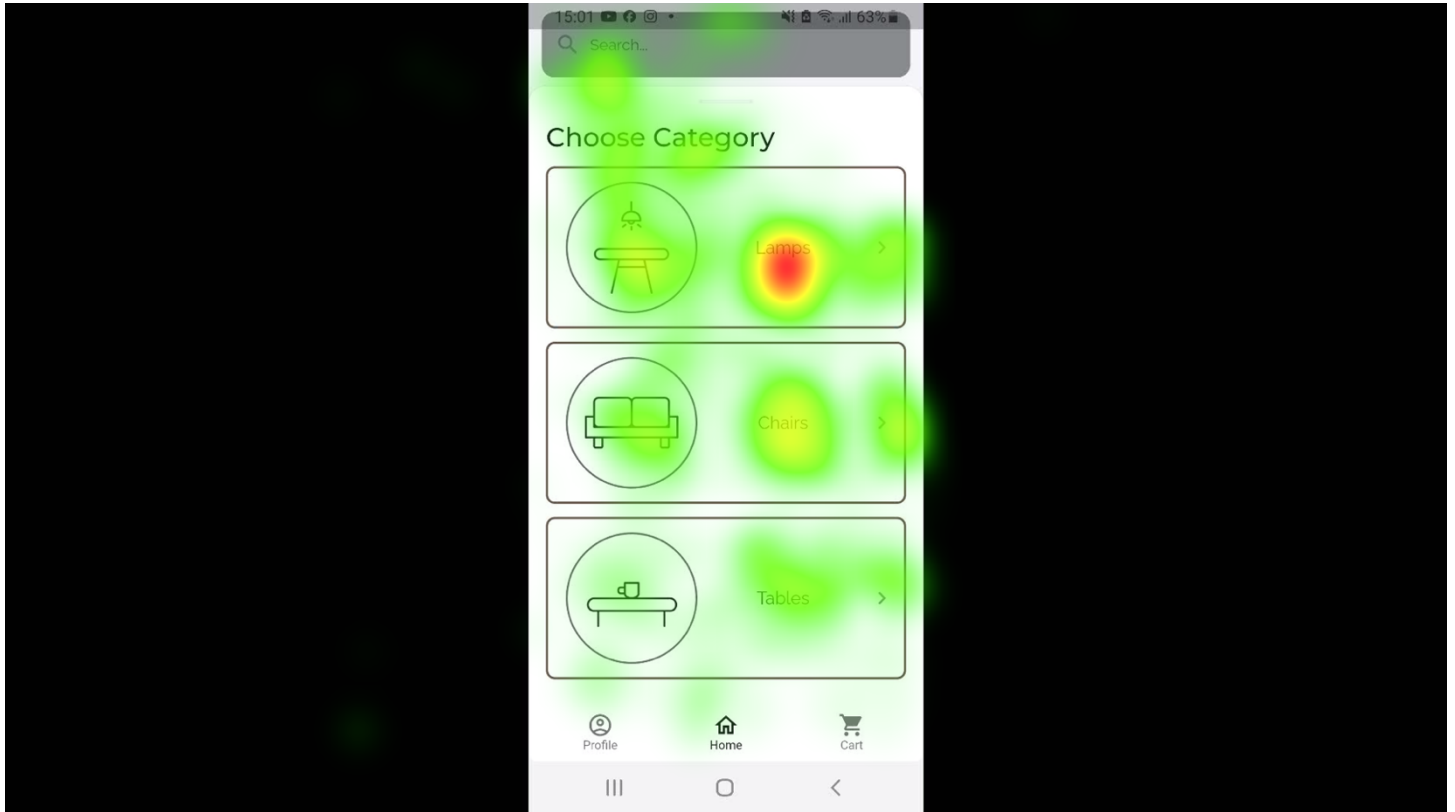


Figure 32: Heatmap App 1, Products page

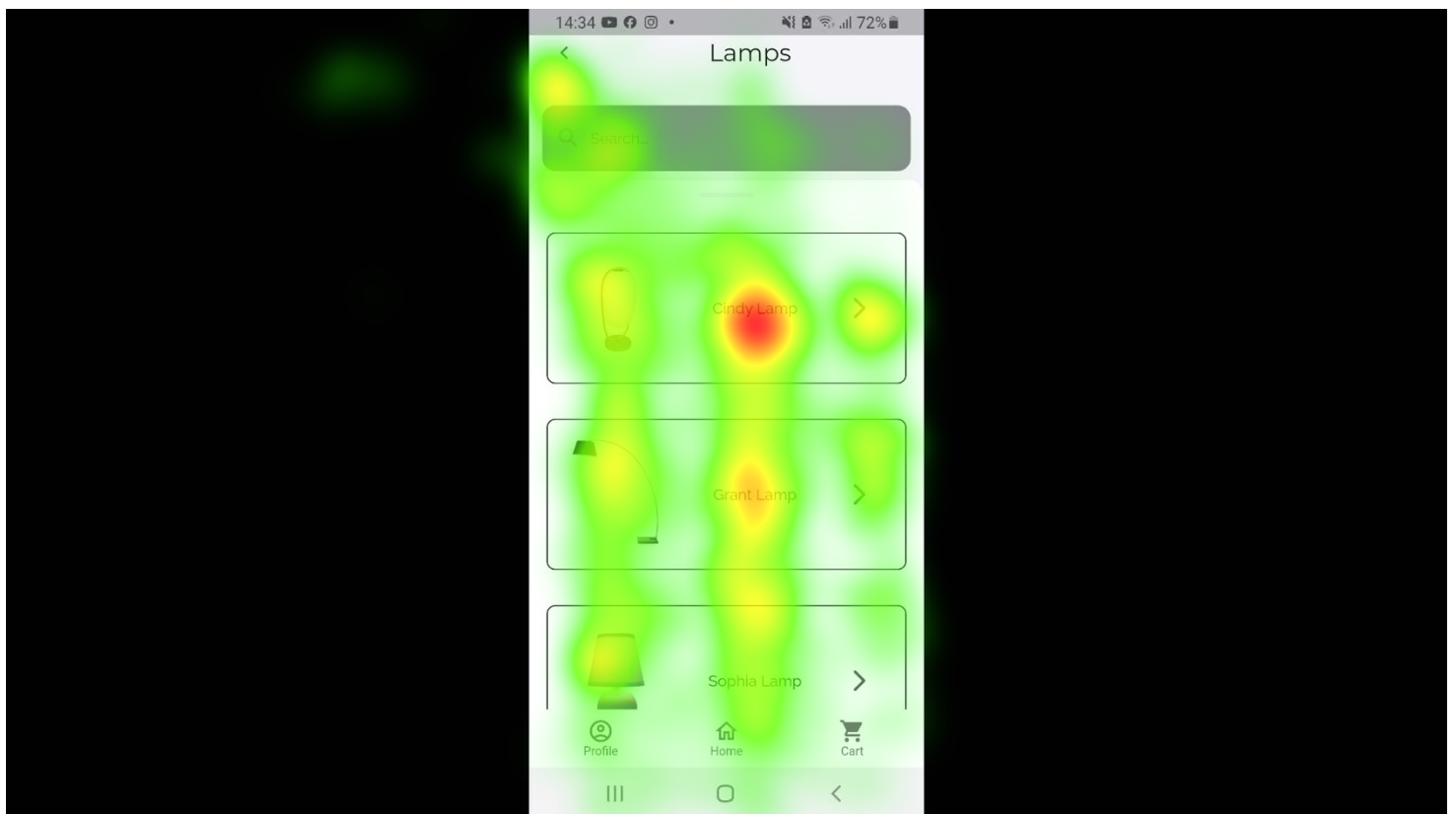


Figure 33: Heatmap App 1, Profile page

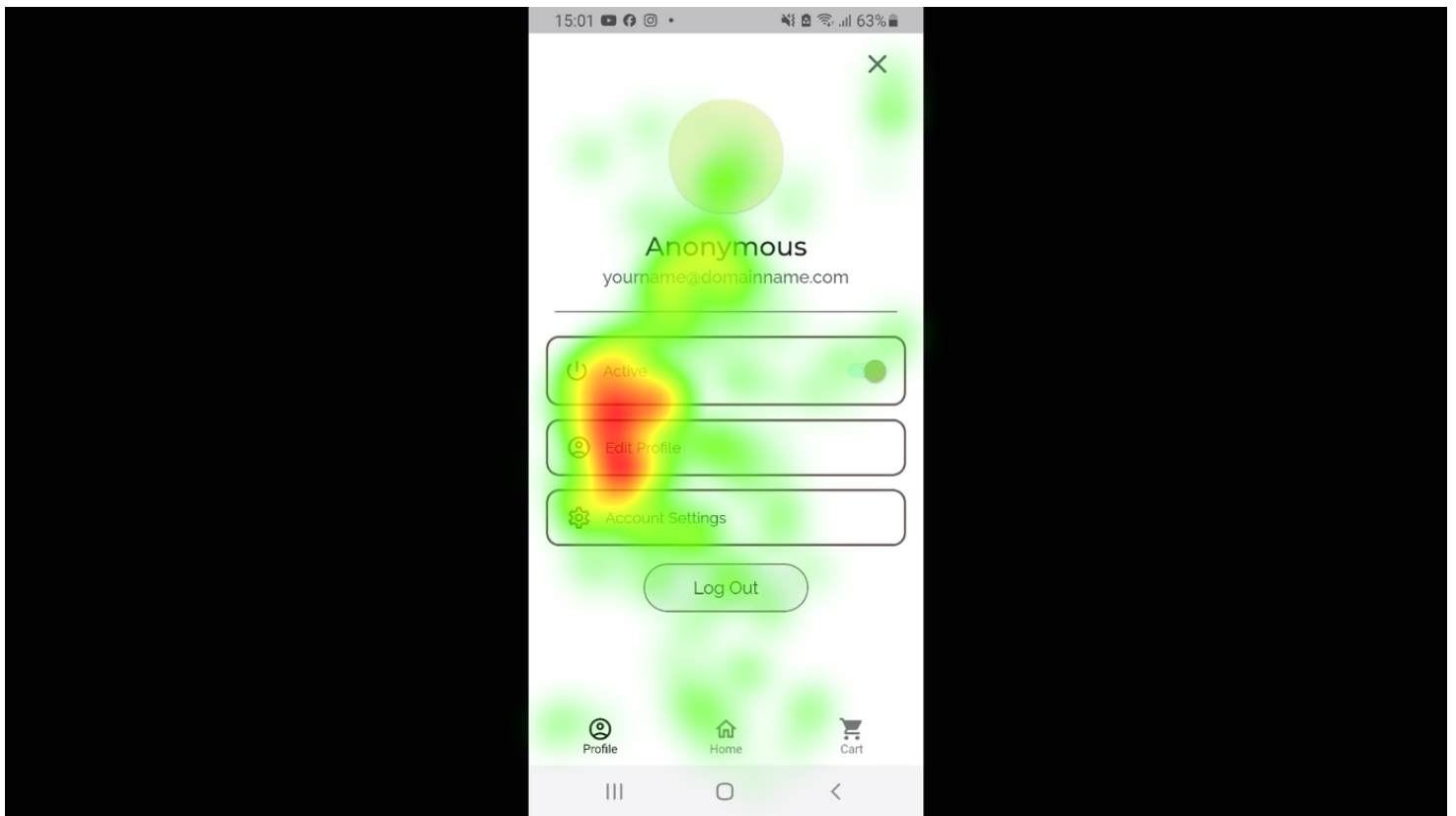


Figure 34: Heatmap App 2, Cart page

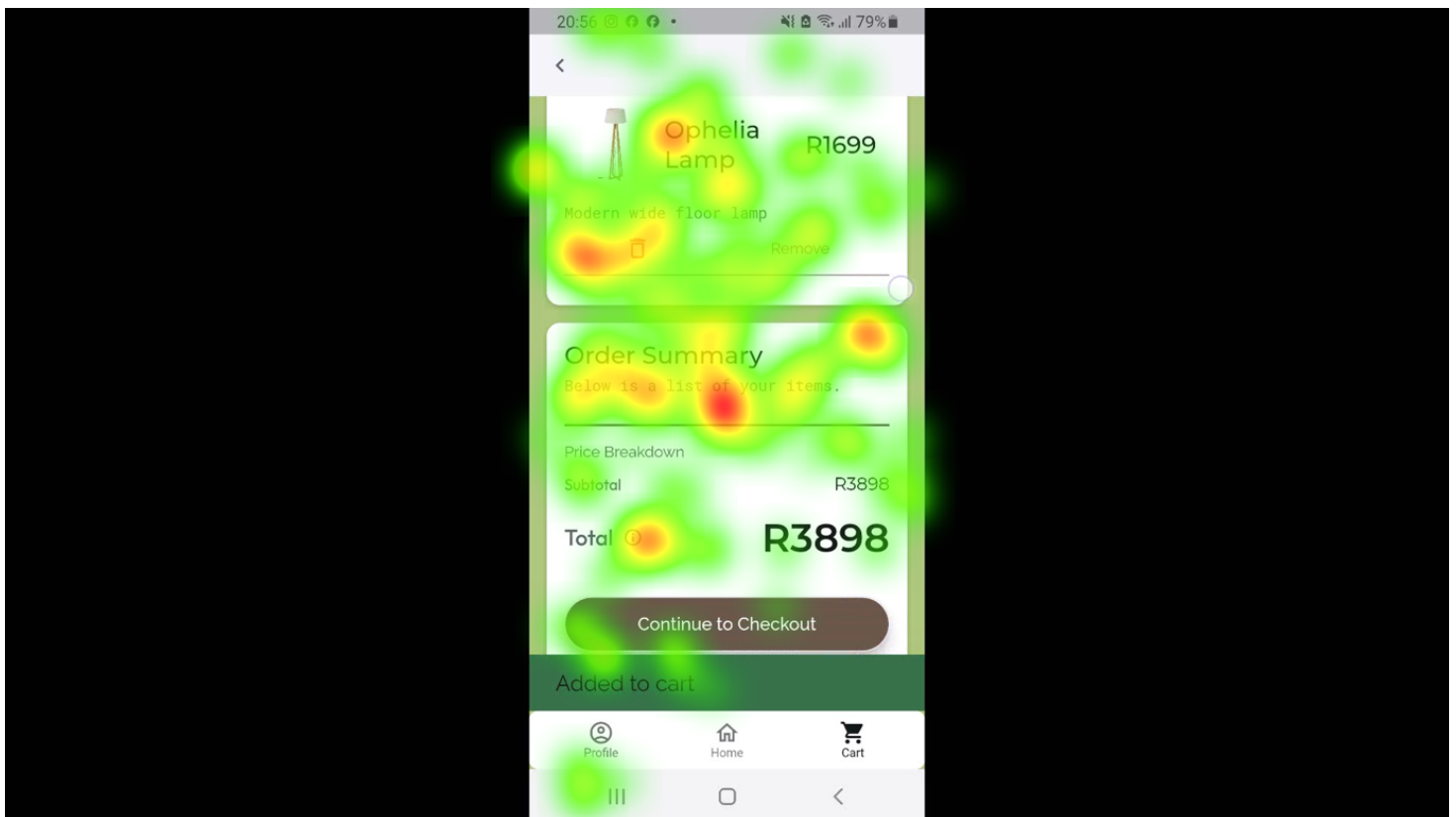


Figure 35: Heatmap App 2, Product Details page

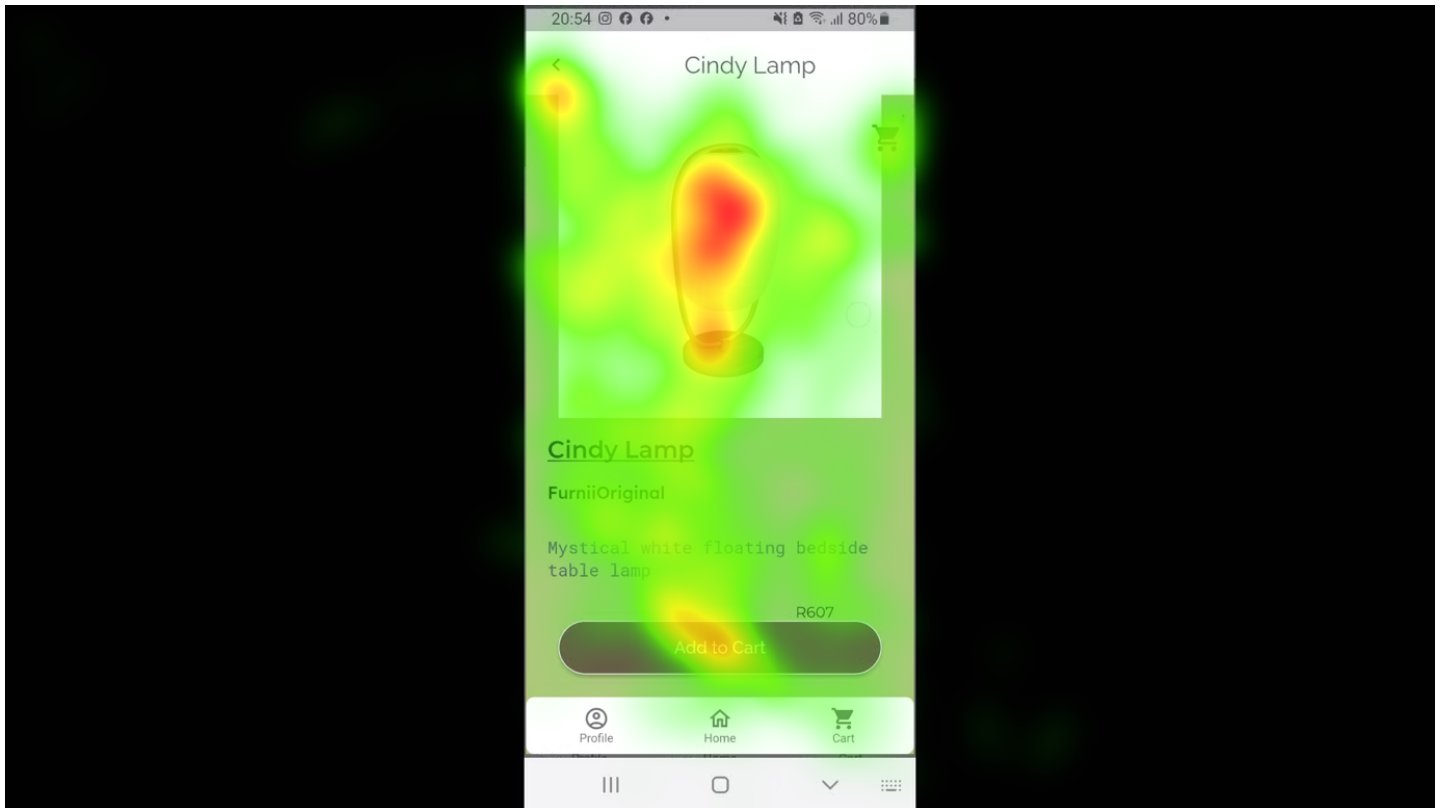


Figure 36: Heatmap App 2, Home page

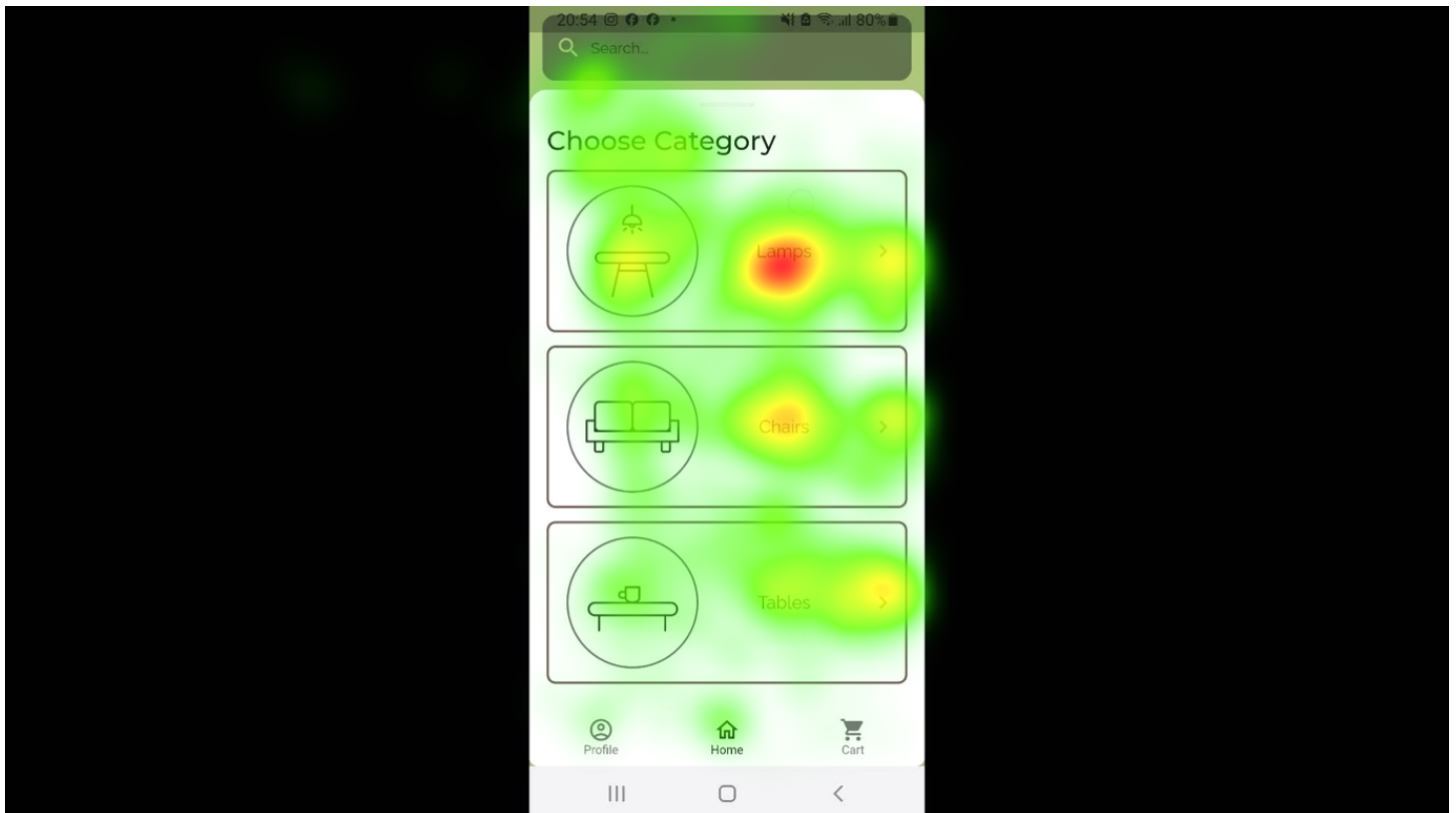


Figure 37: Heatmap App 2, Products page

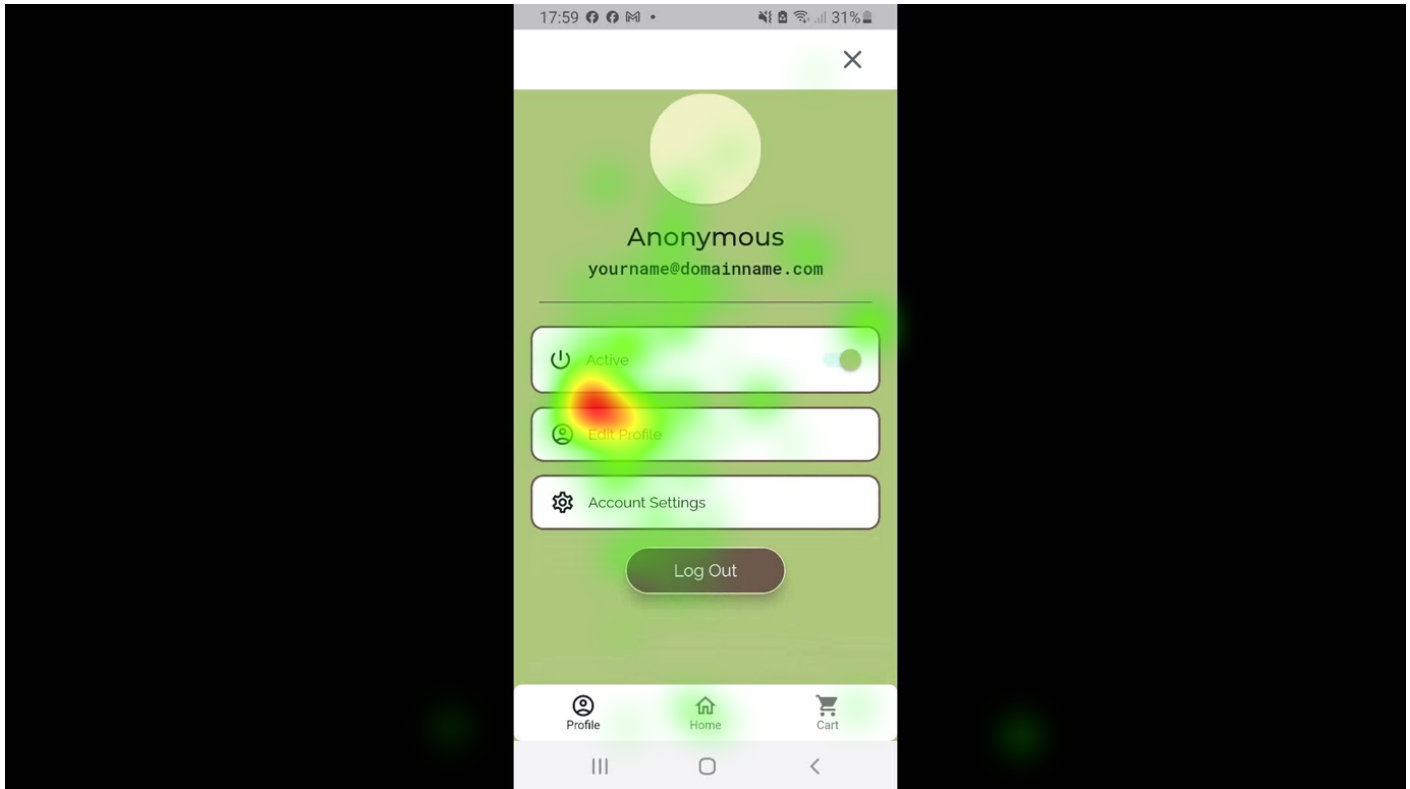


Figure 38: Heatmap App 2, Profile page

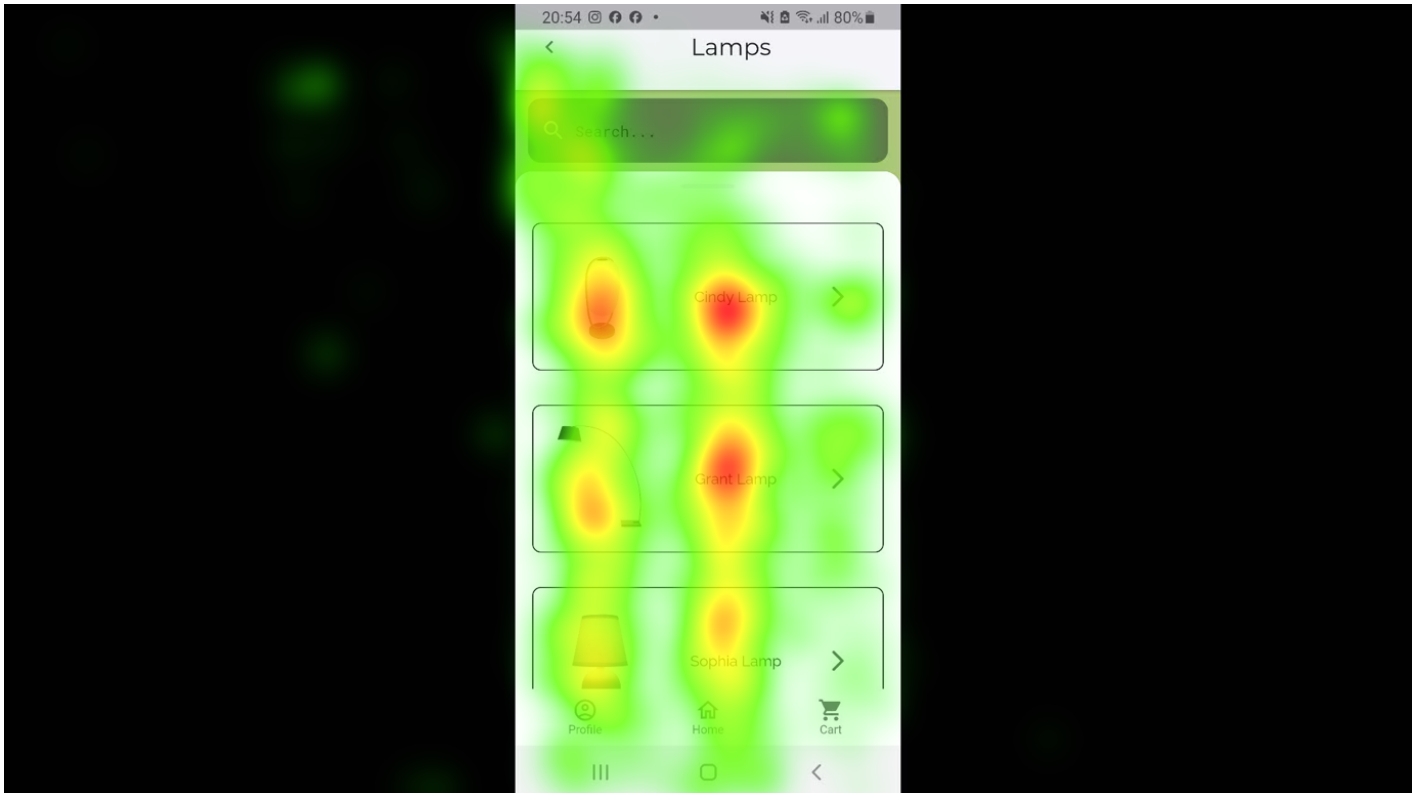


Figure 39: Heatmap App 3, Cart page



Figure 40: Heatmap App 3, Product Details page

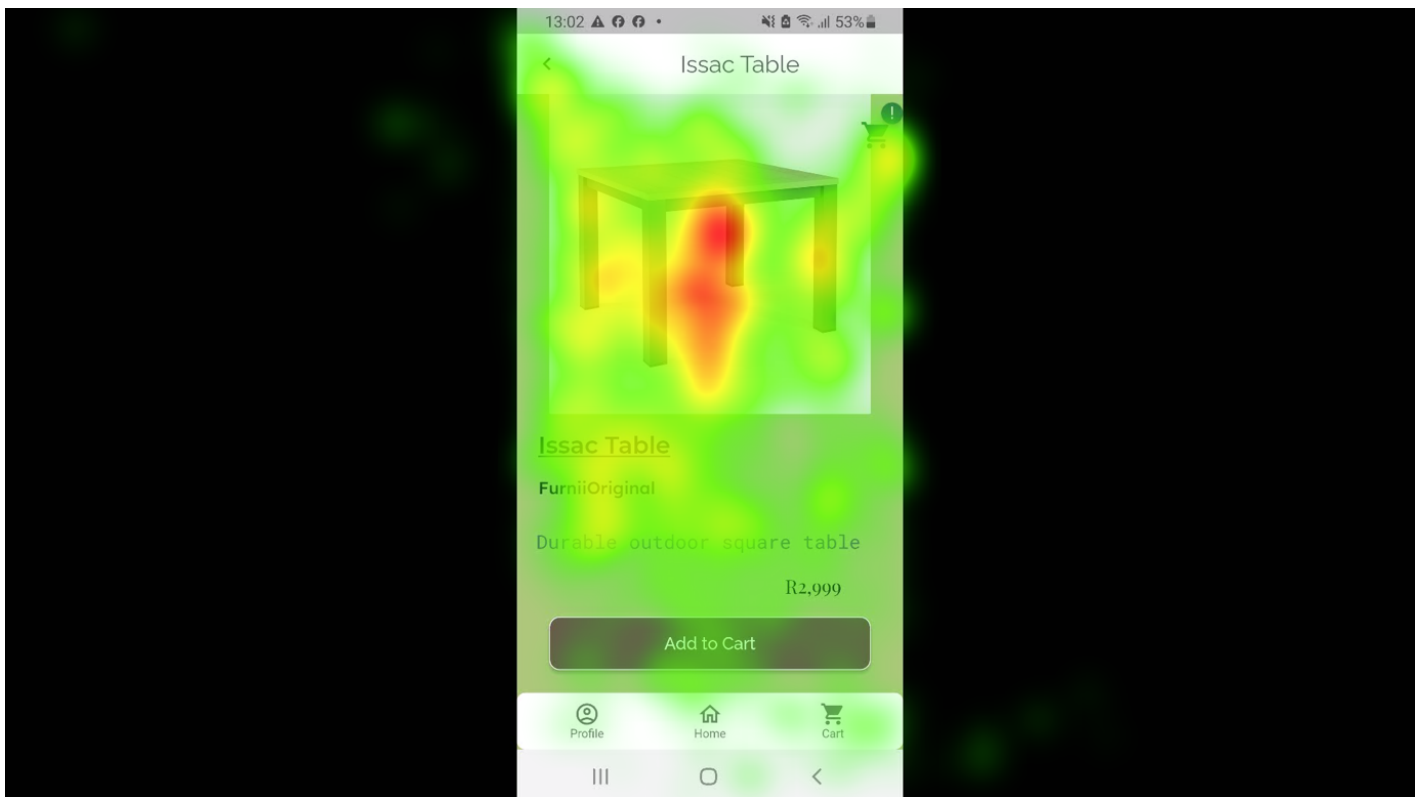


Figure 41: Heatmap App 3, Home page

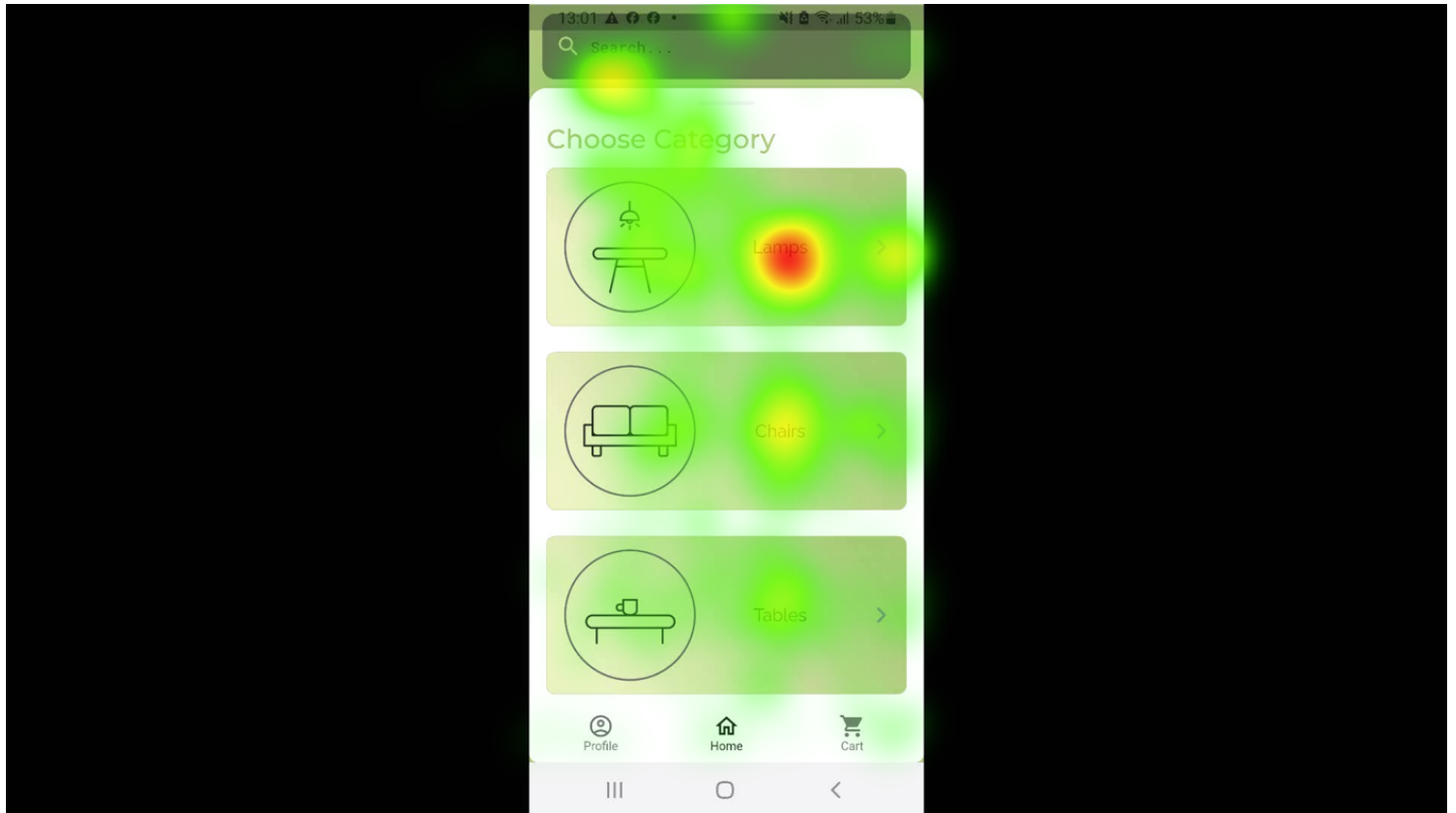


Figure 42: Heatmap App 3, Products page

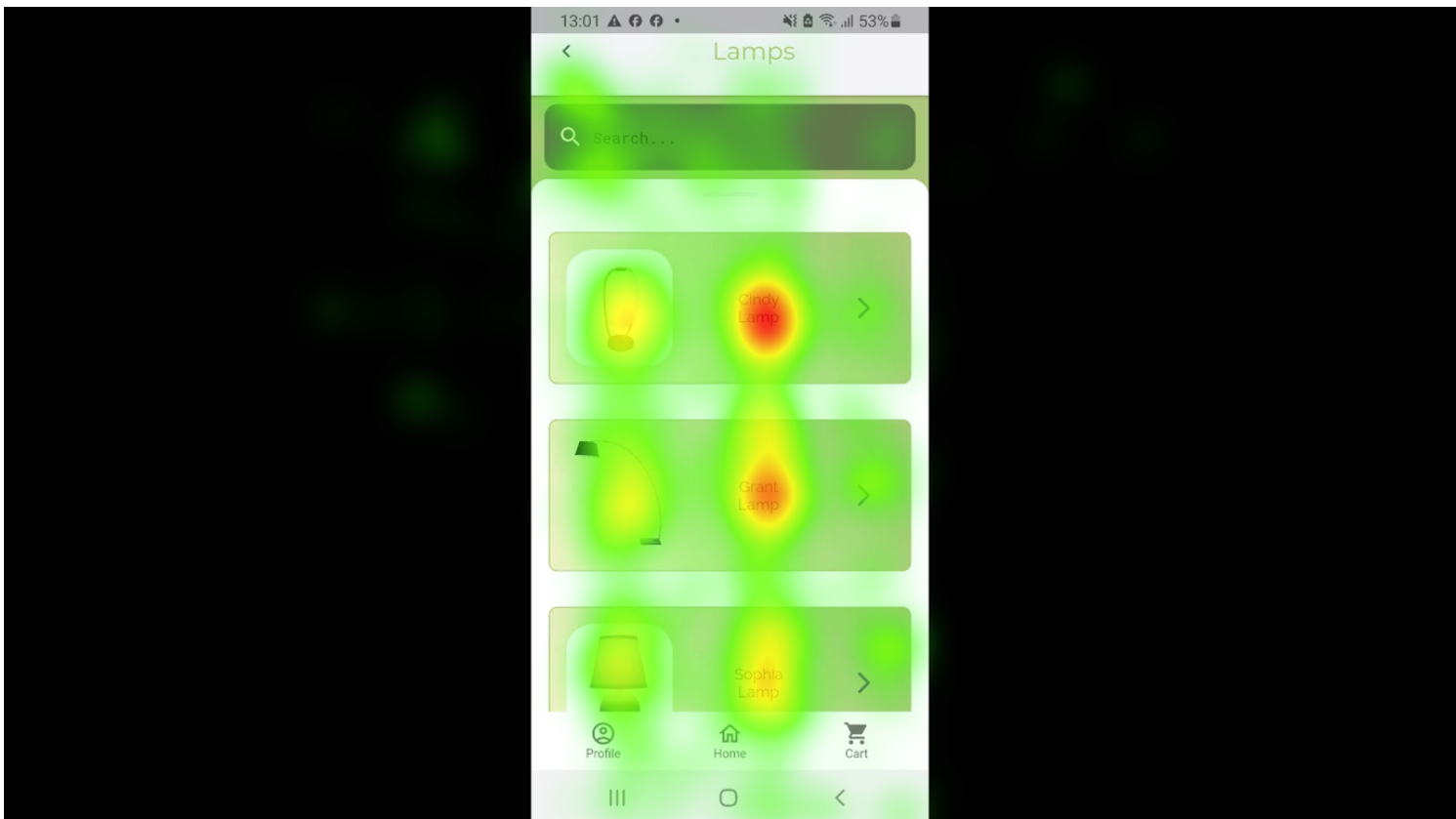
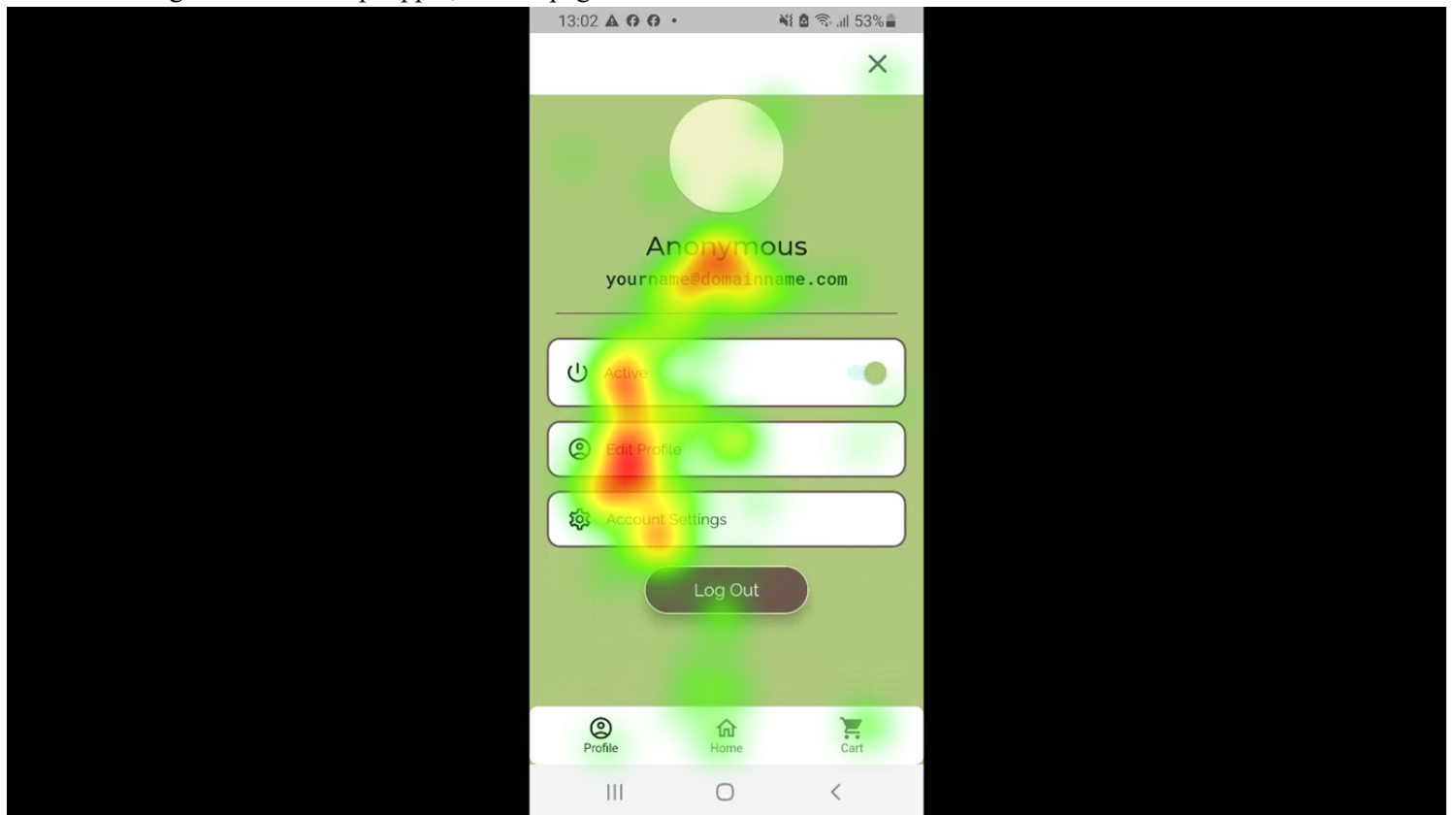


Figure 43: Heatmap App 3, Profile page



Comparison of eye-tracking heat maps for each app presenting concentrated attention:

The heat map results indicate that for the **cart** page app 3 the back button, information about the cart, price breakdown and total label were the most concentrated on, while for app 1 the remove button, total price and total label were the most concentrated on, while for app 2 the total more information button, product name, remove button and order summary information received the most concentrated attention, shown by the red colour. Thus, across all three apps the total text was important to viewers as most focused on this visual element. The remove button for both app 2 and app 1 received a lot of attention. This could indicate that users were unsure about the items they add to their basket and often contemplate removing said items throughout their initial exploration of an app.

The heat map results indicate that for the **product details** page app 1 and app 2 the back button, product image, and add to cart button had the most concentrated attention, while for app 3 only the product image was the most concentrated visual element. This indicates that across all three visual complexity levels the product image was the most concentrated on, this could mean the image of a product is of high importance no matter the visual complexity present. The reason that the back button and add to cart elements were the most concentrated on for app 1 and 2 but not for app 3 could be because there were less elements for the viewer to focus on and no distractions for the viewer on so the buttons that were used the most were focused on.

The heat map results for the **home** page all apps show that the lamps category name was focused on, while for app 2 the chair category name and the lamp icon was slightly focused on, while for app 3 the chair category name was focused on. This could indicate that often the first category of a list of categories are focused on by users when browsing a mobile shopping app for the first time.

The heat map results for **products** page show for app 1 only the first two item names were focused on, while for app 2, all three item names and the first two item images were focused on, finally for app 3 all three item names and the first item image was focused on. This indicates that the first item name or information is always focused on no matter the visual complexity level. The initial impression for viewers of a mobile shopping application does not change much when looking at items, but viewers who claimed to be focused on app 2 and app 3 could have been more focused on gathering information about the items especially for app 2. It could also indicate that a moderate level of visual complexity could render consumer attention to important information better than a highly visually complex app or little visual complex app.

The heat map results for **profile** page show for app 1 the activate button label and edit profile information received the most attention, while for app 2 the same area was concentrated the most on between the activate button label and edit profile information, and finally for app 3 the activate button label, edit profile label, account settings label and profile email address received the most attention. This could indicate that people place importance on editing their profile and name across all app levels. Users might place high importance on customization that allows personalization, thus they care about their own information even on a mobile shopping app.

Appendix J: Qualitative Data Transcripts

START APP 1

Respondent 1

Interviewer: OK. So, first question, how do you explain the mobile application you experience?

Speaker 2: It was easy to use, and it was clear. Colour scheme was not straining on the eyes, and it was intuitive.

Interviewer: And second question, how are your eyes feeling after interacting with the mobile app?

Speaker 2: My eyes are completely fine. No strain, no irritation, no watering.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think that maybe instead of using grayscale for the search bar, use a lighter colour and then a darker colour for the rest of the application and maybe a checkout. In green that symbolizes cash or if you have payments then that would be in red. Then you know that that's funds leaving your account and then discounts in green or something like that.

Interviewer: OK. Thank you.

Respondent 2

Interviewer: OK, cool. How would you explain the mobile application you experienced?

Speaker 1: I think it was really easy to use and the layout was like very simple with the lamps, chairs and coffee tables. There weren't that many products within each category. And also, what I think would be a drawback for some people is that the price isn't displayed when you're browsing over it like it's only displayed when you click on it, which I guess is also. Enforcing people to click on the product.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: They feel fine. I usually do actually wear glasses. Like when I read or. Like look at a screen, they all kind of a little bit tight. I also think it's because we have to sit at a certain distance away from the screen. But yeah, other than that they're not too bad.

Interviewer: OK, cool. And then how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: The visual stimuli, or only the visual stimuli OK.

Interviewer: Yeah.

Speaker 1: Maybe. Maybe by all of them having the white background, but like so like that one lamp I clicked on had it was like I think it was. Black. For the background like I think it was, it was like see

through. So, I think like if it was white, it would actually be easier to see it and like zoom in on it. And yeah, I think that's about it. Maybe also having pictures of like the coffee tables or the lamps like in a like set up like dining room or living room or, you know, just to see it how it would look. Within a space, cause like obviously just viewing it like individually, you can't really see how it would look. You know what? I mean, OK, cool. OK, cool. That's all if I. Much.

Respondent 3

Interviewer: OK, cool. So yes, we can get. All the things how would? How would you explain the mobile application you've experienced?

Speaker 1: It is very simple. One word explanation, OK.

Interviewer: That's OK, that's OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: They feel fine. There's not, like too much going on. So, like, they're not darting all. Over the place.

Interviewer: And then how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: Maybe add more colour and more like. Texture to the layouts. I don't know that makes sense.

Respondent 4

Interviewer: OK, so first. Question. How would you explain the mobile mobile application you experienced?

Speaker 1: I think. Well, the app itself. I think it was quite limiting, so there's not much to choose from, so you just. I was just choosing things that go well with each other, like the colours, so yeah.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: My eyes, they don't feel any different. They feel OK. I'm just a bit tired though.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: I think I'd. Add a bit of. Maybe colour to it, maybe it's just more bland and also maybe add more options to the app there.

Interviewer: OK, well, that's the interview.

Respondent 5

Interviewer: OK. So, first question, how would you explain the mobile application you experience?

Speaker 1: I'd say it was easy to navigate. It was. It was nice the pictures were very clear. But I would say otherwise it wasn't very gripping in the sense of like the icons and things like that.

Interviewer: And how are your eyes feeling after interacting with them?

Speaker 1: My eyes feel normal. OK, cool.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: Maybe just add a little more. More colour or some more interactive features? OK, thank you. OK.

Respondent 6

Interviewer: The first question, is how would you explain the mobile application you experienced?

Speaker: in terms of?

Interviewer: Just the how you used it and the look. Wow. Of the app.

Speaker: It was a simple look. So it wasn't, so it wasn't anything. To catch their eye or to like, make my eyes really tired. Because sometimes when you have a mobile app, especially the shopping apps, when all the ads pop up and the widgets so it can get very tiring. So, it was a simple look and it stated exactly what it was. So like tables, chairs, lamps and then you go in then each. Category simply stated what it had and it was very easy to. You know, open it and to add to the cart, I wish there was a bit more pictures though, because but. Otherwise, it was the easier experience to use the app.

Interviewer: OK, cool. And how are your eyes feeling after interacting with the mobile app?

Speaker: Fine.

Interviewer: OK, cool. How would you improve the visual stimuli on the mobile app? To enhance the user experience.

Speaker: Again, I think just adding more pictures of each of the items, maybe from different angles or. For example, in real life settings, so like when you have like really self-example they have stagings so use. Some of the products and show how would be used? I mean, everyone knows what a table would look like but it. Looks better. When? You have, like a vase and flowers, and it will. For example, but other than that it's it really is simple to use. I just wish that maybe also before you click on the item the price was already indicated on the on the scrolling on the home page instead of having to click into the item to find the price.

Respondent 7

Interviewer: Hey, how would you explain the mobile application you're experience?

Speaker 2: It's quite a very nice app where you can like choose whatever you like based on the categories that's on the app. So, it's kind of, it's kind of decent, it's good, it's right.

Interviewer: OK, cool. How are your eyes feeling after interacting with the mobile app?

Speaker 2: They're fine. Just that the front was a little bit small.

Interviewer: OK, that's perfect. How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: Obviously, make the front a little bigger so you can like see and don't have to like squint. Your eyes to. Everything else is like perfect and then.

Respondent 8

Interviewer: OK, so how would you explain the mobile application you experienced?

Speaker 2: It was good. It was nice. Browsing through each of the items.

Interviewer: OK. How are your eyes feeling after interacting? With the mobile app.

Speaker 2: OK. Yeah, they're a little tired, but it's been a long. Day.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: Maybe more pictures like a different variety of pictures and the font is a little small, so making the font bigger as well.

Interviewer: OK, cool.

Respondent 9

Interviewer: How would you explain the mobile application you have experience?

Speaker 2: It's. Easy to work with, yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app? How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: Feels normal. Maybe like add more? I don't know more than features like colour in the items or like change the items that you have the yeah. OK.

Interviewer: OK, cool. Thank you.

Respondent 10

Interviewer: OK. First question, how would you explain the mobile application you experienced?

Speaker 1: UM. It was a mobile furniture shopping app that was pretty interactive and allowed users to look at the. The furniture presented. OK.

Interviewer: How are your eyes feeling up to interacting? With the mobile app.

Speaker 1: Oh. The white back drop will always make my eyes a little bit tired, but it was. Pretty. Comforting, especially because when I looked at an image, I could click on it and there was a back. Like a black background.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance? A user's experience.

Speaker 1: UM. I would maybe add more products that have different colours. And., I don't want to give you something too difficult to do, but I would if you could figure out how to make it so that the furniture could be seen in somebody's house like they could take a picture and see what it looks like in their house. That would be really cool. Is that kind of like?

Respondent 11

Interviewer: OK, so how would? You explain the mobile application you experienced.

Speaker 2: Unrefined, like quite something refined. Things that pop up when they're unnecessary. So, when you went into a single product, it was like. A pop up for the keyboard and that's like completely unnecessary for the situation. So that's definitely the one thing. Yeah, visually like it's. Quite simplistic in a very positive manner. So, like the categories are very obvious to pick and they're very like sensible groupings and like the visual like picture of the category makes a lot of sense like OK lamp like a light source couch chair, yeah.

Interviewer: Hey cool. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Perfectly fine. OK.

Interviewer: How would you improve the visual stimuli on the mobile app to? Enhance a user's experience.

Speaker 2: I think maybe like. Touch of colour like a. But like not a very like bold palette of colour, like subtle changes and like have that consistent across the whole app. Awesome.

Respondent 12

Interviewer: OK. How would you? Explain the mobile application you experienced.

Speaker 2: Like going in depth. I just feel like. It's easy to navigate. I just don't think there are a lot of products on the thing, so I didn't feel like staying on the app for that long.

Interviewer: And how are your eyes feeling after interacting with the mobile app?

Speaker 2: They feel fine. Yeah, they feel normal.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance? A user's experience.

Speaker 2: I don't know if it's the right thing. I think maybe it's the right thing. Or it just looks very minimalistic. Yeah, I need like a home page. That's different from this. This could have been like on the side, you know how. On the side, yeah, yeah.

Interviewer

OK, so like more visual stuff. OK.

Respondent 13

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: Like in terms of the design of it, yeah. So, it was fairly simple to understand like the arrows and everything was very like easy to follow. The categories were very descriptive and like the fact that there was like a generic image of what the category was. So, it was pretty easy to figure out how to navigate throughout the website. The only annoying thing was every time you clicked on an item then it would prompt you for a review. Which was frustrating if I was shopping in real life, I would not enjoy that, but overall, it was. It was a very simple design but very easy to navigate.

Interviewer: How are your eyes feeling after interacting with the mobile app?

Speaker 2: I'm a little bit tired I'm I usually have everything set to dark mode so because it was a very bright, very white design I do feel like you know my eyes had to strain a little bit. More than they usually do.

Interviewer: How would you improve the visual stimuli on the app the mobile app to enhance a user's experience?

Speaker 2: I think maybe having a little bit more colour because it is very simple. So, I think maybe just having a little some pops of colour maybe having the option to enter dark mode so that there's less strain. Especially if you're like, if there's maybe like a night mode for example, or like a low lighting mode perhaps. But overall, like I thought, it was simple enough.

Respondent 14

Interviewer: First question, how do you explain the mobile application you experience?

Speaker 2: It was a great experience I guess, and it is easy. Yeah, it's easy to navigate the app right? , yeah.

Interviewer: Yeah. Yeah, OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: They feel the same, yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Enhance it? I think it's already fine.

Interviewer: OK.

Respondent 15

Interviewer: First question, how would you explain the mobile application you experienced?

Speaker 2: Well, it. It was like usable, like it didn't freeze or anything like it gave me access to like the things that I wanted to like, see and everything. And then the good thing about it is that I could view it and like, if I like wanna zoom it in, I could like see other things around the couch or the table, even the lamp.

Interviewer: How is your eye feeling after interacting with the mobile app?

Speaker 2: They are normal, but then there were a bit teary in the like in the first one when I was like scrolling, yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I'd say like. In some things like add a bit of colour like furniture like add a bit of colour because like they're all like greyish and like kind of like the darkish colours to a point like it can like accommodate my eyes. In a way. Because like in in, in some others I could view them (items), but they like. I would like my eyes would get teary. I think maybe it's because like, I don't know, maybe like I was looking for like colours to be like, OK, OK, yeah.

Interviewer: OK. Thank you. Thank you very much.

Respondent 16

Interviewer: OK. Question one, how would you explain the mobile application you experienced?

Speaker 1: As in my experience with just the application?

Interviewer: Your experience with the app.

Speaker 1: For the application, it's very easy to use. It's not problematic and simple for the user, no problems whatsoever. And also, I enjoy the simplicity of it.

Interviewer: OK. How are your eyes feeling after interacting? With the mobile app.

Speaker 1: I do not feel strain. Or do my eyes feel watery so. I'm alright with it yeah, OK.

Interviewer: How would you improve the visual? Stimuli on the mobile app to enhance the users experience.

Speaker 1: Well, currently it's just black and white. I feel like an introduction of more colour. While still entering the app before you get to see the products would be. Just a nice visual stimulus to get a user engaged.

Interviewer: OK. Thank you. And then.

Respondent 17

Interviewer: So how would you explain the mobile application you experienced?

Speaker 1: It was quite navigable. There wasn't much on it, but I feel like if it's an experiment, perhaps not. But it was quite navigable and it was everything was really clearly laid out, like how much it was and whatnot. There wasn't specs on the sizes, but. I did work full furniture company, so that's why I'm looking for specs and whatnot, but otherwise it's really navigable and like I like how everything's quite like it's like background on, it's easily, easily viewable and easily. Yeah, we'll say quite OK.

Interviewer: How are your eyes feeling after interacting with? The mobile app.

Speaker 1: A little different, actually. No. I think about it. I think like when I put my glasses back on, I was like, hold on. But no, I think I think it's because I kept my, I stayed focused on the phone. I didn't look. All away from the phone that is like, like looking away from the phone. I was like, oh, hold on. Like, not. I don't feel eye strain, but it was just like, I felt like I had to readjust. Yeah. So, it was less uncomfortable.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance? A user's experience.

Speaker 1: I think how it is with the white background and black writing is pretty clear. I think things like. The descriptions and whatnot. Obviously, the description will be smaller than the title, but when

it's in like a Gray colour, you have to like look forward straight a little bit more I think also. So I'm trying to think. Yeah. I think for on the mobile app, because everything you have to scroll for a lot of things. And I feel like you have to regard because on the phone and not. The laptops you can't. See all the information. But even when you have to scroll, the information was written quite small, but that's quite normal the blocks. I mean like, yeah.

Respondent 18

Interviewer: How would you explain the mobile application you experience?

Speaker 1: Pretty user-friendly, could use it quite well. So, what I needed. Yeah, it's pretty easy to use.

Interviewer: How are your eyes feeling after interacting with the mobile app?

Speaker 1: Still OK.

Interviewer: How would you improve the visual stimuli on the?

Speaker 1: Mobile app to enhance a user's experience. I think so. Far, I don't think there's anything you can because I see everything that needs to lamps, chairs, tables. Then when I click on it I see the different types of lamps, chairs and tables available. So yeah, so far, I don't think there's anything. That you could. Enhance, I guess, yeah.

Interviewer: OK, that's all. Those are the three questions. Very good.

Respondent 19

Interviewer: How would you explain the mobile application you experience?

Speaker 2: Pretty basic, easy to navigate. Easy to look at.

Interviewer: OK. How are your eyes feeling after interacting? With the mobile app.

Speaker 2: Pretty fine. The phone is a bit bright, I like to keep my phones brightness really low, so that's like kind of right, but that's fine. OK.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Maybe add some colour. It's very boring. Yeah, I would say add colour and I don't know, like some descriptions. It's very basic. Like you don't really know what you're getting out of it. Yeah. OK.

Speaker: Thank you.

Respondent 20

Speaker: How would you explain the mobile application you experienced?

Speaker 1: Like my experience, yeah. It was pretty easy to navigate. The symbols were. Like helped with what you were actually looking at. Yeah. I think in terms of each product, maybe like within. It could have been a little bit more descriptive. More photos could have been nice as well, but yeah, the layout of. The layout was pretty easy, a little bit boring, but pretty easy to navigate, yeah.

Interviewer: How are your eyes feeling after? Interacting with the mobile app.

Speaker: UM. A little bit. A little bit sore, but that's just because I am used to having like a dark mode on my phone, so this is just a little bit harsh, yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance? A user's experience.

Speaker: Yeah, I would maybe have an option for a dark mode. But yeah. I think that's. The only thing I would change, I mean the font is pretty big, which is nice.

Interviewer: So yeah, OK, cool. Thank you. Sure.

Respondent 21

Interviewer: So how would? You explain the mobile application you experienced.

Speaker 2: Umm. It was like easy to use. OK, yeah.

Interviewer: How are your eyes feeling after interacting with the mobile?

Speaker 2: I don't know. Like they feel like kind of like like it's kind of difficult to look at other things like to, like, focus on other things, yeah.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Providing my more pictures on different angles OK. Oh.

Respondent 22

Interviewer: So how would you explain the mobile application you experience?

Speaker 1: It's very easy and accessible. Yeah. OK.

Interviewer: How are your eyes feeling after interacting with the mobile app?

Speaker 1: It feels fine, doesn't feel like really strained. Yeah.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's expert?

Speaker 1: I think it was OK. It doesn't need anything because it wasn't like bright bright lights that sometimes the apps have, like really bright things that hurt your eyes. And it was like more neutral tone. So it was OK. I wouldn't change anything.

Interviewer: OK, cool. OK.

Respondent 23

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 1: In full.

Interviewer: Yeah.

Speaker 1: About what it is or like my experience using it.

Interviewer: Just yeah, you're experience (using the app).

Speaker 1: It was OK. There was a lot of. Bugs and issues with it. Not a lot of options. Very pricey. Yeah, there was just weird things. And it's so like it had a delivery in a section which. Shouldn't probably be. There should probably be in the cart section. It didn't have many pictures of the item, so it could have had like. More side views and stuff like that. I don't think I even saw like dimensions and stuff. UM. Yeah, the home tab could have been like out of the home tab. It's weird. It's fine. In the centre was like it could have been on the left or something. But otherwise, it was like. You are a general. Let's see home. Commerce website. Yeah.

Interviewer: OK. And how are your eyes feeling after interacting? With the mobile.

Speaker 1: OK they're fine.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: Um. More colour and more. The text could also be larger in a lot of the places. So, like I think the ohh the prices, the prices were really small in the actual viewing of the. Item. Yeah, the price could be shown better the. Yeah, more colour. Yeah, it's very. It was quite likable and I think some more colour would help a lot and branding and stuff like. Yeah.

Interviewer: OK, cool. That's all the questions

Respondent 24

Interviewer: OK. How would you explain the mobile application you experience?

Speaker 2: It was. Easy to use because of the contrast. I would say the icons really help. I think the lack of colour. Is. Slightly. Boring. I'm not sure exactly what you. Mean when you say explain it.

Interviewer: So just explain your experience with that, yeah.

Speaker 2: OK. Like is it more from a marketing point of view?

Interviewer: For marketing from just a user. OK.

Speaker 2: Yeah, I would say that the icons help a lot and that the. Kind of more. It's almost like a more modern design with very much more simple. Layout also is really helpful. It also follows the kind of average. E-commerce app that you would see with the profile homepage with the little kind of same icons that you would see normally. And that obviously there's nothing new that you're kind of trying to have to figure out, which helps as well to work your way around it, yeah.

Interviewer: OK, cool. Umm, how are your eyes feeling after interacting with the mobile app?

Speaker 2: Actually, kind of. Like I can feel the eye. Strain. Not, I think Iran is average for me though, but overall, the only thing I can feel is the strain. There's no kind of aching or anything like that, yeah.

Interviewer: OK. OK. Would you in how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think the one thing that jumped out at me was the colour. The contrast is very nice, but having no colour makes me want to leave that and not spend like lots of time. Get all the details and things like that because there are not a lot of details. Very practical though. But yeah, I think the main thing is colour. Otherwise, I cans are amazing and. Yeah. Just colour.

Interviewer: OK, cool. That. That is all the questions of interview.

Respondent 25

Interviewer: How would you explain the mobile application you experience?

Speaker 2: Uhm, quite easy to navigate. I assume. Yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: My eyes are feeling just fine. Yeah. No strain. No, they're fine, OK.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I have no comment on that.

Interviewer: OK, so it's fine. So OK, cool.

Speaker 2: Yeah, it's, it's fine. It's just a little more items. Yeah, nice items.

Respondent 26

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Simple aesthetic, easy to use. Accessible, yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile?

Speaker 2: No, fine. I actually feel like I'm a little energized. You know, if it's just easy to go through it all.

Interviewer: OK, cool. How would you? Improve the visual stimuli on the mobile app to enhance a user's experience.

Speaker 2: How would I improve it? Maybe add a little bit more colour through it. Make it more pop like make things pop out. You know, like sale items, etcetera. Yeah, just make it more in your face, you know?

Respondent 27

Interviewer: So how would you explain the mobile application you experienced?

Speaker 1: So how to explain the experience or? Anything else?

Interviewer: Yeah, how the mobile application? You experience, so your experience is?

Speaker 1: It was quite simple. It wasn't too much like distracting you, which was quite cool. Just click on the product and it's there, yeah.

Interviewer: OK. How are your eyes feeling after? Interacting with the movement.

Speaker 1: It's fine now they're all good.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance? A users experience.

Speaker 1: A little bit more colour, but other than that, yeah, it's quite nice the non-distractions.

Interviewer: OK, cool. So that's the end.

Respondent 28

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 1: I would say it was quite seamless and user-friendly. Minimalistic. So yeah, not much to think about.

Interviewer: How are your eyes feeling after interacting? With the mobile app.

Speaker 1: My eyes are feeling OK. They feel fine. Granted, I didn't do anything. I didn't have to stare at the screen for too long so, but I still OK.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: Possibly upon clicking a button, maybe getting like a cute animation or a cute graphic or something just makes it more fun.

Interviewer: Thank you.

Respondent 29

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It was like what kind of? I'm sorry, just like.

Interviewer: So, your experience interacting with it basically.

Speaker 2: It was good, but my one problem with it was just that when I click into something, It immediately wanted me to write a comment which I was like. I just want to look at the. Thing first, so yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: OK, OK.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: So instead of like in that. Let me just. In this place, instead of having just icons of the chairs, I'd like put an actual chair like to see you. It's like. What kind of chairs we're going to be looking into and kind? Of like that. Yeah. Yeah. Thank you.

Interviewer: OK.

Respondent 30

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: It's pretty straightforward, I would say.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: Fine. OK.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: Maybe if the app is in dark mode? And the images to be a little bit bigger than the font the see more of the font than what the thing. Looks like.

Interviewer: OK, cool. Thank you.

Respondent 31

Interviewer: How would you explain the low application you experience?

Speaker 2: Fairly minimalistic, generally good. Just the arrows are a bit too small.

Interviewer: OK. How are your eyes? Feeling after interacting with the mobile.

Speaker 2: Slightly irritated.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's expert?

Speaker 2: As much can be done, it's just the length of time you spend on the app to deal with what you want. Want to do what you want to do.

Speaker: OK.

Interviewer: Thank you. UM.

Respondent 32

Interviewer: How would you explain the mobile application you experience?

Speaker 2: I would say easy, simple and. Very sleek, very proper design. Nothing too flashy, nothing too thick on your eyes that it keeps you looking when everywhere to see how to work things you know.

Interviewer: OK. How your eyes feeling after interacting with the mobile app?

Speaker 2: Pretty fine. Just yeah. Sometimes I when I use apps, I would adjust the light depending on what kind of room I'm in. So, if I'm perhaps maybe in a very little room then I have to put it way up. Or if I'm in at night when I have to put on my room light and then I'll just lower it a little bit more.

Interviewer: OK. How would you improve the visual system that on the mobile app to enhance a user's experience?

Speaker 2: I would say. Not much, to be honest. Just maybe. Uhm. I think I struggled with the tapping a little. Maybe I was. Looking at the wrong place to tap with my eyes and then when I taped it properly. It helped maybe be the indicators or selection buttons that you can make you go where you need to be, I guess.

Interviewer: OK, cool. Thank you.

Speaker 2: Yeah.

Respondent 33

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: So, from the beginning, like with the numbers or just here the app OK.

Interviewer: Just the app, just.

Speaker 2: Can you please repeat the? Question.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: OK, so I firstly find the app. Flexible. And easy also to navigate cause it's because of its flexibility. And when I looked also at the items that I hear, I looked at the lamps category and then saw a lamp that I think I liked out of the ones that were available. And also, for some reason looked at their prices. But then when I looked at the lamp, I found one that maybe I could use also for things like studying that could also be maybe good for like an office space, things like that. And then when I tried to look at the chairs that includes the couch and everything, then I didn't find one that I threw him I like because I was also looking into. Origin of the type of lamp that I saw, so I was trying to look for things that I can like core. But to combine maybe to say but good idea, so also in terms of one that grows allow me to lean back. But when I look at the one that was tall, I felt like it's a hard chair that I can choose. Hence our funny, difficult to pick. Also look the tables also saw the tables but I didn't get a chance to look at them again. So also, I think it's also difficult to choose current thing as one that I would. I. Would like so, but All in all I think it's just a good app that's easy to navigate and also yeah, it's it's not complicated. Yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile?

Speaker 2: I didn't feel any effects on my eyes, but all I could say like since I previously saw something else from a different category, it was affecting what I see because I would look at it with also kind of seeing what I saw earlier on. So hence I'll try to see which one fits with which. Yeah.

Interviewer: OK. How would you improve the? Visual stimuli on the mobile app to enhance. A users experience.

Speaker 2: I'm not sure cause for me for instance, I didn't find any challenges or anything because the brightness level I think it was at a reasonable level for me as well because even though I wasn't quite bad, I didn't find difficulty seeing everything because I think it was so much bright for it that I was able to see everything. So, I don't think there's anything that would save me to be, like recommend, because I think if I would say to increase the brightness, it would also become too much. I think so, I think I. Like how standardized it is.

Speaker: OK, cool. Yeah, those are all the great.

Respondent 34

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: I think really simple to use and very easy, but it was a bit sometimes irritating when you have to click on the icon to go to the next page like it, it would be better for just like you could get an idea from where you were trying to go.

Interviewer: How are your eyes feeling after interacting with the mobile? App.

Speaker 2: They're all quite tired, but I think that's just also because it's like the end of the day and my eyes have been busy the whole day, yeah.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think a bit more colourful and but I liked that it was a very simple layout and it just tells you the information that you need to know. But yeah, I think it's a bit more colourful like with the icons and the. The way it says like cheer lamp, the pictures could be a bit more colourful as well, yeah.

Interviewer: Cool. Thank you.

END APP 1

START APP 2

Respondent 35

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: Sure. The and it's good. It is easy to use and it's allowed me to access the things that I needed to easily.

Interviewer: Cool. How are your eyes feeling after interacting with the mobile app?

Speaker 1: Fine. Very good. Yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I would say just the pictures in, yeah, just like seeing them in the actual like maybe setting, yeah.

Interviewer: OK, cool. That's.

Speaker 1: Is that it?

Interviewer: Yeah.

Respondent 36

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Pretty normal, like it's like the others I use so.

Interviewer: How your eyes feeling after interacting with the mobile app?

Speaker 2: Fine.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: UM. I don't know the layout is a. Bit. Like, it's straightforward, but it doesn't really catch your eye. Like it's mainly just the pictures. And the pictures are not so good. Maybe better items, I don't know. Yeah. OK.

Respondent 37

Speaker: OK. That's kind of like.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: I think it was good, yeah. Yeah, it was pretty simple and easy to navigate. So yeah.

Interviewer: How are your eyes feeling after interacting with the mobile app? With the mobile.

Speaker 2: Normal. still fine.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I don't know if this is just me, but the errors were not erroring. So yeah, I don't know, but other than that I would say like maybe the background could be a bit more. Like less plain? Yeah, that's what I would say would grab me more. Yeah, but I like the font and everything. That's all fine. So yeah.

Speaker: OK. Thank you.

Respondent 38

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: I think it's simple and minimalistic, but I find sometimes found it difficult to navigate and when I entered each item. But the review thing popped up first, it was difficult to see the item first and foremost. And the details of it. But otherwise, I like the colours and the neatness of it, and I like the items, that's. All.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: They're feeling fine. Normal. They don't feel strained. It's just the difficulty of knowing what to focus on. I think after a longer while it may become difficult to see or something.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think maybe have everything more compact. I like that. The colours are calm and neutral, but maybe just having some things like important information stand out more so that my eye is more drawn to the important things first and then I know exactly where to focus. Yeah, OK, cool.

Respondent 39

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Uhm. I think it's simple. It's not, doesn't seem like it's difficult to, you know, find whatever it is that I'm looking for. I feel like the different. Yeah. Different categories are that's labelled clear enough. So, I know if I am looking for lamp or chair or tables. It's. Yeah, it's easy to work. I don't. I don't feel like I'm struggling. To look for (items). Nice. Ohh yeah.

Interviewer: OK. How your eyes feeling after interacting with the mobile app?

Speaker 2: fine. Not. Not too strange or anything, feels alright.

Interviewer: OK. And how would? You improve the visual stimuli on the mobile app to enhance an user's experience?

Speaker 2: Oh. Much, I mean probably maybe just a little bit brighter would say not really much else.

Interviewer: OK. Thank you.

Respondent 40

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Pretty user friend name it had. You only have three options, but from there you can navigate it quite well. And yeah, I like the colours quite calming. Uh, green and Browns, yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: UM, normal. A normal amount without glasses I think. Yeah, pretty pretty decent.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Hmm. I think it does quite a good job. Maybe the I know from a well what from what perspective are you asking us from the whole design looks OK.

Interviewer: The yeah.

Speaker 2: I think the icons for the different. Categories could jump out a bit more. As the maybe a different colour from the IT takes. Maybe if it isn't because I spin, I think I spent what I'm reading than if I actually saw a picture of it or a more illustrated icon that might have just helped me. Choose it faster than nothing to read furniture or chair or lamp. But. Overall, it's pretty easy to. To see.

Interviewer: That's all right. Question.

Speaker 2: Cool.

Respondent 41

Speaker: Yeah.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: I don't know. It was, uh, it was easy to use, I guess.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Like a little bit strenuous maybe from.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Maybe add like a bit more colour to it like yeah, it's just not like very white, which makes it very bright. So yeah, OK, cool.

Respondent 42

Speaker 1: OK.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: It was OK. The site is very plain and easy to get through and look through.

Interviewer: Your eyes feeling after interacting with the mobile.

Speaker 1: They're fine for now. Yeah. OK.

Interviewer: How would you improve? The visual stimuli on the mobile app to enhance a user's experience.

Speaker 1: UM. I don't know the pictures can be loaded a bit faster when you go into it, and I think the home screen can be a little bit more like catchy, yeah.

Respondent 43

Speaker: OK.

Interviewer: How would you explain the mobile application you experience?

Speaker 2: Can you like explain how?

Interviewer: So just a clean interface and your experience interacting with the.

Speaker 2: Yeah. No, the. That is easy to use. Yeah, I think yeah, there is easy to use.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Yeah, my eyes are fine.

Interviewer: OK. How would you improve the visual stimuli on the mobile app to? Enhance a user's experience.

Speaker 2: I think a way to be going to give it a better contrast.

Interviewer: OK.

Speaker 2: Yeah. Oh.

Respondent 44

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It was very easy to use. The interface was very welcoming. It wasn't difficult to navigate. It was also very aesthetically pleasing and all the information it wasn't. An overwhelming amount of information where you have to click and look and look for small infograph like info things and like pull. Means to understand more, so it was very friendly. I feel was very user friendly and easy to use as well as like. I feel the green helps with the eyes. Versus having like a brighter warm tone colour.

Interviewer: OK, cool. And how are your eyes feeling after interacting? With the mobile app.

Speaker 2: They feel. A little bit more focused, actually, I came in like I didn't sleep a lot, so my eyes are feeling tired, but then engaging with it in terms of like the focusing my eyes feel a little bit weird but like just a little bit strained tired but. I also feel like I'm slightly more alert now. Because I had to focus on something.

Speaker: Hmm.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I would say there's not much. I feel like the arrows and way like the click on the accessibility that. Could have been better, but I also don't think it's one of those issues where it's like it's affecting my eye. It's more of just like the digits of your finger, like being able to press and like the touch screen. I think it's more of a touch screen problem that maybe some people have and I like some people will zoom in. But otherwise, I think. Especially for. A group of people that maybe have strained as the funds or it's very easy to read.

Interviewer: OK.

Respondent 45

Interviewer: OK. So, first question. How would you explain the mobile application you experience?

Speaker 1: How to explain the model? The user interface is great, the text is visible. In in the navigation like moving from 1 from 1 place to another. Please look forward.

Interviewer: OK. How your eye is feeling after interacting with the mobile app?

Speaker 1: They are still in great shape, feeling nothing. Actually, there's something in my ear, I guess. Fine, alright.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: How do I? Um, OK maybe to have a dark mode and the light mode something? Yeah. But it's not. It's not related to this I don't know.

Respondent 46

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It was pretty good. I just think sometimes hard to push some of the buttons, but besides that pretty flow, I like things when I can basically click like anywhere on the screen where I think it is. Then you can move forward but otherwise pretty good. I like the products on offer. High quality photos were easy to understand, good descriptions. So pretty good experience overall.

Interviewer: OK. How are your eyes? Feeling after interacting with the mobile app.

Speaker 2: To be honest, slightly strained. It's like the top of my eyes. Like if I like the top of my eyes, feel slightly strained, like eyelids were a little bit heavier, but besides that it's pretty good, but I feel like now if I look at other objects. It feels a little bit harder, but yeah.

Interviewer: OK. How would you? Improve the visual stimuli on the mobile app to enhance a user's experience.

Speaker 2: So, I would say I think maybe the reason my eyes are so strange is because I'm used to everything being dark mode like I programmed in dark mode. My phones in dog mode but locks in dark mode. So, I think the blaring white of the app. I think that's maybe what's making my eyes feel. And maybe also you have only things that in colour only things that are needed should be in colour based. Everything else should be like dark basically and that helps you people have less strain on their eyes basically because you're focusing on what's important. So, at the moment being all white eyes kind of there's a lot of light in my eyes. I would assume.

Speaker: OK, cool.

Interviewer: And that's it.

Respondent 47

Interviewer: So How would you explain the mobile application you experienced?

Speaker 1: So I call it like a furniture store, online furniture store, but like limited an option. So there's only chairs and tables and lamps, and there's not a lot to choose from, but like. The ones that I did view, I really did like.

Interviewer: OK, cool. How are your eyes feeling after interacting with the mobile app? Speaker: I don't feel anything. Well, like I don't feel any. Different.

Interviewer: OK, cool. How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker: I think you should be able to press on things like pressing the arrow like if you just pressed on the bar it says chairs on it. Then it should take you to chair. Is that OK?

Interviewer: Cool. Yeah.

Respondent 48

Interviewer: How would you explain the mobile application you experience?

Speaker 2: So, I'll describe it as a mobile online shopping platform that specializes like in furniture and maybe like home decor because it's also lamps and stuff like that. But yeah.

Interviewer: OK, OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: I don't think there was like a major. Difference like I didn't feel any. Maybe eye strain today and or like tiredness. It's just like just specifically about my eyes feel I think it is also like.

Interviewer: Yeah, after interacting with the mobile app.

Speaker 2: Visually, everything was quite like simple, like it wasn't really maybe picture heavy maybe or like text heavy, so it was like easy on the eyes. And I feel like maybe even this green colour. It's like calming almost. I don't know. Like really. It gives off, it's like peaceful kind of energy, I guess.

Interviewer: So how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker: Hmm. So, does that mean like? If I would like add any features or stuff like that.

Interviewer: Like Icons, colour, pictures, anything maybe like that.

Speaker 2: I think maybe like for people, if it's like a dark mode and a light mode like sometimes they can help them choose like what kind of visual experience they want. And I think maybe. I don't know this is now just limited to experiment, but if there was like. More categories maybe or like more range within like the categories, I think. And then I would say like when it's on the product description, if there was maybe different like angles of the picture or maybe like close-ups or something like that. I feel like I didn't actually check now, but I'm not sure. It's like a description of the product was like OK then that's fine.

Interviewer: There's like a short (description)

Speaker 2: And then maybe there's like other views, I don't know if. There were existing. Reviews like already, I think maybe that can also help with some like furniture, that's like a. Big. Like investment, I think for someone so. But yeah, I think those that's what I would suggest.

Interviewer: Thank you.

Respondent 49

Interviewer: How would you explain the mobile application you experience?

Speaker 1: This mobile application I would say it's nicely laid out, the categories are clear, but I don't like the fact that when I click on a product, it instantly goes to the use the keyboard and then says write something. I don't like that.

Interviewer: Yes.

Speaker 1: And also, I would like it would be nice to have more pictures than just one. So yeah, otherwise I like that it's not too much in your in. My face and all of that, OK.

Interviewer: How are your eyes feeling after interacting? With the mobile app.

Speaker 1: UM. They feel OK, not like before, when I came in here, it's like. I feel like the by the end of this, they're probably going to be watery or as soon as I get out of the of this place. So yeah.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I would. Create an option to like decrease the brightness like maybe like a darker colour because I'm quite sensitive to bright colours like this. So yeah, like this green to match like that dark green over there on the search bar to match the whole thing. So yeah, OK, cool. OK.

Interviewer: OK.

Respondent 50

Interviewer: How would you explain the mobile application you experience?

Speaker: I'd say it's a furniture store, fairly craft or indie. I think they've done the limited selection, high quality sort of trade off. Interestingly, they didn't sort of link the items by sort of overarching them, but yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile?

Speaker: It's a bit brighter than I'm used to, and my normal glasses have a blue light filter and also on my phone I enable the blue light filter and generally turn the brightest brightness down and also my

phone is on the settings so that it's on night settings so all my screens instead of being white. A dark, yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker: I think that you go with. Darker colours as your background or on the bits that were white, I'd probably have as more neutral, so probably dark grey because that doesn't really bias people in terms of the colours and what else would be useful when you click on the. Item it shows an enlarged version of the item, not just. The option to add to cart, yeah.

Respondent 51

Interviewer: So how would you explain the mobile application you experienced?

Speaker 2: In terms of aesthetics?

Interviewer: Yeah. Aesthetic and the layout, how you experienced it, things like that.

Speaker 2: Well, I think it's very simple and easy to read, which is cool, but I think there was the old items had the same style. So, I didn't really find something that I actually like, because they all felt like they're in the same kind of like range, but otherwise I like the fonts that were chosen. It like some of them pop, which is cool. It makes them different from each other. And yeah, and it's very simple to use. Which is cool and I like the colours. They feel very like internal decor like the green. It's mellow and stuff and the brown is also good.

Interviewer: How is your eyes feeling after interacting with the mobile app?

Speaker 2: Because the colours weren't that bright, it was not so bad. I feel like if there was, like, red, yellow and very bright colours, it would be tough for my eyes. But these colours were quite mellow, and they're fine, but the screen brightness was actually not too bad. Yeah.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Improve the?

Interviewer: Visual stimuli.

Speaker 2: What is that?

Interviewer: Like the colours, the icons, buttons anything you can like see, kind of.

Speaker 2: Improve them to be more?

Interviewer: And to enhance the user's experience.

Speaker 2: I think the scrolling was taken away from like so. If for example the items were Like next to each other and not have to scroll because there it's only three items and I still have to like scroll to see if it was just like next to each other that would be easier. UM and then? That's really about it. Everything else, I think it's simple and easy to use, which is the most important thing.

Interviewer: ok cool

Respondent 52

Interviewer: Cool. How would you explain the mobile application you experience?

Speaker 2: It was actually. It was a decent app to use. It was quite easy; it was quite accessible to figure out what to do and what not to do. And I think adding things to cart, also wasn't too difficult.

Interviewer: OK, cool. How are your eyes? Feeling up to interacting with the mobile app.

Speaker 2: Actually, wasn't so bad, I think, because everything was quite structured and strategic and there wasn't, like you didn't have to click so many things to find one specific. I mean it my eyes weren't straightened, no.

Interviewer: OK, cool. How would you explain the visual stimuli on the mobile? Sorry. How would you improve the visual stimuli on the mobile to enhance the users experience?

Speaker 2: I actually don't think there is much to be improved. I think that like colours were quite subtle, it wasn't something that was too bright, whereas a lot of apps are like. Either super dark or super bright, so I think that was a pretty it was kind of neutral, so it wasn't too bad for people to also pick up. On reading a lot of people. Have like difficulty with reading it. If it's too dark or if it's a specific colour, but I think because it was also white and it had the like green bits on it so it wasn't too. Too bright of a colour, too difficult to actually read or interpret what was what you were trying to. Figure out on the app I'm trying to think of the right answer.

Interviewer: OK, that's all.

Respondent 52

Interviewer: Cool. How would you explain the mobile application you experience?

Speaker 2: It was actually, it was a decent app to use. It was quite easy; it was quite accessible to figure out what to do and what not to do. And I adding things to cart. Also. Wasn't too difficult.

Interviewer: OK, cool. How are your eyes? Feeling up to interacting with the mobile app.

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Interviewer: OK, that's all.

Respondent 53

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 1: It is a furniture app and has options between lamps, tables and chairs. And as. A few options each and. Unfortunately, I chose an outdoor table for an indoor space.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: They feel fine is. Slight strain, but not too bad, I think. Compared to before I started. It's not too much of A change.

Interviewer: OK. How would you improve the visual stimuli on the? Mobile app to enhance a user's experience.

Speaker 1: Uhm, I think. I think the calendar so like I think the it's very bright and. Perhaps the darker palette, or maybe a change in colours like from the green to? Something. Else, otherwise it should be.

Interviewer: OK.

Respondent 54

Interviewer: How would you explain the mobile application you experience?

Speaker 2: I thought the app was quite nice. The functionality of the the back button wasn't great, but apart from that my thing was quite nice. It's quite clean.

Speaker: OK, cool.

Interviewer: How are your eyes feeling after interacting? With the mobile app.

Speaker 2: They feel fine how I normally feel after using most of my mobile apps.

Interviewer: Cool. How would you improve the visual stimuli on the mobile app to enhance a user's?

Speaker 2: There was a lot of whites and I think most of the time when I do my online shopping it is at night, so I think the white wood hurts a little bit more. So maybe slightly tone like more muted colours might help. And then maybe just some of the buttons could be made a little bit brighter, so it's easier to spot, OK, this is the bin and the profile and home because that's right above the other one for the phone. So, it makes it. Hard to distinguish.

Interviewer: OK, cool.

Speaker: Cool.

Respondent 55

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Well, it's quite simple and easy to use. It's quite quick and responsive if you're not waiting for things to load. Yeah, I would give you the. Good review. It's quite easy to understand and easy to use and the like. The filters and categories are quite like easy to get to as well.

Interviewer: How are your eyes feeling after interacting with the mobile app?

Speaker 2: Fine.

Interviewer: OK. Yeah. How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: As in like the?

Interviewer: So yeah, all the visual stimuli is like pictures, the icons.

Speaker 2: Products and stuff that. I think I'd make it like more colourful. Maybe the font could be a little bit bigger. Yeah, just make it a little bit more colourful and. Yeah, like the icons could maybe be coloured instead of keeping it Gray. Yeah. And maybe use like colour blind friendly colours at the same time.

Interviewer: Ok

Respondent 56

Speaker 1: OK. Yeah. OK, cool.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: It's very urm, well organised and like clean. If that's a good word to use, like very simple and easy to find everything. And yeah, and. Think it's also easy to read everything? I think the only thing that was a little bit irritating was the keyboard popping up. Yeah, but that's fine because I mean it happens sometimes, but you could still see everything even with the keyboard up. So that's actually perfectly fine. And I like the use of the different pictures. You can clearly see like the products as well with their like little descriptions and the price and all of that. So that was overall fairly easy to use. And yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: I feel fine. I have my eyes are a little bit sore but I don't know if that's also just because it's been a long day, but I do sometimes get like headaches, like right above my eyes so it does sometimes feel a little bit uncomfortable, but I'm feeling that now. But like I said, it might just be. Because it is late in the day, yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: What would you say for visual stimuli?

Interviewer: The buttons, the colour, urm text.

Speaker 2: Ohh I see OK. I think I like the like smoothness of everything like it's very like welcoming and like I said clean, I think. The only thing that would have been nice that I could say is that, you know, like when you have the the items listed under like couches or whatever. If you could have like the prices there. So, it's like quick and easy to like compare the prices. If you were going to buy it, maybe then you would want to, if you're looking for a cheaper option or something like that. I'm just thinking of when I've bought furniture in the past and then it's like you're comparing like ohh I like this look, but maybe it's more expensive than something else. So, to quickly compare prices would be nice. I like the colours. I think they're like very warm, which is which I like warm colours. So, I don't know, maybe I'm biased. Trying to think what else would be nice. Yeah. No, I think everything was fine. I think the only thing I wished was be able to compare the prices because I did go back and check that. For myself, yeah.

Interviewer: OK, cool.

Respondent 57

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It was cool. I thought, I like the colours. Think you should add more colours on the like the. The main page, but by the profile I like the colours there. Yeah, usually I feel I felt like I looked. At the pictures more.

Interviewer: OK. How are your eyes feeling after interacting? With the mobile.

Speaker 2: Feel fine.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance? A users experience.

Speaker 2: Like I have more colours, let's say, but that's just my preference.

Interviewer: Ok. Anything else?

Speaker 2: No.

Respondent 58

Interviewer: So how would you explain the mobile application you experienced?

Speaker 2: It was OK. UM. Yeah, it's OK. It's easy to use the phone made. It hard to click some of the buttons but it's fine.

Interviewer: OK. And how your eyes feeling after interacting with the mobile app?

Speaker 2: OK, doesn't feel different.

Interviewer: Yeah. OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I would have all the font to be the same. Because some of the descriptions were different from the font, should all be the same and then I would not add the option to add review and then also somehow not have that keyboard there every time you because that's also annoying. But other than that. It was OK. It's pretty easy to use.

Interviewer: Yeah.

Respondent 59

Interviewer: OK. How would you explain the mobile application you experienced? Experience.

Speaker 1: I think it was, it's fine, but the issue is maybe if we put it in dark mode it will be far much better. Yeah, but I think you know the usability and user interface. It's seemed point straight to the point there. You can easily find what you what you want.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: Eyes are feeling OK? Yeah, they're not feeling strained or watery. They're feeling fine.

Interviewer: OK, cool. And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: So probably maybe I would make it at home page. People would also include like images other including those icons. I think it will be more catchy if I use like proper images, not just like icons, yeah.

Respondent 60

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: It was rather bland from what I'm used to. Not a lot going on. I'm used to having a lot more. It kind of felt boring in a sense. There wasn't much to it. With technology, technological advancements, you know, expecting maybe more stuff on the back end, yeah.

Interviewer: OK. How your eyes feeling up interacting with the mobile app?

Speaker 2: OK, I did have a late night yesterday so. It was quite strenuous. But maybe that's just my eyes. Yeah, yeah.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: Umm. Maybe having things with the choice of colour is definitely, I think, on the application. The green is rather dull and it makes you feel tired as well. The choice of brown, I mean they're all complementary colours, but the scheme has, or even the description of the item. It doesn't stand out, so it's difficult to read. The price is small, which is the main thing that I'm looking for is the price. Yeah, even the pictures, the background, having a plain white background on a green. Backdrop isn't enticing overall improved colours maybe go for more vibrant colours, bold things, more like the prize that should be much bigger. Dear.

Interviewer: OK, cool.

Respondent 61

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: I quite liked it, but there are a couple of bugs like little things that were annoying, like when you selected something then it immediately went to leave a review, which was pretty annoying. And also, when you wanted to select. Like either the chairs or the tables or whatever, you just click on the like tiny arrow instead of just like the whole would have been easier as the whole. Box could have been clicked on. And. Also, the descriptions, there's no like dimensions, so I don't know how big my hypothetical coffee table is going to be. Yeah, that's.

Interviewer: Mm-hmm. How are your eyes feeling of the interacting with the mobile app?

Speaker 2: Feels fine.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think maybe the text could be a little bit larger, especially in the descriptions. Yeah, I didn't try. Can you like? Yeah, maybe if you could also just like zoom pretty much and any at any stage could be better. And I quite like when you have like if you click a picture then instead of like zooming in, you just like scroll through different magnifications of the picture. I prefer that. Yeah.

Respondent 62

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: How would I explain it? It seemed to be a home decor online shopping app.

Interviewer: OK, cool. How your eyes feeling after interacting with the mobile app?

Speaker 2: Actually, a little bit itchy. I would say fatigued.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think for me. The white background was it. It's a bit glaring, but also every time you go into a category and the text box pops up, I think like minimizing it all the time increased like the fatigue of using the app. Yeah, cool.

Respondent 63

Interviewer: OK. So how would you explain the mobile application you experienced?

Speaker 2: It was easy, bright. I like that there was a certain theme, like the colour green. Yeah, there wasn't like, much options, but just still good variety.

Interviewer: OK. How are your eyes feeling after interacting with the mobile application?

Speaker 2: Feels OK and I think now just because my head is sore it's a bit like you know, but other than that it's OK, just a lot going on like with the scrolling up and down. But I think that's. Usual, so yeah.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker: Improve it?

Interviewer: Would you add anything or take anything away? Colour, icon, images, buttons?

Speaker 2: Like does the keyboard always come up on like every phone or like is it just?

Interviewer: It's just for this app, I think.

Speaker 2: OK. Then maybe take away the automatic keyboard that comes up cause having to like, you know, yeah.

Interviewer: Yeah. Yeah.

Speaker 2: Yeah. Is maybe more like options like categories in a household? I don't think there's just like lamps, chairs and tables that's in it and also more variety of couches and more variety of lamps and tables to choose from.

Interviewer: Yeah. OK, cool.

Speaker 2: Yeah. OK.

Respondent 64

Interviewer: So how would you explain the mobile application you experienced?

Speaker 2: I thought it was quite fun. It was quite easy to use quite self-explanative like everything was like there. So you just had to read like the labels are quite the names is quite easy and like you could just see chairs, tables, lights. You could find everything easily. Yeah.

Interviewer: Ok cool and how your eyes feeling after interacting with the mobile app?

Speaker 2: They feel normal.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Maybe more colours cause it's mainly just white. And maybe some different fonts and maybe slightly bigger fonts. Yeah, maybe some more visual things. Like pictures, fonts, words. Yeah.

Interviewer: Yeah, yeah. OK, cool.

END APP 2

START APP 3

Respondent 65

Interviewer: All right. So how would you explain the mobile application you experienced?

Speaker 1: It's a shopping application that lets you buy furniture. And Yep.

Interviewer: OK, cool. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: Everything is fine. Yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: urm like what?

Interviewer: So, like buttons, colour, text, icons, images, anything. What would you change?

Speaker 1: Well, so the text is text is. Good. The contrast is sufficient. Maybe would make it a little bit bigger. Let me think. And. Yeah, the buttons. I think the buttons it just requires some familiarity with how they normally work. But yeah, that's fine. I think I noticed that the writer review had white text like a brown background. I could see that fine, but I'm not sure if that. Would be an issue for some other people.

Interviewer: All right, cool.

Respondent 66

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: It was pretty simple, pretty easy to use.

Interviewer: OK. How your eyes feeling after interacting with the mobile app?

Speaker 2: They feel alright, like I don't like they don't really strain or anything like that.

Interviewer: How would you improve the visual stimuli of the mobile apps to enhance the users experience?

Speaker 2: I don't know, no. I'm good. Nothing to add.

Respondent 67

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: I would say that it had a simple interface, but it was really easy to use and I didn't feel overwhelmed because sometimes mobile applications can feel like they're bombarding you every second with like another product or an ad or something.

Interviewer: How are your eyes feeling after interacting with the mobile app?

Speaker 2: Eyes are actually fine because it's like this light green colour and I don't have perfect vision so my eyes can get easily strained. But I was OK with this.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Maybe more than one accent colour, because right now it's just green, so maybe different colours can like draw attention to different places. If you need to. So for example, if I wasn't looking at the pictures on the sides, then I would have to look at the writing which is small. But something like coordinating colours by like bedroom or kitchen and stuff. Like that, OK.

Interviewer: Cool.

Respondent 68

Speaker: OK.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: It was very simple to use. Not too distracting and I think it got all the points across that it needed to quite effectively.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: UM. No, like really no effect on my eyes.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I wouldn't change much, to be honest. I think the colours are not too bright and distracting and that helps quite a bit too maintain my attention.

Respondent 69

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 2: In terms of using (the app)?

Interviewer: Yeah.

Speaker 2: It was easy to use. The visuals were the same, so it wasn't like I wasn't getting distracted. And. Yeah. I don't know.

Interviewer: No, that's fine. How are your eyes feeling after interacting with the mobile app?

Speaker 2: I was. I was straining them quite a lot just to try to stay on the screen, but they feel, they feel fine. They feel good.

Interviewer: All right. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Change. Maybe make it a darker colour and in it not, not green.

Interviewer: OK, cool.

Respondent 70

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: There was a furniture shopping app. There was 3 categories, lamps, tables and chairs and there were four options in each and in each option you could add it to cart. Or leave a review or add delivery instruction.

Interviewer: Cool. How your eye feeling after interacting with the mobile app?

Speaker 1: Quite strained looking at it for quite a while, but they were a bit strained before since looking at my computer.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I would maybe do a darker, dark mode and more pictures for each thing.

Interviewer: OK, cool. Thank you.

Respondent 71

Speaker 1: Cool.

Interviewer: How would you explain the mobile application you experience?

Speaker 1: Just interesting a little glitchy, but yeah, I found it interesting.

Interviewer: OK. How are your eyes feeling after interacting with mobile app?

Speaker 1: Urm Neutral. I have no problem.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I think there were a lot of things popping up at the. Same time which. That was like. Yeah. Overwhelming on the eyes, but everything else was fine.

Respondent 72

Speaker: Again.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: Simple like it's easy to look at everything and it wasn't over complicated.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 2: And why is it perfectly fun? Not really good.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2

I think just. Dimming the white a bit down because it is a bit bright, but yeah, other than that I think it's pretty nice.

Interviewer: OK, cool.

Respondent 73

Speaker 1: OK.

Interviewer: How would you explain the mobile application you experience?

Speaker 1: I didn't like that every time I. Opened it went straight to the reviews. But other than that, I thought it was really simplistic. So, I like that like in the pictures right next to the name. It's really big.

Interviewer: OK, cool. How are your eyes feeling after interacting? With the mobile app.

Speaker 1: A bit strained.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: Umm. I think I might have made the font a bit bigger for the names of the thingy and for the price make it also a bit more bold. Because I felt like the font was quite thin and yeah.

Interviewer: OK, cool. Thank you.

Respondent 74

Interviewer: How do you explain the mobile application you experienced?

Speaker 2: Uh. Wasn't that great? Like it was a bit irritating that I couldn't click on it like and I had to click on the arrow and then like that arrow at the top to like go back was a bit small. So yeah.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Fine. I think maybe like slightly strained.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Hmm. Maybe like instead of having the images or like the products in like a straight list, kind of like fashion, maybe making more of like a? Like a gallery kind of thing, like three in a row or something like that, like.

Respondent 75

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 1: I think it's very simple. It was easy to navigate. It wasn't very complex, it was straightforward and I liked the simplistic look behind it like it was very, very visually appealing because it was to the point for me. So

Interviewer: OK, cool. How your eyes feeling after interacting with the mobile application?

Speaker 1: Not too bad because it wasn't over stimulating. Like I said it, it was simple to the point in terms of its format. So, I like. I didn't feel like I was straining my eyes to figure things out.

Interviewer: Cool. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: How would I improve? Honestly, I feel like I don't have any anything to say. I feel like this is my kind of app simple to the point. So Yeah.

Interviewer: OK.

Respondent 76

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It was good, easy to use.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Yeah, they feel fine.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Sorry, can you repeat that?

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience? So, like the colour, icons, text, things like.

Speaker 2: I would leave it as is. I think the colour, the nice light green is good and yeah, you can see all the layouts. So, it's easy to use.

Interviewer: OK, that's cool.

Respondent 77

Interviewer: How would you explain the mobile application you experience?

Speaker 2: The app was easy to use, like the categories were like defined lamp chair. It was simple, easy and I could add to cart really nice and like the review was right there and so everything was quite simple and. Not too straining. Yeah, it was like good. I think. Yeah, maybe. One thing I would add is maybe like in categories like as you click on it, it pops up down. Thing comes up so that you can see everything still on one page. It's like the bigger picture but yeah, but I actually do enjoy this because it's easy to use. It's like a normal like. Superbalist you know?

Interviewer: And how your eyes feeling after interacting with the mobile app?

Speaker 2: My eyes actually feeling OK. For yeah, because I enjoy like seeing the app that you made and the things that you put in. Yeah, mine is OK for now.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: And what do you, what do you mean? Like, how do I improve?

Interviewer: So what would you change about the visual stimuli like the icon, colour, text?

Speaker 2: oh, Maybe like animation wise you want to like you know when you play some.

Interviewer: Yeah anything.

Speaker 2: You know when you press something (a button) it goes tudalu (sound) And then it makes the sound effects and then it does the thank you for buying (animation).

Interviewer: OK.

Speaker 2

Or you put a pop up that says “Are you sure you want to buy this?” and people will be like, OK, they, they don't want to see my money and like immediately because some apps are like that. Because they just like you, press it and then it's like oh, oh, no. And also make it simple for people to reach out. And if they made a mistake or something, didn't go right, like be accessible. I mean the colours I think are nice. I like the colour personally the sage and the brown. The brown. I like the aesthetic and maybe more options at the bottom because I see these three. But if people want to like comment to like they want to do something else and more options would be nice to put in at the bottom, yeah.

Interviewer: Thank you.

Respondent 78

Speaker 1: OK, cool.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: I think it's quite easy to use, simple to navigate through the different options.

Interviewer: Ok, cool. How are your eyes feeling after interacting with the mobile application.

Speaker 1: Same as before, normal.

Interviewer: Cool. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: Well, I think the colours are quite attractive. It's easy on the eye, the text is quite clear. If I were to say one particular thing to improve...

Interviewer: You can zoom. You can scroll by the side if you want scroll on.

Speaker 1: The green. Yeah. Ohh. OK. Well, I think perhaps that could be the only aspect that would change the scrolling the scrolling feature.

Interviewer: OK.

Respondent 79

Speaker: Cool.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: How do I explain it? It was quite straightforward. There wasn't very complicated ... like easy to follow. OK, cool. Yeah, simple.

Interviewer: OK, cool. How are your eyes feeling after interacting with the mobile app?

Speaker 2: Hmm. To be honest I I've been working the entire morning so my eyes are a little like ... (tired) and usually I do actually wear glasses, which I didn't wear now. Mm-hmm. So, my, my, they wouldn't say they feel extremely tired, but they definitely feel like. They've been at work

Interviewer: Ok. And how would you improve the? Visual stimuli on the mobile app to enhance a user's experience.

Speaker 2: I mean, for me personally, I always make my font very big. Just and people think I'm ridiculous, but that that helps me. Maybe. I don't know. Yeah. Make it like black and white. Maybe not a colour. Yeah.

Interviewer: Cool.

Respondent 80

Interviewer: Explain the mobile application you experienced.

Speaker 1: Quite simple, straightforward. I think it was difficult to press buttons, but I think that might because my fingers. However yeah it was, it was. I think keyword is simple. Yeah, not too busy.

Interviewer: OK, cool. How are your eyes feeling after interacting with the mobile?

Speaker 1: My right eye. There's a little. Just a little like a tiny bit more. Yeah, strained.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: Hmm, that's a good question. May I press till I see something (interacting with mobile app)?

Interviewer: Yeah.

Speaker 1: I think the. White background's nice, during nights they will need they will. There will need to be like a dark mode just to decrease the amount of light shooting in my eyes. But is there a reason why there's like a gradient with regards to the change of lighter colours, the darker colours? Maybe a bit more consistency there, however. I don't want to say the font could be bigger cause then that's giving me like old man vibes. You know, I don't want to say I'm like that old, but. Like, yeah.

Respondent 81

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: So, it's an e-commerce site for furniture. I'm not really sure what to say beyond that, I guess like.

Interviewer: OK. How are your eyes feeling after interacting with the mobile app?

Speaker 1: Same as before, not really noticing any major discomfort or anything like that.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I guess maybe like brighter colours, more effects, things like that, but Other than that I think it's pretty cool, yeah.

Interviewer: OK, cool.

Respondent 82

Interviewer: OK. How would you explain the mobile application you experienced?

Speaker 1: Pretty simple and intuitive, didn't really struggle looking for the stuff. It's in your face so.

Interviewer: And how are your eyes feeling after interacting with the mobile application?

Speaker 1: I'm pretty good. Can't complain.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1

UM I would say. The visual stuff. probably, right? OK, let's say. Maybe. Brighter colours. Because the green is a bit bland. More pictures of the product so that people get a better sense of what they're actually buying. And. Yeah, I think that's pretty much it for me. Yeah. And then obviously easily readable reviews of products. Yeah, that's a bit clear because people want to know what? Other people think.

Interviewer: Yeah. OK, cool. All right.

Respondent 83

Speaker: OK.

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: What?

Interviewer: The mobile application you experienced. How would you explain it?

Speaker 2: It wasn't actually difficult, but yeah, it was. Yeah, it was fine. OK, yeah.

Interviewer: Ok. And how are your eyes feeling after interacting with the mobile app?

Speaker 2: Not bad because I came here where the sun had actually, the sun has actually affected them already and my glasses are not that dim. OK, yeah.

Interviewer: OK. And then how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think it's fine. Yeah, it's actually I think everything is fine, yeah.

Respondent 84

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It's effective in that everything is laid out very clearly and there are pictures, so you know exactly what you're getting and the interface like the how to find things via the arrows. Very clear, but I would say that it's quite tedious to go back and forth via the back button, whereas there could be suggestions for other purchases if you scroll rather than going back.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile application?

Speaker 2: They're feeling normal. No strain, no tiredness. My focus, went blurry at some points. But that was the constant moving across the street across the screen, which can be solved by the back button and the scrolling function.

Interviewer: Yeah, yeah. OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: What I previously mentioned, so the back button so rather the back button. You could rather introduce a scrolling function so make it more friendly in that the eye can have continuous movement rather than discrete movement or where it's moving back and forth and then those are open with the focus of your eyes. And also just the interface of the app will improve that way.

Interviewer: Cool. Yes.

Respondent 85

Interviewer: So how would you explain the mobile application you experienced?

Speaker 2: Basic, glitchy. Yeah, basically like basic and like a good like, it's simple, but it's just, yeah, it's just the end. When you place on the on the product and then obviously the review part always pops up, yeah.

Interviewer: OK.

Speaker: yeah.

Interviewer: And how are your eyes feeling after interacting with the mobile app?

Speaker 2: I think actually, more aware than that like than when I yeah more focused than when I began, yeah.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I think the colour I think with the products where you view the products or you view the different categories, I wouldn't have the gradient because I think I know it just throws like a gradient going from light-to-light green to darker. I mean, I just have simple colours even though the app itself was simple, but the colours also need to be correspondent. With that, it doesn't happen too many colours or complicated colours. Sometimes they can work, but it's a shopping site, not a media site, yeah.

Respondent 86

Interviewer: Cool. How would you explain the mobile application you experienced?

Speaker 1: What do you mean?

Interviewer: So how would you explain the app?

Speaker 1: I think it's an e-commerce application which you can use to buy some stuff. Some of the things, yeah, they quite, easy to understand and to use. I think it goes along with how most of the applications work these days, yeah.

Interviewer: OK, cool. How are your eyes feeling after interacting? With the mobile.

Speaker 1: Quite normal, I think. I was on my laptop for last three hours, so yeah. Yeah.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 1: Oh well, the colours and lighting is great from the application. Umm. I think, yeah, they're quite studded as well. They pull you to it. Just some of the buttons that don't really seem to be like if I could click that and then open sort of actually having to kick the arrow or something, that was something. That was. But on the UI side, I think it looks good. Thank you.

Respondent 87

Interviewer: OK, cool. So how would you explain the mobile application you experience?

Speaker 2: What do you mean by that? Like in terms of my experience or OK, it was good. I guess, I think.

Interviewer: Yeah, of the app.

Speaker 2: It was good, I guess. No, I'm just disappointed about the lack of couches. But besides that, it's good. It's easy, it's simple and it's all well categorized so.

Interviewer: OK, cool.

Interviewer: How are your eyes feeling after interacting with the mobile application?

Speaker 2: Slightly strained, I think. But I'm not sure if that is because I was sweating or not. I think a bit from a bit more from the trying to focus.

Interviewer: OK, cool. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: I'd say. Maybe including the prices in the main category like section where the lamps were split out for example, but besides that it's pretty good thing.

Interviewer: Yes. OK, cool.

Respondent 88

Speaker 1: Very cool.

Interviewer: Cool. How would you explain the mobile application you experienced?

Speaker 1: Very easy to navigate, wasn't too difficult. I knew exactly what was being displayed to me. All the details were quite visible. Yeah and no. No complaints.

Interviewer: Yeah, OK, cool. How are your eyes feeling after interacting with the mobile app?

Speaker 1: Not much of a difference. I think it's because I've always. I'm always on mobile apps and I feel like my eyes have been accustomed to it, so I don't really feel much of a difference so yeah.

Interviewer: And how would you improve the visual stimuli on the mobile apps to improve a user's experience?

Speaker 1: I think maybe. You know, when you go into the actual item. Sometimes it's difficult. I don't know. I really, I don't really like the fact that you have to scroll up like this. OK, so maybe there was like a way in which, like when you enter, you can see the actual image. You can see everything. Yeah. So instead of like having to scroll like this, I don't know. I just don't really like that. A lot of apps have that so. If you could do that, which I feel like is an easy fix, yeah. And then. Ah, what else could I say?

Interviewer: Anything about like the colour, the icons, the text.

Speaker 1: A lot of green, lot of green. I don't know. I feel like that's just stupid thing to say, but yeah, maybe like a different colour. Maybe like, you know, but I guess, you know, maybe this is specific to

the branding of like. Yeah (the company), but nothing. What else? Maybe the front can be like bolder, yeah.

Interviewer: OK.

Speaker 1: Because it doesn't seem like it's like, you know, it's not like screaming lamps. You know, it's like lamps. OK.

Respondent 89

Interviewer: Cool, cool. How would you explain the mobile application you experienced?

Speaker 2: This this little. OK, it was very user friendly, didn't overwhelm me with too much information and I liked how there was a picture for everything because I think I look at pictures 1st and really like reading the details. So, I liked how that was quite visible.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile application?

Speaker 2: Good. They don't feel sore or anything. Didn't put any pressure on my head because I usually get headaches. So, it was good.

Interviewer: And how would you improve the visuals on the mobile app to enhance a user's experience?

Speaker 2: Experience for me, maybe just a bit more colour and more things like bolded because I usually gravitate towards things that like stand out. So yeah.

Interviewer: Awesome, Yeah.

Respondent 90

Speaker 1: OK.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: I would say it's very simplistic. It's very minimalist so it makes the user interface is very easy to navigate. And it's just nice and calm colours.

Interviewer: Cool. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: They're OK, a little. It's just a little bit hazy, but that's what I said. So umm. Yeah, I feel OK. My eyes are fine.

Interviewer: OK. And finally, how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: How would I improve?

Interviewer: The visual stimulus is like the colour, the text, the buttons, icons, anything like that.

Speaker 1: OK. I think maybe some of the text could be a little bolder. And. Maybe like arrows like in the main menu. The arrows maybe like a little bit larger. OK, because I don't know. But that's I think that's a personal thing. It just didn't look as obvious. But yeah, just all the text. I think OK.

Interviewer: Cool.

Respondent 91

Interviewer: I'm just going to put it. Yes, OK. Can you hear you? OK. How would you explain the mobile application you experienced?

Speaker 2

I think the interface was. Not good enough. It was quite difficult to navigate because the scroll bars are only accessible specific points. Also, you had to click a specific point to access a certain option, which is quite annoying.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile application?

Speaker 2: We're all quite tired because you have to look at exactly the specific point to click on and also a specific point to scroll on. And because there is no visible scroll bar. So, you actually have to the hand eye coordination.

Interviewer: Yeah, yeah. OK.

Interviewer: And how would you improve the visuals to rely on the mobile app to enhance users experience?

Speaker 2: Sorry, please repeat the question.

Interviewer: How would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: So, if I was programming the app. I think I would first of all have an actual scrollbar, right? So, to help scroll up and down helps. So yeah navigation and. Hmm. I'd also make the touch points. So, for example, if I want to access the option touch points quite larger because then you don't have to look at concentrated point to click on something.

Interviewer: OK, cool.

Respondent 92

Interviewer: So how would you explain the mobile application you experienced?

Speaker 2: The mobile application. It's navigable, you can like... it's easy to navigate.

Speaker: Hmm.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 2: My eyes. My eyes are feeling fine, normal.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 2: Visual stimuli?

Interviewer: Yeah. So, like buttons, colour icons, text, layout, anything like that?

Speaker 2: I think. From my experience, I feel. Like this is good for me, yeah. Very cool.

Respondent 93

Speaker: OK.

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: The mobile application is nice, yeah.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile app?

Speaker 1: There was a bit of discomfort? Yeah, and a little bit blurry. I would say a little bit blurry.

Interviewer: OK. And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: I think I could choose the brightness.

Interviewer: Yeah, like a dark mode?

Speaker 1: Yeah, but everything is fine. Definitely, everything is fine. Yeah. OK. Yeah.

Respondent 94

Interviewer: How would you explain the mobile application you experienced?

Speaker 1: It was quite simple. It's easy to follow and understand, like where, how to get to your cart, how to get to your product, see the price, how to review things like that. You know, I think the categories and everything is very clear. I don't really know much more, I just think it's quite a. Simple layout, it's. Not like complicated or anything.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile application?

Speaker 1: Maybe a bit dry. But I think they were feeling dry beforehand, so I wouldn't say that that's the right, the right thing. I think they feel fine. They didn't feel like necessarily tired or anything like that, didn't feel like I had to straighten my eyes or like, make an effort.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance a user's experience?

Speaker 1: In terms of like what it visually looks like?

Interviewer: yeah.

Speaker 1: Maybe make some of the writing a bit bigger in terms of like the. Product names where we highlighted prices in a different colour or like important information in a different colour. I kind of like the green. It makes it like and the like. Squaring of it makes it.

Interviewer: Yep.

Speaker 1: Like focused on that specific things, you know that all the information in there is about that thing. And I also like the colour. I think it's calming. I don't think it necessarily makes you squint. It's not harsh. What else? Can I look through it?

Interviewer: Yeah sure.

Speaker 1: I'd like change grey information on a coloured background and. I kind of like the picture of the colour background. I think the colour in comparison to white is also less harsh in your eyes. Mm-hmm.

Interviewer: Right.

Speaker 1: I like that you can view the pictures, like that as well. I think the cart makes sense to be linked. Don't know why, but. And everything is clearly laid out like the sizing of that, like you can see exactly what you're getting type of thing and the and red isn't like harsh. It's like kind of soft, subtle colour, but also makes it clear that you're going to like take it away. I think that's about it. Don't really think there's. I think the lines hope with like. Navigation. In terms of like separating your things. Yeah, cool.

Respondent 95

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: I thought it was simple and like easy to see, it wasn't too complicated. It wasn't too much stuff. The little pressing down of the arrow was a bit annoying. Yeah.

Speaker: Hmm.

Interviewer: OK. And how are your eyes feeling after interacting with the mobile application?

Speaker 2: UM. I say a little like ... not too strained, but my eyes do get a bit strained. So, like. If I blink a little, I'm like, OK, but fine wasn't looking at it for too long.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: Oh, I really liked that. It was simple, that there wasn't too much to look at. So that's like, I really thought that was good. And. I would, the arrow thing like making maybe making the little. Like it was just very small, you know, like the little. Yeah. So, like, looking at it is nice and big, but the little icons are like little small and I. Got like OK.

Speaker: Yeah, cool.

Respondent 96

Interviewer: How would you explain the mobile application you experienced?

Speaker 2: It is an e-commerce app that sells furniture.

Interviewer: And how are your eyes feeling after interacting with the mobile app?

Speaker 2: Fine. Yeah, normal.

Interviewer: And how would you improve the visual stimuli on the mobile app to enhance the users experience?

Speaker 2: I think. The. When you tap on a, a product that the keyboard doesn't immediately come up so that you make a review, maybe more description about the products and also the, that they're, the shopping cart isn't, doesn't, have an exclamation point on it if there's nothing in it.

Interviewer: OK.

Speaker 2: Yeah.