Guidelines for the User Interface Design of Electronic Medical Records in Optometry

A thesis submitted in fulfilment of the requirements for the degree of
MASTER OF COMMERCE IN INFORMATION SYSTEMS
(FACULTY OF COMMERCE)

RHODES UNIVERSITY

by

DINA NATHOO

NOVEMBER 2019

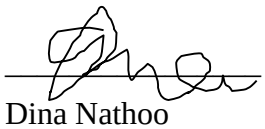
Abstract

With the prevalence of digitalisation in the medical industry, e-health systems have largely replaced the traditional paper-based recording methods. At the centre of these e-health systems are Electronic Health Records (EHRs) and Electronic Medical Records (EMRs), whose benefits significantly improve physician workflows. However, provision for user interface designs (UIDs) of these systems have been so poor that they have severely hindered physician usability, disrupted their workflows and risked patient safety. UID and usability guidelines have been provided, but have been very high level and general, mostly suitable for EHRs (which are used in general practices and hospitals). These guidelines have thus been ineffective in applicability for EMRs, which are typically used in niche medical environments. Within the niche field of Optometry, physicians experience disrupted workflows as a result of poor EMR UID and usability, of which EMR guidelines to improve these challenges are scarce. Hence, the need for this research arose, aiming to create UID guidelines for EMRs in Optometry, which will help improve the usability of the optometrists' EMR. The main research question was successfully answered to produce the set of UID Guidelines for EMRs in Optometry, which includes guidelines built upon from literature and made contextually relevant, as well as some new additions, which are more patient focused.

Design Science Research (DSR) was chosen as a suitable approach, and the phased Design Science Research Process Model (DSRPM) was used to guide this research. A literature review was conducted, including EHR and EMR, usability, UIDs, Optometry, related fields, and studies previously conducted to provide guidelines, frameworks and models. The review also included studying usability problems reported on the systems and the methods to overcome them. Task Analysis (TA) was used to observe and understand the optometrists' workflows and their interactions with their EMRs during patient appointments, also identifying EMR problem areas. To address these problems, Focus Groups (FGs) were used to brainstorm solutions in the form of EMR UID features that optometrists' required to improve their usability. From the literature review, TAs and FGs, proposed guidelines were created. The created guidelines informed the UID of an EMR prototype, which was successfully demonstrated to optometrists during Usability Testing sessions for the evaluation. Surveys were also used for the evaluation. The results proved the guidelines were successful, and were usable, effective, efficient and of good quality. A revised, final set of guidelines was then presented. Future researchers and designers may benefit from the contributions made from this research, which are both theoretical and practical.
KEYWORDS: *Electronic Medical Record; EMR; Electronic Health Record; EHR; User Interface Design; UID; Usability; Optometry.*

Declaration

I declare that the dissertation entitled, "***Guidelines for the User Interface Design of Electronic Medical Records in Optometry",*** which I hereby submit for the degree, Master Of Commerce at Rhodes University, is my own work. I also declare that this dissertation has not previously been submitted by me for a degree at this or any other tertiary institution and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



Dina Nathoo

Acknowledgements

The completion of this thesis would not have been possible without the help of so many people whose names may not all be enumerated. Their assistance is sincerely appreciated and gratefully acknowledged. However, I would like to especially express my gratitude to my supervisor, Professor Greg Foster. His unwavering faith in me, encouragement and contagious enthusiasm pushed me through this long journey, and helped shape me into a better, more mature researcher, and person. I am sorry for spamming your inbox, emailing you on the weekends about work, and for having to put up with me for so many years. You have been a remarkable mentor and role model. Thank you to my bursars, and Rhodes University for being an amazing support system and institution. The help I have received is greatly appreciated.

To my family; Mum, Dad, Trisha and Tasha- your love and support helped me through the toughest of times, and I am forever indebted. You never doubted, nor lost faith in me. This is for you guys. Trisha, your advice and guidance is forever appreciated, you are an incredible sister, truly. A special thank you to Nikeel and his family (Aunty Sandra, Uncle Ravin and Kershia), for helping me throughout this journey- I am very grateful, and thank you from the bottom of my heart. Nikeel, thank you for putting up with me over the last few years. I would not have been able to do it without you by my side. You've made each day better for me, enlightening my path every step of the way. I hope to continue this journey with you by my side. God bless you all, thank you.

Table of Contents

Contents

List of Tables

List of Figures

Chapter 1: Introduction

This chapter introduces the research study and offers a background to it via the description of the research context, as well as the problem statement and motivation for the study. The context of Optometry as a niche medical field is discussed, as well as the importance of good usability and user interface design (UID) for Electronic Health Records (EHRs) and Electronic Medical Records (EMRs). The terms EHR and EMR are also distinguished. The research questions and ancillary ones are defined, proceeding with the methodology used being described. The scope is defined and the chapter concludes with an outline of the various research chapters.

1.1 Background

With rapid advancements in societal digitalisation coupled with the increasing complexities of healthcare, there has been tremendous progress in the use of informatics and e-health technologies within the medical field. This digitalisation has driven the move from paper-recording systems to electronic medical recording systems (Edwards, et al., 2008; American Medical Association, 2018). As practice has lagged behind knowledge by at least a few years across most medical domains, decision support delivery using Information Systems (IS) with Electronic Health Records/Electronic Medical Records as the platform (Bates, et al., 2003; Edwards, et al., 2008) have been a great aid to physicians.

1.1.1 EHRs vs EMRs

Electronic Health Record (EHR) and Electronic Medical Record (EMR) are distinguishable terms that are often synonymised and used interchangeably (Garets and Davis, 2006; Kohli and Tan, 2016; Kruse, et al., 2016; CMS.gov, 2017). However, two general characteristics distinguish an EMR from an EHR (Woo and Pfeffer, 2013). Firstly, there is an emphasis on “medical” versus “health” (Garrett, 2011). EMRs copy their patients’ charts and tend to function like a “medical” repository of diagnoses and treatments. In comparison, the term “health” includes a wider perspective view of an individual’s wellness. As a result, EHRs tend to have wider functions to enable health and wellness (Edwards, et al., 2008), like "care coordination and patient engagement”. EHRs are often used in more general and holistic medical settings such as hospitals or general practices, and offer greater functions than EMRs. This is because EHRs focus on a patient’s overall health, and not just the standard clinical data, but a broader view of the care being provided (Hedges, 2019). EHRs facilitate sharing data outside the workplace/practice with other health care providers, like specialists and laboratories. Thus, EHRs record information from all the clinicians involved in the patient’s

care. Essentially, EHRs are EMRs with interoperability (i.e., it integrates with other providers' systems) (Hedges, 2019), and from EMRs joining together, EHRs may be created.

The second distinguishing characteristic is the "role of connectivity and information sharing" (Woo and Pfeffer, 2013). An EMR is a digitalised copy of a patient chart in a physicians' practice. EMR's are usually connected within the physicians' practice or across a health enterprise. However, if a patient leaves the enterprise, the electronic chart does not follow, and is confined to the enterprise electronically. Thus, EMRs are often used in specialist medical settings (such as Optometry, Radiology, or even Dentistry), as they are tailored in their designs to support the more intricate and unique workflows. In contrast, with EHRs the information follows the patient. EHRs have retrospective, concurrent and prospective health information, and overall the data is more reliable than manual records (Hayrinen, et al., 2008). It is therefore of utmost importance for the total usability of these e-health systems to be favourable and have meaningful use (Charles, et al., 2015), in order to influence and encourage their adoption by professionals especially in these technologically dominated times (Coffey, et al., 2015).

1.1.2 EMRs and Niche Medical Environments

This research realises the interchangeability used in defining EHRs and EMRs, but notes the distinction in order to focus its efforts (scope) within the niche medical environments that characteristically use EMRs; with physicians as their primary users (Garrett, 2011; Vant, 2017). More specifically for this research, the environment is Optometry and the physicians are optometrists. The niche medical environments comprise Allied Health professionals, who commonly identify as physicians or specialist doctors, such as optometrists. Physicians have a great influence on other user-groups in a medical practice, such as administrative staff and nurses, therefore having a large impact on the overall EMR adoption rates (Boonstra and Broekhuis, 2010; Castillo, et al., 2010; Garrett, 2011; Ajami and Bhageri-Tadiet, 2013; ASAHP, 2018).

1.1.3 Usability and Consequences of Poor UID

EHRs and EMRs as medical decision support tools and systems have been recognised as having significant potential for enhancing the overall quality, service and delivery of healthcare for both global populations and individuals. These EHRs and EMRs have become the replacement for the traditional paper recording methods (Bates, et al., 2003; Armijio, et al., 2009), providing

physicians with access to the latest information for diagnoses and treatments (Patel, et al., 2000). This enables connectivity and information sharing with other physicians, greater task efficiency, less risk of errors and patient harm, as well as improved decision support (Woo and Pfeffer, 2013). The benefits of these systems have, however, been overshadowed by poor usability (Ratwani, 2017; American Medical Association, 2018), and attributed to poor UIDs of EMRs, which are typically used in specialist medical fields. Specialist medical fields have unique features that translate into greater complexities for providing care. Their EMRs thus require user UIDs that are able to accommodate for physicians' unique and intricate workflows (Boonstra and Broekhuis, 2010; Wilbanks and Moss, 2018). While numerous studies have evaluated the usability of EHRs and attempted to provide guidance to improve the usability (Nielsen, 1993, Tognazzini, 2014), there is limited research that provides guidelines or recommendations on how to specifically (within a particular context/setting) improve EMR usability, and even less on how to improve UIDs.

In previous years, certification standards focused on EHR usability and often neglected the EMR evaluation, whose focus on certification standards are scarce. Guidelines for usability of EMRs in niche medical environments have also been scarce. However, software certification bodies have begun, and part of this evaluation includes the UI and its designs, reinforcing the need for this research (Jens, 2011). Efforts to address the challenges have been made by means of development of standards and directions (Nielsen, 1993, Tognazzini, 2014), literature has provided guidelines on improving the usability and UID of systems such as EHRs (Rose, et al., 2004; Zhang and Walji, 2011; Parush, et al., 2014; Payne, et al., 2015). These guidelines, however, are very general and when applied within the niche medical environments utilising EMRs, they cannot be simply transferred as a "one-size-fits-all" approach (Zheng, et al., 2009; Boonstra and Broekhuis, 2010). Unique workflows characterise niche medical fields, and thus require UIs matching the physicians' specialist workflows. Standard UID approaches may have worked well in lesser complex industries such as banking, finance, and insurance. However, the healthcare sector has diverse settings, workflows and stakeholders. General guidelines often do not undergo any systematic consensus-building process, and usually "provide general guidance that may be applied to most user interfaces (UIs)" (Reed, et al., 1999). This may be problematic for specialist EMRs. Common problems may overlap in various specialist fields, but different impacts of the adoption factors of EMRs, are reported by some studies to depend on the category of practice, setting, or attention level (Castillo, et al., 2010). Each field contains specific workflows and routines, requiring parallel supporting systems. Thus, a particular specialist medical field was chosen (Optometry), instead of all or a greater number (Smelcer, et al., 2009; Blumenthal and Tavenner, 2010; ONCHT, 2010; Wilbanks and Moss, 2018).

The UI is the "lens" through which customers make critical purchase judgements about an application (Schumacher, 2010), and may be categorised as an attribute closely linked to, and influential upon usability. Within the EMR context, poor UID may contribute towards difficult interoperability and use, causing inefficiencies and possible risks to patient safety from physician errors (Edwards, et al., 2008; Scholl, et al., 2011; Zhang and Walji, 2011). UIs need to support good usability and not present as an "obstacle" to physicians that affect their interactions and productivity (Henning, 2012). Whether electronic or paper-based, the presentation of patient information has a direct impact on clinical decision-making. When unfinished or inconsistent displays of information are combined with the variability that fundamentally exists in physician knowledge, inconsistency in clinical decisions may be anticipated (Armijo, et al., 2009). Rudimentarily designed UIs, vague tasks and poor workflows draw physicians' attention away from their patients and aggravate irritability and frustration (Schlossman and Schumacher, 2014). When EMRs are designed with conformance to the basic principles of UID, usability and user experience (UX), the advantages amassed are significant, and ultimately impact the quality of care provided to patients significantly. Ahmed et al (2011) compared the effects of two EHR UIs, and discovered that the design of the UI significantly contributed towards physicians' task loads, errors of cognition and overall performance. A further conclusion from this study was that the UIs designed for enhanced task and work flow provided significant benefits for conducting tasks and overall service delivery (Ahmed, et al., 2011).

It is important to realise that, despite the advantages often outweighing the disadvantages (Xu, et al., 2016; Wright, et al., 2017; Tutty, et al., 2019), some negative aspects such as the poor UID considerations may be so profound in their impact, that they may greatly overshadow the many benefits amassed. The safety of most medical devices is closely linked to UI quality, because design defects may lead directly or indirectly to user errors, with dire consequences that can include, but are not limited to patient injury and death. The UI has been identified as a major component of medical systems that often heavily influences the usability of EMRs, and thus supports the further need to address its design and specific guidelines for its improved use (Wiklund, 1998; Miller and Sim, 2004; Haux, 2005; WHO, 2012; McVeigh, et al., 2013; Noraziani, 2013; Wachter and Goldsmith, 2018). Rose, et al. (2004) and Roman, et al. (2017) add that to support the healthcare process and decrease medical errors, EMRs ought to support clinical workflows and have "interfaces that are easy to understand and navigate". Different physicians often need to view varying information regarding the same patient, and unfortunately, the interfaces of many EMRs do not account for these variations. Task differences ultimately feed into the challenge of designing a usable EMR (Smelcer, et al.,

2009). Additionally, EMR implementation often varies due to the inadequacy of standards even for the same vendor, and the low levels of system monitoring hinder the continual improvement processes (Luna, et al., 2017).

Figure 1.1a illustrates a UI of an EMR's "Results Manager" in a study by Rose et al. (2004). This UI displays features that considered poor to the usability and design for clinicians' use. An example is the "Alerts and Guidelines" dialogue box being poorly placed, away from clinicians' direct line of sight. This is an important component, further emphasised by the red boarders to draw clinicians' attention, and yet its poor placement failed to efficiently enable its purpose to be served. Moreover, the data fields and action buttons in the left potion of the UI appears bunched together, making it challenging to determine which objects are related. The model was redesigned (Figure 1.1b) to incorporate clinicians' desires, and better usability, thus positively influencing their use, adoption rates, and UX (Rose, et al., 2004). The "Alerts and Guidelines" component was repositioned at the top of the UI, with an accompanying icon that is frequently and consistently used on screens, and thus familiar to users, existing as a close representation to realistic metaphors (Nielsen, 1993; Shneiderman, 2004; Tognazzini, 2014). There is also better use of colour, suitable and distinct labels, appropriate groupings of features that were desired by the clinicians, and a clearer, neater presentation that enables easier navigation and use. With use of a soft coloured box, the "bunched-together' icons have been visually regrouped in relation to their actions. This redesigned UI with a suitable user, task and knowledge centric focus, contributed towards an improved usability and adoption rate (Rose, et al., 2004).

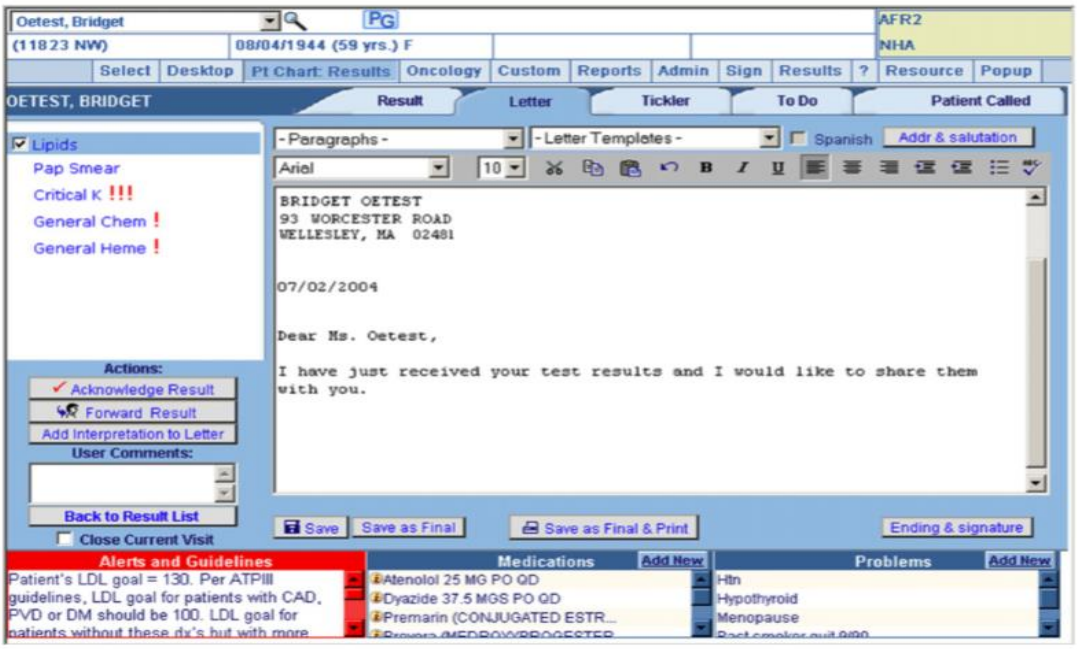


Figure 1.1a: A screenshot of an EMR's Existing Results Manager User Interface (Rose, et al., 2004)

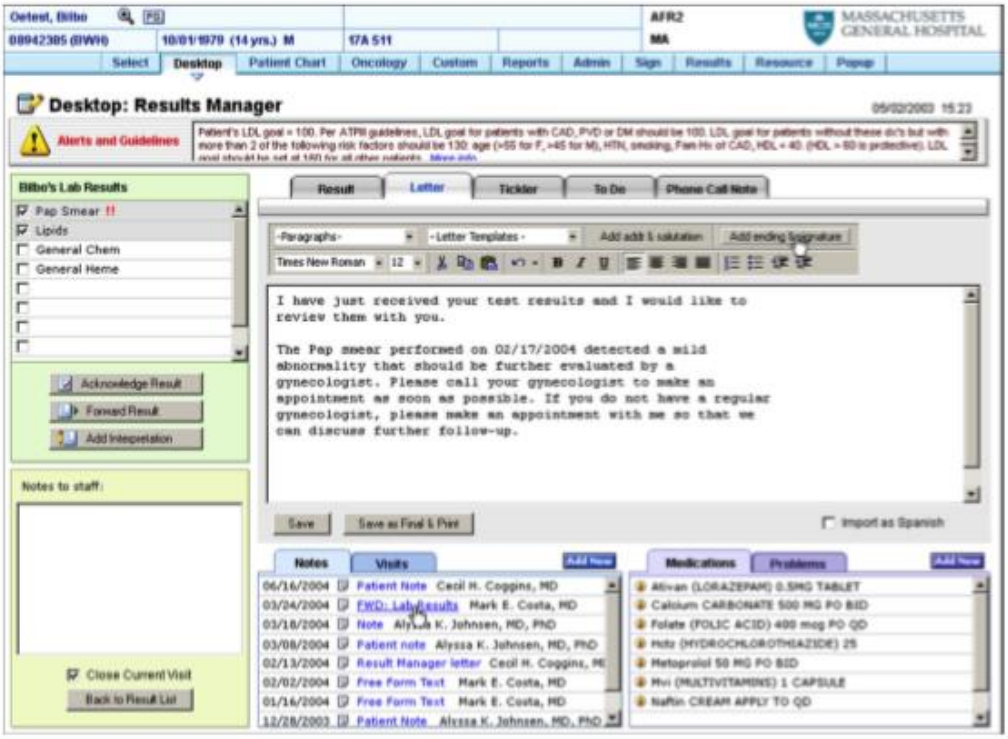


Figure 1.1b: A Mature Mock-up of the Redesigned Results Manager User Interface (Rose, et al., 2004)

1.1.4 UID in Optometry

The success of physicians depends on the effective use of heuristics or guidelines, as they allow for the skipping of task-steps that save mental energy (Vaughn and Linder, 2018). As aforementioned, physicians in niche environments typically have unique workflows that require EMRs with UIs effectively designed to match their workflows; of which the higher level guidelines for EHR usability and UID often fail to meet these requirements. Thus, guidelines that enable for this intricate support provide great value for the clinicians and ultimately the patients. The provision of effective UID guidelines also contributes to better decision-making support to physicians through "diagnostic stewardship" (Vaughn and Linder, 2018). This is enabled via EMR UI designs that are effectively designed with support of guiding principles that provide for better usability (Nielsen, 1993, Vaughn and Linder, 2018). Heeks (2005) identifies a "design-reality gap", revealing a misalignment between designers' conceptual models of an EMR and the users' psychological and perceived workflow of how the EMR ought to work. Hence, when designing for the UI, it is important to prioritise the provision of good usability (Reed, et al., 1999; Ratwani, et al., 2015), and apply or adapt suitable guidelines, principles and/or methods that are aimed at improving it (Nielsen, 1993; Shneiderman, 2004; Middleton, et al., 2013). Good UID increases usability, improves healthcare, decreases patient safety problems and encourages EHR and EMR adoption (Edwards, et al., 2008; Zhang and Walji, 2011; Middleton, et al., 2013; Ratwani, 2017).

To further support the necessity of good UIDs for EHRs/EMRs' improved use, the "Report of the AMIA EHR-2020 Task Force on the status and future direction of EHRs" presented a recommendation regarding UID (Payne, et al., 2015). This recommendation (number ten) stresses the importance of improving interface designs in order to support and build upon how individuals think (that is, cognitive-support-design) (Payne, et al., 2015). The UID problems have been long-standing, with Reed, et al. (1999), Ratwani, et al. (2015) and Zahabi and Kaber (2015) being a few of several authorities also agreeing with the significance surrounding UIDs.

This research intends to explore the field of Optometry (in Allied Health), whose field has had little EMR usability research (McVeigh, et al., 2008; Stolee, et al., 2011; Heidarian and Mason, 2013; Pandit and Boland, 2013). Optometry is a typical example of a niche medical field whose EMRs usability has suffered, with the poor UID of their systems greatly affecting the efficiency of, and hindering their workflows (DeBry, 2001; McVeigh, et al., 2008; Stolee, et al., 2011; Heidarian and Mason, 2013; Pandit and Boland, 2013; pers.comms).

Large numbers of optometrists have been adopting “state-of-the-art” equipment for imaging the eye or evaluating visual functions to improve eye care, and Optometry has been shown to be prolific in the use of IT. However, despite the increasing prominence of IT in Optometry, the overall adoption rates as compared to many other specialist fields has been low (Edlow and Markus, 2008; Chiang, et al., 2011; Myint, et al., 2011; Heidarian and Mason, 2013; Dabasia, et al., 2014). Many of the challenges with optometric EMRs are created because computer programmers/designers are not trained to think like optometrists, particularly when it comes to practice operations and medical documentation (Chou, et al., 2011). In the absence of proper and careful direction in software development, the unfortunate result includes reduced efficiency, compromised patient care, incorrect documentation, less profitability and even legal implications (Chou, et al., 2011). Current EMRs have been shown to have many usability problems (Smelcer, et al., 2009; Hyppönen, et al., 2013; Mosaly, et al., 2015; Tutty, et al., 2019). Optometrists have expectations or standards that need to be met for them to do their jobs, which entail unique workflows. Optometry software is in a continual state of enhancement from both a regulatory as well as additional functionality and usability, and sharing information on how to improve usability is key. To help achieve this, discussion of the usability and thus UID of EMRs is essential, which has not been done in the past (Murphy, 2012).

Each field of medicine and individual discipline has different workflows (Knotternus, 1991; IMSANZ, 2018). Aligning with this, the field of Optometry has a several unique characteristics when compared to other medical specialties regarding data management and clinical workflows. Absence of these specialty-specific characteristics in EMRs, namely in systems that were originally developed for primary care physicians or other medical specialists, has been an ongoing challenge (Chiang, et al., 2011). UIs that are similar to the old, preferred paper records have been shown as preferable by optometrists who rely heavily on paper recording (Scholl, 2011). Often the EMR UIs look good on screen, but are highly inefficient with too many clicks and steps, for example. These considerations have not been adequately met by the current EMR systems utilised in Optometry, and result in numerous errors being made. These errors in turn, lead to optometrists often disregarding their EMRs and replacing them with the old paper-recording methods. As a result, this places great importance on the UIDs of EMRs, which can be used intuitively and efficiently by optometrists and that can promote improved quality of care.

Some specific characteristics to Optometry are the heavy reliance on interpretation of diagnostic imaging, annotations and documentations. Optometry has intricate mixes of

numerical, text-based and image-based data elements (Chiang, et al., 2011; Jens, 2011), for which there is inadequate EMR support. Optometry is a visually intensive field, often incorporating sketches or informal drawings (DeBry, 2001), and this has been shown as cumbersome to replicate on EMR UIs. This is especially true for optometrists who have trained prior to the EMR era, whereby they document clinical findings using hand-drawn sketches (Chiang, et al., 2011). Often the traditional paper optometric-examination records include anatomic drawing templates that have annotations. Optometrists have expressed dissatisfaction that the EMR and UID support fail to account for this and integrate adequate drawing features, and that mouse and keyboard drawings are inefficient. Traditional vital signs (blood pressure, height and weight, for example) are not the primary recordings taken. Rather, Visual Acuity (VA) and Intraocular Pressure (IOP) are routinely collected data that serve as the vital signs of the eye (Chiang, et al., 2011). Consequently, there is a need for specialised support for these, of which high level guidelines fail to provide. Specialist measurement and imaging devices are used in Optometry. There is need for these photographs and images to be translated and reflected on the EMR UIs for further action, which is often not supported. Furthermore, assistants often take these tests which need to be uploaded onto the EMRs for reference by the optometrists. This support for efficient and safe transfer of information is often not attained by the EMR designs, and high level guidelines do not provide adequate help. Optometry practises require electronic ordering of optical and contact lens materials, which is often erroneously conducted due to poor UIDs (Jens, 2011). The field of Optometry is very prominent, evidenced in its long-standing existence as well as being part of the Health Professional Council of South Africa (HPCSA) as one of the twelve major medical fields nationally (HPCSA, 2014).

The World Council of Optometry (WCO) aims to improve the practises of Optometry worldwide, standardising practises via education, policies, models and frameworks within each country's relative context (WCO, 2019). The WCO presents a "Global Competency-Based Model of Scope of Practice in Optometry" which aims to encourage greater uniformity when applied to teaching syllabi and constitutional definitions of the scope of practice (Padilla and Stefano, 2009). The model may also help regulatory bodies assure practitioner competency when confronted with the movement of optometrists across national borders (Padilla and Stefano, 2009; WCO, 2019). This contributes towards minor workflow differences, with the practises of Optometry essentially being standardised (Pickwell, 1987; WCO, 2019). As this research was conducted within South Africa, which is a member of the WCO (WCO, 2019), under the professional body of the South African Optometric Association (SAOA) (SAOA, 2019), the practises followed by South African optometrists should be standardised.

Thus, the main outputs/artifact from this research (EMR UID guidelines), are intended for application across Optometry at large (WCO, 2019; WHO, 2019). The guidelines (artifact) serve as the “recipe" to inform EMR UI designs, whose systems may be tailored to fit various practices, settings or contexts in Optometry.

1.2 Problem Statement

Usability problems associated with EHRs/EMRs are well reported in literature. However, guidelines aiming to address these problems are generalised and do not cater for the specific needs and workflows of specialist medical environments in Optometry.

1.3 Research Objectives

The aim of this research is to create a set of UID guidelines for EMRs in for Optometry, which will improve its usability.

This research intends to assess the present state of EHR/EMR related efforts on usability and UID, and to gain an understanding of standards and guidelines, relevant for EHR systems. Heuristics developed by Nielsen (1993), Shneiderman (2004), Rogers, et al. (2011) and Tognazzini (2014) provide guidelines on usability and UID that have been useful for improving more general systems. These guidelines, however, provide “general heuristics” and ignore critical elements of a specific application. Thus, it is necessary to develop new guidelines specifically to design or evaluate EMRs in Optometry.

1.4 Research Questions

In order to achieve the research objective (Section 1.3) the following main research question is asked:

What user interface design (UID) features should be incorporated into guidelines to enhance the usability of EMRs in Optometry?

For this research, features are identified as various interface elements that assist users to interact with a product. The features will be the practical elements informing the guidelines for the UID in terms of the interface design and functionality.
The main research question is supported by the following research sub-questions:

RQ1: What user interface design problems are associated with EHRs and EMRs?

This helps to obtain a sense of what the existing UID challenges with EHRs and EMRs are, their current state, and gain a better understanding of their implications (i.e., what results from having poor EHR and EMR UIDs?) This also helps to then address the challenges with UID features to overcome or mitigate them.

RQ2: What user interface design features should EMRs for Optometry contain?

Knowledge of the implications of poor EHR and EMR UIDs help to obtain a sense of what features are needed to overcome or mitigate the identified problems, and help guide the creation of EMR UID guidelines. Within the context of Optometry, this question assists in finding out what specific optometric EMR UID features would address the identified challenges faced, in order to improve optometrists' EMR usability. Thus, the Optometry EMR UID guidelines are able to be created.

RQ3: How do the user interface design guidelines affect the usability of EMRs in Optometry?

This question is asked to evaluate the artifact's (guidelines') utility, quality and efficacy, in order to determine whether or not, and how, they improve optometrists' EMR usability.

1.5 Research Methodology

To effectively attain the goal of this research DSR was chosen as a suitable approach, since it is a "problem-solving paradigm" (Hevner, et al., 2004), which aims to produce design artifacts that may be used to contribute towards research and provide solutions to real world problems. The design artifact produced may be a model, construct, method or instantiation (Hevner, et al., 2004), and in our case the artifact will be a set of UID guidelines that enable the improved UID of EMRs in Optometry. In addition, this methodology is now well established within Information Systems research (Gregor and Hevner, 2013). In order to fulfil the Design Science Research (DSR) requirements, the Design Science Research Process Model (DSRPM) (Figure 2.3) of Peffers, et al. (2006) will be followed to guide the research.

The six steps of the DSRPM are: ***1. The problem identification and motivation:*** This activity involved understanding the problems related to the research. To understand this, a literature review will be conducted, focusing on EHR and EMR usability issues that pertain to the UID (Chapters 1, 3 and 4). ***2. The definition of objectives and a solution to the problem identified:*** The process of defining the objectives of a solution will be undertaken by analysis of the literature. Task Analysis (TA) with optometrists will also be undertaken in order to determine their unique work flows and requirements (Chapters 4 and 5 (TA)). ***3. The design and***

development of an artifact (guidelines) to address the problem: In order to assist with the design and development of the artifact, Focus Groups (FG) (Chapter 6) will be undertaken to uncover possible UID features that optometrists may require and find desirable (which was elucidated in Chapter 5). ***4. The demonstration of the artifact proposed to solve the problem:*** Once a solution or artifact has been proposed it is vital to demonstrate the effectiveness of the artifact to solve the defined problem. The proposed UID guidelines (Chapter 7) will be followed to demonstrate how they can influence the design of a prototype UI for an Optometry EMR. ***5. Evaluating the artifact proposed:*** The prototype interface will be evaluated by Usability Testing (UT) to determine the efficiency, efficacy and quality of the guidelines. ***6. The communication of the produced artifact to the stakeholders or communities:*** This research will communicate the findings in the form of a final thesis.

1.6 Scope of Study

The scope considers the niche medical environment of Optometry. The focus of this research is not on all aspects of EMR usability, but "rather on those that are part of critical user interactions"- the patient-physician reference (Lowry, et al., 2012). The patient-physician appointment constitutes as one of the main, if not *the primary* interaction times that EMRs optometrists encounter. The user interaction with the UIs are most crucial and frequent. As such, this crucial window was chosen as the main scope in which to focus the study, instead of including other EMR modules/functions such as the billing aspects, or staff registries, etc.

The perspectives and usability from the optometrists' side are considered rather than from the patients', as the optometrists are the primary EMR users. For the fieldwork (TAs, FGs and UT), optometrists in the Eastern Cape of South Africa were accessible and thus used. These optometrists' practises should be standardised, as they are a part of the South African Optometric Association (SAOA), which is a member of the World Council of Optometry (WCO). The sample size for the research was limited to small groups and not exceeding six participants per method. However, given these numbers, there is great value in the qualitative data that was shown in order to create the UID guidelines. The assumption for this research is that the UID guidelines created can be applied to other EMRs in Optometry. Another limitation is that this research explores the private sector of Optometry only, and not the public, corporate franchise.

1.7 Ethical Considerations

Since human subjects (optometrists) took part in this research, ethical approval was required from the Rhodes University Ethical Standards Committee. The ethics approval tracking

number is **CIS 180-05**. All ethical considerations concerning informed consent, voluntary participation, non-disclosure, confidentiality, utilisation and storage of the data collected were adhered to throughout the study. All participation was voluntary and required informed consent (Appendix A). Participant IDs were kept anonymous as were their practises, software products and EMRs.

1.8 Outline of Chapters

The thesis chapters are in sequential order:

Chapter 1: Introduction

This chapter introduces the research study. A background to the research is offered via an outline of the research context. The research goals and the methodology are also described, and the scope of the research is described.

Chapter 2: Research Methodology

The research methodology undertaken (DSR approach) to create UID guidelines for EMRs in Optometry is explained.

Chapter 3: User Interface Design (UID)

The importance of UID is explained, as well as the major supporting components such as User Centred Design (UCD), Human Centred Design (HCD), UI, usability, UX, their various constituents, and how they interlink within the domain of this research. The aim of this chapter is to attain an understanding of the domain theory for EMRs and to address the first research sub-question.

Chapter 4: EMR Usability

This chapter outlines the current usability/UID problems with EHRs and EMRs, and goes more in-depth into the EMR problems. It also introduces guidelines and frameworks for improving usability in EHRs/EMRs. It attempts to start addressing the second sub-question whilst continuing with the first sub-question.

Chapter 5: Task Analysis

This Chapter focuses on the Optometry context. It describes the context in which optometrists operate and use their EMRs, in an attempt to identify the commonly performed tasks whilst operating the EMRs. This chapter further seeks to understand what functionality or UID features currently support physicians' activities or negatively affects their usability when operating their EMRs. It also attempts to understand what UID considerations ought to be

included in EMRs. This chapter aims to address a combination of the first (mainly) and second sub-questions.

Chapter 6: Focus Groups

This chapter explores (design) solutions to address the usability and UID challenges faced by the Optometrists from the EMRs, and thus aims to improve the usability and overall UXs. This chapter aims to address the second sub-question.

Chapter 7: Proposed Guidelines

This chapter proposes a set of UID guidelines for EMRs used in Optometry. The guidelines created draws from all the literature reviews and results from the prior research chapters. The proposed UID guidelines (artifact) are utilised as a foundation to inform the building of Optometry specific EMR UIs (prototype).

Chapter 8: Prototype Evaluation and Usability Testing

This chapter evaluates the EMR UI prototype via UT in order to gather Optometrists' experiences regarding the EMR prototype usage. This testing validates or invalidates the application of the proposed set of UID guidelines. A SUS questionnaire and PSSUQ will also be used for usability and user satisfaction feedback. This chapter aims to address the third sub-question.

Chapter 9: Discussion and Conclusion

This chapter concludes the thesis by summarising the findings of the research and highlights areas that call for future exploration and investigation. The conclusions of the research are described and future research areas are indicated.

Chapter 2: Research Methodology

This chapter describes the methodology utilised for structuring this research to address the research problem. Design Science Research (DSR) and its application to this research is discussed, together with its origins, various approaches and models. The Design Science Research Process Model (DSRPM) was chosen, after considering the guidelines from many Design Science (DS) approaches.

2.1 Overview of Design Science Research

Paradigms, often referred to as philosophies, serve as an investigative probe into an inquiry offering "a broad view or perspective of something" (Taylor, et al., 2007), whilst usefully highlighting patterns of "beliefs and practices" by "providing lenses, frames and processes through which investigation is accomplished" (Weaver and Olson, 2006). The Information Systems (IS) field is considered a "multi-paradigmatic research community" (Vaishnavi and Kuechler, 2004) with several availing research paradigms or philosophies such as "Positivism", "Interpretivism", "Realism", "Hermeneutics", "Critical Theory", "Phenomenology" (Saunders, et al., 2009) and more recently "DSR" to help guide researchers. Each entails different advantages dependent upon their needs (Saunders, et al., 2009).

This research considers Pragmatism as the most applicable paradigm, with DSR as the approach due to its underpinnings or foundations being pragmatic. Pragmatism infers that theory is only significant after it has been successfully used in a specific context and within the period in which it is recognised to hold value, or be useful (Levy and Hirschheim, 2012). It assumes value of a proposition or theory to be judged by the results of "accepting the proposition or theory" (Kelder, et al., 2005). Hevner (2007) presents pragmatism as a school of thought accounting for "practical consequences or real effects" to be essential constituents of "both meaning and truth". DSR is fundamentally pragmatic in nature owing to its prominence on relevance; making a distinct "contribution into the application environment" (Hevner, 2007). DSR is chiefly considered an approach rather than a paradigm, but for performing research in IS, DSR often acts as a "lens" or set of "synthetic and analytical techniques and perspectives (complementing positivist, interpretive, and critical perspectives)" (Vaishnavi and Kuechler, 2004). These separations in philosophical standpoints do not distinguish another research paradigm that is aligned toward practical problem solving which is DSR. DS from the IS perspective views design activities as being scientific ones if they are suitably framed within (as is the case for this research): an appropriate context (Optometry), around theory (Literature Review) and observations (Task Analysis (TA) and Focus Groups

(FGs)) that can make and test assertions about the world (Usability Testing (UT)) (Prestopnik, 2013). There is an increased awareness of the interrelation between technology and the social environment in which it exists (Wright, et al., 2017), and the role that cultural, managerial and financial factors play in the success of information technology projects ought to be considered. Failure to implement effective health information systems cannot be solely attributed to technology elements, and thus the relationships between people, technology and the environment ought to be accounted for.

Vaishnavi and Kuechler (2004) compare the main differences of some philosophical paradigms or approaches with DSR, and the research perspective they offer. This aids comprehension on how DSR views the world (Vaishnavi and Kuechler, 2015) and why it was the preferred choice for this research. Table 2.1 below compares the main philosophical assumptions of three research perspectives of "Positivist", "Interpretivist" and "DSR", with this research relating to the "DSR" perspective.

Table 2.1 Philosophical Assumption of Three Research Perspectives (Vaishnavi and Kuechler, 2004)

Basic Belief	**Research Perspective**		
	Positivist	**Interpretive**	**Design Science Research**
Ontology: The study describing the nature of reality, aiming to discover what is real and not, what is fundamental and what is derivative.	A single reality; knowable, probabilistic.	Multiple realities, socially constructed.	Multiple, contextually situated alternative world-states. Socio-technologically enabled.
Epistemology: The study exploring the nature of knowledge, what knowledge depends on and how certainty may be assured from what is known.	Objective; dispassionate. Detached observer of truth.	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	Knowing through making: objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology: The process to which the research study is conducted.	Observation; quantitative, statistical.	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure artifactual impacts on the composite system.
Axiology: The study of values, what values individuals or groups hold and why.	Truth: universal and beautiful; prediction.	Understanding: situated and description.	Control; creation; progress (i.e. improvement); understanding.

As DSR's underpinnings are pragmatic, rather than being confined to strict quantitative or qualitative approaches (as with Positivism or Interpretivism respectively, for example), this research engages a mixed-methods approach that is not dedicated to any one philosophical system of reality, and accordingly seeks to solve a real-world problem by use of the most opportune and suitable methods to address the main and ancillary research questions (Gregor and Hevner, 2013). This mixed methods approach and use of data triangulation (use of a variety of data sources) is a defining characteristic of Pragmatism (Simon, 1996; Kuniavsky, 2003; Hevner, et al., 2004). Gregor and Hevner (2013) support the idea that it is problematic, if not impossible to make progress in the application without theory. On the other hand, it is challenging to comprehend the theory without knowledge of the technique. This is where DSR fits in, which culminates an integration of an "art" or creative perspective, coupled with a practical approach to solving real world problems (Gregor and Hevner, 2013).

Research rigour is the driving goal when selecting a method (Gregor and Hevner, 2013), and it is argued that DSR offers Information Systems (IS) researchers a rigour that is similar to an applied research technique (Peffers, et al., 2006). Furthermore, Gregor and Hevner's (2013) research accounts for optimum impact of the positioning and presentation of DSR when structuring research. This research aims to develop UID guidelines for EMRs within Optometry using the DSR approach, and since Pragmatism concentrates on practical applications, the paradigm aligns well with the aims of DSR. DSR focuses on contributing to the knowledge base, and on creation of artifacts, aiming to change existing situations into favoured ones (Simon, 1996; Hevner, et al., 2004). DSR empowers researchers to appreciate and learn about the real world and the problems relating to it, challenging problems in IS serving as a problem solving technique (Rittle and Webber, 1984; Pirkkalainen, 2015). DSR involves two main activities to enhance and comprehend the behaviour of aspects of IS. The first is the creation of new and interesting knowledge through design of unique or innovative artifacts (things or processes) that "serve human purposes and thereby creates utility for the stakeholders" (March and Smith, 1995; Weber, 2010). These innovative artifacts are useful and fundamental in comprehending problems, and resultantly contribute to the knowledge base of scientific evidence. This is achieved when designers answer questions pertinent to human problems (Hevner and Chatterjee, 2010). The second activity is the "analysis of the artifact's use and/or performance with reflection and abstraction" (Vaishnavi and Kuechler, 2004).

DSR's pragmatic, or practical and real-life problem solving nature addresses research problems that are "wicked" (Hevner, et al., 2004). These wicked problems represent vast and complex interconnected socio-technical systems in which the outcomes of particular actions are problematic to predict (Hevner, et al., 2004). Human social abilities like teamwork, and field work, to produce effective solutions are critical to problem-solving (Mason and Mitroff, 1973; Ackoff, 1974; Hevner, et al., 2004). This research intends to contribute towards the knowledge base by providing the specialist guidelines, which intend to further the knowledge surrounding usability and interface design problems associated with EMRs in the specialist field of Optometry (Hevner, et al., 2004). It also aims to solve a very real-life, "wicked problem" (Hevner, et al., 2004). This being the scarcity of user interface design (UID) guidelines in the specialist niche field of Optometry, found within a competitive environment; the socio-technical driven medical field. This "wicked problem" will be addressed in a practical manner; utilising the DSR approach, and thus aligning suitably with DSR. Additionally, the human-social ability element to "wicked problems" will be addressed by the researcher conducting the study, interacting with the users or specialists (TA, FGs, and UT).

Artifacts are any designed objects providing a solution to an understood research problem (Peffers, et al., 2008). They depict artificial, or man-made things, as opposed to something naturally occurring (Simon, 1996). Artifacts created through DSR are significant in that they determine feasibility, allowing for specific evaluation of an artifact's relevance to its intended purpose (Prestopnik, 2013). Information Technology (IT) artifacts are defined as "constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems)", and the intended guidelines for this research thereby categorise as "methods" (Hevner, et al., 2004). March and Smith (1995) provide insight into understanding "Constructs" to be conceptualisations and vocabulary that support communication and the description of problems, limitations, solution components and goals for artifacts designed. Furthermore, "Models" utilise these constructs to symbolise a circumstance or problem, and its relative solution space. "Methods" are guidelines used to share this solution space, allowing for the construction of "Instantiations". Instantiations are the realisations of artifacts within their environments, and operationalise constructs, models, and methods. They are physical realisations that act upon the natural world (Gregor and Hevner, 2013). They "demonstrate the feasibility and effectiveness of the models and methods they contain" (March and Smith, 1995). As such, this research's EMR UID guidelines (Chapter 7) inform the design of an EMR prototype ("Instantiation" of the EMR guidelines), which is demonstrated to optometrists during the evaluation stages (Chapter 8). Through the processes of "build" and "evaluate" (March and Smith, 1995; Peffers, et al., 2006),

researchers are able to gain familiarity and a better comprehension of the study area at hand, and thus develop solutions to the identified problems. This approach uses qualitative (TA, FGs and UT) and quantitative methods (Surveys), and uses knowledge created from deep, descriptive theories of how humans interact with machines. As DSR stresses the importance of contributing towards the knowledge base (March and Smith, 1995; Hevner, 2007), Gregor and Hevner (2013) present a framework which includes four types of contributions resulting from conducting DSR (Figure 2.1).

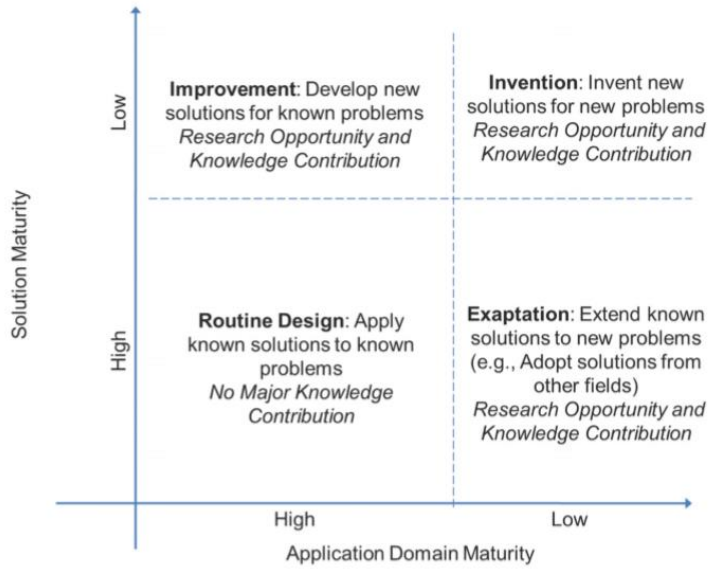


Figure 2.1 DSR Knowledge Contribution Framework (Gregor and Hevner, 2013)

These contributions include Routine Design, Exaptation, Improvement and Invention. In accordance with this research, the contribution leans towards the "Improvement" quadrant, making a contribution to the prescriptive ("How") knowledge base in the form of an artifact (Gregor and Hevner, 2013). Upon the artifact's subjection to evaluation, there may be a contribution towards descriptive ("What") knowledge in the form of extended comprehension of the "kernel theories or the development of new behavioural theories of the artifact in use" (Gregor and Hevner, 2013). Pertaining to this research, the guidelines will contribute towards the knowledge around the usability and UIDs of EMRs used in Optometry, thus expanding the knowledge base.

2.2 Design Science Research Guides

Various DSR frameworks, processes, models and/or guidelines exist which help in providing detailed processes for generating DS knowledge, and share similar perspectives (Nunamaker, et al., 1991; March and Smith, 1995; Gregg, et al., 2001; Hevner, et al., 2004; Peffers, et al., 2008; Purao, 2013). Design as an artifact (constructs, models, methods and instantiations), and design as a process (build, evaluate, theorise and justify) are the two main research outputs and activities focused on by DSR respectively. The activities of building and evaluating are more

concerned with DS, whereas the theorising and justifying are more so linked to the natural sciences (March and Smith, 1995).

Hevner, et al. (2004) posited the Information Systems Research Framework (ISRF) in order to understand, complete, and evaluate IS research combining DS and Behavioural-Science approaches (Hevner, 2007). The ISRF has assisted with the productions and evaluation of IT artifacts, aiming to help development of IS solutions within a socio-technical context and environment. The recognition of the four DSR cycles (Figure 2.2) in a research project distinctly positions and distinguishes DS from other research paradigms (Drechsler and Hevner, 2016). The original IS DSR framework (Hevner, 2007) had three cycles, and was extended to include a fourth one called the "Change and Impact (CI) cycle". This additional cycle covers the design artifacts' second-order impacts to their broader organisational and societal contexts (Figure 2.2), but is out of this research's scope, as the research did not consider the impact of the guidelines in the real world/organisation, or the "design evolution" (Drechsler and Hevner, 2016).

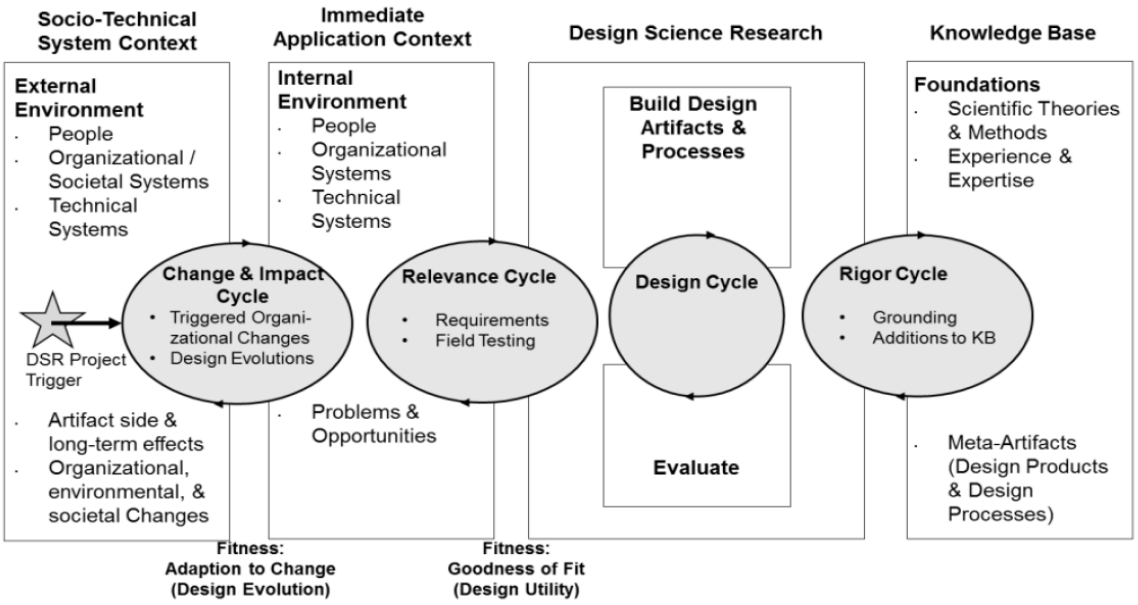


Figure 2.2 A Four Cycle View Of Design Science Research (Drechsler and Hevner, 2016)

Practical utility does not describe good DSR alone. Good DSR is defined by the synergy between relevance and rigour, and the contributions along both the relevance cycle and the rigour cycle (Hevner, 2007).

1) *The Relevance Cycle* comprises of the contextual environment or application domain which the artifact will be developed in, and its requirements and field testing are iterative in nature,

dependent upon the results from this phase. This cycle strives to parallel the developed and designed artifacts to the environment, and includes people, organisational and technical systems, as well as opportunities and any environmental problems (Hevner, et al., 2004; Hevner, 2007). This is highlighted in Chapters 5 and 6.

2) *The Rigour Cycle* offers and draws from previous information or knowledge relevant to the research study, in order to assure its innovation (Hevner, 2007). This previous knowledge may be in the form of grounding theories, methods, domain experience and expertise "from the foundation's knowledge base into the research" (Hevner, 2007). Essentially, this cycle connects the DS activities and the "knowledge base of scientific foundations, experience, and expertise that informs the research project" (Hevner, 2007). This links to Chapters 3 and 4.

3) *The Design Cycle* is central, at the forefront of where DSR occurs. This cycle constructs and iteratively evaluates designed artifacts and processes, thus contributing towards rigour. This links to Chapters 7 and 8.

Evaluation of the designed artifact is conducted via the conformance of particular procedures (Hevner, 2007), and the method followed or activities involved rely upon their categorisation (Pries-Heje, et al., 2008; Venable, et al., 2012). Venable, et al. (2012) state that evaluation is what places the "Science" in "DS". In the absence of evaluation, there is only left an unproven design theory that some developed artifact will be useful for resolving some challenges or making some improvement (Venable, et al., 2012). Evaluating an instantiation of a designed artifact is important as it helps to establish its utility and efficacy (or lack thereof) for achieving its specified purpose (Venable, et al., 2012).

Pries-Heje, et al. (2008) propose "a 2-by-2 framework of strategies of evaluation in DSR", which was then further adapted by Venable, et al. (2012) (Table 2.2). This research produces a process artifact that is socio-technical, thus steering the evaluation process to the "Ex-Post" and "Naturalistic" quadrant of the DSR Evaluation Strategy Selection Framework (Table 2.2) (Pries-Heje, 2008; Venable, et al., 2012).

Table 2.2 DSR Evaluation Strategy Selection Framework (Venable, et al., 2012)

DSR EVALUATION METHOD SELECTION FRAMEWORK	EX ANTE	EX POST
NATURALISTIC	• Action Research • Focus Group	• Action Research • Case Study • ***Focus Group*** • ***Participant Observation*** • Ethnography • Phenomenology • ***Survey (qualitative or quantitative)***
ARTIFICIAL	• Mathematical or Logical Proof • Criteria-Based Evaluation • Lab Experiment • Computer Simulation	• Mathematical or Logical Proof • Lab Experiment • Role Playing Simulation • Computer Simulation • Field Experiment

Naturalistic evaluation discovers the performance of a solution technology within its real environment, using tangible situations and people to engender greater face validity. Proceeding the construction, acquiring and/or implementation of an IS artifact, "Ex-Post" (Venable, et al., 2012) evaluation occurs. "Ex-Post" evaluation concerns instantiated artifacts (Pries-Heje, et al., 2008; Venable, et al., 2012). The placement within this specific quadrant can be attributed to the use of UT of the EMR UIs (prototype) demonstrating the guidelines, by optometrists in their "real environments" or Optometry practices (Venable, et al., 2012).

2.3 Design Science Research Guidelines

Hevner, et al. (2004) provide seven guidelines used to guide the DSR, with criteria to be followed. These guidelines and their application to this research are presented in Table 2.3.

Table 2.3 Design Science Research Guidelines

DESIGN	DESCRIPTION	APPLICATION TO THIS RESEARCH
Guideline 1: Design as an Artifact	DSR must produce a viable artifact in the form of a construct, a model, a method, or an instantiation	Development of a set of UID guidelines (artifact) for EMRs in Optometry, to improve usability.
Guideline 2: Problem Relevance	The objective of DSR is to develop technology-based solutions to important and relevant business problems.	The problem recognised is that there is a scarcity of UID guidelines in the niche medical environment of Optometry (evidenced via literature reviews and personal communications with optometrists). These problems also hinder optometrists' practises and workflows. The guidelines are aimed at confronting these problems and improve the current usability challenges regarding EMRs in Optometry. The guidelines are able to be translated into a technology based solution, which is demonstrated via the prototype.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	The set of guidelines (artifact) will be evaluated via a demonstration of them reflected on EMRs' UIs (prototype) in Optometry practices, by optometrists (Ex-Post evaluation), as well as UT (Naturalistic evaluation) to outline the utility, efficacy and quality. This assures rigour too. Utility and efficacy of the artifact are evidenced through the

		demonstration and surveys. The surveys help determine the quality, and will be administered to each participant after the UT to obtain usability feedback on each guideline and the interface in general. UTs aid in the quality assessment by evaluating the pragmatism, semantics (by examining the content) and syntax. Since the artifact is of a process and socio-technical nature, the evaluation process will employ methods relating to the "Ex-Post" and "Naturalistic" quadrant of the DSR Evaluation Strategy Selection Framework. The FEDS Model is used as a guide for the evaluation, justifying a "Quick and Simple Strategy" (Venable, et al., 2012), yet rigorous evaluation process with one iteration.
Guideline 4: Research Contributions	Effective DSR must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	The posited set of guidelines will inform the development of UIDs of EMRs in Optometry, contributing towards their better usability by optometrists and overcome some of the usability problems previously experienced. This will count as the practical contribution. The knowledge generated around this research topic and from the guidelines will add to the body of knowledge, thus serving as a theoretical contribution.
Guideline 5: Research Rigour	DSR relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	The set of guidelines are created by conducting a thorough literature review; which includes EHR and EMR, usability, UIDs, Optometry, related fields, and on studies previously conducted to provide guidelines, frameworks and models. The review also included studying usability problems reported on the systems and the methods to overcome them. TA (Chapter 5) and FGs (Chapter 6) were arranged for further rigour.
Guideline 6: Design as a Search Process	The search for an effective artifact requires using available means to reach desired ends while satisfying laws in the problem environment.	The set of guidelines ought to conform to common-practise usability standards for EMRs. Through current literature analysis, standing theories and previous studies (usability guidelines, User Centred Design (UCD), TURF) (Chapters 3 and 4), the research questions are addressed. This ensures a holistic perspective to ascertain concrete, authentic and relevant results. Both descriptive and prescriptive knowledge were used in formulating the research questions. Quinones and Rusu's (2017), "How to develop usability heuristics: A systematic literature review" was also used as an aid in creating the guidelines. Computer Standards and Interfaces
Guideline 7: Communication of Research	DSR must be presented effectively both to technology-oriented as well as management-oriented audiences.	The developed and refined artifact (set of guidelines) are intended to be presented through this final thesis, and of avail to other researchers in the field, as well as being communicated to significant stakeholders like Optometrists and (EMR) user interface designers.

2.4 Design Science Research Process

Literature provides numerous DS approaches or guides that are in existence (March and Smith, 1995; Hevner, et al., 2004; Carlsson, 2006; Peffers, et al., 2006; Hevner, 2007; Purao, 2013). Peffers, et al's. (2006). DSRPM was found to best align with the aims of this research and is thus the preferred choice because it offers a valuable, synthesised general model, "building on

other approaches" (Gregor and Hevner, 2013). The DSRPM is consistent with previous research (Peffers, et al., 2006), and is a mental model that helps provide a pathway to meet Hevner, et al's. (2004) DSR criteria (Table 2.3). An association is recognised between March and Smith (1995), Hevner, et al. (2004), and Peffers, et al. (2006). These authors' views culminate towards the discussion that problem-insight and current resolutions will assist researchers in creating effective artifacts within an environment, simultaneously abiding by laws of the problem area. Taking this into cognisance, Hevner, et al. (2004) present the Guideline 6: "Design as a search process", while March and Smith (1995) provide "Build", and "Define objectives for a solution" are offered by Peffers, et al. (2006). Hevner, et al. (2004) present Guideline 3: "Design evaluation", mirroring the stage of "Evaluation" in Peffers, et al's. (2006) DSRPM. Both maintain the significance of clear and verifiable contributions (artifact) within a suitable context. Hevner, et al. (2004) and Peffers, et al. (2006) additionally promote the "Communication" of the research contributions to all audiences to ensure that the innovation, effectiveness, usefulness, and rigour of the designed artifact is widely known to all. Hevner, et al. (2004) present this as Guideline 7: "Communication of Research", and Peffers, et al. (2006) as "Communication".

The DSRPM (Peffers, et al., 2006) focuses on both research and design, thus building rigour, and is aligned to the work of Hevner, et al. (2004) and Hevner (2007). For example, the DSRPM by Peffers, et al. (2006) describes the stage "Design and Development", whereas the guidelines by Hevner, et al. (2004) and Hevner (2007) address "Design as an artifact" for Guideline 1. A distinguishing feature of this model identifies the fact that the DSRP can be introduced from several contexts (entry points); the Problem Centred Approach (this research's entry point), Objectives Centred Approach, Design and Development Centred Approach, and by Observing Solution (Client/Context Initiation). The Problem Centred Approach is the entry point as the problem is known (e.g. via thorough literature searches); the problem surrounding the lack of UID guidelines in niche medical fields such as Optometry). In a corresponding phase of the nominal process sequence shown (Figure 2.3), the study can then initiate (Hevner, et al., 2004; Peffers, et al., 2006).

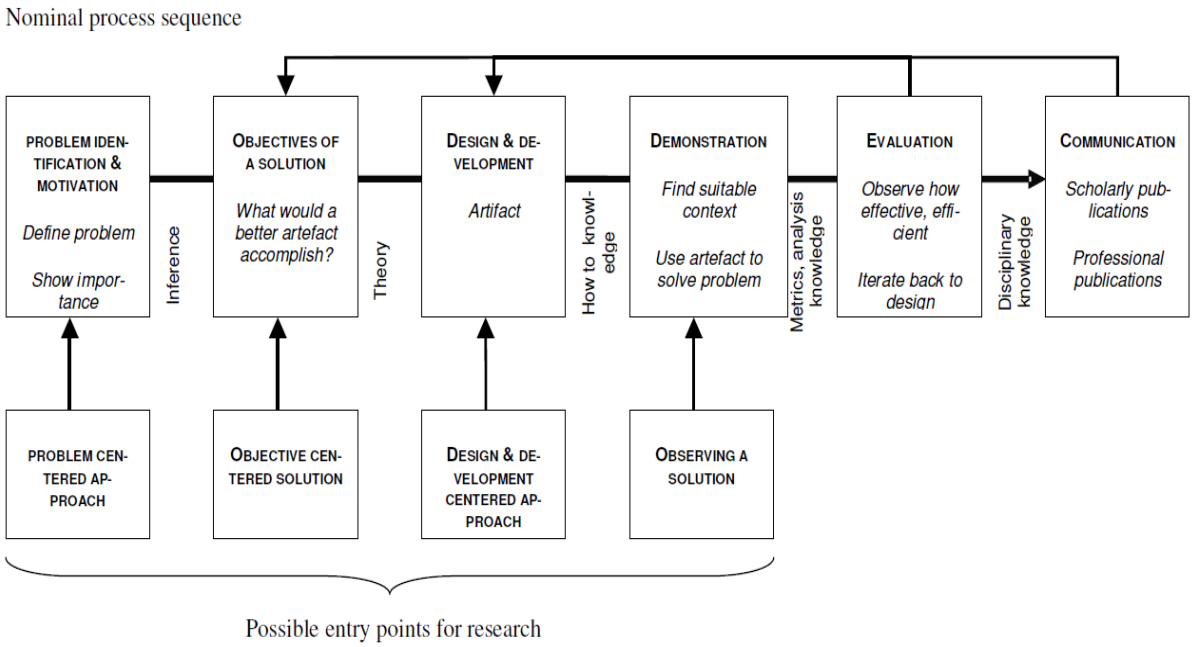


Figure 2.3 Design Science Research Process Model (Peffers, et al., 2006)

The nature of the DSRPM is iterative and flows in the direction of the arrows across the six steps. These steps include: Identify the problem and motivate; Define the solution objectives; Design and Development of the artifact; Demonstration within a suitable context; Evaluation; and Communication of the solution (Peffers, et al., 2006).

2.4.1 Design Science Research Process Pertaining To This Study

The DSRPM in Figure 2.3 (Peffers, et al., 2006) helps guide this research (Figure 2.4), following the six steps employing a real life situation.

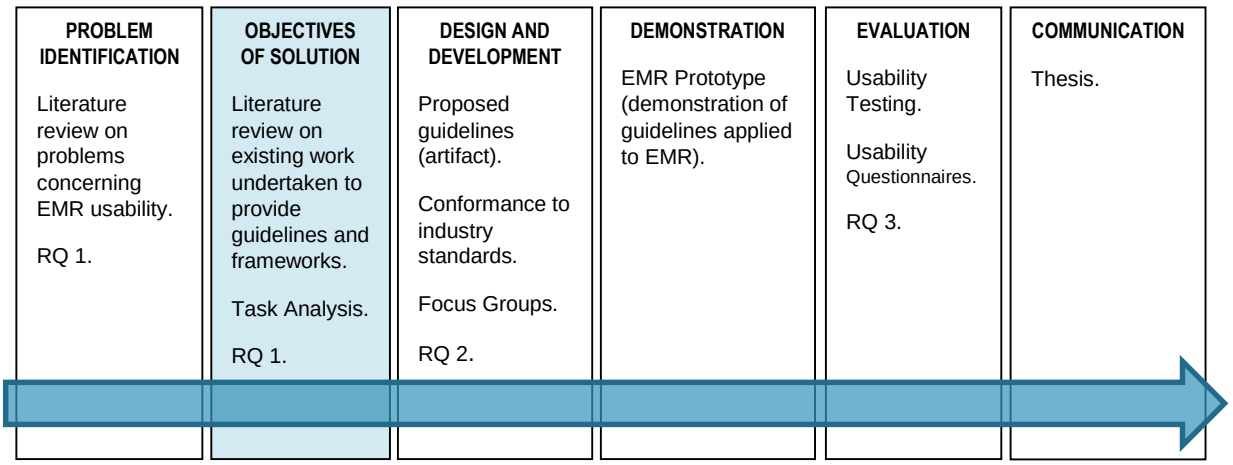


Figure 2.4 Design Science Research Process Model (Adapted from Peffers, et al., 2006)

2.4.1.1 Step 1: Identify Problem and Motivate

Knowledge of the state of the problem and the importance of its solution.

To gain a sound understanding of the problem, a literature review was conducted to discover current studies focussing on usability problems faced with Electronic Health Records (EHRs) and Electronic Medical Records (EMRs). Apart from EHRs and EMRs, the literature review also included topics on usability and related fields like UID and UCD, for example (Chapter 3), Optometry, and studies previously conducted to provide guidelines, frameworks, models and usability problems reported on the systems and the methods to overcome the problems. Relevant prescriptive and descriptive knowledge were drawn upon from literature (Gregor and Hevner, 2013). Studies with guidelines and frameworks on EHR and EMR usability were also referred to. Chapter 5 (TA) aids in identifying optometrists' unique workflows as well as the challenges faced in using the EMR UIs. This first step (Peffers, et al., 2006) helped in answering RQ 1: "What user interface design problems are associated with EHRs and EMRs?"

2.4.1.2 Step 2: Define Objectives of a Solution

Knowledge of the state of problems and current solutions and their efficacy, if any.

From understanding the challenges, step two includes setting the objectives of how the solution can be accomplished. Within DSR, this is achieved by conducting quantitative or qualitative research. For this research, a qualitative (mainly) and quantitative approach is utilised to gain a sound comprehension of how the problems identified in step one will need to be addressed. The pragmatic nature of DSR and mixed methods approach allowed for the most suitable methods to be chosen. FGs (Chapter 6) are suitable as a technique for researching usability and were used (Kunaivsky, 2003). FGs assist in the creation of (UI design) solutions to address the challenges identified from the TAs (Chapter 5) as well as literature reviews. This is aimed to discover any UID and usability elements the optometrists may need. This step is also informed by theories and frameworks from past studies (Belden, et al., 2009; Wiklund, et al., 2015), like the "TURF Framework" (Zhang and Walji, 2011; Middleton, et al., 2013). This step assists in answering RQ 1: "What user interface design problems are associated with EHRs and EMRs?"

2.4.1.3 Step 3: Design and Development

Resources required moving from objectives to design and development include knowledge of theory that can be brought to bear as a solution.

Step three involves the designing and development of the artifact, and includes establishing its necessary functionality and architecture, to then create the final artifact (Hevner, et al., 2004). A consideration here is the utility rather than truth (Hevner, et al., 2004). Therefore, the primary concern is producing an artifact that is useful to optometrists, researchers and designers, as compared to uncovering an underlying truth about the world (Hevner, et al., 2004). The DSRPM's activities allow for this goal attainment with contribution from the supporting elements of "rigour" and "relevance" (Peffers, et al., 2006). This research develops a set of guidelines informing the UID of EMRs in Optometry, created from the past literature and existing literature identified from the previous steps, and a user centred approach (Kuniavsky, 2003). The category of knowledge contribution achieved from these guidelines may be described as "Improvement" (Gregor and Hevner, 2013). This is because the problems are already known; discovered through evaluating past literature, personal communications with optometrists and TA. FGs are the main aid to the design of the artifact. FGs' brainstormed UID recommendations are then able to guide the development of UID guidelines for EMRs in Optometry, in efforts to improve optometrists' usability (which may affect their overall experiences). This third step (Peffers, et al., 2006) helped in answering RQ 2: "What user interface design features should EMRs for Optometry contain?"

2.4.1.4 Step 4: Demonstration

Effective knowledge of how to use the artifact to solve the problem.

After the artifact's solution is proposed, the demonstration of its efficacy to solve the problem (discussed in Chapter 1) is crucial, that is, how well the guidelines are actually serving their intended purpose, and if they are relevant. This step is part of the evaluation activity (Venable, et al., 2012). Instantiations help demonstrate the effectiveness and feasibility of the methods and models they contain (March and Smith, 1995), an EMR prototype is created, with the guidelines informing the UID design of the EMR prototype. In order to attain a successful demonstration, effective knowledge of how to utilise the artifact to solve the problem(s) is the resource required, and utility is reflected upon in this step. The demonstration of the EMR prototype helps exhibit, define and explain how it can be applied within Optometry, and also aids in actively showing optometrists the effects of them and contributes towards determination of the artifact's efficacy (Peffers, et al., 2006). The prototype will be tested by users

(optometrists) to further evaluate and assess the utility, usefulness and application of the proposed guidelines. The designed EMR UIs serve as a vehicle which visually represents the guidelines in a practical setting, providing visual representation, and essentially are not the main artifact to be evaluated; which are the guidelines.

2.4.1.5 Step 5: Evaluation

Resources required: Knowledge of relevant metrics and analysis techniques.

This step concerns observing and measuring the extent to which the artifact supports a solution to the challenge (Peffers, et al., 2006). The artifact evaluation needs to be conducted through assessment of the utility (demonstration and UT), efficacy (UT, surveys and feedback), validity and quality (UT and surveys) of the designed artifact (Hevner, et al., 2004). This assists in assessing its usefulness and demonstrating its worth, assuring rigour (Venable, et al., 2012). The nature of the research may command whether iteration is feasible or not (Peffers, et al., 2006). The Framework for Evaluation in DS (FEDS) Model is used as a guide for the evaluation, justifying a "Quick and Simple Strategy" (Venable, et al., 2012), yet rigorous evaluation process with one iteration. This research uses one iteration, elaborated in Chapter 8. To evaluate the success in terms of usefulness, utility and application of the proposed guidelines in this research, the guidelines will be evaluated by using them to implement EMR UIs, which will undergo UT (a naturalistic evaluation activity). This evaluation method does not primarily aim at testing the EMR UI prototype per se, but rather the proposed guidelines. This relates to whether it is relevant, can actually be applied in practice, and if it provides details concerning to the application process (for applying the guidelines). User satisfaction and performance will also be tested by means of UT. This will essentially assess the trustworthiness, validity and credibility of an instantiation of the proposed guidelines. UT (Chapter 8) involves optometrists completing a set of tasks in order to understand if the proposed UID guidelines are successful or not, in creating a more usable Optometry EMR. Surveys will be administered after the testing, also helping to measure the usability and overall user satisfaction; System Usability Scale Questionnaire (SUS) and A Post Study System Usability Questionnaire (PSSUQ) (Lewis, 1995; Brooke, 1996; Drew, et al., 2018) were used. Since the guidelines (artifact), are subjected to evaluation after creation and deployment, it falls to the "Ex-Post" quadrant (Pries-Heje, 2008; Venable, et al., 2012). This step helps to answer RQ 3: "How do the user interface design guidelines affect the usability of EMRs in Optometry?"

2.4.1.6 Step 6: Communication

Knowledge of the disciplinary culture.

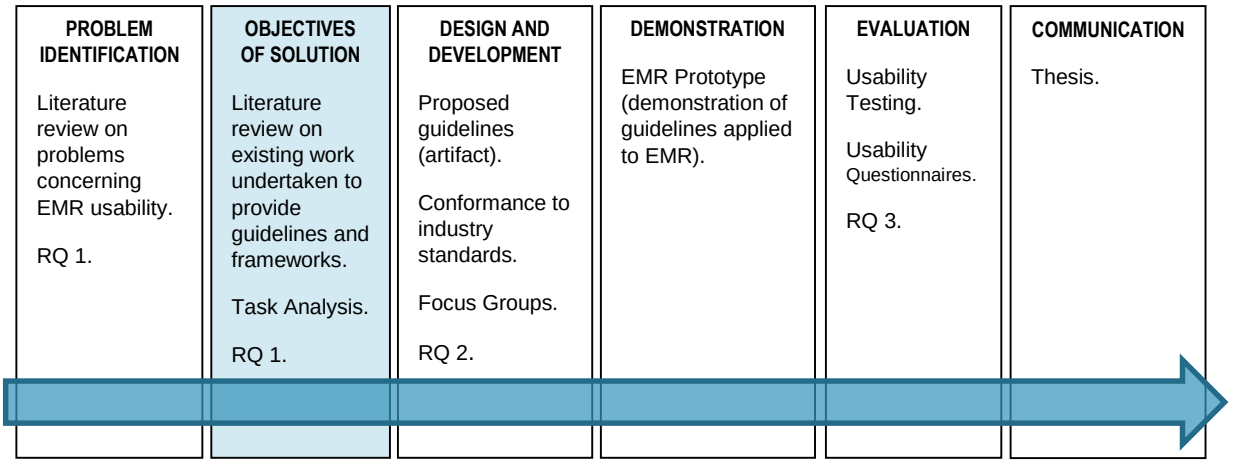
The aim of this final DSRP step is conveyance of the problem and its significance, the artifact, its utility and innovation, the design's rigour, and its effectiveness to researchers and other important audiences (Peffers, et al., 2006). For this research, the entire research project intends to be communicated via this thesis. Sections, however, are broken down into relevant chapters within the thesis.

2.5 Conclusion

This chapter focused on the core of DSR, discussing some related DS research methods offered. The DSR approach was the principal research approach chosen and utilised as it focuses on developing useful artifacts that can be used in solving problems within real world conditions. To prevent useless and ineffective guidelines (those that do not ultimately address the usability and UID challenges of EMRs in Optometry) from being created, a rigorous and formal process to establish and validate the new guidelines is essential. DSR as the chosen methodology allows for such a process to be followed. Hevner, et al's. DSR also provides clear validation procedures to assess the effectiveness and efficiency of the proposed set of guidelines. It is inadequate to establish the new set of guidelines for a specific domain; it is also essential to validate that guidelines find specific domain-related usability issues. Hevner, et al. provide seven criteria to be met in order to conform to DSR, and Peffers, et al. provide a DSRPM which helps in the achievement of this, thus utilised in this research. The DSRPM navigating this research includes six steps applicable to the various stages in the research progression.

The proceeding chapter provides the theoretical background for this research, explaining relevant design concepts such as UID, UCD, Usability and user experience (UX). The various concepts are discussed in detail, establishing their importance and relationships with one another. The importance of a good UID is highlighted, as well as the role of usability in helping users attain their goals efficiently, effectively and with satisfaction.

Chapter 3: User Interface Design



This chapter aims to provide further context and theoretical backing for supporting this research study. The concepts and link between user interface design (UID), usability and user experience (UX) is discussed first; as the UI is the primary interaction point, which users are faced with when using a system. A poor UID hinders their usability (often of entire systems), and thereby negatively influences their UX. The significance of maintaining the user at the forefront of the interface design process is crucial and its relevance is thus expounded next via User Centred Design (UCD). Thereafter, various UID and usability guidelines are discussed, with a supporting table of UID categories emerging. At the end of the chapter, relationships between the above concepts ought to be appreciated, as well as their relevance within this research.

3.1 User Interface Design

The user interface (UI) is often regarded as the "lens" through which customers make critical purchase judgements about an application (Schumacher, 2010), and may be categorised as an attribute closely linked to, and influential upon usability. The UI is often considered to represent entire systems, as users initially and primarily interact with it (Boonstra and Broekhuis, 2010). When users are unable to optimally interact with their interfaces to meet their wants and needs, their overall experiences are influenced. As such, poor UID as a grave usability issue, translates to hindered usability, and thus negatively affects users' experiences (Nielsen, 1995; Kendall and Kendall; 2013; Ng and Tilliss, 2018). According to Alben (1996), successful UIDs are one of the factors contributing to a quality UX, usability and user satisfaction. Arhippainen and Tahti (2003) also support the above statement, stating that UIDs

and particular designs of products' interfaces are influential to users' interactions, ultimately forming part of their UXs.

UIs with good usability are quick to learn, efficient and pleasant to use, and easy to return to. A lack of attention to users' characteristics, preferences and task flows, along with other human usability factors, ultimately increases user resistance towards adopting and accepting systems (Zhang and Walji, 2011). It is, therefore, imperative for UIDs to be as efficient and usable as possible, which will ultimately affect their overall satisfaction and UX (Zhang and Walji, 2011; Middleton, et al., 2013; Zaroukian, 2013).

The UI consists of all the components of an interactive system (hardware or software) that provide information and controls for users to accomplish particular tasks with the interactive system (ISO 9241-210, 2019). Morville (2004) argues the need for UIs to have valuable purposes, fulfilling users' needs when they are used, and having UIs serving no purpose or having no use are therefore seen as futile. Resultantly, the UCD approach which encompasses the techniques used in this research, involving the users (Task Analysis (TA), Focus Groups (FGs), Usability Testing (UT), surveys), help to avoid this "futility". Moreover, it is imperative for UIs to not only be intuitive, but also easy to use (usable) in allowing for optimal user engagement and interaction with the UIs to fulfil their needs. Quesenbery (2001) views "usability" to extend beyond having just "ease of use", offering that UIs are evaluated against the amalgamation of the "5 Es"- Engaging, Effective, Efficient, Error tolerant and Easy to learn- which best describe user requirements for satisfaction and success. Similarly to the aforementioned considerations and design approaches within this chapter, this research considers these attributes and intends to apply them during the creation of the UID guidelines. The design of UIs ought to be engaging with well thought out behaviours, and produce interactive products to support the way users communicate and interact in their daily and working lives. The designs should proceed beyond the aesthetic appeal of systems and their interfaces, and extend to justify the significance of systems being usable, useful and satisfying to use (Saffer, 2009).

According to Morville (2004), users find value in UIs that possess characteristics extending beyond functionality, to include aesthetically pleasing designs, are fun, easy to use and desirable UIs. UIDs, therefore, ought to consider these aspects to maximise use and efficiency, which may be accomplished through a visual design supporting clear and concise information and features, simple components, and aesthetically desirable UIs (Arhippainen and Tahti, 2003; Maassen, 2008). Users need to be able to locate (findable) features within the UI, which have

a good information architecture (Nielsen, 1995; Shneiderman, 2004; Tognazzini, 2014). If features within the UI are not easily located, or "findable" (Morville, 2004), and have difficult navigation schemes with a poorly structured information architecture; then it is pointless to have UIDs that are visually pleasing or even highly usable (Morville, 2004; Ng and Tilliss, 2018). Despite the UI being just one of several constituents of a system, it is important to recognise that for many users the interface is the system (Kendall and Kendall, 2013; Ng and Tilliss, 2018). Consequently, the visual representation (UI) ought to be designed well with conformance to design principles and user requirements (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014), as this essentially encourages a positive UX through improved interactions and usability. This resultantly increases users' inclinations to adopt systems (such as EMRs), and UIs with designs focusing on ease of use and accessibility will likely attract more users, regardless of their abilities (Ng and Tilliss, 2018). It is essential to design for good usability of UIs beforehand, rather than relying on user adaptation to them.

A poorly designed UI discourages users' willingness to accept, use and adopt systems, regardless of how it is designed and developed internally (Kendall and Kendall, 2013). In contrast, when the UIs of systems are designed to match the specifically defined tasks within a context, the technology and the users, the probability of a system's success increases tremendously (Kendall and Kendall, 2013; Usability.gov, 2018). This is referred to as a ubiquitous design, whereby designs accommodate different contexts of use of users (Gkatzidou, et al., 2015). This is also why TA is used (Chapter 5). UID concentrates on anticipating what users might need to do, and guaranteeing that the UI provides easily accessible elements that are understandable, and enable the facilitation of users' activities. Effective UIs prevent user contact with the inner workings of systems, and the UIs are "visually apparent and forgiving" (Tognazzini, 2014), implanting a sense of control with their users (Nielsen, 1995). The users are able to quickly see the span of their control, and then discover how to perform and execute their tasks. Work is cautiously and constantly saved, with complete "undo" (Tognazzini, 2014) options for users who have made mistakes. The proposed guidelines (Table 9.1) reflect this.

The ultimate motivation of designing good UIs is to promote smoother system usability, to direct users and assist them with the information they require in and out of a system, in order to achieve their goals, tasks and business or practices as a whole (Kendall and Kendall, 2013). Kendall and Kendall (2013) suggest objectives to help users obtain the information they require to feed in and get out of a system. These objectives are considered throughout the designing of

a system's UIs. Some include making the UI efficient, matching the UI to the task, providing users with suitable feedback, improving the system users' productivity, and generating usable queries. Kendall and Kendall (2013) also stress the importance of clear communication and feedback provided by a system to users, in order to minimise any confusion or errors. This feedback may be in any form, communicating something of meaning to the user. For example, this feedback may be in the form of messages acknowledging input has been accepted, input is in the correct or incorrect form; when there is or will be a delay in the system, successful or unsuccessful completion of a task or command (Ng and Tilliss, 2018).

UIs ought to exploit the findings from psychological literature inferring that individuals are significantly better at recognition as compared to recalling information from memory, and integrate such features in the UI designs (Patel and Kushniruk, 1998). The designing of UIs for systems (like EHRs/EMRs) to maximise adoption has not been an easy task (Kendall and Kendall, 2013), as evidenced by literature and studies which identify many barriers and usability problems (Edwards, et al., 2008; Smelcer, et al., 2009; Hyppönen, et al., 2013; Mosaly, et al., 2015). Emphasis should be on the users when designing UIs (Love, 2005; Nwiabu and Adeyanju, 2012), and an understanding of the environment in which users are making use of the technology (context) is crucial, as this has a significant impact on their capacity to interact with the UI in an effective, efficient, and satisfying manner (Thomas, et al., 2017). Designing UIs to suitably consider the relationships between users, tasks and the context is challenging, and necessitates the preliminary understanding and modelling of the typical user's conceptual model and expectations of the system (Kendall and Kendall, 2013). Iterative designs may be considered; and according to Patel and Kushniruk (1998), an appreciation of distributed, as well as individual cognition is crucial in the development of effective UIs, as access to systems (such as health care ones) are becoming progressively extensive. Cultural and national variations in populations also influence users' interactions with UIs. As the UID of systems influences the usability, its relevance ought to be appreciated, and is thus discussed next.

3.2 Usability

Usability is a dynamic quality attribute that evaluates how easy UIs are to use by users, and it relates to how usable, useful and satisfying a system is for these proposed users to achieve goals within their work environments by carrying out certain sequences of tasks (Dillon, 2001; Zhang and Walji, 2011; ISO 9241-11, 2018). According to Zhang and Walji (2011), systems are considered useful when they support the work domain where users accomplish the objectives for their tasks, "independent of how the systems are implemented". Usable systems

are easy to learn, use and error-tolerant. A system identifies as satisfying if users have good subjective impressions of how useful, usable and likable the system is (Zhang and Walji, 2011; ISO 9241-11, 2018).

ISO 9241-11 (2018) identifies as the most unanimously agreed upon definition of usability and defines it as the degree to which a product, system, or service can be utilised by particular users to attain specified objectives with "effectiveness, efficiency and satisfaction in a specified context of use". This definition stresses the measurable criteria of performance (efficiency, effectiveness, and satisfaction) that are context-bound by the user-type, task-type and situation of use. Usability evaluation is therefore performed by having "representative users interact with the design" within a suitable environment whilst evaluators record results like data of task-times, user attitudes and errors (Dillon, 2001). This research consequently utilises UT (Chapter 8) during the evaluation stage.

Usability adds to the quality of a user's experience and overall satisfaction when interacting with products or systems, and is primarily concerned with the design features of interactive products, and how well users are able to utilise the functionality of the system. Usability as a conceptual construct should be designed as well as evaluated through all the development life cycle stages. Usability evaluation activities assist designers in finding usability problems more easily and thus producing better design solutions (Heo, et al., 2009). UID principles may be referred to for usability evaluation, despite being chiefly developed to support the design of good UIs. They are helpful in the organisation of different factors affecting usability, and also provide insights regarding translation of evaluation results into design improvements (Lewis, 1995; Brooke, 1996; Heo, et al., 2009).

The main purpose of designing and evaluating products, services and systems for usability is to assist users to attain goals efficiently, effectively, and with satisfaction, whilst considering the context of use (Quesenbery, 2001; ISO 9241-11, 2018). UX is affected by usability, whose interpretation may be in terms of satisfaction and user performance, accentuating that usability is reliant on specific circumstances in which a product, system or service is used (ISO 9241-11, 2018). Nielsen's usability and design guidelines (Nielsen, 1993; Nielsen, 2012) are similar to the ISO 9241-11 (2018) standards. However, Nielsen (1993) specifies principles of memorability, learnability and errors, which may be collected under the International Organisation for Standardisation (ISO) standard of effectiveness. The ISO 9241-11 (2018) standard additionally contrasts Nielsen's (1993) guidelines in that it includes the context of use as a factor affecting usability. Usability principles are imperative to good design and usability,

forming the basis on which UIs may be evaluated. Consideration of, and application of principles and frameworks (Nielsen, 1995; Shneiderman, 2004; Zhang and Walji, 2011; Middleton, et al., 2013; Tognazzini, 2014; Payne, et al., 2015) when designing UIs affect the usability.

Nielsen (1993) offers a set of usability (and design) guidelines which express usability as a multi-dimensional module. This module is divided into five usability metrics, aiding measurement of it qualitatively (or quantitatively) (Nielsen, 1993; Nielsen, 2012). These metrics are also considered and reflected within the Table 3.1:

1. Satisfaction- Refers to how pleasant users find their experience of interacting with the system and electronic records. Users who are content with their system or UI interactions and experiences are more likely to continue and promote use of their technologies, and perform their tasks with greater pleasure.
2. Efficiency- Refers to how fast users may perform tasks using the system. ISO 9241-11 (2018) provides the most holistic definition of efficiency. It not only accounts for task execution time, but also the mental and physical effort, materials utilised, and financial costs. Efficient systems idealy enable for accurate, greater task completion in less time.
3. Learnability- Ease of use for novice users in basic task accomplishment, and how easily they can discover and access the system's higher advanced features. Systems that match or "map" (Rogers, et al., 2011) to real world conventions or actions are more easily learned through recognition rather than recall (Nielsen, 1993; Nielsen, 1995). Additionally, systems/UIs with simple yet effective features are more easily learned and operated when compared to complicated ones, and this allows for greater task completion/operation especially by novice users.
4. Memorability- How easily can users re-establish their prior proficiency with the system if they stop using it for some time? Memorability is a big advantage when users like physicians are able to refer to older records, identify trends and work more efficiently. Features that allow for auto-saving and permit users to continue tasks where they left off not only saves time, but also reduces cognitive pressures from recalling information, which may lead to inaccuracies. Simple interfaces and features with easy navigational options also contributes towards improved memorability, further reducing risks of errors.
5. Errors- Refers to the number of errors made by users whilst interacting with the systems, severity, and ease of rectification of errors (Nielsen, 1993; Nielsen, 2012). Users are often afraid of exploring the various features available due to not being able to find escape routes or help features to return to their intended tasks. Support for the undo/redo of errors by means of "fix", return, "home" buttons or help features ought to be provided for, which encourages users to engage and interact with the system fully. Confident users are more

likely to better interact with/utilise the various features available, and also complete their tasks with greater satisfaction, thus continuing their use of the systems.

Usability is an essential element to the UI, and also refers to approaches for enhancing ease-of-use during the design process (Quesenbury, 2001; Nielsen, 2012). These five quality components defining usability may assist in identifying particular aspects in systems to improve upon, and enhance the usability (Nielsen, 2012). They describe the core of usability, whose impacts result in the adoption or not of systems. There are several other key quality attributes apart from the five aforementioned. Utility is one main attribute, and refers to the design's functionality, i.e., does it do what users need? Usability and utility are equally significant and together determine whether or not something is useful. It is futile for a system or UI to be easily operable if it is not what is actually wanted (Nielsen, 2012). It is additionally pointless if the system can hypothetically perform what is wanted, but the user cannot make it happen due to the UI being too difficult to use. Utility refers to whether or not the users' required features are provided for, and usability is how easy and pleasurable these features are to use. The combination of usability and utility delivers the term "useful", which is also a key attribute (Nielsen, 2012). A useful system or interface is one which includes all the required and necessary features for optimal performance, whose operation is both enjoyable and easy.

Historically, usability (of an application) has drifted from a concern with characteristics of a UI to address features of the "interaction expressed in terms of human action" (Dillon, 2001). This implies that the usability of systems has increasingly incorporated the UCD approaches; focusing on closely "mapping" (Rogers, et al., 2011) system characteristics/features with human interactions, rather than necessitating humans to match the systems. This intuitive mapping of characteristics to match real-world conventions allows for users to more easily achieve their tasks through natural actions and recognition, and experience a reduced cognitive burden in terms of learnability or memorability (Nielsen, 1993; Tognazzini, 2014). Good usability ultimately impacts users' satisfaction and experiences (UX), whose outcomes largely influence the continued use of systems (Quesenbery, 2001; ISO 9241-11, 2018). Thus, when aiming to attain optimal usability during UID and use, influence upon the users' experiences should be expected, whether positively or negatively. Consequently, some reflection upon the UX ought to be considered, as it is a result of the UIDs and usability.

3.3 User Experience

UX advances comprehension beyond usability (Nielsen, 2012), explaining the various facets of UX design and defining priorities (ISO 9241-210, 2019). It brings on a more human element to usability (Hassenzahl and Tractinsky, 2006), and a positive UX is the ultimate aim for users. Some factors that may influence UX of systems are desirability, perceived value, accessibility, usefulness and credibility (Nielsen, 2012). When a person interacts with a product or system, the overall experience is considered the UX. This UX accounts for the emotional, affective responses that result from the combined interactions within a context of psychological states, software design and the corporate environment. The usability of systems affects the users' experiences. The aim of UX is to increase the efficiency, effectiveness and satisfaction with which users perform their work, chiefly by aiding them to work at a faster pace, and by helping to decrease the potential for human mistakes and errors (Garrett, 2011; ISO 9241-210, 2019). Hassenzahl and Tractinsky (2006) further support that UX is a result of users' internal states, the designed systems' characteristics, and the environment or context within which the interaction occurs. This creates countless design and experience opportunities (Hassenzahl and Tractinsky, 2006). Pleasure is an aspect of UX that also adds greatly to overall satisfaction with a product or service. Thus, in order to encompass the overall UX, UX needs to be concerned with satisfying both hedonic and pragmatic user goals (Bevan, 2008). Some pragmatic user goals are:

- Acceptable perceived experience of use (pragmatic aspects are inclusive of efficiency).
- Acceptable perceived consequences of use (inclusive of safety).
- Acceptable perceived results of use (inclusive of effectiveness) (Bevan, 2008).

A UCD approach (Garrett, 2011), and examining users' views, behaviour, and interactions is important when designing for positive UXs (Maasen, 2008). This assists in discovery of the emotional relationship between the system and users, and enhances efficiency. Maasen (2008) further stresses the importance of understanding who will be using and interacting with the system, and also that users' "needs, wants, capabilities and desires" must be investigated and examined within the specific context of use.

3.4 User Centred Design

UCD is a design philosophy which places the intended system users at the centre of its design and development, and shifts "techno-centric" systems to become more user centric (Whetton, 2005). This is accomplished by including the users at significant stages in the project to guarantee that the system meets their requirements (Nwiabu and Adeyanju, 2012). Human

Computer Interaction (HCI) is alike UCD in its user centricity and focus. HCI is the study of the manner in which human work and activities are influenced by computer technology (Dix, 2009), and the extent to which technologies are (or not) developed for successful interaction with people (Love, 2005; Carroll, 2013). A key focus of HCI relates to comprehension of the processes included in utilisation and creation of more useful and effective computer systems. HCI is an associated design discipline with UCD and is occasionally referred to as UCD, which concentrates on how to design computer technology to ensure usage is as easy and satisfying as possible. The acknowledgement of the association between UCD and HCI allows for greater appreciation into the relationships between users and technology, and how these relationships may contribute towards better UI designs. Elaborate UIDs do not necessarily guarantee that they will be of effective use, and this reiterates the need for the user to be at the centre of designs (Maasen, 2008).

Applying UCD methods nurtures collaboration between researchers and practitioners, and it is therefore imperative to preserve the users' needs at the forefront of considerations when designing any system (Garrett, 2011). This results in enhanced performance, decision making (Nwiabu and Adeyanju, 2012) and good usability (Quesenbery, 2001). A system ought to be built with user needs at the centre of the "plan" or design, as they will be the operators, whose usability and satisfaction determine the ultimate efficiency, effectiveness and overall success of the system. A system that fails to serve its purpose of accommodating or adapting to user needs is a wasted resource, and the UCD approach aims to mitigate this realistic and frequent threat. UCD promotes positive usability and user satisfaction, with system interaction, and aims to produce a system that is highly usable. This "usability" (Al-Sa'di and Parry, 2017) is related to the efficiency and effectiveness of the UI. UCD is one of the only design methodologies, which places users at the heart of the design process, and is therefore ideally suited to developing products that must be simple and easy to use. Humans that interact with an application's interface share common characteristics, yet each user's needs and personality are unique and rely on their own knowledge, competence, gender, age, cultural background, and other factors (Al-Sa'di and Parry, 2017). Despite their genetic comparability, human experiences contrast extensively. Adapting a system to a user's thinking is much simpler than changing the user's thinking, and user centred systems ought to help users to achieve their goals by being designed with their needs at the centre of the designs.

Conceptualised from the same roots as, and often considered interchangeable with UCD is Human Centred Design (HCD) (Kent University, 2019). HCD complements existing systems design approaches and is a crucial component to the success of interface designs (Elmansy,

2018; ISO 9241-210, 2019). According to ISO 9241-210 (2019), HCD is an approach to interactive systems development that targets to make systems useful and usable by focusing on the users, their requirements and needs, and by applying "human factors/ergonomics, and usability knowledge and techniques". It is a reputable approach for bringing people, their social contexts, needs, and requirements in to design processes (Thomas, et al., 2017). This method increases the effectiveness and efficiency, and enhances human satisfaction, well-being, sustainability and accessibility. It counteracts potential negative effects of use on human performance, health and safety. HCD extends beyond UCD in that it places greater consideration on the impact that stakeholders face, rather than just those "typically considered as users" (ISO 9241-210, 2019). Thus, the ISO standards (ISO 9241-210, 2019) use the term "human-centred" rather than "user centred". HCD considers the overall human UX, and the usability of artifacts and their applications in the real world. UCD does the same, but focuses on the overall human UX and "stakeholders" to a slightly lesser extent. It concentrates more of its efforts on the practical utility of artifacts, and the "typical users" (ISO 9241-210, 2019). The distinctions between the two are slight, and thus often synonymised (Thomas, et al., 2017; ISO 9241-210, 2019; Kent University, 2019). This research appreciates the efforts of both UCD and HCD, but primarily uses the term UCD. This is because the usability of the artifact is focused on more than the UX and the "stakeholders" *per se* (ISO 9241-210, 2019). In application, this research acknowledges that the consequences of the guidelines created may be influential on the overall satisfaction and UX faced by users (optometrists), granted there will be an improved usability of EMRs.

UCD (and HCD) aim to develop UI solutions that are less vulnerable to potentially damaging use errors (Wiklund, et al., 2015). Additionally providing assistance to ensuring a UCD and HCD approach, some main UID principles may be considered (ISO 9241-210, 2019), which share linkages to some of the well-established UID principles in previous renowned studies (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014):

1. *The design is based upon an explicit understanding of users, tasks and environments:* Users generally do not interact with systems' core components, but rather experience the system, and the synergistic effects of the components working in unison which results in, for example, a UI. Thus, the users' needs, environments and objectives are essential to first understand, in order to create interfaces which allows them to effectively access the system's functionality.
2. *Users are involved throughout design and development:* Users, as the primary and end users of systems interact the most with it. Thus, their inclusion throughout the design and

development processed ensures a closer match to their needs (and future needs), and greater usability with fewer risks of errors. This ultimately affords a greater UX and encourages continued use of the systems.

3. *The design is driven and refined by user centred evaluation:* Users generally evaluate or assess (entire) systems based on whichever parts of it they are presented with, like the UI. Thus, they view the UI as the whole system, which may be an unfair representation if the rest of the system is designed well, yet has poor UIDs. Consequently, users ought to be continuously maintained at the centre of designs, and also in the evaluation stages to determine if their needs are met.
4. *The process is iterative:* Iterative designing ensures a more thorough end product in that errors may be revised, or improvements made before the final launch. Users are able to interact with the prototypes, evaluate them and suggest any alterations to designers over several stages or rounds, which leads to a more quality, adaptable product.
5. *The design addresses the whole user experience:* Functionality of systems may be of good quality, with many features or options available. If, however, the designs are poor and users cannot find or use these features on the UI, then they will have poor UX.
6. *The design team includes multidisciplinary skills and perspectives:* It is important to include designers with varied talents and characteristics as this variation affords a more diversified approach to designs. Different skills and perspectives allow for more dynamic and three dimensional designs or approaches, which are better able to meet user needs that frequently grow and change at a fast pace (ISO 9241-210, 2019).

3.5 User Interface Design Guidelines

Literature provides several UID and usability principles with many coinciding elements (Nielsen, 1995; Wiklund, 1998; Wiklund, et al., 2015; Shneiderman, 2004; Rogers, et al., 2011; Macintosh, 2013; Johnson, 2014; Ng and Tilliss, 2018; ISO 9421-11, 2018). Appreciation of other guidelines such as Gestalt Theory and Principles (Hampton-Smith, 2017), information architecture and Fitt's Law, for example, are also considered as helpful to good UID (Chang, et al., 2002; Tognazzini, 2014; Hampton-Smith, 2017). Many sources from literature birth imperfections, including incomplete considerations of user requirements, technological limitations, and aesthetic decisions that may not necessarily match all users' preferences. Consequently, designers should aim for an optimal rather than a perfect UI (Wiklund, 1998). Progressing beyond core design attributes like a cohesive conceptual model, total UI quality is found within the "details the superficial elements like navigation cues that" (Wiklund, 1998), when used most suitably, may aid in creating a more user-friendly design. Accordingly, this chapter enables the creation of UID guideline categories (Table 3.1), which aim to help the

enhancement of usability and the UIDs of EMRs. Presenting and explaining the various, guidelines, which literature offers allows for a reflection on their applicability within this research, as well as the relationships towards one another (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Consequently, the analysis discussed further below allows for this research to realise these commonalities and utilise the most efficient, applicable guidelines/principles for this research.

Nielsen (1993) and again in Nielsen (1995), provide ten UID guidelines to assist with efficient designs to improve usability of systems. These renowned guidelines are often referred to as heuristics, as they allow for an inspection method that allows for usability heuristic evaluations to be performed to help determine design aspects that contribute to poor usability (Nielsen, 2012). These guidelines or heuristics by Nielsen (1993), as well as Norman's Design Principles (Rogers, et al., 2011) may be comparable with Shneiderman's (2004) Eight Golden Rules, as they share common ideas and overlap. The Eight Golden Rules (Shneiderman, 2004) are also UID guidelines aiming at improving usability, an overall positive user satisfaction and UX. These UID guidelines by Nielsen (1993) and Shneiderman (2004) are further supported by Tognazzini's (2014) "First Principles of Interaction Design". These principles are concrete to the designing of effective UIs for an array of purposes, including the web, smart devices, mobile devices, wearables and traditional Graphical User Interface (GUI) environments (Tognazzini, 2014).

After an extensive analysis of the several leading UID principles/guidelines, common categories to all of these were derived and are presented in Table 3.1. The columns in Table 3.1 present these common, relating guidelines from each authority, forming a new set of categories (Nielsen, 1993; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Table 3.1 illustrates the main UID guidelines and principles, as well as their linkages, whose categories will be added to and expanded upon as the study progresses. Many of the guidelines relate to one another, and may be interpreted to fit into different categories. Consequently, these relations have been appreciated, but the main, most complementary guidelines have been categorised together. The well-established authorities providing these guide include Nielsen's ten UID guidelines (Nielsen, 1993), Shneiderman's Eight Golden Rules (Shneiderman, 2004), Norman's Design Principles (Rogers, et al., 2011) and Tognazzini's (2014) "First Principles of Interaction Design. This research realises the importance and differences of the various authorities' guidelines, but focuses more on the format of Nielsen's (1993) ten UID Guidelines, having found them to be most suitable for this study.

Greater depth follows in the narrative proceeding the table, which provides a visual overview and summary of the principles and/or guidelines, which helps with their comparisons. Mere awareness of the UI features alone is inadequate. Rather, a knowledge of how to put them together and practically apply them is more useful, as Schlossman and Schumacher (2014) purport that designers who build, bear a responsibility to those who experience. Figures 1.1, 1.2 and 4.1 may be referred to as examples of the effects of designing UIs according to UID guidelines (Tables 3.1 and 4.1 may be referred to).

Table 3.1: Prominent UID Principles and Guidelines Forming Categories

CATEGORIES	NIELSEN'S TEN UID GUIDELINES	NORMAN'S DESIGN PRINCIPLES	SHNEIDERMAN'S EIGHT GOLDEN RULES	TOGNAZZINI'S FIRST PRINCIPLES OF IxD
SYSTEM STATUS AND FEEDBACK	Visibility of System Status	Visibility; Feedback	Offer Informative Feedback; Design Dialogs to Yield Closure	
REAL-WORLD CONFORMANCE	Match Between System and the Real World	Mapping; Affordance		Human Interface; Objects; Metaphors
FLEXIBILITY OF CONTROL AND CUSTOMISATION	User Control and Freedom		Support Internal Locus of Control; Permit Easy Reversal of Actions	Explorable Interfaces; Autonomy; State
CONSISTENCY	Consistency and Standards	Consistency	Strive for Consistency	Consistency
ERROR MITIGATION AND RECOVERY	Error Prevention; Help Users Recognise, Diagnose and Recover from Errors	Constraints	Prevent Errors; Permit Easy Reversal of Actions	Protect Users' Work
COGNITIVE LOAD	Recognition Rather than Recall		Reduce Short-Term Memory Load	Visible Navigation and Interfaces; Learnability
EFFICIENCY	Flexibility and Efficiency of Use		Enable Frequent Users to Use Shortcuts	Defaults; Efficiency of the User; Fitt's Law; Latency Reduction; Anticipation
DESIGN SIMPLICITY	Aesthetic and Minimalist Design			Aesthetics; Readability; Simplicity; Colour
HELP AND REFERENCE DOCUMENTATION	Help and Documentation			Discoverability

3.5.1 System Status and Feedback

Analysis of several usability and UID guidelines (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014) allowed for the discovery of those sharing common attributes.

These included: “Visibility of System Status”; “Visibility”; “Feedback”; “Offer Informative Feedback” and “Design Dialogs to Yield Closure”, which in turn created the category, “System Status and Feedback” to emerge (Table 3.1). This category includes always updating users of their task progression and system awareness, as well as providing constructive, timely and informative feedback to them regarding their tasks or any relevant system information.

The system (and UI) should always present users with an updated, informative system status/feedback, so they are kept informed and are aware of their current task status. The feedback should always be timely, clear, constructive, and related to their tasks or actions, or any system delays. It should be dynamic and repetitive if necessary, and possibly in the form of colour, sound (aural), text or shape. This also enables users to be informed that the system has responded to their selections or interactions (Nielsen, 1993; Wickens, et al., 2004; Subramanya and Yi, 2008). For example, a button depressing and changing colour upon selection.

When systems’ processing times are longer than four seconds, supplementary feedback (haptic or sound) is advisable. Similarly, if button presses or mouse clicks do not evoke system responses, provision in the form of a moving icon to reassure users that the system has not crashed is also sensible. Despite users possessing no control over systems’ feedback speeds, it is still important to give them timeous feedback when these systems take longer than usual to respond (Stockbridge and Mughal, 2008; Shneiderman, 2004; Nielsen, 1995). A lack and delay of system feedback or visibility of system status’ (Nielsen, 1995; Shneiderman, 2004; Tognazzini, 2014) contribute towards user frustration, compelling them to over-click or select icons which may induce system mal-functions (Huang and Lai, 2008). Small windows or task bars that show task progress or statuses could be utilised, with options for hiding, expansion or moving it. Pop-up boxes or messages for relevant feedback, alerts/notifications could also be used. Frequent and unnecessary alerts may desensitise users over time, and may ignore them (Nielsen, 1995; Rogers, et al., 2011). The alerts ought to be concise, customisable, may be visual, aural or tactile. Scales of severity indications could be incorporated too, for example, using modal message boxes for important alerts. Modal messages as well as mandatory field entries may be utilised for high risk tasks or feedback requiring attention, which addresses the challenge of desensitisation or ignoring of alerts. “Design Dialogs to Yield Closure” (Shneiderman, 2004) refers to the arrangements of actions that ought to be organised into groups, having a start, middle and end. The informative feedback at the conclusion of a group of actions contributes towards operator satisfaction from their task accomplishment. It provides

an indication of a clear path to prepare for the next group of actions; for example, a "Task Success!" alert after a certain task was undertaken.

3.5.2 Real-World Conformance

The common guidelines and principles of "Match Between System and the Real World"; "Mapping"; "Affordance"; "Human Interface Objects" and "Metaphors" (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014) enabled the creation of the category, "Real-World Conformance" (Table 3.1). This category includes designing interfaces that follow practical, real-life conventions, that users are easily able to understand without much need for training or learning.

Features available on the UI should function as if they would do so in the real-world, or "map" (Rogers, et al., 2011; Ng and Tilliss, 2018) according to real-world conformances (Nielsen, 1995; Shneiderman, 2004). Any new or arbitrary designs should be made known to users, who may face difficulties in discovering such features' functionalities, and an explanation ought to accompany them (Tognazzini, 2014). For example, a compass icon representing the web browser "Safari" for Apple products (Galitz, 2007; Tognazzini, 2014). Similar situations call for constant arrangements of actions, and thus should be considered during the design process (Nielsen, 1995; Rogers, et al., 2011). "Metaphors" (Tognazzini, 2004) used should match real-world situations, or are instantly associable to their functions. For example, a saving feature represented by a "floppy disk icon". They should be brought "alive" by appealing to users' different senses when suitable. Use of buttons/icons that are metaphorically parallel with real-world norms exploit users' existing knowledge, affording them an instant awareness on how to interact with the UI. Usability, inclusive of memorability and learnability of the UIs increases, as well as user satisfaction (Nielsen, 1995; Tognazzini, 2014).

Metaphors should expand beyond "literal interpretations of real-world counterparts" (Tognazzini, 2014), having a balance between skeuomorphism and abstraction (Ng and Tilliss, 2018). "Human Interface Objects" (Tognazzini, 2004) may include folders, buttons, icons ringtones, menus, trashcans and appear within user environments, easily seen and familiar to GUIs. They may include less familiar objects, such as auditory cues like ringtones. Human Interface Objects ought to conform to standard methods of manipulation, like buttons being pressed, sliders dragged, and include standard resulting behaviours, for example, dragging documents to temporary deletion into trash cans icons. Users should be able to interact with them as needed, for example, a well-designed button on the display affords clicking. Contrarily, an embedded hyperlink without any visual cues (underlined blue text), regardless of whether it

supports the action clicking, identifies as poor affordance. This is because users are not able to perceive it through its visual cues. Human Interface Objects should also be logical, consistently represented and stable, thus likening to the guideline of "Consistency" as well (Wiklund, 1998; Ng and Tilliss, 2018). Objects resulting in different behaviours or working differently ought to have updated or different looks to their associated, previous ones. "Real-World Conformance" also encompasses Norman's Principle of *"*Affordance" (Rogers, et al., 2011).

3.5.3 Flexibility of Control and Customisation

The relatable guidelines and principles of "User Control and Freedom"; "Support Internal Locus of Control"; "Permit Easy Reversal of Actions"; "Explorable Interfaces"; "Autonomy" and "State" (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014) enabled for the creation of the category, "Flexibility of Control and Customisation" (Table 3.1). This category includes designing interfaces that allow users to be in control (autonomy), with easy options for customisations. It also includes provision for users to be able to continue where they left off previously (State), and have the option or easily undo their actions if required.

Users should be able to customise their tasks according to their preferences and experiences, with the options of shortcuts and work-arounds provided. As such, systems like EMRs should be designed for personalisation, whereby the systems identify the users and deliver to them the content, functionality, or experience that matches their role. The UIs may reflect this via certain colours, shapes and sizes being used on screen, or even particular frequented icons being made visible and other less prominent (Wiklund, 1998; Wiklund, et al., 2015). Novice users should not be at a disadvantage as compared to experienced ones, provided with functionalities that are easily learned, simple and customisable (Ng and Tillis, 2018). To relieve any design tension between the need for user customisation and the "one-off, fast interaction" (Gkatzidou, et al., 2015) context of use of EMRs, a balance with reasonable customisability options ought to be applied.

Direct manipulation should be considered. Users should be able to manipulate onscreen objects directly, as this interaction style is likely to increase interactions' intuitiveness, efficiency, and error resistance in comparison to other interaction styles (Wiklund, et al., 2015). Navigation should be easy with the provision of adequate, unobtrusive features, such as scroll bars or search features. When information proceeds the immediate screen, scroll bars and navigational features should be available to users, suitably positioned on the screens as to not obstruct view of any information. For example, disappearing or "invisible" navigation features may relieve

potential visual-obstructions, especially for smaller screens (Tognazzini, 2014). Linking to this is Tognazzini's (2014) Principle of "Explorable Interfaces". Well-structured Information Architecture (IA) additionally assists with the findability of features within UIs, as well as with ensuring good navigation and logical placement of features on UIs (for example, refer to Figures 1.2, 7.1, 7.2, 7.3 and the Appendices, such as F21 and F22). This is through organising information and features in a clear, concise manner, reducing confusion or cognitive pressures, a short user learning curve, and making it relatively easy for users to locate what they are searching for (Maassen, 2008, Ng and Tilliss, 2018). When presenting users with novel features, the provision of familiar and consistent methods of task execution that they are used to should be continued. Stable visual elements should be present to speed up navigation, as well as in serving as reliable landmarks to reassure users of a sense of "home" (Tognazzini, 2014). Visual features such as home icons or menu bars should be standardised on the various UI screens, allowing for faster user navigation (Nielsen, 1995). Historical navigation features (Tognazzini, 2014) may help users map out their routes and return to previous screens, and graphical elements such as back buttons assist in this navigation through the UIs. These back buttons for example, contribute towards user efficiency and in the logical task-step flows, as well as not straining users' mental models of the UIs.

Users should also have features enabling their actions to be undone, or reversible, with clear navigation (Nielsen, 1995; Shneiderman, 2004). Features for "undo" and "redo" are believed to relieve anxieties faced by users, as they are aware that errors may be undone. This encourages confidence and thus system exploration. These guidelines thus link "Flexibility of Control and Customisation" to "Error Mitigation and Recovery". as well as relating to "Consistency" in terms of the UI elements conforming to standard layouts and functions so as to not confuse users and permit errors. Some enabling features to encourage "Flexibility of Control and Customisation" could be the provision for free-text entry, customisation options, and adjustable templates. Auto-save functionality could assist in picking up tasks at a later time, from where it was previously left off, as well as preventing any data losses. The auto-saving may also serve as a data protection method, backing up user information in a secure database. In the event that a user may not have their data or files available, a backup would be available for restoring onto their system.

The continuation of tasks afforded by the auto-save features also contributes towards systems linking to each other, between various EMRs and UIs for example. Tognazzini's (2014) principle of "State" also influences the concept of task continuity. "State" (Tognazzini, 2014), refers to the user activity often being tracked regarding their interactions with browsers or the

system. User information is often saved, enabling for task continuity when users return to the pages or UIs. As a result, information stored ought to protect their privacy, integrity, and should be encrypted.

Privacy policies ought to provide the users with full details regarding what will be stored or not (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Under Nielsen's (1995) guideline of "User Control and Freedom", the provision for better support in error recovery, with support for undo and redo options is a strong recommendation. "Support Internal Locus of Control" (Shneiderman, 2004) refers to the idea that systems ought to be designed to make users the initiators of actions, instead of responders. This is attributed to experienced operators desiring the sense of system control. Supporting this is Tognazzini's (2014) principle of "Autonomy", whereby users should have a sense of control and freedom to use and customise the system according to their desires, yet still be aware of the boundaries which also help reassure them (Tognazzini, 2014). Ultimate control however, ought to rest with developers to maintain the systems' intended functionality and operation. There should be use of accurate, current and easily visible status mechanisms which update, inform and keep users aware at all times.

3.5.4 Consistency

The guidelines and principles of "Consistency and Standards"; "Consistency"; and "Strive for Consistency" share commonalities, thus creating the encompassing category of "Consistency" (Table 3.1) (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes designing interfaces, which include information that is uniformly presented across the system, and whose functions afford consistent interactions each time they are used. UIs that are aesthetically pleasing do not guarantee user efficiency. Consistency is often violated, confusing users and leading to user frustration and errors especially when they are new to the systems (Grudin, 1989; Nielsen, 1995; Shneiderman, 2004). Grudin (1989) states that consistency is regarded as essential when linked to the regularity with which users perform tasks, and it is a goal that often conflicts with other more pertinent ones at times. This infers that consistency ought to be kept in mind at all times when designing UIs, but not be the sole goal. The UIs should include consistent wording, layouts and features, which should perform the same actions when used or selected (Shneiderman, et al., 2011; Tognazzini, 2014). For example, icons could be harmonised and refined; icon elements may represent nouns (objects like a syringe, patient, or glasses), thus preventing situations where many elements represent the same thing (Wiklund, 1998; Ng and Tilliss, 2018). Terminology ought to be identical in prompts, menus, and help screens, and consistent commands should also be employed

throughout (Wiklund, 1998; Shneiderman, 2004, Ng and Tilliss, 2018). The terminologies and languages used should cater for the majority of users, with provision of help facilities for users speaking other languages or for terminologies misunderstood (for example, SNOWMED-CT, ICD-10 Codes) (Rogers, et al., 2011; Tognazzini, 2014). Wording, acronyms and abbreviations should be simple, descriptive, clear and commonly understood. Text should not all be in uppercase, which indicates "shouting", increases the perceived density and takes longer to read (Belden, et al., 2009). Predictability is also another key factor in enabling efficient use and decreasing errors (Tognazzini, 2014). Platform conventions should be followed, and users must not be left to wonder whether varying actions, circumstances or words mean the same thing. This relates to "Real-World Conformance". Consistency is regarded as even more important when associated to the frequency with which users carry out an activity, and greater considerations towards ensuring it assist in reducing user-errors (Nielsen, 1995; Rogers, et al., 2011). Tognazzini (2014) discusses "Induced Consistency", which stresses the imperativeness of being "visually inconsistent when things act differently as it is to be visually consistent" when they act the same. Objects acting differently ought to look different, and pages that have modifications made should also look changed. This helps reduce any potential user errors and confusion.

3.5.5 Error Mitigation and Recovery

The Category, "Error Mitigation and Recovery" (Table 3.1) encompasses the related guidelines and principles of, "Error Prevention"; "Help Users Recognise, Diagnose and Recover from Errors"; "Constraints"; "Prevent Errors"; "Permit Easy Reversal of Actions" and "Protect Users' Work" (Table 3.1) (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes designing interfaces which protect users' work, as well as providing for recovery methods if mistakes are made. This category also includes provision for assisting users to become familiar with their system constraints and workarounds, allowing for them to learn how to minimise risks of errors.

Regardless of where fault lies, users' work should always be protected, with error-recovery methods, contingency plans, back-ups and help tips/tooltips available (Nielsen, 1993; Nielsen, 1995). Systems' designs should also incorporate intuitive features, which prevent errors occurring in the first place (Nielsen, 1995). Error-prone conditions may either be excluded or checked for beforehand, and users should be presented with confirmatory options prior to committing to any actions (Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Auto-save features may assist in allowing for users' work to be saved, protected and have easy continuation from where they left off previously. Auto-fill and predictive features may enable

more efficient task-conduction, and customisable pre-set templates contribute towards error prevention. Error messages ought to be presented in calm, user friendly language, with precise warning of the issue and constructive suggestions for solutions (Nielsen, 1993; Nielsen, 1995). This links to the guidelines of "System Status and Feedback", as well as "Consistency". The design concept of constraining refers to determining ways of restricting the kind of user interaction that can take place at a given moment. Placing restrictions for certain activities could prevent errors from performing erroneous or harmful tasks, and guide them for better performance (Rogers, et al., 2011). The inclusions of error recovery features (like "Undo" and "Redo" buttons) relieve anxieties faced by users as they are aware that errors may be undone. This encourages confidence and thus system exploration, and a sole action, data entry or complete group of actions may formulate the reversibility method (Nielsen, 1993; Nielsen, 1995).

3.5.6 Cognitive Load

The guidelines and principles sharing common attributes under the category of "Cognitive Load" (Table 3.1) are: "Recognition Rather than Recall"; "Reduce Short-Term Memory Load"; "Visible Navigation and Interfaces" and "Learnability" (Nielsen, 1993; Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes the designing of interfaces to reduce the mental strain on users. This may be via the layout and the navigational structure of the UI, for example, or relying on the use of familiar and recognisable interface objects rather than reliance on users' learning abilities for new objects/features. Task steps should be few, with short learning curves, and users should not have to rely on recalling information from memory.

Tasks should not be cognitively demanding, heightening potential risks of error, and not conforming to simplicity in design, naturalness (mapping) and consistency thus increasing cognitive pressures (Belden, et al., 2009). Steps to completion should be simple and few, with easy navigation. Learning curves should be minimal, with reliance on recognition rather than recall (Nielsen, 1995; Rogers, et al., 2011). Users should not have to recall excessive amounts of information as this strains their memory loads. Instructions for system use and option use ought to be readily available or visible when needed (Nielsen, 1995). Pre-set templates, auto-fill documentation and shortcuts contribute towards task efficiency, as well as minimising mouse clicks and selections on the UI by the user (Shneiderman, 2004; Tognazzini, 2014). To minimise user confusion and frustration, numeric layouts could be used for numeric entry, and letters to construct words. Additionally, mental models ought to be followed to correctly group functionalities, and buttons following sequences for performing tasks should be grouped

together, and in a sequence that is similar to users' mental maps. Users such as optometrists often work under immense time pressures and in environments with several demands for their attention. Staggering information overloads faced combined with cognitive overloads lead to patient safety risks. EMRs should anticipate physician needs and present the relevant information to them at the actual time they need it presented on the UIs (real time). Cognitive pressures threaten error occurrences. Thus, displays should be simplistic, distinct, few in number (by use of smaller screen overlays), multiple page displays consolidated, window-motion rates decreased, and adequate training time be allotted for mnemonics, codes and action sequences (Shneiderman, 2004; Tognazzini, 2014). Tognazzini (2014) presents "Visible Navigation and Interfaces", which is linked to his principle of "Discovery", encompassed under the guideline of "Help and Documentation" (Table 3.1). Navigation patterns of users should be visible, and they should not be expected to create their own mental maps, risking cognitive overload and user-error. "Explorable Interfaces" (Tognazzini, 2014) refers to when presenting users with any novel features, there should be continued provision of familiar and consistent methods of task execution that they are used to.

3.5.7 Efficiency

The Category, "Efficiency" (Table 3.1) emerges from the related guidelines and principles of, "Flexibility and Efficiency of User"; "Enable Frequent Users to Use Shortcuts"; "Defaults"; "Efficiency of the User"; "Fitts' Law"; "Latency Reduction" and "Anticipation" (Table 3.1) (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes designing interfaces, which enable users to carry out their tasks as efficiently and accurately as possible. This may be via the provision of defaults, shortcuts, accelerators, particular arrangements of features/objects on the UI, and predictive features, for example.

Tailoring of common actions or practises should be accommodated for in systems' designs, and the incorporation of "accelerators" (Nielsen, 1995; Chou, et al., 2011; Ng and Tilliss, 2018) may enable more efficient user interaction and engagement for both novice and expert users. Users should also be able to use shortcuts as their usage frequency increases. This is supported by users' desires to decrease the number of interactions whilst increasing the pace of interaction (Shneiderman, 2004; Rogers, et al., 2011). When users activate fields, the current entry should be selected automatically so that pressing "Backspace/Delete" or starting to type will get rid of the current entry. This refers to "Defaults" by Tognazzini (2014), which should be intelligent, responsive and only used when applicable. If the default is purposeful, this can lead to better care and decreased overuse (Vaughn and Linder, 2018). Good design of defaults is crucial to err on the side of caution and deliver a "balanced solution between zero-configuration and

counter-productive personalisation" (Gkatzidou, et al., 2015). User tests should be used to help identify what users associate the term "Default" with, which may then be replaced with it instead. For example, the use of "Revert to Standard Settings" instead of "Default" (Tognazzini, 2014). Vocabulary and visual designs ought to clearly communicate the scope of a reversion, and not leave anything ambiguous. When designing tabbed objects, like preference windows and properties, it should be ensured that the visual design makes the scope of a restoration button clear. Users should always be fully aware of the extent their restoration option will take them, for example, the entire system restoring or just a few previously saved field entries. "Efficiency of the User" is highlighted by Tognazzini (2014), whereby user productivity is considered significant, instead of just a machine's efficiency. Additionally, efficiency should include all the departments and employees, and not just one. System response time should be quick, reducing waiting periods faced by users. Efficient systems are the result of close and constant communication between the human interface designers and the engineers, and these relationships ought to be maintained. In the event of errors, useful and understandable messages ought to be available. "Latency Reduction" and "Readability" also affect the efficiency (Tognazzini, 2014).

Contributing to "Efficiency" is "Fitts' Law" (Tognazzini, 2014), whereby the time to reach a target is a function of the distance to and size of the target. Consequently, large objects should be used for important functions, as big buttons are faster to reach, save time and reduce possible errors from mis-selections. Similarly, small objects should correspond to functions that are preferable for users to perform less frequently. Fitts' Law should always be effected, regardless of the natures of pointing devices or targets. Multiple Fitts should also be considered. The time to reach many targets is the sum of the time to acquire each one. This means that apart from distances being reduced and target sizes increased, the total number of targets (virtual and physical world) that must be acquired to perform a task should be reduced (Tognazzini, 2014). Latency Reduction refers to users' experiences of inactivity being minimal. This may be achieved by means of using multi-threading, pre-fetching data, acknowledging all button clicks by aural or visual feedback within fifty milliseconds, and trapping multiple clicks of the same objects or buttons. Users should be informed at all times when facing delays, with appropriate delay feedback times and indicators (Tognazzini, 2014). For example, use of an animated mouse cursor for a delay of up to two seconds, and an animated progress bar or indicator for a delay of up to five seconds. Unnecessary elements that slow the processes ought to be omitted. This principle of "Latency Reduction" (Tognazzini 2014) also relates to "System Status and Feedback". Tognazzini (2014) presents "Anticipation", whereby all the tools and information concerning each step of a process should be brought to the users, fully present and visible.

Hardware and software systems should aim to anticipate the user's desires and requirements else risk the loss of users. Designers need a thorough comprehension of the users and the task domain to predict the requirements. Adequate UT is imperative to ensure the goal has been met. Regardless of any tools or sources for information being present on a screen; if users are not able to find it, it may as well not even be there. This also relates to "System Status and Feedback".

3.5.8 Design Simplicity

The Category, "Design Simplicity" (Table 3.1) emerges from the related guidelines and principles of "Aesthetic and Minimalist Design"; "Aesthetics"; "Readability"; "Simplicity" and "Colour" (Table 3.1) (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes designing interfaces, which are simple, easy to learn and use, yet aesthetically pleasing, whist still including sufficient functionality for users of varying technical expertise.

Credibility relates to the initial judgments based on surface characteristics, and in the context of UI interactions, which is primarily nonverbal, it is often based on the way it looks and feels; the aesthetics or design of a UI (Gkatzidou, et al., 2015). UIs should be intuitively designed to incorporate all the necessary features and relevant information, yet maintain a design that is, consistent, uncluttered, balanced in terms of density (character count, resolution, font size, font, grouping techniques, screen element), colour, contrast and accounting for different user types/preferences (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Excessive information competes with relevant units of information, diminishing their relative visibility (Nielsen, 1995). Interfaces ought to be aesthetically pleasing to induce user-desire and enhance their satisfaction, maintaining a balance between simplicity and functionality.

Buttons may be considered as icons with images, and are clickable features that often have accompanying text. Button locations within a window are reliant upon the type of button, whether it be "command buttons", "toolbars" or "push buttons". For example, command buttons like "close" or "exit" buttons are generally located at the top right, or in corners of screens. Buttons ought to have adequate spacing between themselves, especially when adjacent to each other, as well as relative to other surrounding screen features. They should be easily selected or clicked on if needed, thus preferring plain, geometrically structured shapes (squares, circle, rectangles). Important features should correspond to larger buttons, which allows for users to quickly and easily reach their intended targets. Smaller and closely spaced buttons or targets require greater concentration and take more time to reach, thus decreasing usability

(Galitz, 2007; Tognazzini, 2014). All interface objects (like buttons) should be of proportional size to the UI, as well as on based on their prominence (Wiklund, 1998; Ng and Tilliss, 2018). The shapes should be regular, intuitive, distinct, easily selected and located for fast navigation, conforming to Fitts' Law (Tognazzini, 2014). The number of buttons should be minimal, with non-essential ones hidden or removed.

Aesthetics refers to the visual appeal of UIs, and usability should not be compromised in order to achieve aesthetically pleasing UIs. User tests of the visual designs should be done as comprehensively as the behavioural design to ensure there is (or not) improvement, and no negative consequences (Tognazzini, 2014). Presbyopia, a condition of hardened and less flexible lenses, as well as decreased light transmission into the eye, affects most individuals over fourty-five years of age. Thus, design tests should be performed on the oldest expected user population. Approximately ten percent (10%) of human males, and less than one percent (1%) of females suffer from some form of colour blindness. About zero point four percent (0.4%) of females and eight percent (8%) of males have red-green colour blindness, with only 0.01% of all humans having blue-yellow colour blindness (Tognazzini, 2014). Sites ought to be tested to see what colour-blind/visually impaired individuals are able to see, and accommodate for them. When colours are used to convey information in the UI, there should additionally be clear, secondary cues to transfer the information to those who are not able see the colours presented (Wiklund, 1998; Ng and Tilliss, 2018. Colours used should be complementary, un-clashing, and noted that softer ones are less distracting. Colours that contrast assist in providing distinctions, and the consistent use of them should be used; like for buttons/labels, conforming to real world conventions (red is danger and green is good) (Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Social influences however, ought to be accounted for in cases such as red being associated with danger in western countries, but wealth and good fortune in eastern ones like China.

External lighting may affect the display of screens, and should be accounted for. Screen resolution has been commonly identified as optimal at ten thousand and twenty-four by seven hundred and sixty-eight pixels (1024 x 768) pixels, and thus designers should consider this during design processes, yet provide adaptability for alternate resolutions. In terms of "Readability" (Tognazzini, 2014) and text presentation, text ought to have high contrasts, such as black text on white, and not clashing colours such as bright green on red (Wickens, et al., 2004; Tognazzini, 2014). They should have suitably large font sizes, and "menu button labels should have the key word(s) first, forming unique labels" (Tognazzini, 2014). Font styles should be complementary to the UI, easily distinguishable and legible, for example, Arial

twelve point (12pt) (Wiklund, 1998; Ng and Tilliss, 2018). Human vision systems respond to sharp edges. Consequently, care should be taken when choosing fonts that seem visually appealing due to its style (Galitz, 2007; Beymer, et al., 2008).

"Simplicity" links to "Visibility" (Tognazzini, 2014), and designers should not hide system complexity just to offer the illusion of simplicity. Sufficient help and documentation ought to be available (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011), as well as the use of "Progressive Revelation" (Tognazzini, 2014) to flatten learning curves, whereby novice users are exposed to more advanced features as they become more experienced. Relatable elements ought to be grouped/placed together, with adequate spacing (Gestalt Principles) (Hampton-Smith, 2017). This increases efficiency, and grouping of alike elements contributes towards minimising mouse-clicks and selection. Arrangements of task bars and frequently used features should be included, and menus should have shallow hierarchical structures for simple navigation (more in Section 3.3 for menus). Features should be easily located for optimal use, and not in the way of users' immediate screen space. Features should be quick to access, allowing for easy UI exploration; frequently used buttons may be placed in easy to access places. There should always be preservation of context, whereby there are minimal screen changes and visual interruptions/distractions during completion of a particular task (Wiklund, 1998; Ng and Tilliss, 2018). Changes made should be immediately seen on the UI in the expected format, which links to "System Status and Feedback" (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014).

3.5.9 Help and Reference Documentation

The Category, "Help and Reference Documentation" (Table 3.1) is created from the related guidelines and principles of "Help and Documentation" and "Discoverability" (Table 3.1) (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). This category includes designing interfaces which allow for users to easily obtain assistance or help/support when needed. It additionally aims to provide for UIs to be fashioned in ways that minimise the need for additional help documentation, and have easy learnability.

Systems and their UIs have increasingly been designed in a manner that minimises the need for additional support/help documentation, and has easy learnability (Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Regardless, UIs should still have help features, reference documentation or links to online help services available if required, and support from the respective vendors when users are in need of assistance. Information or documentation should be easy to search and concentrated on users' tasks, with concise and

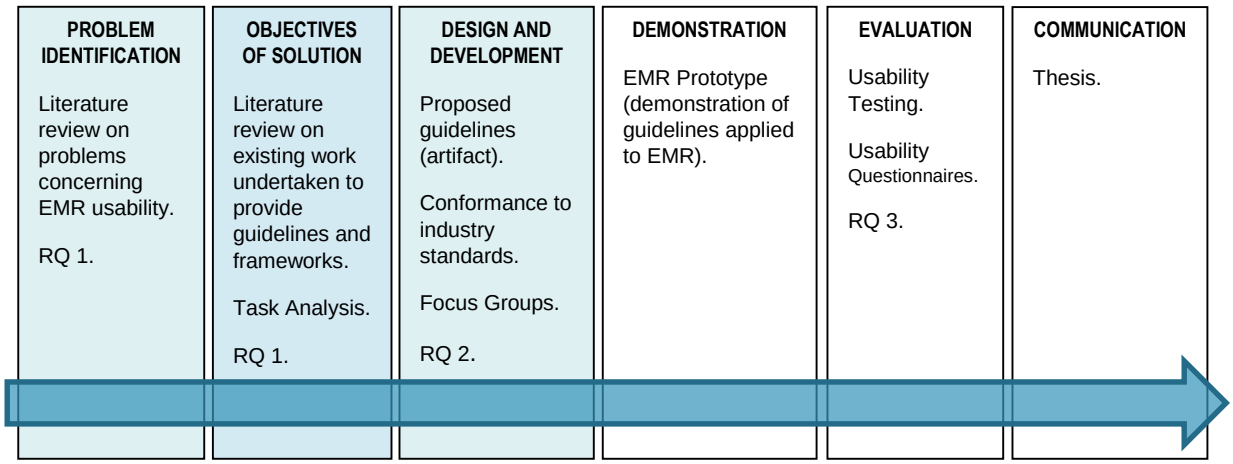
helpful steps to be followed (Nielsen, 1993; Nielsen, 1995). Design considerations should also include good “Discoverability” of elements within or on the UI (Tognazzini, 2014). Just to provide the illusion of simplicity, functionalities should not be hidden, especially if they are basic ones or those frequently used. Contrarily, nor should controls be placed obtrusively, like at the centre of UIs, which conceals information. UIDs should ensure control-visibility, and accommodate screens for both novel and expert users, as well as being able to switch appearances based on needs. Users should be presented with hints and tips, as a form of “active discovery” (Tognazzini, 2014), whereby information regarding features is offered to them. Help features and menus should be provided to assist users.

3.6 Conclusion

This chapter served as the theoretical basis for setting the scene in which this research may be conducted, explaining concepts (UID, usability, UX, UCD, HCD) that ultimately guide and relate to creating the UID guidelines for EMRs in Optometry. The link between UID, usability and UX was discussed; this being that a poor UID hinders users’ system usability, which negatively influences their UX. This is because the UI is often regarded as the “lens” which represents entire systems. As the primary stakeholders and users of systems, meeting user needs/requirements are essential to ensuring a good UID, usability and UX. Involving them in the research process is important, and the need for a UCD approach was thus discussed. For systems such as EHRs/EMRs to be accepted as "partners" to assist with providing effective patient care, it is imperative that the end-user is central to their design and that the UX is fluid. The relevance of HCD was discussed. HCD was recognised as extending beyond UCD, as it places greater consideration on the impact that stakeholders face, rather than just those normally considered as users.

Additional to the information provided by literature, various UID guidelines and principles provided by prominent authorities were compared and analysed. The UID guidelines and principles were reflected upon with their common elements identified and discussed, which helped discover the most relevant ones to this research. Via the analysis, a more cohesive, amalgamated set of categories was created (Table 3.1). These categories are intended to assist in the proceeding chapters by providing a foundation for UID guidelines to be created (for EMRs in Optometry), which will be further refined as the research progresses. The proceeding chapter, Chapter 4, draws upon the knowledge from this chapter, and intends to apply it within the EMR context, introducing usability and interface design problems with current EHRs/EMRs.

Chapter 4: EMR Usability



This chapter mainly contributes towards the first and second step of the DSRP model, which concerns the problem identification and motivation for the research, defining objectives of a solution, and to an extent, its design and development (which is the third step). This is accomplished by means of reviewing the literature pertaining to the usability/user interface design (UID) problems with Electronic Health Records (EHRs)/Electronic Medical Records (EMRs), whose systems are the preferred means of recording, managing and delivering healthcare (Rose, et al., 2004; Heeks, 2005; Shneiderman, 2011; Quinones and Rusu, 2017). Literature reviews include work previously undertaken to provide guidelines and frameworks, and usability problems reported on the systems and the methods to overcome the problems. This chapter discusses the usability and UID problems pertaining to EMRs, including their various attributes and challenges; with assistance from the categories from Table 3.1 in identifying what aspects to search for regarding EMR usability and UID problems. Two main aspects are focused on; 1) the understanding of usability problems associated with EMRs, and potential solutions; 2) frameworks and guidelines that are more contextually suitable for EMRs, which may assist in the study. This discussion will ultimately assist in the creation and development of the final UID guidelines for EMRs in Optometry (Table 9.1) whilst more directly addressing the sub research questions of RQ 1: “What user interface design problems are associated with EHRs and EMRs?” (mainly), and RQ 2: “What user interface design features should EMRs for Optometry contain?” (lesser extent).

The reflection of core concepts related to UID in Chapter 3 allowed for an understanding of how all these elements related to and affected one another, as well as impacting the overall

usability of the user interface (UI), and thus EMRs. This contributes towards Chapter 4 in that it provides a basis to appreciate how and why some EMR UID and usability problems arise, and thus allows for possible methods of relief to be conceptualised that are more concrete and contextually suitable. The UI is often reflected as the entire system, and it is therefore crucial for it to exhibit an optimal usability and user experience (UX). Chapter 4 considers and applies this knowledge to a more specific context of EMRs (in niche medical fields like Optometry), in order to attain optimal usability and UIDs, with further guidance from Table 3.1 (which reflects good usability and UID).

4.1 Usability of Electronic Medical Records

EMRs aim to deliver efficient and effective healthcare "services in pursuit of the wellbeing of individuals" (Kohli and Tan, 2016). These systems, however, have yet to concretise their presence within the medical field in spite of their potential benefits (Smelcer, et al., 2009). One of the chief explanations attributed towards this failure concerns the lack of usability in the implementation of the systems. This lack also risks patient safety and increases potential error rates (Zhang and Walji, 2011; Middleton, et al., 2013; Payne, et al., 2015). Utility refers to design functionality, and its conformance to user requirements. This feature ought to be considered, as well the usefulness of EMRs. Usefulness is determined by combining utility and usability (Nielsen, 2012).

As the influence of technology within our daily lives continually develops, the standard for contemporary and aesthetically pleasing UIDs in the healthcare domain continues to evolve. From "gestural controls to long form content scrolling" (Ng and Tilliss, 2018), and flat to material design, physicians' and patients' expectations for what medical devices ought to look and behave like are greatly influenced by the UI trends that are seen in consumer products (Ng and Tilliss, 2018). Unfortunately, several contemporary UI trends within the consumer space often ill-translate to safety-critical applications within the medical domain. In the consumer domain, an overlooked header or erroneous button press typically do not have severe consequences. However, such use errors within the medical domain may result in harm (Ng and Tilliss, 2018). There is a need for development of knowledge-based techniques that support contextual presentation, improvement of pen-based technology, and development of novel strategies and metrics to evaluate UIs (Tang and Patel, 1994; Roman, et al., 2017).

Careful consideration of (1) The users, (2) Their tasks and goals, and (3) The context of use is crucial for designing effective and efficient UIs. It is also argued by Patel and Kushniruk (1998)

that interfaces should be designed with attention to the cognitive capabilities, information requirements and restrictions of the end users.

1. Users- UIDs for EHRs/EMRs are challenging when compared to other common applications (Schumacher, 2010), mainly due to their user groups who require intricate functionalities. These physicians generally possess high educational levels, specialisation and skills (like optometrists) (Schumacher, 2010). This advanced skill-set requires greater attention in comprehending the characteristics of the intended EMR users, who are specialist physicians, ranging from novice to expert users.
2. Tasks- The tasks carried out by specialists are in their own right, also complex and specialist. There are additional factors to consider, such as maintaining patient safety, avoiding errors, preserving legal and accurate medical records, maximising efficiency, and offering supplementary support at the point-of-care (Schumacher, 2010). Additionally, the tasks conducted in each specialisation are unique. For example, the tasks performed by optometrists vary from those of orthodontists, or radiologists. This is a reason why Task Analysis (TA) (Chapter 5) and Focus Groups (FGs) (Chapter 6) are employed in this research.
3. Context of Use- The context of use concerning EMRs is frequently a neglected area in UID (Schumacher, 2010). EMRs in medical practices or settings are significantly different in comparison to typical systems that are designed and developed for traditional office environments. EMRs are used in more complex and dynamic settings, where teamwork and decision support (concerning medical matters) is crucial. The context of use is critical to the designing and developing of EMR UIs, and Usability Testing (UT) (Chapter 8) in the defined context is strongly recommended to ensure good usability (efficiency, effectiveness and user satisfaction) (Smelcer, et al., 2009; Schumacher, 2010).

4.1.1 Critical-User Interaction

This study applies specifically to the clinical functionality of EMRs, rather than the administrative functionality also offered by modern EMR systems. It is not that these administrative functions are unimportant, but it is primarily the clinical functionality that drives adoption behaviour. The UI is central to the part of critical user interactions as physicians use the UI to access and utilise the systems as part of their workflows. This is also a reason as to why there is great focus on UCD and UID. The patient-physician appointment is considered and more focused on within this research and during TA, as this area falls mostly under the “critical user interactions” (Lowry, et al., 2012).

Critical user interactions may be defined as interactions between a user (physician, i.e. - optometrist) and the EMR, which can potentially lead to errors, workarounds, or negative events that are related to patient harm. In use of the word "critical", this refers to the safety-critical interactions with the EMR. In safety-critical environments (like hospitals or specialist practises), the significance of well-designed, usable interfaces is increased precisely due to the potential for catastrophic results. The significance is further heightened in the "presence of time pressure, as is the case in much of healthcare" (Lowry, et al., 2012). Time pressure decreases physicians' opportunities to detect signals in the face of noise, and may also result in inadvertent confirmation bias, so appropriate UID is all the more important in such environments. As the UI is often viewed as the "lens" to the EMR system (Schumacher, 2010; Kendall and Kendall, 2013), and thus considered as representing the whole system, this research often uses the term system and UI interchangeably.

4.2 Usability and UID Challenges of EMRs

Identifying and discussing the various advantageous attributes, as well as disadvantages (usability and UID design challenges) associated with EMRs may assist in better understanding of the many problems to be overcome, and contributing towards how they may be relieved (UI guidelines for EMRs in Optometry). Many EMRs are not designed with a thorough understanding of the cognitive or perceptual needs of physicians (Ratwani, et al., 2015; Ratwani, 2017; Tutty, et al., 2019). Resultantly, the UI, workflow within the EMR, and incorporation of EMRs into clinical routines has led to safety hazards, inefficiencies, and overall dissatisfaction during use (Craig and Farrell, 2010; Benda, et al., 2016). There is often a lack of training and support when EMRs are implemented. This leads to resistance from physicians, citing computer anxiety, especially when the interfaces do not represent real-world and natural conventions and are difficult to learn and use (American Medical Association, 2018). To obtain the maximum benefits offered by EMRs, physicians are required to actively support and use them, and it is thereby crucial to understand the likely barriers to their implementation from the physicians' perspectives (Boonstra and Broekhuis, 2010). The EMRs' designs reciprocally ought to support their demanding workflows (Ash, et al., 2004; Rose, et al., 2004; Roman, et al., 2017).

E-health systems' adoption rates have been slow despite their many benefits, with physicians lagging in adopting EMRs (Belden, et al., 2009; Boonstra and Broekhuis, 2010; Craig and Farrell, 2010). According to Meinert (2005) and Morrissey (2005), the slow adoption rates propose that resistance among physicians must be strong, as they are the chief frontline user-

group of EMRs (Tutty, et al., 2019). Whether they support and use EMRs or not, will have a large influence on other user-groups in medical practices, such as administrative staff and nurses. Consequently, physicians have a significant impact on the overall EMR adoption levels (Boonstra and Broekhuis, 2010). Transitioning from the traditional paper-based recording systems to EMRs present a change in the way the physicians and individuals involved perform their tasks. Past documentation habits thereby have to adapt and electronic methods have to now "become the paper", which often comes with challenges (Hyppönen, et al., 2013; Middleton, et al., 2013; American Medical Informatics Association, 2017).

Many EMR products were designed with billing, payer requirements, and meaningful use criteria in mind, rather than physician use. This has resulted in an experience laden with data entry that causes decreased productivity and efficiency, and a diminished patient-physician relationship (Sittig, et al., 1999; Saleem, et al., 2005; Edwards, et al., 2008; Hyppönen, et al., 2013; Tutty, et al., 2019). The lack of intuitive designs may also infer that physicians or users are not able to easily adapt the EMRs to meet their needs, and integrate it smoothly into their daily workflows. Intuitive designs include uncluttered, neat interfaces, smart and predictive features (including both obvious and latent needs) (Bates, et al., 2003), easy navigation, support for physician adaptability or customisation, and display of relevant information (Rosenbloom, et al., 2007; Ludwick and Doucette, 2009; Viitanen, et al., 2011; Moores, 2012). As task complexities increase with physician demands in parallel, the challenge of non-intuitive designs to support activities further inhibits efficiency (Cho, et al., 2016; Medjobnetwork.com, 2016), especially when designer and physician mental models are misaligned in EMR designs (Saleem, et al., 2009).

In designing UIs for EMRs in specialist medical settings, which have unique and intricate workflows, the diversity of experience, expectations, and prior knowledge that physicians will map to the systems need to be considered. Expert users accustomed to media-rich UIs may have less patience with EMRs that do not immediately match their aesthetic preferences or functional expectations. On the contrary, novice users are found to prefer neat and simple UIs that unambiguously map to their workflows or current tasks (Nielsen, 1993; Ash, et al., 2004; Rose, et al., 2004). This infers that close attention needs to be paid to ensuring usable designs for EMRs, as this may impact physicians' perceptions regarding the EMRs' utility, and potential patient safety and healthcare quality. Moreover, aesthetically pleasing UIs add character, and provide physicians with a sense of pleasure, satisfaction, trust and professionalism.

The following sections, Sections 4.2.1-4.2.11, discuss some noteworthy areas relating to the usability and UID challenges of EMRs. Many of these overlap with Table 3.1's Categories, but are more focused within the context of EMR use.

4.2.1 Patient-Physician Relationships

Interactions between physicians and patients were very complex prior to EMR implementation, and they have now become even more complicated with poorly designed and/or configured systems (American Medical Association, 2018). Effective communication and engagement between patients and physicians ought to be of central importance in EMR design. The EMR should fit seamlessly into the practice, and not distract the physicians from patients (American Medical Association, 2018). EMRs can require a great amount of attention from physicians, which reduces the time available to interact with their patients, as well as interference with face-to-face patient interaction visits (American Medical Association, 2018). Additionally, many physicians report that using poorly designed EMRs present challenges such as: requirements of more time documenting patient encounters; compelling the collection of time-consuming information of questionable value; and slower access to required information during patient encounters (American Medical Association, 2018).

Time consuming data entry also reduces physicians' direct consultation time with patients during appointments (Ash, et al., 2004; Miller and Sim, 2004; Smelcer, et al., 2009). To maintain their patient-physician relationships, some physicians prefer to record entries after their appointments (Miller and Sim, 2004). In such circumstances, as well as where individuals who could correct any misconceptions are unavailable, entries may be error-prone. EMRs ought to support communication and provide the flexibility required for the systems to better match real work practises, which should reflect on the UIs. For example, the provision of audio recording or verifiable pre-typed entries that are commonly used may assist in saving physician entry time during appointments, and also maintaining their patient relationships; all through a more intuitive UI.

4.2.2 Consistency

Clinicians working in multiple care settings' using disparate EMRs with poorly designed UIs may struggle with variations in the interface design, and incorrectly use the systems like in data entry or prescription recordings. Many EMRs allow for variability in methods concerning task execution that accomplish the same result. Particularly with novice users, this frequently leads

to user confusion despite the variation offered providing for some user control and freedom (Nielsen, 1993; Tognazzini, 2014). This is especially true of EMRs not following some form of consistent layout (Hwang, 2016). Efforts at aligning standards to ensure consistency and universally efficient EMR use, and jargon/terminologies that are widely understood may be agreed upon as the norm. Referencing could possibly be according to the renowned “SNOMED CT”; the terminology standard for health information contained in the patient clinical data repository (Luna, et al., 2017). Furthermore, regulatory policies and practises may be followed as a form of guidance (Boland, 2010; American Medical Informatics Association, 2017). Adherence to platform conventions helps users in that they are not left wondering whether or not terminologies or actions used refer to the same thing, which increases their cognitive pressures (Nielsen, 1993; Hwang, 2016).

4.2.3 Freedom of Control and Customisation

According to Kushniruk and Patel (1998), ill-adaptability, and rigidly structured UIs challenge users, decreasing their efficiency. As such, methods to improve UI adaptability should be provided for, ranging from those that permit users to customise their UIs centred on their preferences, to systems that automatically adjust their information presentation based on contextual factors and the significance of information for specific medical circumstances (Patel and Kushniruk, 1998; Roman, et al., 2017). In developing adaptive and intuitive UIs, deliberation must be given to the EMR system’s abilities to "calibrate" to the physicians’ needs, as well as to the evolution of their knowledge and skills “over time as they interact with the system” (Patel and Kushniruk, 1998).

User control and freedom is often considered empowering to users, who feel the need to be in control of systems. This is especially true with physicians, who have been known to be stubborn with set ways of practises they prefer to stick to despite system alerts or suggestions. Thus, a suitable balance between mandatory EMR functions, and override features and options for supplementary “free-text” should be provided (Bates, et al., 2003; Luna, et al., 2017). Additionally, changing the manner in which certain features operate is often easier to persuade physicians’ changing their directions with, rather than completely removing features (Bates, et al., 2003). For example, alterations of set defaults of a drug dosage a lower level, if the drug has shown to be less useful than previously thought. This could aid in reducing prescription levels by stubborn physicians who refuse to stop using the drugs over newer, enhanced ones. Over time this strategy could be more effective rather that totally phasing out the drug (Bates, et al., 2003; Chou, et al., 2011). The suggestions presented to the physicians should have

credible foundations, so as to not be completely disregarded by untrusting and skeptical physicians (Khorasani, et al., 2014).

Referring to a qualitative study to improve usability by Rose, et al. (2004), many physicians stated their desire for greater freedom of control and customisation of the UIs to meet their preferred workflows (Nielsen, 1993; Tognazzini, 2014). For example, some physicians would like to be able to choose larger default font sizes for "letters to elderly patients". Others would like to have the option of a "Popup for Notes" and "Flowsheets to check vital signs" (Rose, et al., 2004). Tasks that required frequent access to other modules of the EMR for more information often took a long time, costing physicians' valuable time whilst also shifting their focus temporarily away from the activity, making it more challenging to maintain system context. This also resulted in physicians' mental fatigue, risking patient safety from potential errors such as in prescription entry. Time consuming processes such as data-entry and recording were also identified as a challenge that physicians face when there is a shortage of user adaptability, control and training (American Medical Association, 2018). This, again, essentially leads to resistance of EMR adoption within their practises, and the risk of user-errors that inadvertently affect patient security and safety increases (Miller and Sim, 2004; Linder, et al., 2006; Rosenbloom, et al., 2007; Kearns, 2014; Pare, et al., 2014).

4.2.3.1 Methods of Data Entry

EMRs utilise a variety of data entry methods that are frequently customised to physician requirements. Data entry interfaces ought to be aptly designed to maximise benefits whilst minimising any unintended consequences (Wilbanks and Moss, 2018). Little evidence in literature stands to provide guidance to the selection of specific data entry methods correlating to the type of data documented, and some EMRs require laborious and extensive data entries, which are more time consuming than traditional paper predecessors (Ash, et al., 2004; American Medical Association, 2018). Thus, the UIDs should accommodate various data entry needs. Clinicians consider the act of "writing" as a "think-aid" (Ash, et al., 2004), which is useful when determining patient diagnoses, and over-structured data entry leads to their loss of cognitive focus and overview. "Writing-as-thinking" can be greatly assisted by some structure like grouping of related types of information, but is ultimately hampered by an excess of structure (Ash, et al., 2004).

Literature has also shown that structured data entry utilises predefined charting elements to restrict acceptable "data entry to standard coded data and improve completeness and data reuse at the expense of correctness" (Wilbanks and Moss, 2018). Unstructured data entry methods utilise language that is natural and improve correctness, at the expense of data reusability and

completeness. Semi-structured data entry combines these methods of data entry to complement the strengths and minimise flaws of each method (Wilbanks and Moss, 2018). Consequently, the quality of documentation is influenced by the method of data entry, and it is crucial to select the methods based on the type of data that is to be documented.

4.2.4 Complete Information and Errors

Many EMR UIs present amalgamated information on screens as a result of physicians entering data beforehand. Often, incomplete, erroneous records or data have been entered, resulting in an inaccurate presentation on the UIs for physicians' reference. This missing data may also lead to erroneous diagnoses and recommendations of contraindicated drugs (possible interaction of the recommended drug with another one prescribed for the patient) (Goldstein, et al., 2002). A challenge has been presented in EMRs' order entry systems, whereby results reporting may only receive the raw data and not the interpretations. This may affect clinical decisions and work, as the physicians are not able to consider all the information together. This separation may also result in physicians being too specialty focused, not seeing what others have written (Ash, et al., 2004).

Some systems, with their "smart" or "intuitive" designs attempt to combine physicians' calendars and related information regarding patients, schedules and activities, automatically rearranging their priorities and tasks. Essential data fields may be left blank or contain incorrect inputs by physicians, especially when these systems do not necessitate any confirmatory steps or contain mandatory-completed fields. All this information feeds into the presentation on the UI for physicians' use. The busy physicians who trust and depend on these systems are presented with incorrect information and priorities to attend to, that may not necessarily be in the correct order. This may ultimately lead to patient harm, knowledge gaps and clinical errors (Goldstein, et al., 2002). The dependence on EMRs that are poorly designed generates false expectations on the part of physicians that the systems to alert them to all problems (Goldstein, et al., 2002; Ash, et al., 2004). The use of mandatory fields, verification and validation steps, as well as modal alerts may help with reducing errors and incomplete data entries.

4.2.5 Recovery and State

Further risking patient safety is the inadequate provision of EMR error recovery features, which inhibit physicians from easily deleting erroneous input, or returning to previous system states prior to errors being made. For example, back, next, undo, redo, cancel and exit buttons (Nielsen, 1993; Tognazzini, 2014). The incorrect information may be retained on the current

UIs, mistakenly being utilised as it is perceived as being correct (Middleton, et al., 2013; The Pew Charitable Trusts, 2016). To help with recovery, the greater provision of features such as auto-save, undo, redo, cancel and exit buttons should be incorporated. Options to return at a later stage and complete any unfinished tasks should be enabled, with automatic saving of work available, as well as undo and redo features (Nielsen, 1993; Rose, et al., 2004; Shneiderman, 2004; Tognazzini, 2014).

4.2.6 Design Simplicity

4.2.6.1 Density, Clutter and Information Relevance

Ash, et al. (2004) reported that several system UIs are still so impractical that using them significantly wastes precious users' time. Cluttered, information-dense interfaces present a cognitive overload to physicians, especially when UI screens are small and referral to more than one patient is required simultaneously, and the information presented is not all relevant (Roman, et al., 2017). It is also a risk to patient safety when their information or records entered into the systems do not update automatically or in a timely manner, relying on manual screen refreshments (Refer to Figure 1.1a which illustrates a poor EMR design).

The "clutter" or information density presented to physicians on their UIs is often aggravated by the overuse of UI features such as help and shortcut ones, and a balance ought to therefore be found. For example, the ability to cut, copy and paste information affords users the opportunity to exacerbate the information overload problem. Instead of picking the relevant facts on reports, physicians often copy the entire document, employing a previous thought process, which could be harmful if new illnesses have arisen in patients (Ash, et al., 2004; Pare, et al., 2014; Xu, et al., 2016).

According to Rose, et al. (2004) many physicians rely on shortcuts for quick access to relevant information, and become frustrated when they are not able to quickly navigate through the UIs. Some physicians express discomfort towards use of EMRs. In part, this is attributed to the many screens required to display all necessary patient information, instead of conveniently having it on one UI. When these physicians are navigating across screens, they often mistakenly close the windows, losing patient information as well as their cognitive process (Roman, et al., 2017). This is especially frustrating when automatic save features, or a lack thereof, are scarce. When multiple screens are displayed for various patients, physicians may become confused, thus presenting a risk to patient safety (Rose, et al., 2004). A great challenge in EMR UID is the balancing of physicians' information needs with the limited amount of

available screen, or screen size. Many physicians require relevant information to be presented on a single screen, with options for expansion as well as quick access. However, many physicians simultaneously complain of these interfaces being information-dense and cluttered, pressuring their cognitive abilities. Even when the information is presented on a single screen with the aid of navigational features like scroll bars, this becomes a tedious task when scrolling through countless pages (Miller and Sim, 2004; Rose, et al., 2004; Smelcer, et al., 2009). A form of relief to these challenges may be in the form of smart filters; whereby only the most commonly referred to and pertinent information is displayed. Additionally, the use of grouping of similar information, colour coding, cascading menus with options to venture in-depth may be implemented. This decreases user "mental energy" (Rose, et al., 2004) and risky dependence on recall over recognition (Nielsen, 1993; Tognazzini, 2014). Only necessary information should be asked of patients, such as sensitive information pertaining to their weights, and personal details. This helps to reduce the information density and overload on the UI (Bates, et al., 2003).

It may be helpful for the demographic panes of EMR UIs (normally located at the top of the window), to contain generic information regarding a patient (name, age, date of birth and address) to allow for physicians to easily identify which patient is being attended to when multiple records are open. Additionally, the demographic pane, unlike others, should be unmodifiable (resized and closed) so as to maintain its omnipresence and ensure physicians never lose focus of the patient currently being attended to and preserve their overview (Craig and Farrell, 2010). The patient's interface could incorporate inter-linkable sub-panes to allow for easy separation of health aspects over time for better viewing, yet retaining an overview (Craig and Farrell, 2010). Each sub-pane could have the option for expansion, collapsing, zooming and scrolling to reveal more or less information as required by the physician, as well as provide for annotations and free-text entries. Panes acting as repositories of additional resources like templates, requisitions and formularies may be placed on the side of the window for physicians to expand upon selection or hovering over the desired options. The options could be arranged alphabetically or by frequency of use, and have the ability to "drag" onto the current screen for viewing and use. Provision for physicians to add onto the repositories or remove items may also be useful for easier navigation and task efficiency.

4.2.6.2 Colours

Colour, when used inconsistently on screens often confuses users. Shapes may be used in conjunction with colour, as well as the use of boarders, thicker lines to differentiate features and even different shades or hues of colour. Support for users with visual inhibitions such as

colour blindness, or disabilities ought to be available, for example, complementary aural or tactile cues (Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Screen contrast is important for UI designers. When UIs in their designs pay little attention to the effects of colour and use them liberally with poor contrast; poor visibility is expected. Additionally, having objects with bright borders may not be as effective as intended if placement on the UIs is not suitable or adequately prominent (Rose, et al., 2004). It is also important to consider the UI screen brightness, relative to users' preferences and the external lighting available, allowing for adjustments.

4.2.7 Navigation and Natural Mapping

Many EMRs and similar medical systems possess outdated UIs, containing no intuitive graphic navigational aids, no windows, and have unending lines of text that appear identical. Despite the information being present in such cases, it becomes exceptionally tough to locate (Ash, et al., 2004). A reduction in the challenging navigation may be via the use of "in-line", or non-interruptive, clinical decision support "in lieu of additional dialogue boxes during a physician-user's workflow" (Roman, et al., 2017). Incongruity between use context and the UI frequently leads to a "juxtaposition error". This error occurs when an object is close to another on a screen, and the incorrect "option is too easily clicked in error" (Ash, et al., 2004). When there is excessive clutter on UIs, this error is often provoked (Figure 1.1a illustrates this.).

A common UID error faced by physicians is them reporting on not being able to find the required and relevant information in a timely manner, or having access to certain information or screens without first navigating through tedious entry-fields (Roman, et al., 2017; American Medical Association, 2018). As a result, UI design considerations could address these issues through the provision of more or enhanced navigation features (Smelcer, et al., 2009; Zhang and Walji, 2011). For example, consistently placed and distinguished search bars, buttons, icons, shortcuts, menus and scroll bars for ease of use. More so, manual override features could be a selectable option for emergencies (Nielsen, 1993; Ash, et al., 2004; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). Significant data objects should be placed on more prominent places on the UI, like at the top of pages. Figure 4.1 illustrates an EHR UI with easy navigation, conforming with UID guidelines (Tables 3.1 and 4.1). The UI designers also ought to organise visual elements logically according to groups defined by space (proximity) and alignment, which gives important elements prominence by way of contrast (Rose, et al., 2004; Roman, et al., 2017).

Efficient and easy navigation is crucial towards providing good EMR usability, as information within an individual patient record tends to be dispersed across many screens and sections. This obligates physicians to navigate repetitively through the digital space in order to produce an adequate conceptual model of the patient's condition (Roman, et al., 2017). This experience (keyhole effect) of observing information "through" a GUI compares to attempting to view the contents of a whole room "through a keyhole in a door to that room", and risks user-error and increases cognitive loads (Roman, et al., 2017). A further risk to user errors are when physicians are often limited to interacting with one screen at a time, cumulating the challenge of adding information together (display fragmentation). A strategy to develop EMR navigation is to decrease the number of actions required by physicians to display necessary information. This may be attained through the juxtaposing or placement of pertinent information/features together on the screens to facilitate cognition. Such juxtaposition of information elements within the digital space of the EMR is a "predictable form of intelligent use of space" (Roman, et al., 2017).

When EMR navigation is "awkward", with "too many clicks and screen flips" to complete tasks (Rose, et al., 2004), physicians address this unclear navigation by returning to common, familiar points on the UIs (Bates, et al., 2003; Shneiderman, 2004; Tognazzini, 2014; American Medical Association, 2018). This stresses the importance of having icons or features that navigate users back to main UI pages or the home-screen. An alternative to the obstacle around navigation may be through recognising features on screen that map closely to real world conventions, thus enabling their functions to become more familiar (Nielsen, 1993; Shneiderman, 2004; Tognazzini, 2014). Studies have indicated system speed to be a substantial determinant of user satisfaction in clinical settings, and UIs ought to reflect this in their designs and presentation.

4.2.8 Interoperability and Interrupted Workflows

Working on computers are seldom isolated tasks. Physicians are in constant communication with each other, and with patients that may be in outpatient settings. Interruptions are also common, and physicians' agendas frequently change during a single patient workflow (Wiklund, 1998; Belden, et al., 2009; Ng and Tilliss, 2018). Often different or multiple tasks are performed concurrently, and interruptions from telephones, beepers, and even peers are ceaseless. Several UIs, however, appear to have been designed for physicians undertaking their work individually, completely and expansively concentrating on the screens. This assumption of a single-task is provoked by the fact that several screen designs in existence are already "suboptimal by current office standards" (Ash, et al., 2004).

Interoperability and data sharing between EMRs within practices is often a challenge to physicians who maneuver from one room to another, still requiring access to the same patient information. The EMRs frequently fail to allow for multiple and inherent logins by users on different UIs, which interrupts workflows and often increases chances of duplicate and multiple data-entries (Bates, et al., 2003; Smelcer, et al., 2009; Khorasani, et al., 2014).

Systems that do enable multiple and inherent log-ins often have time-delays and outdated information, which is a risk to patient safety. Clinicians' entire workflows should be considered during the designing of EMRs, and include an array of practice styles rather than just the workflow relating to the activity at hand (Nielsen, 1993; Bates, et al., 2003; Rose, et al., 2004; Tognazzini, 2014).

Many physicians require a single GUI to display relevant information from multiple screens, as navigation between multiple UIs work against their ability to acquire, maintain and refine a conceptual overview of the case or task at hand (Ash, et al., 2004; Roman, et al., 2017). Physicians have shown a need for improved accessibility to information (feeding from past records, nurses' notes and databases), into a condensed, expandable and relevant singular view. Interpretations of results are often found within physicians' notes, thus allowing for a complete view of both the results and the interpretation.

EMR systems/UI designs ought to be all-inclusive of the functionalities required for smooth continuation of tasks, as well back-ups to prevent potential data losses. The main focus ought to be on the patient, yet allow physicians to multitask whilst interacting with the EMRs.

4.2.9 Templates

Standard, pre-populated and inflexible EMR templates may constrain entries of pertinent and patient-unique information, also affecting efficiency and patient safety negatively (Poissant, et al., 2005; Craig and Farrell, 2010; Roman, et al., 2017). For example, input as free-text from "patient–narratives" helps physicians' more fluid recording. Additionally, a lack of authentication or verification steps may result in erroneous input that risks patient safety. This likelihood is greater when expert system-users become so accustomed to the UI layouts as being the norm, that they enter information into the various fields without checking the corresponding labels first.

Whilst structured and/or coded data may assist with clinical decision support and administrative purposes like producing reports, it also forces physicians to adhere to the rigid structures and observations that may result in information crucial to patient care being omitted from their health record or recorded in the incorrect field (Craig and Farrell, 2010). Information

extending beyond the domain covered by the restricted coded data of the required software may possibly be forgotten or not communicated to relevant stakeholders (Craig and Farrell, 2010).

In some instances, however, use of such templates have been reported to offer assistance in the form of time-saving, and support to novice users not fully grasping all the functionalities of the EMRs (The Pew Charitable Trusts, 2016). In order for these templates to be considered beneficial by physicians, consideration into their designs and customisation is critical. For example, the provision of mechanisms for smart-data entry, customisation (Roman, et al., 2017), and predictive words or expressions based on frequency of their use by physicians (Rosenbloom, et al., 2007; Viitanen, et al., 2011; Moores, 2012; Tognazzini, 2014). Mandatory fields could be implemented, as well as validation or verification checks (Chou, et al., 2011). For example, confirmatory dialogue boxes. Templates should be more adjustable according to each physicians' preferences, with greater employment for context sensitivities. It is inadequate for the information physicians require to simply be available randomly in EMRs. EMRs should anticipate physician requirements and bring the information to them at the actual time they need it presented on the UIs (real time) (Bates, et al., 2003). Both obvious and latent needs (needs not consciously realised) should be anticipated and provided for (Bates, et al., 2003). For example, notifying a physician to lower a drug dosage when their patient's liver function deteriorates. Displaying suggested orders across wide ranges of order types significantly increases the chances of desired actions occurring (Bates, et al., 2003).

4.2.10 Standardisation and Effective Communication

Often UIs within an EMR system greatly vary in their layout across screens, confusing physicians and decreasing efficiency. Different systems also have such vast differences from one another, that learnability and transitioning from one to another is difficult, challenging interoperability and effective communication. Adding to the challenge regarding standardisation of UIs lies in the use of phrases in reports. Several physicians argue that too many standard phrases actually decrease the information value and readability of reports (on the UIs). Over-complete reports often become useless and hinder effective communication (Roman, et al., 2017). The phrases' similarities, coupled with the impossibility of determining if a sentence is part of a template or a consequence of a "thoughtful weighing of words" (Ash, et al., 2004), threatens the transparency that such systems try to introduce. Furthermore, the exaggerated use of technical jargon, over-complicated terminologies and a lack of consideration for users not speaking the "systems' language" challenges effective

communication. Simplified language, appropriate jargon and provision for help features ought to be available. For example, a "language translation" feature available for users, which is easily located on their current screen (Edwards, et al., 2008; Tognazzini, 2014). Additionally, designs of the UIs could be more standardised by closer conformance to relevant design guidelines (Nielsen, 1993; Belden, et al., 2009; Zhang and Walji, 2011).

4.2.11 Alerts, Feedback and Transparency

Communication extends beyond just the transfer of information, and embodies the need to generate effect. When the EMR systems fail to effectively alert users through appropriate methods that are effected via the UI (alert boxes, prompts), pertinent issues may be overlooked. This presents a potential risk to the work practises, but also to patients that may require attention (Ash, et al., 2004; Luna, et al., 2017). Without feedback, a common problem arising is that physicians are not able to determine whether or not an order has been carried out, or that another person has entered a similar order. Uninformed physicians may erroneously prescribe double doses of medication for patients, or even revert back to their previous recording methods from fear of losing work with no backups available.

Workflow systems are plagued by the ubiquity of expectations. This may be addressed by ensuring the UIDs provide for easy distinction of unalike features, or alert users to any changes in the layouts when they normally do not alter frequently. Physicians should be constantly aware and informed of their tasks and activities to yet perform. System feedback on their task progresses should always be available, with relevant changes, interruptions or system delayed providing adequate alerts. For example, "hour-glass" icons to represent system progress or delays, and "Alert", "!" icons as warnings to physicians who have not saved their progress. Mandatory fields and confirmation dialogues may also be introduced, alert-tiers, pop-up boxes, colourful prompts, aural (sounds) or even tactile feedback (vibrations) (Ash, et al., 2004; Heo, et al., 2009; Tognazzini, 2014; Luna, et al., 2017). Indicators could be used that show which records have been successfully printed, and icons presented when patients have been called to their appointment (Rose, et al., 2004). As physicians type out the notes within an input pane or field, dynamic analysis of the text and data extraction may take place. This means that whilst characters are typed, phrases and words are able to automatically change colour to notify physicians that something of interest has been detected or understood by the EMR. This offers physicians' instant and real-time feedback regarding the EMR's successful extraction of information from the note. For example, data like blood pressure and the heart rate could be recognised, given that a consistent syntax is used (Craig and Farrell, 2010; Luna, 2017).

It is crucial, however, to not abuse the feedback or alert mechanisms. For example, sounds, alerts or pop-up messages that arise on the UI after every selection on the UI. Overuse desensitises users to what may actually be pertinent to immediately address or not (Shneiderman, 2004; Tognazzini, 2014). Clinicians' conceptual hierarchies of priorities are confused, and this may further present a risk to patients' wellbeing. Irritated and time-constrained physicians often disregard these warnings, reminders or alerts, especially when too many of them are either irrelevant or overly predictable (American Medical Association, 2018). The use of "snooze buttons" with timers may assist in differentiating between completed tasks, and those yet to do.

The usability/UID challenges discussed are more specific to EMRs, but evidently share some similarities to those discussed in Chapter 3. Thus, Table 3.1's categories and guidelines are applicable within this chapter, but further guidance is useful for contextual relevance (EMRs). Hence, some EMR and health domain-specific guidelines are considered in the section below.

4.3 EMR Guidelines and Frameworks

Each EMR system consists of features that differentiate them, especially with EMRs existing in niche medical domains that characteristically include specialist workflows (for example, Figures 1.2, 4.1 and the Appendices illustrate three different systems). Thus, traditional guidelines (Nielsen, 1993; Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014) aimed to improve UIs may not adequately address certain unique features for the specific domains, ignoring critical elements to consider. This is a main attribute to the reason for having references to several authors' studies on guidelines regarding usability and UID guidelines, instead of just using one (Quinones and Rusu, 2017). Using existing guidelines as a base to form new, more usable and specific ones (to a specific domain) make it possible to know: 1) which guidelines already exist (to evaluate a specific domain); 2) how guidelines were designed; and 3) what new guidelines have been added to cover the gap that exists (Quinones and Rusu, 2017).

The intended guidelines to be created will encompass some foundations from existing ones (Chapters 3 and 4) as well as from the actual problems faced in practice. The categories in Table 3.1 created also help in the evaluation of what EMR usability issues are present. Based on existing guidelines and heuristics, new guidelines enable the affordance to discover which guidelines are already in existence (to evaluate a particular domain); how the guidelines or heuristics were designed; and what new guidelines or heuristics have been added to bridge gaps that exist, with Nielsen's (1993) heuristics to help evaluate usability (Quinones and Rusu, 2017).

Relevant guidelines for (EMR) UIDs in niche practices within the Allied health sector (ASAHP, 2018) are scarce. While numerous studies have evaluated the usability of EMRs, there is a limited number, which provide guidelines or recommendations on how to intricately improve their usability, especially pertaining to the UIDs (Bates, et al., 2003; Armijo, et al., 2009; Wiklund, et al., 2015). Many of the guidelines lack relevance to certain contexts, are too general and are also not followed when in practise (Bates, et al., 2003; Carvalho, et al., 2009; Craig and Farrell, 2010). Such literature relating to the EMR usability was examined and many were found to overlap with one another. Most of their content was also found to be included within Chapter 3 (Table 3.1).

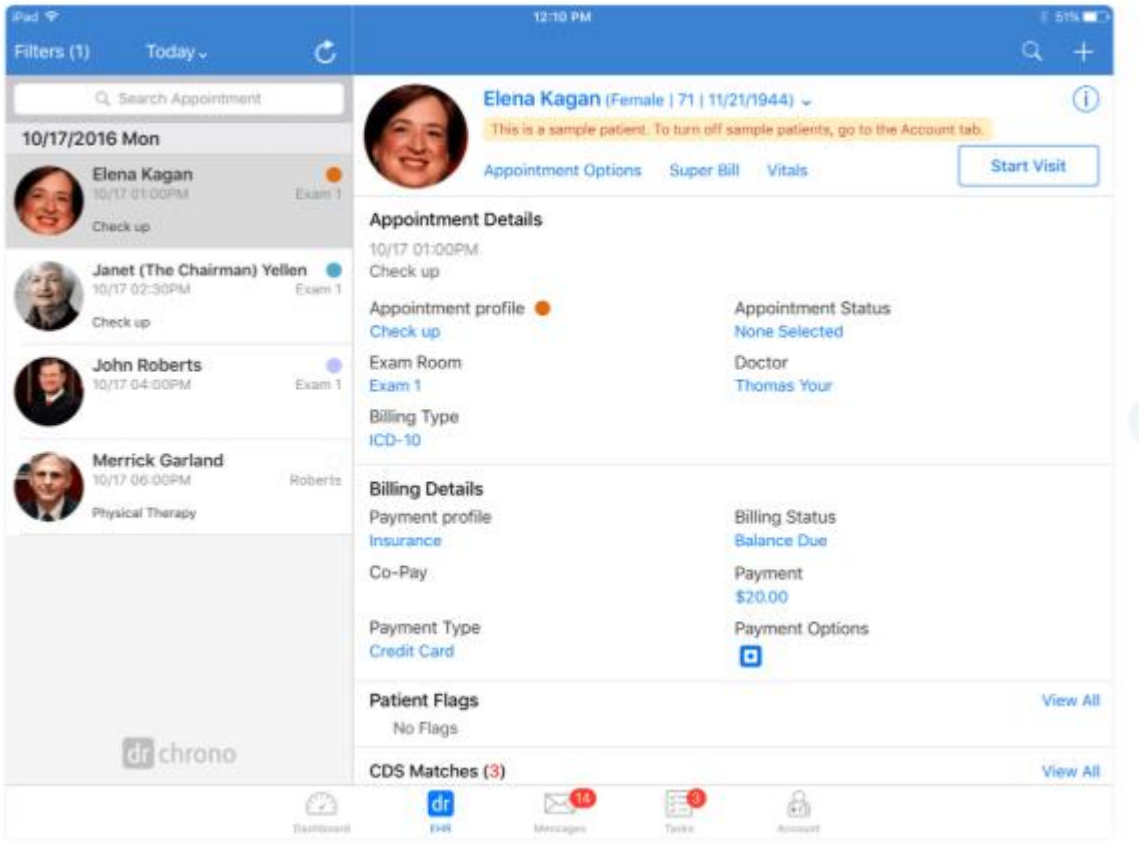


Figure 4.1 A Screenshot of a well-designed EHR UI (User Profile) (Cleveroad, 2019)

Figure 4.1 illustrates a User Profile UI of an EHR system (Cleveroad, 2019). The simple and user friendly design enables users to easily navigate the UI. The use of pictures and different colours are not only aesthetically pleasing, but serve as visual aids. The icons used are also familiar, mapping to real-world conventions (Nielsen, 1993, Schneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014; Cleveroad, 2019). This UID may be considered positively, and its design has links to Tables 3.1 and 4.1's guidelines.

4.3.1 Analysis of the EMR Guidelines

After analysis of the various sources (Nielsen, 1995; Shneiderman, 2004; Armijo, et al., 2009; Lowry, et al., 2012; Middleton, et al., 2013; Payne, et al., 2015), some notable guidelines were identified that were suitable for the health domain, concerning EHRs/EMRs.

Belden, et al. (2009) provide some EMR Usability Principles (Table 4.1) which overlap with Table 3.1's categories (presented in Table 7.1). Zhang and Walji (2011) present Principles for EMR/EHR Usability within their TURF framework, overlapping with Table 3.1 (presented in Table 7.1). Additionally, Wiklund, et al. (2015) provide EHR UID Principles which overlap with Table 3.1, Belden, et al's. (2009) Usability Principles, and Zhang and Walji's (2011) TURF: Fourteen Principles for EMR/EHR Usability.

According to Wiklund, et al. (2015), the principles represent best practices that are likely to improve a given EHR's/EMR's usability and use safety. However, they are just guidelines and might not be wholly applicable to a given EMR. Hence, different guidelines are referred to, and not just one source.

Upon analysis, Wiklund, et al's. (2015) EHR UID Principles were found to be more relatable to general health IT, and not EMRs. The principles were also applicable to various types of health IT systems rather than just a special class of them (Wiklund, et al., 2015). Belden, et al's. (2009) and Zhang and Walji's (2011) guidelines were found to be more EMR and EHR specific, and thus more focused on (Refer to Table 7.1). Belden, et al's. (2009) Usability Principles also shared relationships with Zhang and Walji's (2011) TURF: Fourteen Principles for EMR/EHR Usability better. As such, the works by Wiklund, et al. (2015) were considered, but not the main focus. The guidelines by Zhang and Walji (2011) are also influenced by Nielsen's guidelines (Nielsen, 1993), and relate to Table 3.1.

Zhang and Walji (2011) present a unified framework of EHR/EMR usability, called TURF, which is (1) a theory for describing, predicting and explaining usability variations; (2) a method for defining, assessing, and objectively measuring usability; (3) a process for designing good usability that is built-in; and (4) once completely developed, a potential principle for developing EHR/EMR usability guidelines and standards. Figure 4.2 presents the TURF Framework for EHR/EMR usability (Zhang and Walji, 2011), illustrating the framework's various components and their relationships.

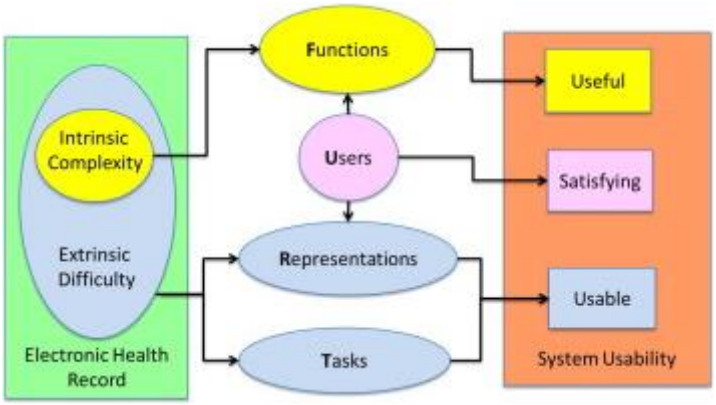


Figure 4.2 TURF Framework For EHR/EMR Usability (Zhang and Walji, 2011)

Task, User, Representation, and Function constitute TURF (Zhang and Walji, 2011), which are the four components that determine the usability of an EHR/EMR system. These four components are described with theoretical descriptions accompanied by examples of how usability is measured in many case studies (Zhang and Walji, 2011).

To facilitate the adoption and meaningful use of EHRs/EMRs, an EHR/EMR-specific usability framework is needed, that can be used to increase productivity, efficiency, ease of use, ease of learning, user retention, satisfaction, decrease human errors, decrease development time and cost, decrease support, and also decrease training costs (Zhang and Walji, 2011). TURF is not only a framework for evaluating the usability of existing EHRs/EMRs, but it is also a method for redesigning EHRs/EMRs for better usability. As such, under the TURF's "Representational analysis", or "Representations" (Figure 4.2), some principles emerge for EHR/EMR usability (Table 4.1), of which the first six principles (Consistency, Visibility, Match, Minimalist, Memory, and Feedback) are all about representation properties of UIs. For "Users" (Table 4.1), a user analysis provides user information needed to conduct function, representation, and TAs (Zhang and Walji, 2011). User analysis is the process of identifying the types of users and the qualities of each type of users (Zhang and Walji, 2011). As such, a UCD approach is undertaken, as it always maintains the users (optometrists) at the core of the study in order to best meet their needs and understand their EMR usability challenges, which helps in the UID guideline creation. For "Tasks" (Figure 4.2), TAs (Chapter 5) enable for the observation of optometrists' workflows, how, and why they perform certain tasks, which also helps gain some insight into the EMR usability challenges faced. For "Functions" (Figure 4.2), Focus Groups (FGs) (Chapter 6) allow for an understanding of what UID features optometrists would like in their EMRs, which will improve their usability. Suitable for usability within the health domain, EHRs/EMRs and health IT, Table 4.1 presents the works/guidelines of Belden, et al. (2009), Zhang and Walji (2011) and Wiklund, et al. (2015).

The three authorities' guidelines are presented in Table 4.1 (Belden, et al., 2009; Zhang and Walji, 2011; Wiklund, et al., 2015). It may be noted that the columns share similarities, as well as with Table 3.1. the wording may vary, however, yet the concept remains the same. For example, "Simplicity" (Belden, et al., 2009) and "Minimalist" (Zhang and Walji, 2011). Within each column, it may also be seen that some of the guidelines are related, and may be categories under Table 3.1's Categories. For example, "Visual Design", "Buttons Controls", "Graphics", "Typography" and "Workflow" (Wiklund, et al., 2015) relate to Table 3.1's "Design Simplicity". Table 7.1 further compares the guidelines from Table 3.1 and 4.1. Table 4.1 illustrates that despite the columns each not having equal numbers of guidelines, many overlap, share linkages, and thus most authorities' guidelines relate to one another (Nielsen, 1993; Zhang and Walji, 2011). This reason is why the comparisons in Tables 3.1, 4.1 and 7.1 are helpful, in order to categories them into relevant, applicable categories that are suitable for this research. In addition to Table 3.1's guidelines and categories, Table 4.1's guidelines from the first two columns are considered as favourable for this research (Belden, et al., 2009; Zhang and Walji, 2011), and thus recommended. They are more EMR/EHR specific, as aforementioned.

Table 4.1 EMR/EHR Usability Guidelines

EMR Usability Principles (Belden, et al., 2009)	TURF: Fourteen Principles for EMR/EHR Usability (Zhang and Walji, 2011)	EHR UID Principles (Wiklund, et al., 2015)
Naturalness; Simplicity; Consistency; Efficient Interactions; Effective Presentation of Information; Forgiveness and Feedback; Reduction of Cognitive Load on Users; Effective Use of Language; Preservation of Context	Consistency; Visibility; Minimalist; Memory; Feedback; Flexibility; Message; Error; Closure; Undo; Language; Control; Document; Match	Accessibility; Affordances; Alerts; Clinical Decision Support; Conceptual Model; Content Organisation; Customisability; Data Entry; Efficiency; Error Prevention; Detection, and Recovery; External Consistency; Feedback; Information density; Internal Consistency; Language; Metaphor; Navigation; Patient Identification; Search; Security; Status Indication; User Support; Visual Design; Buttons Controls; Graphics; Colour; Typography;

		Workflow; Miscellaneous

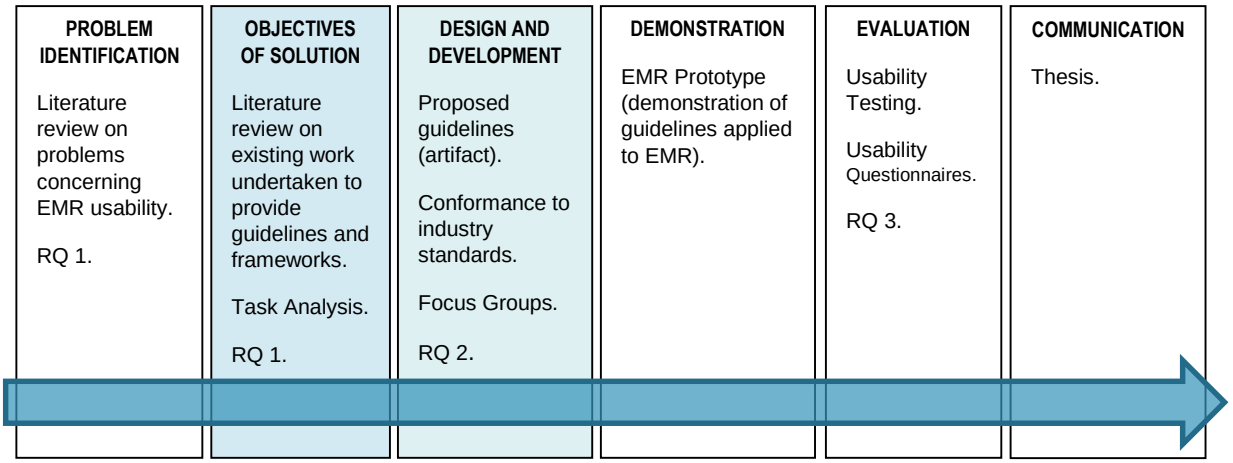
The guidelines intend to increase ease of use and learning, efficiency and productivity, user retention and satisfaction, and reduce human errors, costs associated with support and training, and also decrease development time and costs (Zhang and Walji, 2011). These objectives are reflected within Table 3.1's explanations, whose categories also encompass the guidelines. These categories similarly conform to the format that Nielsen's ten UID guidelines or "Heuristics" use (Nielsen, 1995), which was found to be the most holistic in terms of encompassing most of the guidelines and principles provided by other supporting authors, as well as being the most widely accepted guidelines established (Nielsen, 1993; Nielsen, 1995; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014). The application of standard UI guidelines are a vital constituent for EMR design and effective use (Middleton, et al., 2013). These guidelines ought to provide direction on screen layouts, controls, colour, and application flow to users and developers who are customising an application. It must also be noted that implementing a large number of guidelines that are weak may actually decrease their perceived trustworthiness and credibility, and thus the idea of "quality over quantity" should be considered during the formulation and development of them (Khorasani, et al., 2014). To be considered useful, EMRs must allow for physicians to query and record information in a natural way that accommodates the non-linear nature of their workflow. More specifically, a UI must allow for physicians to record the particulars of a patient's condition whilst simultaneously preserving the physician's overview of the patient's record, so that any part of the patient's health may be easily queried and reviewed (Craig and Farrell, 2010). Features available on the EMRs ought to streamline physicians' tasks and assist in ensuring a continuous flow of work, and prevent interruptions. The UIDs ought to provide for a natural mapping of the workflows, made possible via the layout/provision of certain features, right down to the actual information displayed.

4.4 Conclusion

This chapter discussed EMR usability, challenges faced regarding EMR UID and usability, as well as possible recommendations of relief. This discussion was significant in that it provided greater insight into the actual challenges physicians face within the niche medical setting context which utilises EMRs; as well as allowing for an opening into exploring the more specific context of patient-physician appointment, which is required for this research (critical-user interaction).

The recommendations were based on literature reviewed from the previous chapters, as well as guidance from Table 3.1. Additionally, several EMR and health domain guidelines were studied to identify those most relevant to this study, within the EMR context. Mainly, Zhang and Walji's TURF framework and Belden, et al's. EMR Usability principles were found to be most suitable as they were most applicable towards EMR usability. It was also interesting to observe the similarities between the various guidelines, as well as to Table 3.1; which helps to add to its applicability and credibility. The proceeding chapters further serve to refine the table, adding to it in a greater contextual depth; within the domain of Optometry. Chapter 5 proceeds to conduct Task TAs, which help to understand the context of use for optometrists interacting with their EMRs during their patient appointments. The TAs further help identify the workflows and common tasks accomplished by the optometrists whilst operating their EMRs, and to additionally gain insight into the positive and negative aspects of their EMRs' interfaces, as well as identifying usability/UID issues.

Chapter 5: Task Analysis



This chapter mainly contributes towards Step 2: "Define Objectives of a Solution" of the DSRP model. This is accomplished through Task Analysis (TA) (often referred to as Contextual Task Analysis (CTA)) and elements of Contextual Inquiry (CI) of optometrist(s) operating their current EMRs as part of patient appointments. The purpose of this chapter is to gain insight into the context of use for optometrists interacting with their EMRs during their patient appointments, and to help identify the workflows and common tasks accomplished by them whilst operating their EMRs. It is also intended to help gain insight into the positive and negative aspects of their EMRs' interfaces, as well as identifying usability/UID issues. This chapter purports to answer the second ancillary research question RQ 2: "What user interface design features should EMRs for Optometry contain?" It also addresses RQ 1: "What user interface design problems are associated with EHRs and EMRs?"

Within this chapter, the workflows observed and their various tasks and attributes involved during each stage are presented. Proceeding this, a table summarising the essence of the workflows, sorted according to positive and negative aspects with their EMRs (Table 5.2) is presented in the conclusion.

5.1 Rationale for Technique

TA compares the demands of a system (EMR) on the operator (optometrist) with the competencies of the operator (optometrist), and if required, to modify those demands thus decreasing errors and attaining successful performances. TA offers a particular framework for matching individuals' existing behaviour and satisfying their immediate needs. Furthermore, it can demonstrate redundancies and weaknesses in the EMRs since it has been described prior

to the analysis being done (Kuniavsky, 2003). In TA, the steps are both physical and mental ones. The consideration of mental steps allows for the identification of cognitive factors which make a task easy or difficult. Moreover, the steps required to carry out the same operation are different with different representations (e.g. using a bar chart vs. using a spreadsheet for results). A significant objective of TA is to discover which representation is more suited for certain tasks, the reasoning for it being better, and how to generate an improved representation. Similar to TA, CI is also a UCD method, centrally involving the user in the observation. Forming part of the TA, CI is a semi-structured interview method to obtain information about the context of use, where users are initially asked a set of standard questions, and then observed and again questioned while continuing with their work/practises (Kuniavsky, 2003).

Kuniavsky (2003) posits that TAs are best used when researchers already have some awareness surrounding the problem they are attempting to solve, and wish to know how people are solving it. For this research, the problem is partially known with input from literature reviews, and via fieldwork. This problem surrounds the poor EMR UIDs (user interface designs) that challenge the efficient, effective and satisfactory usability of EMRs in Optometry by physicians (optometrists) (Chiang, et al., 2011; McVeigh, et al., 2013; Pandit and Boland, 2013; Senathirajah, et al., 2014; Zahabi and Kaber, 2015). TAs focus on the task itself and allow for limitations to a particular scope within the context (patient appointments, for example). The techniques of TA and CI are suitable for this research, allowing the researcher to start gaining deeper insight into the specific UID challenges that optometrists face in their routines (workflows) whilst using EMRs as part of patient consultations. Consequently, this could assist in the creation of more specialist EMR UID guidelines for Optometry, (Chiang, et al., 2011), which literature has a great dearth of (Boonstra and Broekhuis, 2010; Zahabi and Kaber, 2015).

This chapter focuses on understanding the workflow (Section 5.3), which is a reoccurring problem identified in the literature review (Section 4.2). The aid of the “think aloud” (Kuniavsky, 2003) method may be utilised during the TA, which ensures optometrists convey their thought processes relating to the tasks, to the researcher, “aloud” (Kuniavsky, 2003). This helps the researcher in understanding challenges participants may encounter during task execution through completion, when using the EMR, and also allows participants to suggest preferences of task performance in order to improve their overall EMR usability. In order to clarify he purpose of, and help and help guide the process of TA, objectives are useful. For this research, the TA objectives are:

- To learn and understand the specific workflows that optometrists employ when using the EMRs as part of their patient consultations/appointments. This helps determine EMR design guidelines that may support these unique workflows and practises.
- To gain greater insight into the EMR user interfaces (UIs) that optometrists (physicians) presently interact with; to better appreciate what functionalities should (or should not) be included in EMRs, and what improvements can be made (if any).
- To discover usability issues with current systems.

5.2 Method

5.2.1 Participants

Kuniavsky (2003) indicates that five to eight participants give a good idea of how most people use a product, and so six optometrists were assessed. Since Optometry practices are considered to generally employ standardised workflows and operations (Chapter 1) (WCO, 2019), with variations according to optometrists' preferences, six participants were considered adequate (Fusch, 2015). The participants chosen were from Grahamstown, Port Alfred and East London, all in the Eastern Cape of South Africa. They were not restricted to any specific age, gender, demographic or ethnographic profile, but did, however, have to be optometrists (retired or currently practising) with some experience using EMRs (novice to expert) (Appendix B). The optometrists having some form of experience using EMR was the most important attribute.

Table 5.1 presents the demographic summary for the participants employed. All six participants were confirmed as currently practising optometrists, with prior exposure to EMRs. Participant 4 did not currently use an EMR, relying on a paper recording system. Participant 3 used a an EMR which served as more of an accounting system, which was considered useful, yet did not serve any other purpose that would make it an actual EMR system *per se* (no notes, educational features or patient eye test result images, for example), and was entirely used by the receptionists only. It did, however, allow for patient profiles to be created and edited.

Table 5.1 Demographic Summary

PARTICIPANTS	TIME IN PRACTISE (YEARS)	PERIOD OF EMR EXPOSURE (YEARS)	AVERAGE PATIENTS SEEN A DAY	AVERAGE LENGTH OF PATIENT APPOINTMENT (MINUITES)	EMR INTERACTION PERIOD PER APPOINTMENT	ADDITION OF NOTES TO EMR IN APPOINTMENTS	CURRENT SATISFACTION LEVEL WITH EMR USED	GENDER	AGE GROUP (YEARS)
1	1-8	1-8	10-15	15-25	25%	After	Somewhat Satisfied	Female	20-29
2	1-8	1-8	5-10	5-15	25%	After	Somewhat Satisfied	Male	30-39
3	9+	9+	1-5	30-60	0% (Used an accounting software instead of EMR)	n/a	Not determined as it was Accounting Software used	Male	50-59
4	9+	9+	1-5	60+	0% (All recorded on paper)	After (All recorded on paper)	Not determined as it was "Manual, Paper-Based"	Male	50-59
5	1-8	1-8	5-10	30-60	25%	During	Somewhat Satisfied	Male	40-49
6	9+	1-8	10-15	30-60	25%	After	Somewhat Satisfied	Male	30-39

5.2.2 Procedures

Participants were scheduled separately to partake in the TA on various days within their natural environments (practices) to warrant contextual accuracy. The TA process period utilised about one hour for completion. The independently scheduled TAs were to permit the researcher to observe and question the optometrists in depth to gain greater insight into their typical tasks completed when using the EMR as part of patient appointments (Kuniavsky, 2003). Perceptual observations and recordings of the data were made by notetaking (pen and paper), as well as video and audio recordings. The video recording enabled for a richer and more diverse set of data collection from the TA process of optometrists operating the EMR. This data collection included unique information concerning optometrists' natural environments, as well as the tasks they accomplished using the EMRs. This data was gathered to help appreciate what challenges optometrists encountered when using EMRs, and how the EMRs were used to accomplish different tasks. The optometrists were employed as "masters" in the "master/apprentice" role (Kuniavsky, 2003), with the researcher being the "apprentice" learning about the tasks at hand from the master. To mitigate any possible stress arising from this unfamiliar reversal of roles, the optometrists were encouraged to thoroughly explain their procedures and actions on their tasks. The participants were asked to proceed with their usual task(s) (as if they were examining a patient) whilst thinking aloud, and to narrate all of their tasks as if they were teaching the apprentice (researcher) about their tasks. During this, the apprentice (researcher) could question the master on the workflows, certain processes and

essential points. The role of master/apprentice was undertaken to get the optometrists to clarify and demonstrate how they interacted with the EMRs, and executed various tasks using them within context or according to the scope of this research - a typical patient appointment, as it was identified to be the "critical user interaction" (Lowry, et al., 2012). The optometrists were requested to provide a detailed description of their workflows pertaining to this scenario, especially focussing on their interactions with the EMR and its UIs. This permitted the researcher to focus on any details possibly overlooked if the optometrist had only explained the idyllic situation (Kuniavsky, 2003; Usability-BoK, 2012).

After the TA and as part of the CI, a follow-up discussion was conducted to allow for the optometrists to add any extra comments, and for the researcher to probe matters that needed further explanation and to thoroughly understand the workflows involved (Kuniavsky, 2003). Some discussions included explanations regarding what features used were liked by the optometrists (like buttons pressed and navigation pathways), what they were trying to accomplish, and why they wanted to do so. Predictably, each TA's participant-demonstration included variations. The observations/data was verified by the optometrists, in order to check that the recordings were correct.

5.2.3 Data Analysis

To familiarise the researcher with the data (Braun and Clarke, 2006), the video recordings capturing the data during the TAs and CIs were transcribed, and notes documented were studied to identify main focus points of each session to obtain an overall impression of the findings. Trends were observed, searched for and noted. After a revision, these trends were reported upon (Kuniavsky, 2003; Braun and Clarke, 2006). The main workflow stages were decomposed, to attain a better sense of the actual tasks involved during each stage of the patient appointment, and to better understand the mapping of tasks on the EMR and its UIs (Kuniavsky, 2003). Elements of Thematic Analysis were used to guide the data analysis process (Braun and Clarke, 2006). However, the transcription process was simple enough, and easily understandable as to not require its full employment of it, nor of a tool such as Nvivo (https://www.qsrinternational.com/nvivo/home).

5.3 Results

5.3.1 General Workflow

Two main optometric EMR systems were identified as the most commonly used ones across (mainly private) practices in South Africa. The participants employed in this study either used

these systems, a form of paper-based recording one, or some form of accounting software that did not aid in the medical functions, but rather the billing and administration ones only. Due to these system differences, the optometrists' respective EMRs' data capturing and usage varied to some extent amongst their practises. Their overall workflows however, were similar. During the TA, points focused on were concerned with what tasks are done at each step, alternate methods of doing them and why they were done so, good and bad attributes associated with the tasks, suggestions for improvements and comments. Figure 5.1 represents the observed, typical workflow of optometrists during the critical user interaction/patient appointment. Some variances may exist, however, as with Participant 6 (P6) whose workflow followed Stages (S): 1; 2; 3; 2; 3.

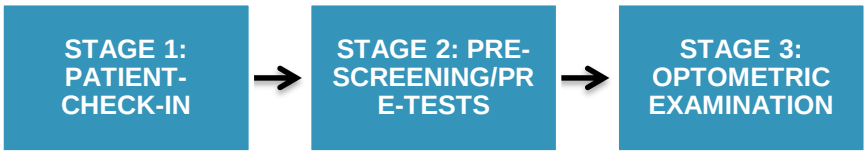


Figure 5.1 General Workflow Diagram Typically Representing The Critical User Interaction and Medical Part of Patient Appointments (STAGES (S) 1-3)

5.3.2 Stage 1 (S1): Patient Check-Ins

This S1 mainly consisted of new or existing patient check-ins, profile creation, editing and appointment management. Data captured for patients included their personal details such as names, postal/physical addresses, contact details, medical aid information, past medical conditions (diabetes, allergies, blood pressure problems, sinus issues and cataracts, for example). Many of the paper forms required filling in by new and returning patients, and also had clauses including acceptance of terms and conditions, which was mandatory to sign for legal reasons. For the appointment management, the data capturing included patient details such as names, contact details and time slots. Slight variations may occur across practices, but Figure 5.2 represents the typical workflow of optometrists observed during the first stage of the critical user interaction/patient appointment. This is the Patient Check-In stage.

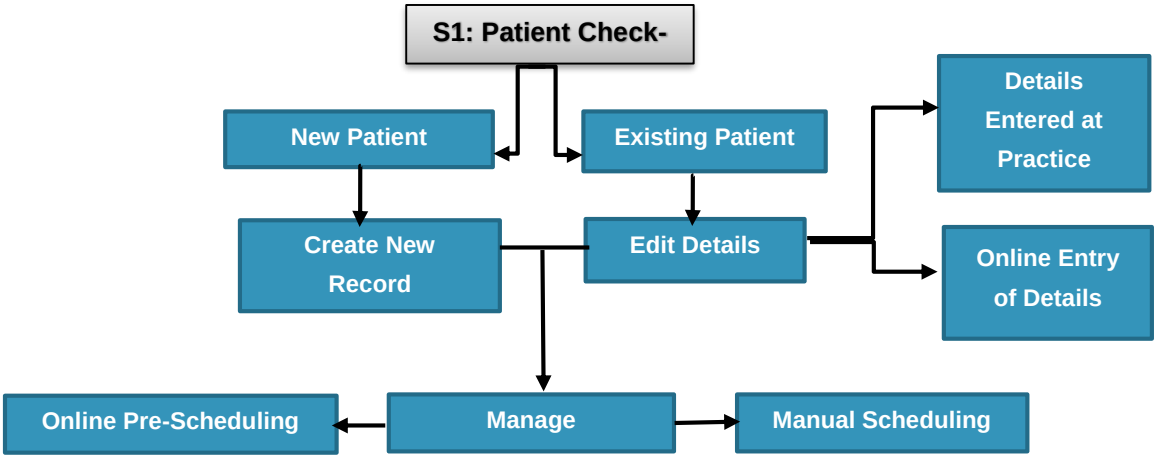


Figure 5.2 S1: Patient Check-In Flow Chart

5.3.2.1 Existing and New Patients' Arrival/Check-Ins, and Data-Entry

All participants (P) used a variation of paper forms for new patients to fill in their details, upon which, with the exception of Participant 4, were then entered into their current EMR systems (done by assistants) to create an electronic record with a unique identifying code. This required extra labour and hence higher costs. Participant 4 kept the paper-based records without any electronic back-ups. When updates were necessary, details were adjusted on the paper-forms, and not on the EMR. This often necessitated many forms to be repeated if mistakes were made. The participants noted that paper-based recording methods often saved a lot of time when notes were recorded during appointments.

Participants 5 and 6's paper forms also served the purpose of recording medical notes on (during the later stages of their appointments). As a new account or profile was generated, this unique code was assigned to the patient, who could then be located easily via a search feature using this number, or by the use of their surnames, which was considered easier and less of a cognitive load. This code also aided in easier patient identification, account management and searching. By all the participants, the use of patient IDs was considered helpful as an alternative search input, additional to the code or patient surname. Participants 5 and 6 motivated their need for the paper form instead of entering information directly into the EMR. They expressed that it allows for easier data capture onto the EMR UIs instead of having to verbally interview patients, which is time consuming. Additionally, it was considered more secure, as *"Paper can't get hacked, it's more secure"* (Participant 6).

Supporting the use of paper, a paper-based file was then created after input into their EMRs, which duplicated patient details from the EMR onto paper forms. After Participant 5's appointment, the paper record/card (prescription information, diagnostics and notes) is then taken to an assistant for entry into the EMR. Entry of the prescription and general patient billing information from the card into the EMR is added, and not the optometrist's diagnosis and optometrist-patient privileged information. The sensitive patient information is not transferred onto the EMR, but retained on the paper-card which is filed and stored manually. Thus, the EMR was mainly considered administrative, used for the patient check-in (new or existing), as well as invoicing, but not as part of the appointment, or eye examination (which remains paper-based). Participant 5 agreed that the tasks were tedious and repetitive, but justified the necessity of the initial paper form; as the patients' signatures were crucial for legal reasons, and the EMR UI did not have provision for electronic signatures. During Participant 5's previous work experience at a different practice, the entire workflow, from the administrative functions to the appointments were completed by each optometrist. This costed extra time but was considered as valuable due to the patients being "high-end" spenders. It may thus be seen that certain workflows are manipulated to accommodate the patient demographics and environment, in order to find a method most efficient and mutually beneficial.

Participant 4's patient information remained on paper-cards with their initial forms attached. For Participants 1, 2, 5 and 6, their existing patients were able to simply have their information updated directly on the EMRs. Participants 3 and 4 required existing patients to repeat their forms. Participant 3 stated that their new patients always had to fill out a new information sheet, rather than having their histories sent from other practices to build upon. This was to avoid any influence from other optometrists, who may have made different diagnoses, with the results being *"chalk and cheese"* to Participant 3's. Contra wise, Participant 4 and 6 believed this sharing of information would be a favourable addition to the workload.

Despite the EMRs' capability of storing patient data, and creating profiles, the paper-card recording method is still used due to "habit", according to the participants. Participant 6 expressed that the typing into EMRs during patient appointments often removes the personal contact, which many patients want. Participants 1, 3 and 4 added that entry of patient data which dates back several years is cumbersome, time consuming, and must be recaptured. The electronic system is thus easier to use for newer patients, as compared to those with long-standing histories; *"If it ain't broke don't fix it"* (Participant 3). Participant 1 furthered that another reason supporting the paper-recording method was that the patient demographics mainly consisted of older members of the local population, and were less technologically

savvy. Thus, they did not influence the practice to adopt more technologically orientated methods, as compared to Participant 2's practice, which had a greater portion of younger, more technology conscious and affluent members of society. Participant 2's practice was in a busier location. The practice was also opened several years after Participant 1's, and benefitted from the advancements of more recent optometric technologies.

5.3.2.2 Verifying Patient Details

Participant 2 stated that patient email addresses were often incorrectly entered into the EMR or online forms, and a verification system, which helped in validating their details would save many errors. Participants 5 and 6 also commented on the lack of verification standards, as well as security levels for viewing sensitive privileged information on the EMR UIs.

5.3.2.3 Recording of Medical Aid Details

With the exception of Participant 4, all the participants' EMR UIs had a drop-down list, or feature for medical aid options available on the patient profiles, from which claims could be applied for. According to Participant 1, this feature was helpful as medical aid options are very important aspects of any patient appointment. However, the separate tab designed specifically for the medical aid in Participant 1 and 2's EMR was hardly used due to the mismatch between the EMR codes and the different medical aid codes. Thus, a manual input of the codes was necessary which required more time and cognitive effort, risking task efficiency. This was also observed and agreed upon by four participants, who added that their medical aid services had independent software which was not integrated into their EMRs, making patient check-in tedious at times if it was not a popular option. The medical aid systems needed to be verified against a manual file with codes, and had different providers which required different means of communicating with them, like through *"old school faxes"* (Participant 5), email and phone calls. Under the patient profile option for three participants, several tabs relating to the patient's prescription, invoices and address details were available, of which only some were used. For example, in one of the two commonly used EMRs, one of their tabs was mainly purposed for patient recall and aided in the invoicing process. Providing little optometric use, it was barely used by the optometrists.

5.3.2.4 Editing Details

Participants 1, 2, 5 and 6's EMRs allowed for editing of patient details directly on a UI. Participant 3's EMR did offer this functionality, yet was insistent that patients still fill in paper forms before their updated details could be input and updated into the EMR. This was suspected to attribute towards habit and for purposes of back-ups.

All the participants expressed that it would be convenient if patients could possibly enter their own information, edit any details or even create their new profile themselves on a separate UI, either before they arrive or upon arrival to the practice. This was considered useful as it could save time, especially if these details could feed directly into the optometrists' EMRs. This could possibly be via a patient portal for allowing new or existing patients to enter their details online, or via an email link with an online form (from the practice). Participant 5 indicated this being a helpful idea, provided the patients were actually capable of using technology and had access to computers, and also if the forms had provision for an electronic signature. Participant 5 expressed enthusiasm at the thought of a finger-print system, whereby existing patients could check-in with their prints as an ID, and their profiles are automatically brought up onto the UI. Participant 5 however, soon reflected that it may be too costly an option to realistically implement.

5.3.2.5 Managing Appointments

With the exception of Participant 4, all the others indicated that the biggest use of their EMR was for scheduling and managing appointments, as well as the billing, transaction, stock report and invoicing aspects of the appointment, "*I do like the fact that it shows you the day's appointments, if I can sum it up in a nutshell*" (Participant 1). In terms of the medical aspect of appointments, the system had *"little optometric use",* and was often not *"even opened"* (Participant 2). Three participants' websites allowed for online appointment bookings for both new and existing patients, which proved to be helpful in its convenience and in reducing the workload of handling appointments in person or via telephone. Participant 6's practice also allowed for appointment bookings via their phone calls, text messages or Facebook. The appointments, however, had to be manually noted into the EMR's diary, after re-contacting the patients to inquire their preferred appointment times against the optometrists' free times. Participants 2 and 6, expressed discontent with their systems as the online bookings were not programmed directly into the EMR's schedule. Emails with the bookings were instead received, whose times then had to be manually inputted into the EMRs, or diarised. Often these emails were not seen in time, risking loss of patient appointments. An automatic entry of these online bookings directly into the EMR appointment schedules was considered desirable, as well as possible audible notifications, reminders or pop-up messages on the UIs. Participant 6 stated that it would be useful to have one "*live*" calendar system that was available to the optometrists and patients so that they could see when available time slots were for easier bookings. This was considered, but the execution of it has to be presented in a manner ensuring patient confidentiality.

Participants 3 and 4's systems did not include an electronic booking system; scheduling was done in a diary, and thus did not have any automated reminders. This placed a considerable cognitive strain in handling follow-up appointments, booking changes as well as the risk of the diary being misplaced. Due to the human error factor, Participant 4 indicated that the diarised method of booking appointments, and overall manual operation used was somewhat flawed and risky. According to Participant 4, at times, the follow-up or after-care check-ins were forgotten, and only done *"When I remember"*. For Participant 3, a letter recall system was available, with patient contact details being imported from the EMR. This, however, was independent of the EMR. This recall enabled for emails to be sent as reminders to patients for appointments, but had to manually be done on a Microsoft Excel Spreadsheet (https://products.office.com/en-za/excel). Participant 4's recall system was also on a Microsoft Excel Spreadsheet, and ran completely independently from any EMR. They stated that having one main channel of booking appointments would be more efficient, as many patients often did not call to book appointments or change them. Patients often arrived unannounced, messaged via "*WhatsApp*" (https://www.whatsapp.com/) and informally booked appointments; *"Tell me when I see them on the street".* Participant 5 also used a manual, diarised method of booking appointments, despite having the functionality of scheduling via the EMR like Participant 1 and 2. This was done as a form of habit, and also due to the small size of the town the practice was situated in. Participant 5 further added that the via *"word of mouth"* method sufficed for them. They also had a website, similar to Participant 1 and 2 which had contact numbers for booking appointments. The EMR used by Participant 6 allowed for different calendar views on the UI, adjustable to each optometrist. This functionality allowing for adaptive viewing was highly appreciated, and considered a valuable feature by all the participants. Colours were also used to indicate different optometrists and events, which was considered very helpful, despite the functionality often malfunctioning. This was similar to Participant 1's EMR. All the participants agreed upon the usefulness of colour as visual aids. With Participant 1 and 2's EMRs, existing patient appointments were easily able to be scheduled for at the practices, simply by selecting the appointment booking option. Their details would automatically pre-load into the various required fields like name, age, and contact details. New patients would have to enter all their unfamiliar details. Participant 5 admitted to not using this feature, despite it being available in their EMR, largely due to habit.

5.3.3 Stage 2 (S2): Pre-Screening/Pre-Testing

This second stage included the tests conducted just before the main eye-examination conducted by the optometrist. These pre-tests resulted in many eye images of the patients for referral by the optometrist, and the data captured included images (from which the optometrist could then

analyse and take notes for prescriptions and records). Additional data captured included numerical figures, of which some related to the measurements in ensuring correct lenses are able to be prescribed, as well as the health of the eye. The pre-screening/pre-testing observed included:

- Checking old specs and prescriptions- A Vertometer was the instrument used.
- Taking pictures of the retina- A Fundus Photographer was the used.
- Taking Retinal Scans- An Optical Coherence Tomography (OCT) Machine was used.
- Checking peripheral visual fields- A Visual Field Machine was used.
- Measuring intraocular pressure (IOP) - A IOP machine or Tonometer was used to conduct eye pressure tests and subsequently record the various measurements.

Slight variations may occur across practices, but Figure 5.3 below represents the typical workflow of optometrists observed during the second stage of the critical user interaction/patient appointment. This is the Pre-Screening/Pre-Testing stage.

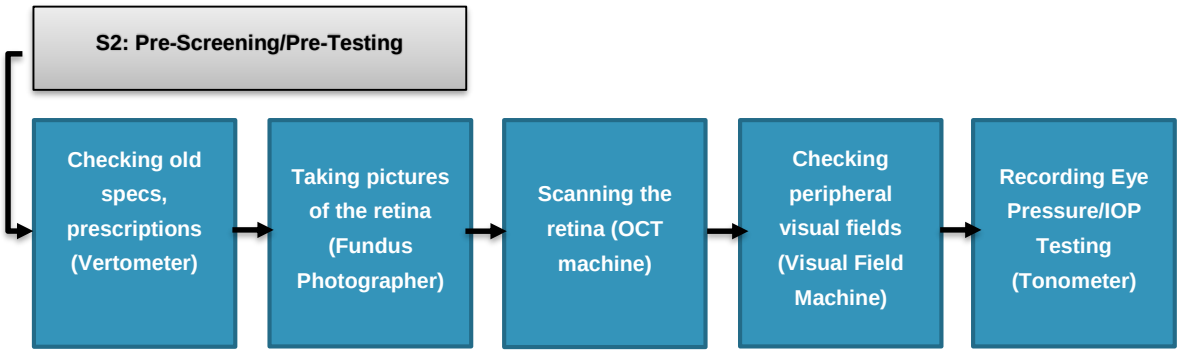


Figure 5.3 S2: Pre-Screening/ Pre-Testing Flow Chart

5.3.3.1 Conducting the Pre-Tests/Pre-Screening

Integration and interoperability between EMRs and machines/instruments

In conducting the various pre-tests/pre-screening as mentioned above (Section 5.3.3), the respective instruments that were observed to be used included a Vertometer, Fundus Photographer, OCT Machine, Visual Field Machine and Tonometer/IOP Machine. Five participants commented that the machines used all require separate operating software that are not supported by their EMRs, and hence the results are not shown when a patient's profile is opened on the UIs of the EMR in use, and instead, is shown on independent UIs. Participant 1 stated that *"It would be wonderful to have a patient profile complete with all their information"*. Some of Participants 5 and 6's machines included Wi-Fi capability and were

able to connect to a computer and thus a system, but again, independent of the EMR being used. The images and test results were all uploaded onto a server independent of the EMR, and there was a strong desire shown by all the participants for all these results from the various machines to feed directly into the system UIs, linked to specific patients. Participant 5's pre-testing process concluded with a print-out from a machine onto a paper which was attached to the patient card, and then taken to the observation room. Participant 2 also used a similar printout, whose information was able to be linked onto the computer and independent (of the EMR) software. This lack of interoperability also meant that this Stage, 2, was the most time consuming due to data capturing, especially since all the machines utilised independent software of their EMRs; *"They don't talk to each other, despite some being of the same manufacturer"* (Participant 2). Some machines' software upgrades had multiple versions, whose updates surprisingly lacked some features of the previous versions. Consequently, this increased the number of programmes having to be run independent of the EMR, and slowed the systems considerably. Thus, data had to be recaptured from each programme separately, and some data was often repetitive, such as the names, address and contact details. This increased information density and UI clutter also meant that the optometrists' cognitive pressures were increased in sorting/navigating through all the UIs. It also meant that more of their time was being taken up, decreasing task efficiency (Nielsen, 1995, Tognazzini, 2014). Purchasing like-branded machines was considered too costly by the participants, who specified that it would be more efficient to rather have a system which integrated them as compared to having multiple programmes to run.

Participants 2 and 5's testing machines were much newer than some of the other participants. Their machines were highly mechanised, and automatically sent patient results to different UIs which ran via independent software. However, the results still then had to be collected for entry into the EMR, again reflecting a challenge relating to interoperability. One of Participant 2's machines that assisted with prescription related data was able to store its details onto a memory card, whose data could then be transferred directly onto the control unit's UI and printed. Despite these machines' communication amongst themselves, which increased efficiency, they were still not integrated into Participant 2's EMR system, and the results had to be opened separately to the EMR's UIs. The machine's prescription still had to be manually entered into the EMR, which was typically done after the appointment. This was considered as an extra task that could be avoided if the prescription uploaded directly into the EMR, according to Participant 2, complaining that the *"machines are not talking to each other".* Participant 1 expressed frustration with the EMR lacking an aid of voice recognition, whose lack thereof required the constant movement between test machines and the EMR, often distressing

patients. The deficiency of integration also contributed to the optometrists spending extra time after appointments inputting additional patient information that came from different devices.

Using the Eye/Visual Acuity (VA) Charts

When using the visual charts, some participants used physical ones, electronic images on their computers (Microsoft PowerPoint Slides), and others utilised independently run software which displayed them via projectors. In Participant 2's practice, a central control unit with dials controlled and manipulated the charts, although it was an independently run software. Participants 1 and 5 had to physically navigate to the computer with an independent software running and manually select each chart. The participants all expressed a want for these visual charts used to be included within their EMRs, which would lessen their movement between the charts and EMRs and increases efficiency. Participant 4 especially wanted an EMR with these *"all-inclusive"* features, as the constant switching and movement of their manual charts were a considered a burden.

Viewing Patient Longitudinal Histories

Participant 1 expressed interest in a feature that could visually illustrate the change of a patients eyes over time, rather than by having to refer back to the numerical and quantitative stored results, which their EMR currently necessitates. None of the participants using EMRs allowed for the integrated viewing of the longitudinal patient histories, or for the comparison of images due to the separate servers storing the patient data. Participant 1 used paper-cards to record the measurements of eye pressure tests, and only entered it into the EMR proceeding the appointment as to offer the patient full attention. Participant 5 also used a paper-card, but entered all the information during appointments, despite having an EMR that allowed for some entry. This was to avoid forgetting any important notes. Their paper-card's information was then transferred on their EMR after the appointment, by an assistant.

5.3.4 Stage 3 (S3): Optometric Examination

This third stage included the main eye examination proceeding the pre-testing phase (S2). Images were further analysed, notes taken, observations all recorded and prescriptions given. Some education concerning the patients' conditions or diagnoses and after-care were also provided. The data captured in this step mainly included notes during the consultation, (free-text and numerical), and those regarding the pre-testing images and test results from S2.

During S3, processes typically included are:

- Refractive process and case history recorded- This aids with the prescriptions. Questions are asked regarding hobbies, usage of glasses and issues with current glasses. Patient histories are reviewed, such as eye histories, medical problems and demographics to form a basis for the rest of the examination. Refraction assesses the degree to which light bends as it moves through a patient's cornea and the lens of their eyes. This test helps optometrists determine whether the patient needs corrective lenses and, if so, what type of prescription is required. A computerised refractor for this part of the test may be used, or the optometrist may simply shine a light into the eyes. In the computerised test, patients look through a machine that measures the amount of light reflected by their retina. With the manual method, optometrists shine a light into each of the patient's eyes and look at the amount of light that is bouncing off their retina to measure their refractive score. For example, a value of 20/20 represents perfect vision.
- Determining a patient's lens prescription- This is called the Retinoscopy, which obtains an objective measurement of the refractive error of a patient's eyes. A Retinoscope is used, which shines light into the patient's eye and the optometrist observes the reflection off the patient's retina. Often more than one prescription is made, before the final one is confirmed.
- Confirmation of correct script prescription- an Optical Path Difference Inferameter (OPD) machine is used, which throws a wave of light at the retina and measures the light that is reflected back. This ultimately helps determine exactly what a patient's script is.
- Health Process- This includes the analysis of (the S2) test images, fundus machine images and slit lamp images (serve to magnify the anterior portion of the eye).
- Summary of exam- This includes the conclusion of the observations and analysis of the tests.
- Prescription issued.
- Diagnoses and reporting- This relates to the relative test results, patient education and after care information.
- Issuing/managing invoices, billing and receipts.

Depending on the practice, some optometrists integrate some of the activities from S2 into S3. For example, the Visual Charts are sometimes used in S3 or S2 interchangeably. As slight variations may occur across practices, Figure 5.4 serves to represent the typical workflow of optometrists observed during the third stage of the critical user interaction/patient appointment. This is the Optometric Examination stage.

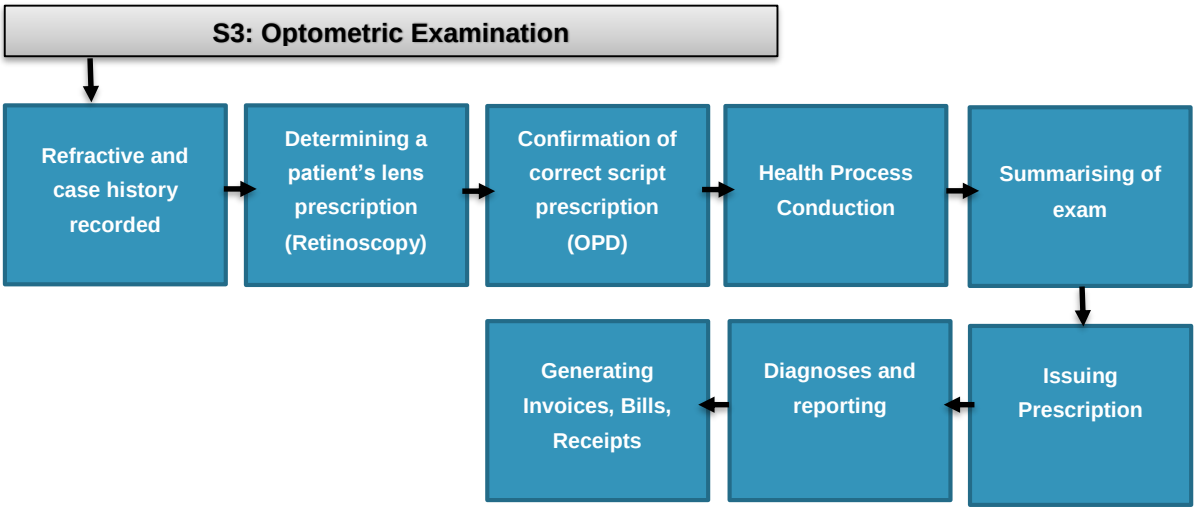


Figure 5.4 S3: Optometric (Eye) Examination Process Flow Chart

5.3.4.1 Refractive Process and Recording the Case History

The participants used a mix of the computerised tests and manual methods for the refractive process, and commented that they just recorded the values on their paper-cards, more often than directly into their EMRs. Participant 2 however, recorded it directly into the EMR. The values were mostly numerical, such as "20/20" representing "perfect vision". Three participants expressed the desire to include functionality for accommodating numerical data input. For example, a number-pad on the UI, or a list of numbers. All the participants agreed that the UI however, ought to include provision for comments, such as a comment box. In recording patients' case histories and general eye health, two participants expressed that a list of pre-determined, common conditions could possibly be displayed for easy selection. The other participants were used to, and content taking the notes down on their paper-cards, or in their EMRs.

5.3.4.2 Determining a patient's lens prescription (Retinoscopy)

Participant 1 expressed interest in having a mechanised Retinoscopy process as compared to the manual one that was currently in use, as this would help with increasing efficiency. The results did not automatically send to the EMR, but rather had to manually be inputted. These results were numerical, and often different for each eye. These had to be remembered for input, which was a cognitive burden and hence mistakes were a common threat as the wrong lenses could be prescribed and ordered. This was especially a realistic threat given that the EMR data entry was primarily done after the appointments for some of the participants. Participants 1 and 5 also expressed great interest in the integration of electronic Retinoscopy results directly into the EMR, which *"would be amazing"* (Participant 1).

5.3.4.3 Health Process

For three of the participants, the images from the Fundus Photography machine and OCT scans (S2) were stored by date and timestamp, rather than by name which was often troublesome if the specific dates were forgotten. This affected their navigation of the UIs. A search feature by name was, however, available which helped in locating patient images, but this was an extra cognitive step. Participant 1 expressed a desire for the images to rather be longitudinally stored according to patient names as compared to timestamps which did not permit for results' comparisons. The participants all shared the interest in being able to have the functionality to view a patient's changes over time, for example, in the form of a chart, or a patient gallery which stores all their images.

According to two participants, the results recorded from the images slightly differ for each practice and patient. However, some would concern the optic nerves, blood vessels and the macular, which are common areas scrutinised during an eye examination. Due to the commonality and importance of these tests, three participants believed it would be helpful to have them and similar ones, as well as their result ranges pre-loaded on the UI; whose results or diagnoses may then be the selected according to the patients.

Participants 1 and 2 both used the time after appointments to enter most of the information, relying on their memory, and both said that despite risks of erroneous data entry, typing during appointments often distracted patients and took too much time to input into the EMR. In general, the notes taken by the optometrists included the eye-health of the patients, test results, prescriptions and any drawings, abnormalities or extra notes considered useful or important.

Participant 3 stated that all the recording of patient information during appointments are done on paper-cards, and the testing machines being used are all manual, with no provision for integration into the EMR software. This was also observed with Participant 4. Participant 3 stated this to be attributed to habit, high costs of the automated machines; *"Money making things",* and the fact that the manual machines still worked well.

Participant 6 recorded all the notes on paper during the appointments, and stated that the typing into EMRs as an alternative to paper-based recording removed the personal contact with patients, which they often desired as it built relationships and practice loyalty. The use of a table with a stylus as a pen could be a possible replacement to the paper, whose information could then be directly recorded into the EMR. Participant 6's patients succumbed to the typical workflow aforementioned, but sometimes returned to the previous, pre-screening phase, called

"post-testing" if further tests were necessary. This was to prevent unnecessary pre-screening tests from being taken.

5.3.4.4 Issuing Prescriptions

A predefined list of patient requirements (such as polarised lenses for hunters or unique tints for example), was not offered by Participant 1, 2 nor 5's EMRs, which was considered as a useful, possible addition. Two participants commented that an input system, which offered the number range for lens prescriptions could be an efficient alternative to the current manual entry of numbers. For example, a separate left and right eye slider bar which had number ranges from *"+20 to -20 in 0.25 increments"* (Participant 6), as compared to empty boxes, which required manual input of the lens numbers, or a long drop down list. The other participants favourably considered this provision for numerical entry, but were content with their current, manual input methods. Two participants commented on their UIs often being too information-dense or cluttered. To reduce any cognitive pressures from these cluttered UIs, Participant 2 conveyed the desire for the EMR to perhaps separate the prescription aspects of the notes (which includes the history of frame measurements, general measurements, angles and related elements), the ocular part (health prescription part diagnosing the eyes), and the frame measurements for the new prescription. Having a separate prescription section was considered favourably by two other participants, who believed that it would simplify any UI clutter.

5.3.4.5 Summarising the Exam, Diagnosing, Reporting and Educating Patients

Another independent software package observed at Participants' 1, 2 and 5's practices allowed for patient report creation, editing and generation, which was considered very valuable to the patient experience and journey, supporting the educational aspect as well as giving them feedback. This software allowed for templates to be created, which enabled quick editing for future patients. The package also had a recall feature, which was favoured by the participants, as it sent automatic reminders to patients of appointments after a year, independent of the practice visited. Participant 4 would have appreciated this feature, as they emphasised that a reminder system would be helpful, whereby follow-up appointments and *"after-care"* were automatically customised to each patient and sent out.

Participant 1 and 2 stated that their EMRs did have a text messaging feature, which was useful, especially as one message could be sent out to many recipients at a time. Another participant commented that their EMR also included an *"SMS"* text message feature, which allowed for the automatic sending of appointment reminders to patients, which was convenient and interactive, especially as some messages could be pre-programmed and were customisable. Despite its usefulness, Participants 1 and 2 expressed frustration with their current EMR not

having this software directly integrated into their system, whose inclusion would enable for patient data to feed directly into the EMR. Reports could thereon be generated and immediately printed. This insufficient interoperability meant that the process is prolonged, inconvenient and reports always have to be generated through memory, which is a cognitive burden and a risk to the report accuracy. The educational features were also limiting at times, as adequate detail was not always available. The optometrists thus had to supplement with their own explanations and additional resources (books, pamphlets, flyers).

Educating Patients and Appointment After-Care

The participants all indicated the importance of educating their patients on their diagnoses and prescriptions. They believed it to also aid in the trust and relationship-building with their patients. Provision for patients' aftercare was also considered helpful in building trust, loyalty and strengthening patient-physician relationships. This is because it reminds patients that their optometrist cares, and going the extra mile for them. This relationship-building aspect is important, especially as optometrists have complained that interaction with EMRs during appointments often takes away from their patient "one-on-one" time. Participant 5 commented that their EMR in use did have some form of educational feature, but was not used much owing to having inadequate experience with it, as well as its limited content. Considered to add a personal touch and build relationships, Participants 4, 5 and 6 rather relied upon discussions with patients, and Participant 4 added that appointments often proceeded beyond an hour due to the extensive educational aspect of them. Participant 6's EMR did not contain any form of educational features. The same, aforementioned independent software package was used for some time, but due to the inadequate internet connectivity, it presented many challenges as the program required the internet to run, which was unreliable according to Participant 6. The software package had an audio option to read aloud instructions or information, which was believed to be valuable especially in accommodating patients that were extensively visually impaired, or those that required additional assistance in following instructions. Participants 1, 3 and 5's EMR systems were purely visual. They favourably considered the audio function, but deemed it to not be an essential feature. According to Participants 1 and 2, the main take-away from the independent software package used was the educational and report generating features, which their EMRs lacked.

Three participants commented that patients often expressed desire for additional, after-care/follow-up attention, *"They like to have a fuss made out of them"* (Participant 4), especially with the elderly patients. This was sometimes instructions on how to cope with given diagnoses, or on general care of their glasses. The after-care treatment and follow-up calls often

brought in many new patients, *"impressing them"* and thus generated more business via *"word of mouth"* (Participant 4). Thus, a reminder to ensure its occurrence was considered important.

5.5 General UI Issues and Attributes

The Participants' EMRs succumbed to rigidly structured and generic layouts, which lacked room for any customisability. This frequently added to their cognitive loads which increased the risks of errors and patient safety. Screenshots as evidence, however, were not put in here as to protect the wishes of the participants, safeguarding the integrity and respect of their doctor-patient confidentiality. However, similar to the participants' EMRs are Figures 1.2 and 4.1. The Appendices, "F" may also be referred to. Participant 2 and 5 added that despite the activities in Optometry generally conforming to similar standards, the particular workflow adopted was largely attributed to having to accommodate for the EMR system's layout and functions. For example, the notes being entered after appointments was previously done during the visits when paper methods were utilised. The participants all agreed that the EMRs ought to accommodate and adapt to their workflows, and not the other way around. Typing into the UI with any patient present was considered "*annoying*" and distracting as compared to using a paper-card/record. Participant 1 and 6 reflected that an alternative to the paper recording or typing during or after appointments could be via the use of a portable device or tablet that mimicked the paper card. This however, was considered as an expensive workaround, which may not be affordable for many practices. Participant 2 conveyed that preloaded patient data would save a lot of time from data entry after appointments.

Attributed to insufficient staff training and general help and support features, the participants often feared making dire mistakes when interacting with their EMRs, as well as losing any sensitive patient information. This often led to preferences of using paper-based recording methods. Neither Participant 3 nor 4 kept back-ups of their paper records used to note patient information or details during appointments, and agreed that the risks of data loss and recovery were a concern. Participant 4 said, "*If there is a fire, we're buggered (in trouble)".* This reflects again on Participant 3's insistence of existing patients always filling in paper forms. Patient profiles were backed up on an external hard drive, but very irregularly, according to Participant 3, who further stated that another reason for not using an EMR for entering patient information was due to the fears of "*hacking*", and not knowing "*where the information all goes*". Participant 3 and 4 stated that in terms of storage and back-ups, an EMR system that allowed for these functions would be helpful. The realistic fears of data loss and hacking could essentially be addressed via the initial training when implementing the EMRs.

Participant 3 stated that the EMR was fairly simple to use, but required some initial training. External support was available, however, *"it came at a price"* and was thus not used much due to the expenses. Participant 6 received no prior training before using their EMR, and had to self-learn over time. Basic features were easily learnt, but more complex functionalities required prior training. It was observed that Participants 3 and 4 had an especially strong support for paper-recording methods over the use of EMRs. This was interesting to note as they also happened to be in an older demographic age group compared to the other participants (Table 5.1), who contrarily appreciated the EMRs more. It may be stipulated that perhaps the elder age-groups of optometrists were introduced to the EMR technologies at much a later stage in their careers, as compared to the younger optometrists. To support this, one elder participant had been in practise for over ten years, and only had EMR exposure for less than five years. The other elderly participant similarly had over ten years of experience in practise, but had exposure to EMRs for less than a year. Thus, in comparison, the younger participants who seemed to be more technologically inclined also had more experience using EMRs in a shorter space of time in their professional careers than the older participants. Essentially, the older optometrists had more years of experience, with less EMR exposure, and the younger ones had fewer years of experience in Optometry, with more exposure to EMRs in this shorter time period. The fact that these differences exist stresses the importance of designing the EMR UIs well, ensuring their ease of use. With the exception of Participant 4 who utilised a manual, paper-based system of recording, the other participants' EMRs helped in their administrative business operations, yet not the actual clinical (health or medical) side to the appointments. They expressed that their systems had little optometric use. Participant 3's EMR helped in the invoicing and patient profiling, and not much else. Participants 1, 2 and 5 agreed that notes' panes which allowed for free text of patient data was helpful, but perhaps an annotatable eye image or template on one UI that allowed for manipulation and comments would be useful. Participant 6's EMR did allow for annotations on an eye-template, but was not used due to the difficulty of drawing on a UI with an external mouse, *"The dexterity is quite weird to draw certain things I suppose"*. The use of paper for direct drawings and notes was *"easier",* according to them, and the implementation of touch sensitive features was desirable.

Despite Participants 1 and 5 having a feature in their EMRs which allowed for note-taking, they hardly used it. This was attributed to the paper-recording method providing the same means of input, but being much faster and more familiar than typing information into the EMR. Participant 2 made more use of their note-taking feature for free-text comments, especially since they entered most information after the appointments, which did not affect the timing greatly. They also admitted to being *"tech savvy".* Participant 2 added that pre-set templates

would be supportive additions to the UIs, but the provision for free text and customisability ought to be maintained. Three other participants furthered that pre-set templates would be useful, but since machine software are not interoperable, this would be difficult to achieve. Three of the participants conveyed their appreciation of a tab within their EMRs, which allowed for the option of attaching documents such as ID's or any scanned images. Video files were not supported, however, which Participant 2 would have like to have.

The lack of automatic saving of information was also considered cumbersome as manual saving had to be done frequently; risking the possible loss of information. Participants 5 and 6's contingency plans were to create backups manually, but indicated that an automatic backup would be more reliable. For Participant 6, patient cards were manually scanned to a cloud server after each appointment, and a separate employee was hired especially for this task.

Many of the tabs on the EMR did not open, or took several moments to open due to the system's capacity not matching the computer's operating system very well. Thus, the EMR's upgrades ought to consider updates that conform to the various platforms available. This was observed with Participant 1, 2, 3 and 5's EMRs. Participants 1 and 2 both expressed that the UIs were cluttered, and not all the functions were actually necessary nor used. They added that many functions were hardly used also due to the lack of training received or information available regarding their uses. Four participants admitted that only about ten to twenty percent (10%-20%) of the functions were actually being utilised to their full capacity, and *"that's where training comes in"* (Participant 1). The UIs were not easily navigable, nor easy to learn without prior training, and the participants indicated that the initial training provided was inadequate, and that external support remained poor. The UIs also did not always use icons or features that were universally understood, or mapping to real-world conventions, which further took time to learn. For example, not using an envelope to represent emails, which is a universally understood metaphor. They all had to rely on experience for learnability. Participant 6 commented that having a cloud-based EMR system that was accessible from satellite sites, and not only from one central location would be useful, especially in terms of data-sharing. They added that their EMR system was able to integrate with other systems running the same software in satellite locations, but the poor internet signals often hindered this data sharing and interoperability, which would otherwise serve a tremendous help in sharing patient information to another practice and saving time.

One of the two main EMRs had a reporting feature tab which was favoured by Participants 1, 5 and 6, as it allowed for views of different statistics concerning their practice's performance;

such as turnover reports and age analyses. It also allowed for patient listings which could sort patients into groups according to their birthdays for example, helping maintain relationships and furthering the patient satisfaction. Another favourable feature in the EMR was a tab whose functionality allowed for the monitoring of patient prescription progress, and tracking them.

Four of the participants considered their EMRs to have a poor response to error tolerance; the verification and validation of any entered information lacked few checks, which risked patient safety. For example, the prescription generation provided ranges for the lenses, which served as the verification, but the actual figures inputted could be erroneous and still be accepted. The *"Are you sure?"* pop-up message for verification before continuing to the next task or step was considered inadequate by Participant 5. Participant 6 expressed that the billing process is where most errors occurred, as it had a *"Minefield of tariffs and codes, where mistakes come".* Participant 1 reiterated the importance of having their initials linked to the patient appointment slots, for accountability purposes and future reference, and a colour code to match this was considered to a helpful addition. Participant 5 indicated a desire for a staff registry function, for accountability purposes. Participants 1, 2 and 3's EMRs also lacked a staff registry function, but Participant 1 manually inputted the physicians' names next to their appointment bookings, which was done on the EMR.

5.6 Conclusion

This chapter enabled for an evaluation of the use of EMRs by optometrists, and the associated workflows involved in Optometry; chiefly during a typical patient appointment (which is considered as part of the critical user interaction with the EMR). Via the TAs, practises employed by optometrists were able to undergo scrutiny, especially regarding the interaction with EMRs and their UIs. This aided in identifying which facets of the workflows were problematic, positive, or could be altered to enhance efficiency (Table 5.2). After a few TAs, the observations and results were mainly the same (Fusch, 2015), with a few, minor and insignificant differences. This may help, to a slight extent, support that the practise of Optometry is generally standardised. The guidelines to be created are therefore intended to be applicable within Optometry as a whole rather than limiting it to South Africa only, for example.

From the results, Table 5.2 presents a summary of the various negative and positive attributes from the participants' EMRs (and UIs), whose various negative and positive elements may be addressed/explored in the proceeding chapter (Focus Groups (FGs)). From Table 5.2, however limited, the main positive attributes concerning the EMRs are the administrative functions; the

appointment booking/calendar (limited); and notes pane for comments. From the negatives, the main points were the lack of general interoperability; lack of clinical functions to support optometric workflows, and rigidly generic layouts; lack of customisability; limited appointment scheduling features; lack of support for displaying longitudinal patient image histories for comparison purposes; and the lack of validation and verification measures.

Some possible usability suggestions (some are also recommended in Chapter 4, Section 4.3) are that EMR UIs ought to support optometrists' clinical or health needs, and not just offer administrative functionalities. The test and imaging machinery should also be integrated and supported by each practice's EMRs, and not leave the optometrists relying on independently running software to reach diagnoses. The UIs should also have simple, uncluttered displays with the options of customisation. The patients' education and after-care/follow-up aspects were considered important. The EMRs observed seemed to lack in this component, and more focus may be helpful in UIDs. These needs reflected and reiterated information from the literature review in the previous chapters, and supported their significance. The patient relationship aspect was identified as an important factor that optometrists considered necessary to account for. The provision for patient education and after care was greatly appreciated as it supported these relationships, furthering trust and loyalty.

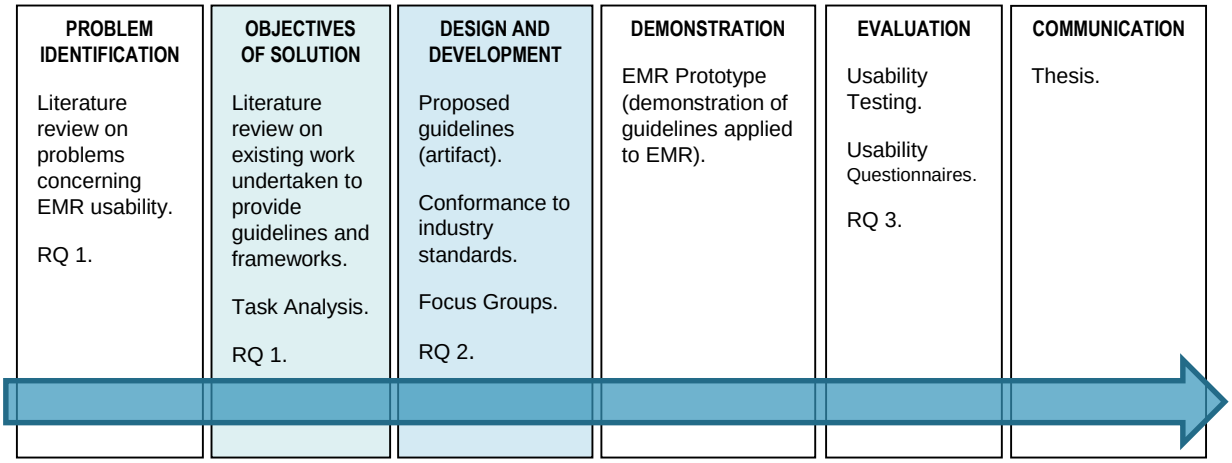
Table 5.2's Positive and Negative UI Attributes are further linked to their effect on usability and/or functionality (whether good or bad). It may also be noted that the use (or not) of some attributes are linked to the guidelines from Table 3.1 and 4.1. For example, the use of "Colour options" in the "Positive Attribute With The UI". Colour is used intuitively, conforming to the UID Guideline of "Design Simplicity" (Table 3.1). In the "Negative Attributes With The UI", an issue arose of having "Too many features that are confusing, and they lack help-information when selected". This is an effect of not conforming to UID guidelines, such as "Design Simplicity" and having a lack of "Help and Reference Documentation" (Refer to Tables 3.1, 4.1 and 7.1).

Table 5.2 Positive and Negative UI Attributes

Positive Attributes With The UI	Negative Attributes With The UI
Appointment management- *Good usability.*.	Inadequate optometric and clinical features to support workflows- *Poor functionality.*
Billings, Invoices and Transactions- *Good usability and functionality of the features.*	Rigidly generic layout, lacking customisation- *Poor usability.*
Stock reports- *Good functionality of the feature.*	Mismatch of medical aid and the EMR codes that requires manual code input- *Poor functionality.*
Online appointment scheduling- *Good functionality.*	Lack of touch sensitive features- *Poor functionality in the absence of the feature*.
Colour options- *Good usability.*	No auto-save feature- *Poor functionality of the feature*.
Medical aid drop-down list of options- *Good usability.*	No Verification nor validation steps for patient details- *Poor functionality in the absence of the feature.*
Automatic code generation for patient profiles- *Good functionality of the feature.*	No provision for patients to enter their own details- *Poor usability in the absence of the feature.*
Notes pane and tab which allowed for free text- *Good usability of the features.*	No eye image template for direct annotations- *Poor usability in the absence of the feature.*
Search and filtering functionalities- *Good usability of the features.*	Emails for appointments do not automatically book into the EMR, nor provide notifications- *Poor functionality and usability of the feature.*
Document attachment option- *Good functionality and usability.*	Lack of (pre-set) templates- *Poor usability in the absence of the feature*.
Control unit having its own UI, and connected to Participant 2's test machines- *Good functionality.*	No provision for electronic signatures- *Poor functionality and usability, in the absence of the feature.*
SMS feature on the EMR systems sending messages to many recipients- *Good functionality of the feature.*	No finger-prints- *Poor functionality in the absence of the feature.*
General reports tab with visually represented statistics- *Good usability.*	No automated back-ups- *Poor functionality in the absence of the feature*.
Laboratory feature for tracking prescriptions- *Good usability and functionality.*	No staff registry for accountability- *Poor functionality.*
High resolution images able to be seen- *Good usability.*	No of integration between imaging devices and the current EMRs- *Poor functionality.*
Eye test results sending prescription directly to linked software (but not the EMR in use for Participant 2)- *Good functionality.*	Lack of support for displaying longitudinal patient image histories for comparison purposes- *Poor usability and functionality.*
Ability to integrate the EMR with various practices also using the same EMR system (EMR interoperability with those sharing the same software)- *Good functionality.*	No voice activation provided to serve as an aid to manual input- *Poor usability and functionality.*
Independent software's comprehensive chart list, with audio functionality- *Good usability.*	Lack of the EMRs' integration with independent software- *Poor functionality in the absence or restriction of the feature.*
Educational and reporting aspects of Independent software: Automatic reminders and alerts, report generation- *Good usability and functionality.*	Manual entry of prescription lens numbers- *Poor usability.*
	Manual input of results- *Poor usability.*
	Storage of images by only by date and timestamp- *Poor usability and functionality..*
	Lack of training and support features which risks the stability of the EMR software- *Poor functionality.*
	Too many features that are confusing, and they lack help-information when selected- *Poor usability.*
	Control unit for Participant 2 was not connected to the EMR- *Poor functionality*.
	Computer operating system often restraints the performance of the EMRs' features- *Poor functionality.*

The proceeding chapter, Chapter 6 introduces FGs. These FGs are employed to best discover and address challenges faced (from Chapter 5, as well as the previous ones). The aim within this chapter is to explore and brainstorm novel design ideas, obtain different perspectives and gain a clearer, deeper understanding regarding EMR UIDs for optometrists in their specialist medical field.

Chapter 6: Focus Groups



This chapter contributes towards steps two and three (primarily) of the DSRP model for this research, relating to "Defining Objectives of a Solution" and "Design and Development". This chapter aims to contribute towards answering the ancillary research question 2: "What user interface design features should EMRs for Optometry contain?" Many differing techniques and methods can be found and applied within the context of Design Science (DS) to build, evaluate and improve artifacts. Whilst still also considering a UCD approach, the flexible, well-established method of Focus Groups (FGs) are used in this chapter. These FGs will be conducted early on in the research process in order to best discover and address challenges faced. The aim within this chapter is to explore and brainstorm novel design ideas, obtain different perspectives and gain a clearer, deeper understanding regarding EMR user interface designs (UIDs) for optometrists in their specialist medical field. This is in an effort to design appropriate EMR UID guidelines which address the problems optometrists face, and collect ideas on how to represent certain UI elements on the EMRs, whilst improving the current EMR functionality.

This chapter explains the rationale behind FGs, why they were used, and this research's objectives in using them. Furthermore, the FGs' results are presented, with common themes or areas of interest arising noted, as well as discussions relating to them. These are summarised in the conclusion, which presents possible features to include in the EMR UID. These suggestions contribute towards the creation of the guidelines for EMR UIDs used in Optometry.

6.1 Rationale for Focus Groups

FGs are interactive discussion groups that collect individuals' ideas regarding certain topics and bring on a qualitative richness to the data and research. They are also part of the UCD approach, as they centrally involve their participants in the sessions/discussions (Kuniavsky, 2003; Lazar, et al., 2010; Goodman, et al., 2012). As a reliable qualitative technique (Kuniavsky, 2003), the use of FGs have gained credibility over time and have been employed in several studies, of which many concern usability/UID (Kinzie, et al., 2002; Bruno and Muzzupappa**,** 2010; Kildal, et al., 2012).

FGs allow for a wide range of perspectives and insights to be obtained, with each group most likely having at least one person who will stimulate others to engage. FGs enable researchers to quickly acquire a wide variety of user viewpoints and possibly a consensus (Maguire and Bevan, 2002), where individuals are made to feel comfortable, and reveal their feelings and thoughts. This allows for them to share their perspectives of the problems and assumptions that lie at the centre of an experience and to relate them to realistic circumstances (Goodman, et al., 2012; Brandtner, et al., 2015). The nature of the FGs partake a combination of "Exploratory" and "Feature Prioritisation". "Exploratory" refers to obtaining general attitudes towards the topics, and "Feature Prioritisation" focuses on what features are most attractive to a group and why, and the participants are interested in a certain kind of product. A general indication regarding the end product's outline is known (Kuniavsky, 2003).

FGs are suitable for research aiming to explore and discover the motivations and needs of why users assume certain behaviours, gain first-hand experiences, and understand values of a group of individuals. FGs purposefully assemble a cross-section of stakeholders in a discussion group format (optometrists from different practices, for this research). A moderator (or researcher) leads the group(s) through some topics and activities, and the group(s) concentrate on a specific set of issues or concerns. This method depends on a collective, shared interest between the participants (homogenous sample), as the synergy between the discussion contributors offers data through comparing knowledge and sharing, rather than individual questioning (Krueger and Casey, 2009). Helping identify problems needing to be addressed, this method is valuable for requirements elicitation and assisting with the design and development phase of DS. Each participant may act to stimulate thoughts in other participants present, and that by a route of discussion, the collective viewpoints become established which is superior to the individual parts (Bruseberg and McDonagh-Philp, 2001; Maguire and Bevan, 2002).

FGs actively offer informal and flexible techniques which assist in communication between users and researchers, allowing for the mutual understanding and collaboration of ideas, within social contexts or environments (Black, et al., 2001; Bruseberg and McDonagh-Philp, 2001). Flexible formats focus on the group's conversation, yet allows for discussion to develop as novel topics arise (Bruseberg and McDonagh-Philp, 2001; Maguire and Bevan, 2002). The participants share homogenous qualities (occupation, past use of product, age, gender, family traits), yet have sufficient variation among themselves to allow for contrasting opinions (Krueger and Casey, 2009). Allowing for an open format, FGs are flexible enough to be applied in a wide range of design topics and domains. By putting the researcher into direct contact with potential users of the artifact and with domain experts, FGs support clarifying artifact design questions and probing respondents on key design issues. The high level of interaction in the course of a FG study allows for deeper understanding on respondents' reactions, on the use of the artifact and on other issues in the respective environment influencing design. Furthermore, the high degree of interaction also fosters the emergence of ideas or opinions that wouldn't have emerged in traditional, individual interviews (Tremblay, et al. 2010; Brandtner, et al., 2015).

FGs have been amicably linked to DS due to their flexible nature and management of design topics and domains, as well as the direct interaction with participants and conversations regarding design issues. Additionally, FGs allow for the gathering of great and rich amounts of data concerning the design itself as well as the situational use of an artifact within context, while building upon the other participants' remarks (Hevner and Chatterjee, 2010). To arouse brainstorming activities or conversations pertaining to specific topics, the researcher raises a question or makes a comment. Generally, multiple perspectives or opinions are raised, triggering discussions, which enable researchers to gain greater insight and collect more data.

Many different authorities suggest varying ranges to constitute FG numbers. Rogers, et al. (2011) suggest that three to ten participants should generally constitute the larger range of FGs, with the group representing a sample of a target population. Nielsen (1993) and Kuniavsky (2003) both support this upper limit of ten participants, but caution the lower limit to maintain six participants. Within these ranges, Krueger and Casey (2009) recommended a group to have five to eight participants, and four to six when they have greater expertise concerning the topic.

Smaller, or Mini-Focus Groups maintain the fundamental characteristic of FGs by providing interactive discussions, but within a more intimate dynamic (Morgan, 2011). Participants are still able to engage in the kind of comparing and sharing that is one of the great advantages of

FGs. Sets of two and three participants can build on each other's contributions in various ways, making use of the dynamics of a conversational setting to lengthen the "data beyond what would routinely be available in a one-on-one interview" (Morgan, 2011). Two and three person structures borrow some of the advantages of one-on-one interviews by permitting the researcher to hear more from the individual participant, with a considerable increase in the amount of depth and detail that is obtainable from each participant (Morgan, 2011; DJSResearch, 2018). This research utilised two FGs from two different practices that are both located in the Eastern Cape of South Africa. In each FG, two same-practice optometrists participated. This in-practice FG dynamic was structured to accommodate the optometrists' comfort; as some felt uneasy in meeting with others from different practices, for professional reasons. These reservations, as well as time constraints of the different optometrists lead to the FGs being of a smaller size, which proved to be ideal in terms of discussion flows and brainstorming ideas for this research. Group interviews inherently necessitate bringing people together at the same time, which was difficult as the optometrists had busy schedules, making the co-ordination challenging (Morgan, 2011; DJSResearch, 2018), hence small groups facilitated scheduling. In order to help clarify the purpose of, and guide the FGs process, stating objectives are useful. For this research, the FG objectives are:

- Gain insight into how the user interfaces (UI) should be designed to overcome the problems highlighted in the Task Analyses (TAs), specific to EMRs in Optometry.
- Discover new possible UID features optometrists desire to have (or remove) in EMRs, in efforts at overcoming the usability challenges of EMRs as revealed previously in the literature (Chapters 3 and 4).
- Create suggestions for possible UI features that effectively support the optometrists' workflows.
- To explore various types of design elements optometrists would prefer to denote certain functionalities on the EMRs.

6.2 Method

6.2.1 Participants

The participants representing the target population comprised of experienced and practising optometrists, and their homogeneity (occupation) allowed for a shared appreciation of the topics discussed. Administration staff may have been able to provide insight or suggestions in terms of EMR usage within the practices, however, the focus was on optometrists who

comprised the main user group. These optometrists also had administrative experience as a result of using their EMRs.

Four optometrists were chosen, divided into two, same-practice groups. This helped reduce the likelihood of breakout conversations occurring; since only one moderator (researcher) was available to control the group. Moreover, the participants were kept to their same-practice groups due to their reservations of interacting with optometrists from different practices. FG one included two optometrists previously used during the TAs. FG two included one optometrist that was previously observed during the TAs, and another one that was new to the research study. Table 6.1 below presents the population sample used:

Table 6.1 Population Sample

Optometrists	Focus Group	Age Group (Years)	Gender	Previously Participated in TA
Participant 1 (P1)	1	30-39	Male	Yes
Participant 2 (P2)	1	20-29	Female	Yes
Participant 3 (P3)	2	30-39	Male	Yes
Participant 4 (P4)	2	60+	Male	No

6.2.2 Procedures

The two FGs adhered to Kuniavsky's (2003) methodology, with the main topics covered outlined in Table 6.2 below, and were constructed with the guidance from the TAs (of which Table 6.2 states the main findings) and literature. The topics were discussed in a conversational flow, and their introductions were mainly in accordance to "S1", "S2", "S3" (Chapter 5's TAs), but were not bound to this sequence depending on the direction of the conversations. The participants were encouraged to converse on any further topics that may have been relative to the study, as well as how any functions that are helpful to their workflows may be supported via their EMR UIs.

Table 6.2 Focus Group Topics

S1 Patients Arrival and Appointment Management
New or existing patients arrive
Appointment management
Reminders and notifications
Verification of information fields and patient details
S2 Pre-Testing/Pre-Screening
Integrated EMR and testing machine software
Capturing information onto the interfaces
S3 Optometric (Eye) Examination/Health Process
Health process
Visual Charts
Data captured and Information Recorded
Educational features
General
Inadequate optometric features, with EMRs stressing administrative functionalities
Rigidly generic layout, lacking customisation
Data sharing amongst different practices

Sufficient time was provided for each topic, permitting the discussion within each FG to coax out the subtleties of the different participants. In order to allow for the researcher to probe deeper into any topics arising during the session whilst maintaining a comfortable environment for interaction, the FG interviews employed a semi-structured nature (Kuniavsky, 2003; Van Kleef, et al., 2005; Lazar, et al., 2010). The FGs were held at each practice respectively, on different days, at the convenience of the optometrists participating. Ethical consent was also obtained from the participants before any discussions began (Refer to Chapter 1, Section 1.7). Prior "small-talk" and greetings were engaged in, which allowed for a more relaxed environment to ease the optometrists into the session.

The problems of group-think and group dominance ("Alpha Jerk effect") risking the data quality were considered, and participants' biases were limited as much as possible. The challenge of group dominance arises when one domineering participant attempts to control the FG discussion. This prejudice was limited by redirecting and distributing focus to the other quieter participant(s), in attempt to draw attention away from the dominant participant when speaking too much (Kuniavsky, 2003). Group-think may be defined as when participants' inclinations lean towards agreeing with other participants in the room. This prejudice was restricted by individually consulting with each participant to ask what they desired, whilst affirming throughout the FG sessions that all participants' opinions were valid and that earnest disagreement or debate was encouraged (Adams and Cox, 2008).

Once the optometrists were seated, the session commenced with an introduction informing them more about the research (to also refresh their memories from the TA), and the objectives of the FG. Participants were informed that no responses were right or wrong, and that their opinions were valuable. They were assured that their viewpoints regarding the topics were of particular significance to the whole process, and that their candidature was welcome during the casual discussions. The sessions were recorded, with use of a video and audio recorder, and general note-taking (pen and paper).

After all the required topics were discussed some open discussion time was allowed to address any further queries. Proceeding this, the FG session was concluded, with salutations and thanks given.

6.2.3 Data Analysis

The narrative information from each participant in the FG was gathered, transcribed and reflected upon, with especially emphasised areas highlighted. The transcription from each session was then categorised according to the topics in Table 6.2; in order to allow for analysis. Analysis was then conducted with the data being organised and described in detail. This was achieved by merging the meaning of the analysis within their particular context (Kuniavsky, 2003; Braun and Clarke, 2006). Common themes/areas of interest were noted, which also helped in determining hierarchies of importance regarding certain functionalities. The common themes that appeared in the two FGs were grouped together and deliberated upon, following in the section below. With these common areas and differences now better understood and outlined via the analysis stage, it was possible to individualise areas or features for the better EMR UI design. Elements of Thematic Analysis were used to guide the data analysis process. However, the transcription process was simple enough, and easily understandable as to not require its full employment of it (Braun and Clarke, 2006).

6.3 Results and Discussion

6.3.1 S1 Patient Arrival and Appointment Management

6.3.1.1 Provision of Electronic Forms for New and Existing Patients

All the optometrists expressed that in order to save their time, and decrease the risks of human errors when typing out the patient details from their current paper forms onto a UI, an electronic form would indeed be useful and convenient. One optometrist stated that an electronic form would be preferred as it addresses *"the issue of time",* as well as alleviating errors from

misreading peoples' untidy handwriting; *"...it's still hard to read".* This electronic form, accessible via the practice website or possibly through an emailed link, would be similar to the paper version in terms of patient information required. One FG reflected that prospective patients would then be able to directly and *"electronically fill it out"*, to send back to the intended practice in order to create a profile in the EMR system. The electronic form was desired to be sent to the practice, possibly via email or uploading it directly via the practice website; and not filled out by hand to scan and upload (which would risk errors in handwriting misinterpretations again). This electronic form was also considered as more secure than paper records. For example, in terms of backups or in the event that the papers *"were lost"* and unauthorised personnel came across them.

Electronic Forms: Hobbies, Easier Patient Profile Capturing and Creation

Common information that was currently required on most of the patient-information forms included names, occupation, contact details, medical aid information and past medical history information (*"Diabetes, blood pressure and Arthritis"*, for example). This was confirmed by the participants themselves, as well as by checking various practice forms. Three of the optometrists agreed that hobbies (outdoor or indoor activities, according to the environment) was considered a suitable addition to the forms, which would be a useful guide for the optometrists to understand their patients' needs better, as well as in helping the patients feel more valued; *"It's great when you know what they're using and what sort of things they're doing"*; *"...well this person loves playing golf, then automatically our eye exam is going to be flowing that way more".* One other optometrist stated that the option to include *"Hobbies"* would *"certainly"* be useful, but the patient privacy in disclosing all these details may cause challenges due to some patients' sensitive natures.

A patient profile picture was considered an additional, valuable feature to the electronic form, to make it more like a patient profile. The picture would help optometrists in quick identification but also give a sense of being valued form the patients' perspectives in that they are more than just a number in the system. *"Tick boxes"* on the form for easy patient selection of relative conditions or options was favoured by two optometrists. In terms of editing or updating the created profiles (for the new or existing patients), the optometrists felt that it *"would be safer"* and more efficient for them to do it, rather than give separate access in the system to the patients themselves. For patients filling the electronic forms upon arrival instead of before their appointments, the optometrists agreed that having a "*tablet*" or even just a separate screen for them to directly fill it in would be useful. This way, patients could ask for help if needed, as well as having the convenience of the electronic form directly filled in.

6.3.1.2 Comprehensive and Personalised Calendar, Colours

Some of the optometrists preferred to have a physical daily planner with the appointments printed out, whilst the others favoured a UI with the appointments and meetings combined on one interface; *"One system that everybody accesses"*. They all however, agreed that having one UI with the appointments all comprehensibly viewable, as well as having the provision for different filters for personalised viewing would be beneficial; "*What I like is different ways you can view it. It's nice when you actually have a block and you can see it"*.

The use of colour for customisation, task depiction, representing represent different appointment types (patient appointments, meetings, and personal time off, for example), or relating optometrists to their appointments was considered convenient to include, and *"pretty nice to have"*, as not all the optometrists' EMRs included this functionality efficiently*; "I don't see it as much…But It was colour coded as well… which optometrists sees which patient"*.

On their website, some optometrists expressed that for prospective patients wanting to book appointments, it would be helpful to include a button that when selected, allowed for them to schedule an appointment directly, and also then fill in the electronic form if they are new to the practice. This booking would then be reflected in the optometrists' schedules and updated immediately (in real time). Two optometrists communicated that an interactive calendar with detail-expansion features upon selection (*"drill-down"* menu), or hovering over the block (showing appointment information or administration commitments), would be useful as a time-saving, visual aid; *"If you click on the appointment, it'll show you all the details...so that you don't really see when you look at the appointment".* A "*pop-up"* box or *"side-panel"* was also suggested as an alternative to hovering over a block/appointment slot on the calendar; *"What would be nice is if you could move your mouse pointer over it and it actually gives you like a popup where it gives you all the stuff".* For example, a calendar showing a summary of the patient names and times which could be viewed as a comprehensive list when the block is selected, and upon further patient selection, redirects the optometrist to their profile aforementioned. The comprehensive list was described to include the patient names, account number, appointment time, medical aid information, status (existing member or new), contact details and reason for visit (follow-up appointment or a specific condition, for example).

The optometrists expressed favour with the addition of a feature that allowed for them to select the time per appointment, depending on the scheduled patient's reasoning for visiting; *"And you can see how long the appointments are"*. This would preferably *"be in fifteen minute"* intervals, maximising at one hour for an appointment on the EMR system. Three or four of the optometrists agreed that they frequently consulted and relied upon their calendar, and used it

as their home-page or starting point for their day. It was determined that this first, S1 stage was predominantly focused on the patient details and demographics as opposed to health data (S3 mainly).

6.3.1.3 Reminders, Alerts and Notifications

The optometrists expressed that often appointments overlapped, and it was inconvenient when patients had to *"wait for their appointments"*, or when they came in late. To address this, a status feature was favourably considered by one participant; *"That would be great to know when they've arrived",* which would notify the attending optometrist of their patients' arrival (S1), pre-testing phase (S2), and optometric (eye) examination/health process (S3*); "Maybe like a check-in where whoever is at the front could click…or like now they're at the pre-screening check"*. Two other optometrists whose current EMR system included a limited form of this feature, added that this was not as practical as it sounded. The issue regarding this was that more work and labour was required, in terms of having a separate person handling this feature; *"…it also might mean something more to do".* Thus, it was considered to be suited for very large practises, and not entirely necessary nor practical when effected.

6.3.1.4 Verification and Parameters

Especially regarding the input of email addresses and patient contact numbers, some participants indicated that their EMR systems lacked verification standards and measures, thus frequently resulting in erroneous contact information stored; *"Definitively not for email"; "No, there's no way of checking"; "…like there needs a 'dot' between the co and the za…they don't check that"*(email addresses); *"Even for like names and things, it doesn't differentiate between capital letters and lower cases."*; "*…Just to tell you that the cellphone number is too short, and you know that you're missing something"*.

They agreed that some form of validation checks for the input of information such as email addresses, contact numbers and medical aid information would be helpful *("That would be great"),* which was agreed upon by the other optometrists whose EMRs did have some (minimal) input field validation checks; *"Like for contact numbers I think if you had limited numbers of spaces, so let's say you can't' go over the tenth digit"*; *"Ya just to check you know, if something was wrong…just to show you. You know when you log into something and it gives you a red exclamation. Something like that"*. For both FGs, their EMRs did not have any checks for patient prescriptions (in S3) *("...Also for prescriptions and things"),* and reflected that it would be a worthwhile addition for patient safety and accountability purposes. One FG added that their invoicing function included some form *("In some ways there are…"*) of verification measures, but this did not extend to the prescriptions, and also suggested that it would be useful to have*; "I do think you could do it more thoroughly, more than what we've got at the moment"*.

6.3.2 S2 Pre-Testing/Pre-Screening

6.3.2.1 Integrated EMR and Testing Machine Software, Capturing Information

Both FGs expressed desire to have an EMR system that integrated with all the test machines, and have a single display rather than operate several different programmes to run each machine; *"One system"; "…All in one place"; "You can have all your health checks there (on the one UI), so you don't have to open this programme then open that...That would be amazing".* Some of the optometrists added that the pre-screening/re-testing stage (S2) could be tabbed for separation on the EMR, and include the various tests within that tab; *"Have a tab for pre-screening, and under that tab there are separate tests you can do"*. They considered a UI that included some of the various, main test options/health checks (Table 6.3). The presentation of these could be as interactive blocks/buttons *"that you could physically click"*, or perhaps tabs; *"Tabs...saying OCT data, and if you click on it, you would see the OCT Scans that they've taken two minutes before. Then you can have a Fundus Photo tab, and you can clock on that, and it'' show you the photos...or IOPs"*.

Table 6.3 Examples of Test Options and Health Checks to include within the Pre-Testing/Pre-Screening UI

Test Option/Health Check	Attributes of Test Options/Health Check
Fundus Photographer	Image scans showing appearance of a retina for optometrists to observe.
Optical Coherence Tomography (OCT)	Image scans which use light waves to take cross-section retina images for observation.
Visual Field	Printed sheet with numerical values and text which help optometrists determine whether the visual field is affected by diseases that cause visual degeneration and sensitivities to varying degrees.
Vertometer	Image and/or numeric values which verify the correct prescription in a pair of eyeglasses; to efficiently orient and mark uncut lenses, and to confirm the correct mounting of lenses in spectacle frames.
Retinoscopy	Printed sheet with mainly numerical values and some text. The Retinoscope provides an objective measurement of a person's refractive error and prescription for contact lenses or glasses. This instrument achieves this by measuring how light is changed as it enters a person's eye.
Eye Pressure and Intraocular Pressure (IOP) Tests	Numerical values mainly, with some text. This is performed to determine patients' eye pressure levels; which if too high, may damage optic nerves and lead to glaucoma. Normal eye pressure ranges from twelve to twenty-two (12-22) mm Hg. Readings greater than twenty-two (22) mm Hg is considered higher than normal.
Blood pressure (BP)	Numerical values. High blood pressure readings can cause changes to the eye that may lead to permanent vision loss, as the eye is a highly vascularised tissue. The retina and optic nerve need a great amount of blood supply to function efficiently. The normal blood pressure reading ought to be one-hundred and twenty over eighty (120/80)). BP values are a manual recording and would need to be entered into the EMR, unlike scanned images, for example, which could ideally transfer and store automatically into the EMR from their respective machines.

Upon selection, these options (Table 6.3) would ideally navigate to the specific patients' results (images or notes for the tests conducted). This display was anticipated for, especially if there

was provision to email, print, store and view a patient's results over time (longitudinal histories) on the EMR UI, as well as upload images or attachments (perhaps using a *"plus icon"*); *"You can look at that (image) and refer back...two or three visits"*. Within each tests' respective UI or window pane, the organisation of images or attachments was desired to be according to various settings, such as date, time, name or size; *"Especially for reoccurring patients, it would be very nice having the data organised date wise as well"*. In terms of the actual data capturing, the optometrists expressed that having the images and results from the various tests displayed on their EMRs' UIs, with provision for any comments if needed, would be adequate, and *"handy"* for reference. There was to be a comments pane (possibly *"On the side"* of the screen), for any free-text relative to each test*; "Where you could add your own comments…because usually you'd do your own interpretations"*.

For the specific tests, the FGs commented that the data-capturing method would be determined by their value ranges and formats; *"Well it depends on their value range. If the value range is large you're going to have to type it in"*. One sole, set method of capturing the data would be inefficient. For example, for the intraocular pressure (IOP) test recordings, a drop-down menu option with predefined figures ranging from *"1-40",* and then *"45+"* would be adequate; *"For intraocular pressures, you could perhaps have a drop down menu because it can be 0 to 40, or you could go 40+... or you could go 45+"; "Then you could just tick or select 45+…"*. The values recorded were said to be, *"Just single numbers"*, and did not have decimal places. For blood pressure readings, a text input method would be more suitable as the number ranges are greater; *"120/80"* is the ideal human blood pressure reading.

6.3.3 S3 Optometric (Eye) Examination

6.3.3.1 Separation of Prescriptions and Health Process Section, Data Capturing

Three of the optometrists stated that completely replacing their current paper-recording method would be difficult, as they were habitually accustomed to it, and the process of writing over typing was considered *"faster".* One optometrist, however, stated that he was "*so used to having a blank piece of paper, on a computer"*. This *"blank piece of paper"* served as the traditional paper-based recording card, but instead was displayed on a UI/electronically. The electronic version replacement was even desired to have, *"Maybe a similar format to what your record card looks like, where you've got your areas where you can put your values. So you'll have your prescription…patient history, any incidental findings"*. Resultantly, if the paper method was replaced by the EMR, the optometrists all approved that a UI with some provision for free-text and even images to annotate/draw as well as possibly having a customisable, pre-set layout would be helpful; *"Well I saw redness over there (and draw)… I*

like to draw things"; "If you have an eye, you can just drag things". This *"Health Process"* UI could include pre-set headers such as (but not limited to); *"Date", "Patient Name", "Account Number", "Age", "Optometrist", "Patient's Chief Complaint and Reason for Visiting", "Ocular Medical History", "Previous Prescription Information", "Chronic Medication", "Hobbies and Work", "Comments", "Annotations/Drawings",* and *"Prescription"*. One optometrist added that when recording patients' medical histories and details, it would be valuable to be able to "*search for certain terms"*, or chronic medications for example, though a search facility or *"bar"*. For the *"Patient's Chief Complaint and Reason for Visiting",* a selectable *"list"* with options (or *"where you can even tick"*) was considered useful to be pre-loaded. Some of these options included, but were not limited to:

- Scheduled appointment
- Near vision worse
- Lost/broken correction
- Scheduled review-3 months
- Scheduled review-6 months
- Post cataract surgery
- Credentialed Diabetes Educator (CDE) annual diabetic check-up
- Other (free-text provision)

Due to the information density and UI clutter that was discussed during the TAs, the recording of the health checks/patient information and the prescriptions was desired to be separated. The *"Prescriptions"* could be a separate part on the *"Health Process"* UI or window pane, and again, include some validation checks when capturing certain prescriptive figures, such as for lenses numbers (an error message or symbol when an out-of-range figure is entered, for example).

The standard numerical increments for lenses was communicated to exist in quarters, or *"0.25's",* but sometimes differing in newer digital machines, and also varying in values for each eye. Thus, the prescription could possibly include two separate sections for the right and left eye, "…*We just have right or left*", with provision for input of the lenses figures. This would also aid in their easier navigation of the UIs. The optometrists further added that the prescription also may include other patient details, for example, like the frames, lenses, coatings, and visual acuity, as well as any other common prescriptive figures or results for each eye, *"whose list could be endless",* depending on the optometrist. Since there were often *"…More than one prescription"* made during an appointment before the final one issued*; "Subjective refraction. Final Refraction",* options for adding multiple prescriptions was also desired, as well as functionality to print *"and email"* them out to patients or for referral if required. In capturing the prescription information, the UI could include a *"list"* of glasses available, such as *"Distance glasses", "Reading glasses", "Office glasses", "Sun glasses",*

"Sport glasses" and *"Other".* For the Subjective Refraction (prescription from the "*testing chair",* but not necessarily the final one) and final prescription *("Final Rx"; "Final Refraction"),* the optometrists suggested that numerical figures could be inputted via a number pad, or just simply a text box for free entry on the numbers. Optometrists have different input preferences, and so provision ought to be made to accommodate them, such as by enabling for more customisability. A text or comment box for extra notes or special instructions was also considered to be a useful addition to the health process interface, or prescriptions section.

6.3.3.2 Integration of Standardised Visual Charts

The optometrists stated that the visual charts used are *"standardised almost everywhere"*, as well as *"mostly patented"*. The most common ones mentioned were the *"Snellen Chart"* (Refer to Appendix F18), *"Tumbling E", "Landolt Chart"* and the *"ETDRS Chart"*. They, however, existed in various mediums such as electronically or physically (charts on walls, for example), which was expressed as frustrating, especially when the optometrists had to run independent software to display the charts; *"It's a separate thing. The chart is its own electronic programme. Doesn't integrate it, it's separate"*. To address this issue, the optometrists communicated the desire to have a separate tab or option within their EMRs, which could directly open and run the charts. The optometrists reaffirmed that this tab option *"...would be great", adding* that it would save money in not having to purchase a *"whole separate licence"; "It's a whole extra licence, you have got to pay for that".* The design of the charts was to remain as the standard ones existed, but to rather have them all as electronic versions, integrated into the EMR system.

6.3.3.3 Educational features and Patient After-Care

<u>Emails and Templates</u>

The use of emails was discussed further, with the optometrists adding that the provision of customisable and pre-set templates may be helpful as writing everything out is *"time consuming".* The template(s) could include the patient's name, salutations, and next appointment reminder, additional to the prescription attachment and possibly some educational information regarding their diagnoses; *"Like you can say email prescription, and then it brings up a template…and then it imports that sort of data given onto a Dear Mrs Smith, please find attached your prescription. The date of your eye appointment was such and such. Your next eye appointment is due… whatever is selected from your recall, because that's what you've selected (to add)".* A link to new products and brands, or information related to them was also

considered as an addition, which may be on the practice website or even in the email. This was considered as useful yet not essential by the FG participants. The education of patients regarding their examination was considered essential by both FGs, with two optometrists exclaiming the education is *"very important!"* and that *"It's usually neglected by busy practitioners".* At times, existing patients were educated during, or even before their appointment. Some of the optometrists relied solely upon discussions and the use of their pamphlets or books/educational material; *"As you can see we use those boards up there currently",* whereas others had educational software that ran independently to their EMRs.

The optometrists desired an EMR that included an educational feature, which could enrich their patient experience, as well as aid the optometrists themselves by decreasing their workloads. As such, a suggestion was the introduction of a UI or function with a list/source of conditions, which upon selection, could provide more information to the patients. This was to supplement the search facility available, and also able to be emailed to, and printed for patients, *"...And email. Nice to email people their things*"; *"For patient's future reference".* Additional options relating to the patient journey during their appointments, after-care and appointment pre-preparation were also considered useful. For example, information relating to what to expect at an appointment, how to take general care of the eye, and the types of lenses available; *"Perhaps a bit of information like before you go…like on Safari, what to bring, or don't wear your contact lenses before you, or we may dilate your pupils so you may find it difficult to drive…"*; *"So they almost come prepared".* One optometrist added that an informational section on the website conveying information to patients about what to expect during their visit, *"or after-care would be useful"*, which could positively contribute towards their overall experience. As previously noted in the TAs (Chapter 5), the optometrists again brought up the educational and after-care features in aiding patient relationship-building and encouraging greater trust. Remembering the patients after their leave would give a sense of them being valued and remembered, encouraging loyalty building their relationships with the optometrists/practices. This not only contributes to the optometrists' greater overall satisfaction and experience, but promotes a more positive patient experience and overall journey.

Some of the educational/informational topics, which were communicated to be fairly standard and common, were noted for possible inclusion on the educational UI in the EMR prototype; *"You can pre-load common things".* Upon selection, these options or *"blocks"* could possibly be further expanded and elaborated upon. For example, the condition "Astigmatism" could be represented as a selectable block, or as a hyperlink. Upon its selection, a separate UI loads with related information, or the current UI is redirected to an "Astigmatism" page. From the many

lenses and diagnoses/conditions, some possible examples that may be displayed on an EMR's *"Education"* UI are included in Table 6.4 below:

Table 6.4 Patient Education: Examples of Lenses Add-Ons and Common Diagnoses

Lenses Add-Ons (Additions to normal lenses to specialise them for individual needs)
Anti-reflective coatings (ARC)
Photo chromatic lenses (transitions)
Polarised lenses
Fixed tints
Hard coating
Refractive index material

Blue Blocking:
• Sun Vision (Lens design)
• Varifocal (Lens design):
  ○ Conventional distance to near
  ○ Office Intermediate to near
  ○ Accommodative support
  ○ Bifocal

Diagnoses/Common Conditions
Myopia (Near-sightedness/Short-sightedness. It is an eye disorder where light focuses in front of, instead of on, the retina. This causes distant objects to appear blurry while close objects seem normal).
Hyperopia (Far-sightedness. It is a condition of the eye in which light is focused behind, instead of on, the retina. This results in close objects seeming blurry, while far objects may appear normal).
Astigmatism (A common condition causing blurred vision. It occurs when the cornea (the clear front cover of the eye) is irregularly shaped or sometimes due to the curvature of the lens inside the eye).
Presbyopia (A natural part of the human aging process. It results from the hardening of the lens of the eye causing the eye to focus light behind rather than on the retina when looking at close objects. It is a type of refractive error along with Astigmatism, Near-sightedness and Far-sightedness).
Strabismus (One eye looks directly at the object you are viewing, while the other eye is misaligned inward (esotropia, "crossed eyes" or "cross-eyed"), outward (exotropia or "wall-eyed"), upward (hypertropia) or downward (hypotropia)).

6.4 General

This section discusses noteworthy points that arose from the FGs, that did not necessarily fit under a particular stage. The following subsections discuss the areas in more detail, exploring what may be useful to include in the designs or not.

6.4.1 Inadequate Optometric Features

The optometrists all agreed that their EMRs were mainly used as administrative systems (*"Billing side"*), and did not *"help much"* in terms of optometric features for use. To extend these systems to increase aid in the actual optometric practises, some ideas were expressed. These included the addition of predictive text in input fields, as well as the uploading of attachments like test scans and images of *"various formats"* for reference and storage; *"The programme can learn what you put in there and as you type in the first options come up. Then you click on the one you like"*.

6.4.2 Greater Need for Customisation

Some of the optometrists commented that their EMRs were rather rigidly structured, with little opportunity for customisation. A "*Favourites"* tab was conveyed as desirable, in which optometrists could add their most frequented files or items, for example. The use of colour in their EMRs other than just in the calendar was also reflected as useful, and *"nice to have".* A social media link for greater marketing purposes and enhanced communication was expressed as a helpful addition to the EMRs; "…*Even social media*".

6.4.3 Data Sharing

Two optometrists expressed that a system allowing for satellite login (at different locations) would be convenient, whereby the optometrists could then access their profiles and calendars from external hardware devices (phones, laptops, tablets) and locations away from their practices. The optometrists also wanted to be able to share their patient profiles and details directly with other optometrists for referral if needed, or with just the patients themselves; and this was to be addressed via an email option.

6.4.4 Workflows

From these FGs, following the flow of the patient journey as well as from the optometrists' perspective, the resultant EMR UIs were considered:

For the optometrists (Primary EMR Users):

Login page→Calendar UI as main homepage with different customisable views →Patient List in calendar, clicked which then opens their profile→Pre-Tests tab→Health Process tab, with the notes and templates→Prescriptions section→Educational tab with list→Email and end of visit.

For the Patients:

Practice website UI→Book appointment tab (amongst others such as contact, information, gallery etc.)→Calendar that is updated and shows availabilities→Confirmation→Electronic patient form for new patients (existing ones can just update at the practice).

6.5 Conclusion

From the FGs and with input from the previous chapters, this chapter allowed for the reflection of possible UID features that optometrists would like to have within their EMRs, which support their workflows. The administrative features currently predominant within most of the EMRs, such as the billing and invoicing aspects, were considered helpful indeed but not as useful for the actual medical aspect of Optometry, namely for the scope, being the patient appointments.

Consequently, this chapter was valuable in attempting to help extend the current "administrative" EMRs to include greater optometric functionality (via some UID suggestions and features), and in addressing the usability and UID challenges that hinder the seamless workflows of optometrists. Past problems relating to the EMRs and their UIs were reflected upon, why they occurred, any current issues, as well as solutions to address them were discussed. The EMR problems in relation to the optometrists' workflows were discussed, and solutions to mitigate them were brainstormed.

Within the three main stages (S) of the workflows (S1, S2, S3) in Section 6.3, some common areas of interest or themes arose. These are summarised in Table 6.5 below, but mainly included the:

- Provision of electronic forms (for both new and existing patients)
- Easier patient profile creation/management (inclusion of hobbies, profile pictures and tick-boxes) within the electronic forms
- Comprehensive and personalised/customisable calendars, and the use of colour
- Up-to-date reminders, alerts and notifications
- Verification and parameters to minimise errors (data-entry, prescriptions, patient details)
- Integrated EMR and testing machine software, and capturing the respective details and information
- Separation of prescriptions and health process section, and their respective data capturing
- Integration of standardised visual charts into the EMR
- Provision for (integrated/EMR-inclusive) educational and patient after-care features
- Use of emails and provision for templates
- Inadequate optometric features
- Greater need for customisation
- Data sharing amongst EMR users
- Workflows and EMRs working in unison

Table 6.5 Summary Of Optometry EMR UI Suggestions To Increase Efficiency

Activity/Feature	Phase of Appointment	Suggestions for EMR UID
Electronic Forms	S1	• Replace the new patient paper forms with an electronic one. • Accessible via the practice website or possibly through an emailed link. • Hobbies included (outdoor or indoor activities, according to the environment). • A patient profile picture. • Tick boxes for easier selection of options. • Tablet or separate UI with the form for filling in at practices.

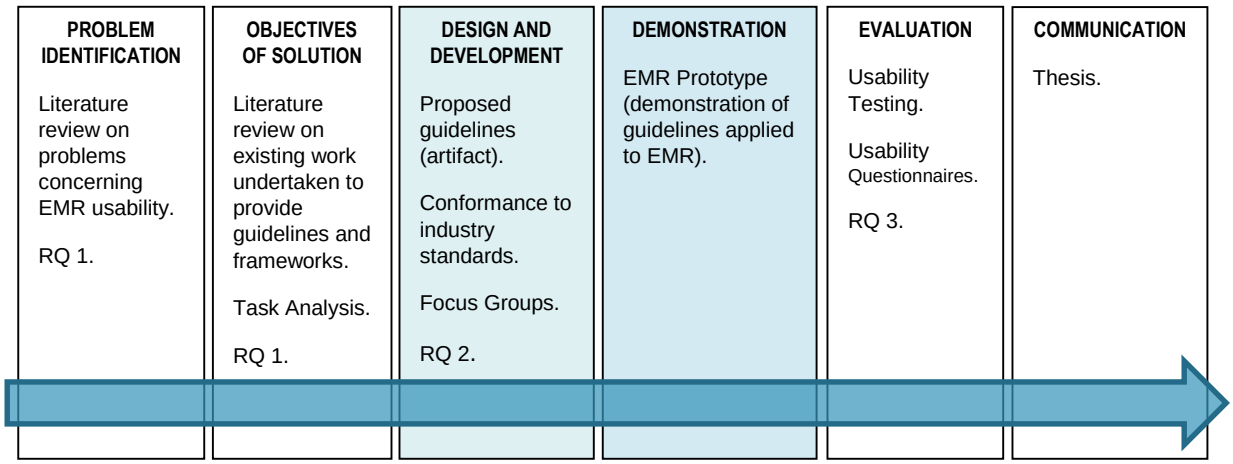
Comprehensive, single Calendar	S1	• Colour used for differentiating appointment types, appointments to their optometrists, and perhaps patient statuses. • Alternative views for optometrists' custom preferences (patient summary, individual optometrist's schedule, all the optometrists' schedules). • Updated immediately, in real-time. • Button on practice website to schedule appointment. • Detail-expansion features (hovering for expansion, drill-down menus, pop-up boxes, side panels). • Adjustment of times per appointment. • AutoSaving.
Informational section	S1, S2, S3	• Practice details on the patient appointment, after-care. • Advertising. • Products available. • Educational facts. • Social media.
Alerts and Notifications	S1, S2, S3	• Patient status for T1, T2 and T3 (although this point was not considered practical).
Verification and Parameters	S1, S2, S3	• Verification fields to ensure correct input of information for email, contact details, medical aid options, and prescriptions (ranges for values, for example).
Pre-Testing and EMR integrated on one UI	S2	• Buttons or icons to display various pre-test options on the EMR UI. • Email, print, store and view a patient's results over time on the EMR UI. • Upload images or attachments (possibly a "plus icon"). • Comments pane for any free-text relative to each test. • Custom organisation of results (date, time, size, name). • Intraocular Pressure Test recordings: Drop-down menu option with figures ranging from 1-40, and then 45+. • Blood pressure readings: Text input method.

Health Process UI	S3	• Free-text provision/comment box.
		• Pre-set template/layout, and headers.
		• Images to annotate, or area to draw.
		• Search feature.
		• Pre-loaded list under "Patient's Chief Complaint and Reason for Visiting".
		• "Prescriptions" has a separate section on UI, or new UI.
		  ○ Validation checks for correct input of information (error message or symbol for out-of-range figures).
		  ○ Two separate sections for the right and left eye.
		  ○ Provision for multiple prescription creation.
		  ○ Print option.
		  ○ Email option (possibly with a pre-set template including patient name, salutations, next appointment reminder, prescription attachment, possibly some educational information regarding their diagnoses link to new products or information related to them).
		  ○ List for the options of glasses types available.
		  ○ Number pad, or text box for free entry for the numbers.

Visual Charts	S2, S3	• Tab or feature within the EMR that includes the charts.
Education		• UI or function with an expandable list/source of conditions. • Search facility. • Print report. • Email report.
General UI attributes and Customisation	S1, S2, S3	• Predictive text. • Uploading attachments of various formats (pdf, jpeg, .doc, for example). • Favourites tab for quick access to frequented ages and actions. • Multiple log-in at different locations for optometrists (not restricted to a single machine).

Table 6.5's suggestions will be used in the proceeding chapter, 7, accompanied by guidance from the literature review, and the TAs (Chapter 5). This will enable for the creation of optometric EMR UID guidelines. These guidelines will be used to inform a prototype design of Optometry EMR UIs (Chapter 7) for subsequent Usability Testing (UT) and further confirmation and modification (Chapter 8). To avoid challenges in the specification of guidelines (i.e., ambiguous definitions; lengthy definitions; or inadequate specification to understand a guideline), it is important to follow a standard template to define clear and homogeneous guidelines; that is; all guidelines ought to have the same format and structure definition. Presenting the guidelines in a tabular format aids in creating this structure. Chapter 7 presents the Proposed Guidelines and discusses the process involved in their creation.

Chapter 7: Proposed Guidelines



This chapter contributes towards Step 3 "Design and Development" and Step 4 "Demonstration" (mainly) of the DSRPM. This is accomplished via the establishment of a set of UID guidelines for EMRs used in Optometry. This chapter aims to amalgamate all the design and functional user interface (UI) guidelines and literature from Chapters 3, 4, 5 and 6; and offer a set of UID guidelines (artifact), which will be used to guide the development of an Optometry EMR prototype design.

The category and guideline formulation process is initially discussed, followed by the presentation of the Proposed UID Guidelines (Table 7.2), their application and demonstration of their use to guide the design of an Optometry EMR. Screenshots of the prototype interfaces are also included to illustrate the reflections of the guidelines.

Aligning with the methodology provided via DSR (Chapter 2) (Hevner, et al., 2004), Quinones and Rusu (2017) provide direction in creating guidelines, that were considered for this research. Quinones and Rusu (2017) suggest some activities to follow, which are necessary to create an effective and efficient set of usability guidelines:

1. Determine the specific features of the application in order to evaluate these features based on the new set of guidelines. This was done in Chapter 5 via Task Analysis (TA), and to an extent, in Chapter 6 during the Focus Groups (FGs).
2. Identify existing sets of usability guidelines in order to determine how these existing sets can help to define the new guidelines (for instance, which guidelines can be reused and which elements to use to define guidelines). This was done in Chapters 3 and 4.

3. Specify the new set of guidelines following a standard template in order to obtain a set of guidelines that is well defined and easy to understand. This will be presented in Chapter 8.
4. Validate the new set of guidelines in order to determine if they make it possible (1) to find usability problems; and (2) to detect specific usability problems related to the application (Quinones and Rusu, 2017). This is done in Chapter 8.

7.1 Category Formulation

As categories were considered useful in the grouping of the UID guidelines, nine emerged that were used (Table 3.1). This was sourced from an amalgamation of the literature reviews conducted in Chapters 3 and 4. A further three categories were added from the information that emerged from the TAs (Chapter 5) and FGs (Chapter 6). These were "Patient Management", "Patient Examination" and "Patient Education".

Chapters 3 and 4's nine categories combined several sources in order to obtain a holistic summary of the guidelines in literature (Nielsen, 1993; Shneiderman, 2004; Belden, et al., 2009; Rogers, et al., 2011; Zhang and Walji, 2011; Tognazzini, 2014). The numerous authorities avail their useful guidelines for usability and UID, but are targeted towards more general electronic UIs, their designs and systems; and are not focused on the niche health domain, which is needed for this research. Consequently, Zhang and Walji (2011), present a unified framework of EMR/EHR usability, called TURF, and give fourteen principles for the health domain. These principles were considered (Chapter 4, Section 4.3) and linked to the guidelines as they overlap with the categories (Table 3.1). They progress to then re-focus them in the context of the health domain.

There were many guidelines in literature that may have been used in this research for the guideline categories. However, each was focused on different aspects of system improvement, and may not have adequately addressed certain unique features for the specific domains, and may ignore critical elements to consider. For example; usability (Belden, et al., 2009; Zhang and Walji, 2011; Wiklund, et al., 2015), or UID (Nielsen, 1995; Tognazzini, 2014). As such, efforts were taken to consider several sources instead of just using one, which enabled for the creation of the all-inclusive guidelines that were used as the final categories (Table 9.1) (Nielsen, 1995 Shneiderman, 2004; Belden, et al., 2009; Rogers, et al., 2011; Zhang and Walji, 2011; Tognazzini, 2014; Wiklund, et al., 2015). Discussed more in detail in Chapter 4, Table 7.1 below presents a summary of EMR Usability Principles (Belden, et al., 2009) and the TURF: Fourteen Principles for EMR/EHR Usability (Zhang and Walji, 2011). These principles are compared to the guideline categories (Table 3.1), which have links/similarities:

Table 7.1 Similarities Between EMR Usability Principles, TURF Principles and Table 3.1 Categories

EMR Usability Principles (Belden, et al., 2009)	**Similarities between EMR Usability Principles and Table 3.1's Categories** (Nielsen, 1993; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014)	**TURF: Fourteen Principles for EMR/EHR Usability** (Zhang and Walji, 2011).	**Similarities between TURF: Fourteen Principles for EMR/HER Usability and Table 3.1's Categories** (Nielsen, 1993; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014)
	Real-World Conformance	Consistency	Consistency; Design Simplicity
	Design Simplicity	Visibility	Visibility
Consistency	Consistency; Design Simplicity	Minimalist	Design Simplicity
Efficient interactions	Efficiency	Memory	Cognitive Pressures
Effective presentation of information	Design Simplicity	Feedback	Feedback
Forgiveness and feedback	Error Mitigation and Recovery; System Visibility; Feedback	Flexibility	Flexibility of Control and Adaption
Reduction of cognitive load on users	Cognitive Pressures	Message	Feedback
Effective use of language	Real-World Conformance; Consistency	Error	Error Mitigation
Preservation of context	Consistency; System Visibility; Feedback	Closure	Feedback
		Undo	Error Mitigation
		Language	Consistency; Real-World Conformance
		Control	Flexibility of Control and Adaption
		Document	Help and Reference Documentation
		Match	Real-World Conformance

It may be noted from Table 7.1 that the categories share similarities between the guidelines (Nielsen, 1993; Belden, et al., 2009; Zhang and Walji, 2011). This is discussed in Chapter 4, Section 4.3.1. In terms of the differences, these are minor, and often found in the variations of the guidelines' names. Also, the guidelines may have the similar naming conventions, but are more focused to particular domains or applications. For example, some UID guidelines may be more applicable for the health domain (Table 4.1), or towards the general UID of interfaces (Nielsen, 1993).

One category may combine more than one guideline. For example, "Consistency" (Belden, et al., 2009) relates to both "Consistency" and "Design Simplicity" (Table 3.1). Hence, the guidelines are combined (Table 7.2). Presenting all the different guidelines in the Tables 3.1, 4.1 and now 7.1, shows that many guidelines are based on similar foundations, despite being

called different names. Some guidelines however, are more focused to different applications, as seen in Table 4.1.

7.2 Guideline Formulation

The key focus is on the guidelines, as they are the artifact. The categories mainly serve the purpose of ordering and grouping them into a logical format, and the guidelines may at times relate to more than one category. Heuristics are generally more methodically structured and follow a set process, in comparison to guidelines which are more flexible in nature. The literature review Chapters (3 and 4) discussed some high level and generalised guidelines. However, Chapters 5 and 6 then progressed to refine, build and add upon their contextual applicability within the field of Optometry. From TAs, positive and negative user interface (UI) attributes (Chapter 5, Table 5.2) emerged. From the FGs, a summary of Optometry EMR UI suggestions to increase efficiency were presented (Chapter 6, Table 6.5). This combined information from Chapters 3 to 6 enabled the guideline formulation (Table 7.2). Well-established guidelines and standards (ISO 9241-11, 2018) within the field of UID were also referred to, ensuring the UI designs still conformed to the well-established design guidelines (Nielsen, 1993; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014).

7.3 Proposed UID Guidelines

This section presents the Proposed Guidelines for the UID of EMRs in Optometry (Table 7.2). It aims to show their applicability, utility and efficacy by demonstrating them via a prototype of an Optometry EMR. The screenshots of the UIs are presented as appendices, and they illustrate how many of the guidelines are used conjunctionally, i.e. - many screenshots may display more than one guideline at a time.

Via the refinement and contextual application from Chapters 5 and 6, the guidelines were hence influenced; contributing towards the addition of guidelines and categories. For example, “Patient Management”, “Patient Examination” and “Patient Education” (Table 7.2). Chapter 3 (Section 3.6) first presented the guideline categories in Table 3.1, and each category is discussed comprehensively. The meaning, characteristics and implications of each one are discussed in detail, with examples given as well. As such, the explanations for each category still apply, and Table 7.2 below presents their accompanying, proposed guidelines:

Table 7.2 Proposed Guidelines for the UID of EMRs in Optometry

SYSTEM STATUS AND FEEDBACK

- Guideline 1: Provide appropriate and timely feedback for optometrist actions and system events;
  - a) Provide indication of system response to actions;
    - E.g. Button depressions, colour changes.
  - b) Have clear closure to inform optometrists of their task completion;
    - E.g. Task success messages, icons.
  - c) Include visual and/or auditory feedback to optometrists.
    - E.g. Sounds accompanying appointment notifications.
- Guideline 2: Ensure that the optometrist is always aware of the system's status;
  - a) Keep optometrists aware of their task progress, from the beginning through the end;
    - E.g. Progress indicators, notification banners, icons, informational text-boxes, alerts.

REAL-WORLD CONFORMANCE

- Guideline 3: Provide support for tasks and functions to closely match optometrists workflows;
  - a) Optometric workflows ought to be seamlessly accommodated in the UI design with adequate support.
    - E.g. Input fields for patient information includes all the necessary fields required, in the correct order.
- Guideline 4: Elements should match to their real-world functions (in functionality and design);
  - a) Human interface objects ought to conform to standard methods of (direct) manipulation;
    - E.g. Buttons being pressed, sliders dragged, and include standard resulting behaviours.
  - b) Use of metaphors (skeuomorphism) and affordance;
    - E.g. Glasses or lens icons could represent the prescriptions. Red colour signalling errors. Buttons should look like they can be clicked on. Sliders dragged. Envelopes representing emails. Hidden affordance to simplify the visual complexity of design, like drop down menus/lists.
- Guideline 5: Dialogue should be appropriate for optometrist profession;
  - a) Clear and easily understood wording should be used.
  - b) Familiar optometric and related medical terminology should be used;
    - E.g. Glaucoma, lenses, visual acuity, ocular.
    - E.g. Snomed-CT and ICD-10 Codes provide standardised, multilingual vocabulary of clinical jargon that is used by physicians and other health care providers for the electronic exchange of medical health information.

FLEXIBILITY OF CONTROL AND CUSTOMISATION

- Guideline 6: Allow customisation of the UI;
  - a) Provide functionality for optometrists to customise the layout of the UIs according to their preferences;
    - E.g. Allowing optometrists to re-arrange pre-test options on the UI according to their frequency of use.
    - E.g. A "Favourites" tab or separate section could be provided as a personal page for optometrists. b) Provide optometrists with a sense of autonomy, yet include boundaries, which also help reassure them;
    - E.g. Choice of shortcuts.
    - E.g. Ability to alter settings but not those integral to system functioning.
- Guideline 7: Navigation should be easy;
  - a) The UIs should be explorable, with features being easily identified and visible (but unobtrusive) on the UI, without much searching for;
    - E.g. Easily accessible patient profiles via an icon or button.
  - b) Provide visual elements to speed up navigation, as well as in serving as reliable landmarks to reassure optometrists of a sense of "home";
    - E.g. A logo on the UIs that navigates optometrists to the home screen when selected. Magnifying glass indicating a search feature.
  - c) Provide features enabling actions to be undone, reversible or saved;
    - E.g. Undo, redo, cancel, exit, back/return, auto save buttons/backup.

CONSISTENCY

- Guideline 8: Use consistent wording;
  - a) Wording and labels used should be consistent, descriptive and clear;
    - E.g. If Hypotension is the term used for low blood pressure, use it throughout. Use of "Next" used consistently, instead of using it interchangeably with "Proceed".
  - b) Features should perform the same actions when used or selected;
    - E.g. The patient profile button when selected should always navigate the optometrist to the same patient UI. Print button should always print the reports.
  - c) Labels should be simple, clear, and well-defined so that optometrists are able to orientate themselves through the various UIs;
    - E.g. Clear and simple UI titles.
    - E.g. Correct semantics for words accompanying buttons (icons).

- Guideline 9: Keep UI elements consistent unless to highlight element differences;
  a) Elements acting differently ought to look different (Induced Consistency);
     - E.g. UIs with consistently behaving features and functions should be visually consistent and act the same.
     - E.g. UIs with modifications should highlight the changes.
  b) Button/element positioning and placement ought to be consistent, allowing for quick navigation;
     - E.g. Provide sufficient spacing between buttons/elements.
     - E.g. Use the left side of the UI to place smaller, less prominent buttons, and the right for more important and larger ones. Frequently used ones are generally positioned more centrally on the UI.

ERROR MITIGATION AND RECOVERY

- Guideline 10: Minimise the risks of human-errors;
  a) Provide verification and validation measures for input;
     - E.g. Confirmatory messages. Ranges for test values (protective restraints), like Intraocular Pressure Test recordings (IOP): 1-40, and then 45+. Email fields requiring appropriate formats.
- Guideline 11: Provide features to ensure task continuity and recovery;
  a) Allow for the use of state, whereby the systems remember and identify the optometrists, and deliver to them the content, functionality or experience that matches their role;
     - E.g. Remember certain colours and shapes.
     - E.g. Previously entered information is saved and presented for selection.
     - E.g. Auto save, backup, undo, redo, cancel and exit buttons.
- Guideline 12: Provide informative error messages (or success of actions);
  a) State which error occurred and give constructive help.
  b) Use language that is descriptive, user-friendly, clear and simple.
     - E.g. An error message for a pre-test, warning that a figure greater than what is provided as an upper limit cannot be used, and to select a lesser value.

COGNITIVE LOAD

- Guideline 13: Provide for predictive text functionality;
  - E.g. Glau- for Glaucoma, IOP- Intraocular Pressure. Patient names on the patient list.
- Guideline 14: Build on existing interface design patterns from optometrists' past experiences;
  a) Use common labels and UI layouts on other websites/programs to reduce the amount of learning optometrists need to do;
     - E.g. Exit buttons on the top right of the UI. Default menu items at the top of the UIs.
- Guideline 15: Provide pre-set templates;
  a) Provide pre-set templates for frequented and standard tasks;
     - E.g. Prescription templates. Email report templates.
- Guideline 16: Avoid visual clutter;
  a) Ensure elements are readily available in plain sight, and easily accessible on the UIs for explorability;
     - E.g. Menu bar displaying the various options available like gallery, practice details.
  b) Use information hierarchies for determining relevance, and only show controls or features that are appropriate for the task being undertaken;
     - E.g. When writing prescriptions, optometrists should be presented with all the information influencing the prescriptive process, and not irrelevant options such as UI theme settings.
  c) Use chunking, or grouping of similar elements;
     - E.g. Information pertaining to lenses are grouped on a portion of the UI.
  d) Provide buttons or elements where possible to minimise interactions;
     - E.g. Tick boxes, radio buttons.

EFFICIENCY

- Guideline 17: Menus should be well organised;
  a) Menus should have a well-structured information architecture (IA), for correct presentation to optometrists, to allow for easy task accomplishment, and to locate what they need quickly;
     - E.g. Well-defined menu and icon labels.
     - E.g. Most frequented items should appear first on the menu list.
     - E.g. Simple, shallow levelled menus (hierarchical structures) for easy navigation.
- Guideline 18: Use accelerators to enable optometrists to conduct tasks more efficiently;
  a) Use of shortcuts to direct optometrists to most frequented tasks;
     - E.g. A patient icon/button navigating the optometrist directly to patient lists, or to tests.
  b) Use of defaults for more frequented options;
     - E.g. Commonly selected test readings which automatically display value ranges: 120/80 as the starting default value for blood pressure, with 120 allowing for up and down correction, as with 80.
     - E.g. Showing the default eye pressure readings as 12-22 mm Hg, or 15 mm Hg as within the normal range.

DESIGN SIMPLICITY

- Guideline 19: Use colour intuitively, serving as a visual aid;
  a) Use colour to differentiate tasks or activities;
     - E.g. Green indicating lens availability. Black indicating lens are out of stock.

b) Ensure the colours used are consistent in the UIs, balanced and well contrasting;
   - E.g. Black against white, as compared to purple against another similar shade of purple.
c) Keep colours consistent with those in the real world, and account for the visually impaired and colour-blind individuals;
   - E.g. Red for danger or caution, green for success.
d) Use colours and appealing designs to draw attention to buttons and features as required.
   - E.g. Proceed/next button highlights when the next step in the prescriptive process is being undertaken.

- Guideline 20: The UI should be minimalistic in design, easy to learn and use;
  a) Ensure the interface layout is simple, intuitive, and uncluttered;
     - E.g. UI layouts ought to present information and features symmetrically.
     - E.g. UID and layouts should be flexible to user customisations.
     - E.g. Designs should be visually attractive, with balance between simplicity and functionality.
     - E.g. Use adequate spacing for elements.
- Guideline 21: Ensure buttons or elements allow for easy operation and navigation;
  a) Avoid redundant buttons or latent elements, keeping their numbers minimal;
     - E.g. Buttons or elements that do not serve a purpose. Radio buttons that cannot be selected. Underlined text indicating a link that does not work.
  b) Provide shortcut buttons for frequently used functions;
     - E.g. Pre-tests button. Calendar button.
  c) Buttons or elements should clearly communicate the content they represent;
     - E.g. A floppy disk to represent save. A printer icon to represent print.
  d) Buttons/elements should be of proportional size to the UI, as well as on based on their prominence.
     - E.g. An important element such as a pre-test button should be more prominent than a button relating to theme settings or colour changes.
- Guideline 22: Font sizes should be large enough to ensure good legibility, and styles should be professional;
  a) The use at least 12 point or a large enough font to ensure good legibility.
  b) The use of styles ought to be professional and clear, and suitable to the context or UI information;
     - E.g. Use of Serif fonts that are easier to read, as compared to Sans Serif fonts depending on the font used (Arial is suitable, although it is Sans Serif. Times New Roman, which is Serif, is also suitable).

HELP AND REFERENCE DOCUMENTATION

- Guideline 23: Provide adequate help functionality on how to use the systems, which enable for optometrists' efficient task conduction;
  a) Allow for optometrists to access the information required for easy discoverability of information related to their tasks, or on how to conduct certain tasks;
     - E.g. Search features that locate information from a repository of information (internal, or external such as Google).
  b) Include tooltip help associated with elements or on the UI;
     - E.g. A message informing optometrists on the function of an icon when hovering over it. "Creates new patient profiles", or "Edit" message appears when hovering over a patient icon.

PATIENT MANAGEMENT

- Guideline 24: Provide appointment scheduling that is easy to manage, accessible and visible;
  a) Use colour differentiation to associate optometrists to their respective appointments;
  b) Include features that allow for optometrists to customise their views on the appointment schedules;
     - E.g. Patient summary view. Individual optometrist's schedule.
  c) Ensure the schedule/calendar is always refreshed and updated;
     - E.g. Auto save and backup features.
  d) Allow for optometrists to select their preferred/customised patient appointment times;
     - E.g. 15 minutes, 30 minutes.
  e) Include automated reminders for appointments;
  f) Ensure alerts and notifications are effectual yet not desensitising (if they constantly or frequently appear);
  g) Include options to adjust the timings and settings of appointment alerts or notifications;
  h) Allow optometrists to view their patients' appointment information and prescriptions;
     - E.g. Informational boxes attached to patient profiles with information such as lens delivery dates to practice, the lens types, or frame types, collection dates of prescription glasses etc.
- Guideline 25: Provide forms for capturing new patient profiles and details;
  a) Include a "Hobbies" section so that optometrists may be better informed when prescribing lenses;
  b) Include the option for including patient profile pictures for better identification purposes;
  c) Include patient demographics and contact details;
  d) Include options that allow for easier input or selection of form information;
     - E.g. Tick boxes, lists.
- Guideline 26: Allow for relevant medical aid information to be accessed and displayed;
  a) Include medical aid details displaying the various options available to patients;

- E.g. Name of medical aid, member option, prescription limits.

PATIENT EXAMINATION

- Guideline 27: Provide for the ability to display information from pre-testing machines;
  a) Display the various pre-tests for easy selection;
  - E.g. Selectable buttons or icons that represent each pre-test/test option, like the Fundus photographer tests, Vertometer tests.

  b) Include a comments box for free-text entry relative to each test;
  c) Include features to enable uploading of test results or images, in various formats;
  - E.g. Upload buttons on the prescription UI to include Fundus Photographer test images, or blood pressure readings.
  - E.g. Pdf, jpeg, .doc, etc.
- Guideline 28: Provide for the visualisation of patient longitudinal data;
  a) Allow for the viewing of patient results over time;
  - E.g. Displaying all the saved Fundus Photography images of a patient over time, alongside each other for easy comparison.

  b) Enable for custom filtering and organisation of results;
  - E.g. Date, time, size, name.
- Guideline 29: Provide eye-images for annotation;
  a) Provide eye images or diagrams to allow for optometrists to annotate;
  - E.g. Insert annotated callouts on eye images.

  b) Include provision for free form text below the eyes images.
- Guideline 30: Integrate the visual/optometric charts (main standardised ones);
  a) Allow for the selection of the various charts from the interface for display;
  - E.g. Snellen, Landolt, ETDRS and Tumbling E Charts.
- Guideline 31: Provide features to increase the efficiency of information input during the optometric examination;
  a) Include layouts which are able to be customised;
  - E.g. Prescription pane could be customised, or the generic layout could be used.

  b) Include pre-loaded options for some entry-fields;
  - E.g. Provide a list of options regarding patient reasons for visiting, or a list of possible common complaints.
- Guideline 32: Provide features allowing for more efficient prescription entry (which is a more specific part of the optometric examination);
  a) Include a separate section on the UI, or a new UI for the prescription entry;
  b) Ensure validation checks for correct input of information;
  - E.g. Error message or hazard signs for out-of-range figures.

  c) Differentiate via spacing, the right and left eye.
  d) Include a print option for the prescriptions.
  e) Include an options list showing the varieties of glasses or lenses available;
  - E.g. Polarised lenses, fixed tints, photo chromatic lenses.

PATIENT EDUCATION

- Guideline 33: Provide links to educational material for patient education during a consultation;
  a) Include educational videos and print materials for references to associated eye conditions;
  - E.g. Videos on the dangers of Glaucoma. Print material on the types of astigmatism.

  b) Allow search functionality to easily and quickly locate the educational material;
  - E.g. Search bar.
- Guideline 34: Provide features for after-care patient education (take-home/post-consultation);
  a) Offer an email option with information relating to the patient consultation;
  - E.g. Include a pre-set template. Include the patient name, salutations, next appointment reminder, prescription attachment, educational information regarding their diagnoses, and a link to new products or information related to them.

  b) Offer a variety of templates that are pre-set;
  c) Include information relating to glasses;
  - E.g. Printed reports. Email summaries available to send to patients regarding their appointment.

  d) Provide a search facility that may provide information regarding eye related conditions;
  - E.g. A UI presenting the optometrist with information regarding searched-for conditions, Glaucoma.

7.4 Application of Guidelines

The proposed guidelines were used to develop a medium fidelity Optometry EMR prototype using Axure RP 9 (https://www.axure.com/); a rich prototyping tool allowing for the creation

of wireframes for many devices like mobiles and computers (Freitas, 2018). Axure was chosen as it allowed the researcher to create an EMR prototype with limited backend implementation without having to develop a fully functional application. Medium fidelity prototypes have rich visual detail and functionality, and are fairly close representations of the final product, but are not necessarily fully functional (Coyette, et al., 2007). The prototype was deployed on a PC, running the "Windows" operating system (https://www.microsoft.com/en-za/windows) which is a commonly used system.

7.4.1 EMR Structure Illustrating the Workflow (S1-S3)

With aid from Table 7.2, the design of the EMR prototype and its UIs that were tested, were ordered in a manner reflecting the typical optometrist's workflow, discovered during Chapter 5 (S1-S3). There were several UIs designed with many features, such as a staff registry, product information and a "Favourites" page. There were also several ways to access each UI as to not ever have the user feel trapped or restricted, allowing for flexibility, freedom of control, as well as efficiency (Table 7.2). The main UIs following the optometrists' workflows most closely, however, were:

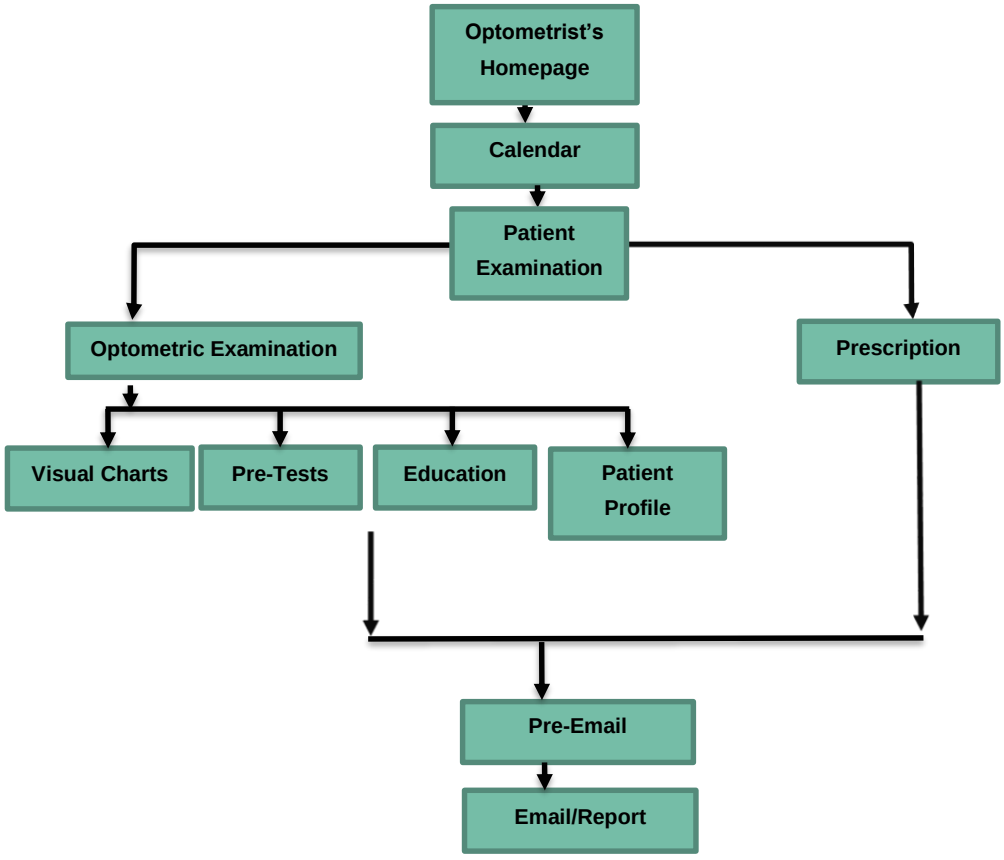


Figure 7.1 Sitemap Of Optometrists' Main Workflows

Typically, the optometrist logs onto their homepage, visits their calendar and selects their next agenda or appointment. Thereon, the respective "Patient Examination" page opens. The "Optometric Examination" and "Prescription" UIs are separated (as per Guideline 32, Table 7.2), and available as tabbed pages. Within the main "Optometric Examination" UI, the "Pre-Tests", "Visual Charts", "Patient Profile" and "Education" UIs options are found, and both tabs have access to the printing, email, saving and settings functions. After the "Prescription" process, the educational aspect of the appointment is done, via the "Education" UI. Proceeding the patient-education part of the appointment, the optometrist would proceed to the "Pre-Email" UI to specify and select information to send to the patient. Finally, the email/report to the patient would be sent, then re-directing the optometrist back to their homepage. This follows the optometrists' workflows closely, S1, S2, S3 as discovered during Chapter 5 (TA), and reflects Guideline 3 (Table 7.2).

Appendices F1-F4 are screenshots from the EMR prototype which show where the three main stages, S1, S2, and S3 start. To allow for easier visibility, the screenshots are zoomed in, but the UI layouts are standard across the various screens, with the main logo, headers and menu bar all consistently placed (such as in Appendix F1). The Sections 7.4.1.1-7.4.1.12 below discuss the guidelines from Table 7.2, and show how they inform an EMR prototype (Screenshots are in the Appendices "F").

7.4.1.1 System Status and Feedback: Guidelines 1 and 2

Appendix F5 displays a UI screenshot of the "Appointment Booking: Patient Form". This conforms to Guidelines 1 and 2. The "Submit" button depresses upon selection, indicating a system response to the optometrist, providing closure. The green task success message provides informative and visual feedback to the optometrist, giving clear closure to them regarding their task. The optometrists are kept aware of the system status, with the help of the information boxes, as well as progress indications such as the save icon, which appears upon saving the inputted information on a form in the EMR ("Saved!" icon).

7.4.1.2 Real-World Conformance: Guidelines 3, 4 and 5

The UI layout/design structure in Section 7.3.2 reiterates the aspect of matching to real-world conformance. Appendix F6 demonstrates Guidelines 3, 4 and 5. The form input fields are closely matching to typical Optometry forms used in practices, as discovered during the TAs (Chapter 5), which closely matches and fits into their workflows. Drop down lists are used which simplify the complexity of design via hidden affordance. The input fields' match with their required entry format (Guideline 3); such as numerical entry boxes for phone numbers

and letters for names. To maintain data integrity, input fields such as “Title” or “Date of Birth” have drop-down options. Simple, common language was used across all the UIs to ensure the dialogue is always easily understood by optometrists (Guideline 5). Guideline 4 is met with the use of metaphors to match real world objects. For example, the use of the envelope icon to represent emails, the trash can to represent delete, and print icon to mean print (Appendix F6).

7.4.1.3 Flexibility of Control and Customisation: Guidelines 6 and 7

Appendix F7 demonstrates Guideline 6, with the provision of shortcuts (icons), and allowing optometrists to customise their UI layouts. The “settings” icon at the top right of the UI in Appendix F7 affords this customisation. The icons in Appendix F7 at the top right of the UI, as well as the header-buttons and main logo demonstrate both Guidelines 6 and 7. The icons help serve as shortcuts, as well as providing for easy navigation within the EMR’s UIs; and give the optometrists a sense of control or autonomy when using the prototype. The button such as “Visual Charts” in Appendix F7 is also an example of a shortcut, navigating optometrists quickly to the “Visual Charts” UI from the “Medical Aid” UI. Appendix F3’s buttons too serve as shortcuts, for example, “Visual Charts” again, or “Pre-Tests”. Back buttons (Appendix F8) are available which prevent optometrists being confined to one UI, and for easy navigation. The main header contains an eye logo which redirects optometrists to the main homepage upon selection, giving them a sense of home. The use of a magnifying glass within the search bar (Appendix F7) also contributes towards the easy navigation, as it is a familiar icon representing search functionality.

7.4.1.4 Consistency: Guidelines 8 and 9

Appendices F7 and F8 demonstrate Guidelines 8 and 9. The wording used within the labels and text are descriptive, clear and consistent. The labels are also familiar and common (Guideline 8). The features perform the same actions across the UIs; the main logo always redirects optometrists to the main homepage, the print button always prints the current UI or selected information (Guideline 9). The placement of icons and features are also consistent across all the UIs. The consistent placement of the icons and features across the UIs additionally contribute towards easy navigation in that the optometrists become familiarised with their placements or locations, thus finding them easily.

7.4.1.5 Error Mitigation and Recovery: Guidelines 10, 11 and 12

Verification and validation measures are demonstrated in Appendices F9 and F10. Appendix F9’s UI allows for optometrists’ successful form submission only upon condition of their correct field entries for; “Full Name(s)”, “Email” and “Signature” fields, and accepting the “Terms and Conditions”. Appendix F10 shows a red error message, and enlarges the “Snellen”

Eye Chart Reading box if the value entered exceeds the range of "6/6-6/240". Upon correction, a green message box appears to indicate the correct entry (Guideline 10). This measure helps prevent any input errors from causing patient harm by means of the incorrect prescriptions being made. These error messages are clear, descriptive and provide constructive help to the optometrists. Thus, Guidelines 10 and 12 are met. The use of autosave and manual saving features prevents any work from being lost, and ensures task continuity and recovery (Appendix F8 and F14). This autosave feature serves as a backup as well (Appendix F14 also illustrates Guideline 24), ensuring that user information is not lost in the event of any unfortunate technical failures. For instance, it would back-up user information in a secure database. In the event that a user may not have their data or files available, a backup would be available for restoring onto their system. The use of predictive text also helps to ensure task continuity, relating to Guideline 11.

7.4.1.6 Cognitive Load: Guidelines 13, 14, 15 and 16

Appendix F11 demonstrates the use of predictive functionality in patient searching, making optometrists' tasks more efficient (Guideline 13). Common and familiar layouts are also used across the UIs (Guideline 14) (Appendices F3, and F7, for example), and the UIDs are simple and uncluttered (Guideline 16). The menu bar for example, is consistently located in the same place at the top of the UIs, with the most relevant and frequented options readily available. This too helps in easy navigation and explorability. Button and elements like tick boxes and drop down lists are provided as selection options rather than having to rely on the users' memory. Grouping of similar information is used, with suitable spacing (Appendix F6, for example). Frequented tasks are made simpler and efficient via the use of pre-set templates, such as in the "Prescription" UI (Appendix F4) and "Email" UI, meeting Guideline 15. A "Pre-Email" (Appendix F12) UI is used to filter and select relevant information the optometrist requires to send to their patient after the appointment. Upon selection, the information is then automatically formatted into an email, which is sent to the patient. These guidelines all contribute towards minimising users' cognitive load.

7.4.1.7 Efficiency: Guidelines 17 and 18

Demonstrating Guideline 17 is Appendix F13. The menus used have a well-structured information architecture (IA) for correct presentation to optometrists, which allows for easy task accomplishment, and in locating what they need quickly. The menu icons and labels are well-defined, and the most frequented items appear first on the menu lists. This is also shown in the figures above which have the main menu in the header. The levels are also shallow, in hierarchical order of importance. Accelerators are used, as well as shortcuts and defaults to

direct optometrists to most frequented tasks. For example, navigating quickly to the main homepage in Appendix F11 (“Back to Homepage” button), or the inclusion of the “New Patient” button with an accompanying plus icon for quick and easy identification.

7.4.1.8 Design Simplicity: Guidelines 19, 20, 21 and 22

The use of colour across the interfaces (Appendices) is consistent and well contrasting. The plain grey background with the black text and icons ensure the optometrists are able to easily distinguish information on the UIs, as they contrast well (Guideline 19). Colours used are consistent with the real world. For example, as red is often associated with danger in the real world, and linked to warnings, the error messages use red (Appendices F9 and F10). When buttons or interactive icons are pressed, their colours and appearances change, to indicate their response to the interaction (Appendices F5 and F8). Appendix F14 (and Appendix F1) also illustrates the use of colour for differentiating tasks or activities. Optometrists are able to customise their calendars views, and “Dr Jane Doe”, for example, is represented using a light blue colour. The green “plus” icon (for adding new patient appointments) uses the colour green as compared to the normal use of black, which draws attention to the feature in its differentiation and signifies its prominence. This also relates to Guideline 9a. These intuitive uses of colours meet Guideline 19. Guideline 20 is demonstrated via the UIs in all the figures having minimalistic, uncluttered and visually appealing designs, which contribute towards their easy usability and shortened learning curves. Information and features are presented symmetrically, with suitable use of spacing and by having a balance between simplicity and functionality. By ensuring the buttons or elements used allow for easy operation and navigation, Guideline 21 is met. Redundant buttons and latent elements are avoided, keeping only the significant ones available. Shortcut buttons for frequently used functions are provided and the buttons or elements clearly communicate the content they represent, such as with “Save”, or “Print” (Appendix F14). The buttons and elements are also proportional in size to the UI, as well as on based on their prominence. For example, the “Pre-Tests”, “Education” and “Visual Chart” functions (Appendix F3) are an essential part of optometrists’ workflows, and their buttons are bigger than the rest of the icons/buttons on the UI. These buttons are also white in colour, easily distinguishable against the contrasting grey background, drawing attention to them. The “Email” UI within the prototype includes a “Send Email” button, which is larger than any other icon or button on the screen, and also is a different colour (green as compared to black), thus also drawing attention to it. To ensure good legibility, suitable fonts and professional styles were used, thus meeting Guideline 22. The font style of Arial was consistently used across the UIs, with font sizes that were proportionate to the respective UIs, for example, twelve and thirteen point for general text entry fields. Sentence case and

capitalisation of each word was used for labels, distinguishing them from the general entry fields.

7.4.1.9 Help and Reference Documentation: Guideline 23

If optometrists incur any challenges using their systems, and do not have the help and support required, then their workflows and task efficiency may be at risk. Resultantly, some provision for help and support on system usage is necessary (Guideline 23). Demonstrating Guideline 23 are Appendices F8, F13 and F14 (tooltips, question mark icon, and search bar feature). Appendices F8 and F14 show a tooltip which appears upon hovering over the icons, informing optometrists of their functions. This is consistent across the icons in the UIs. Appendix F13 includes a search bar, helping the optometrists easily search for information they may need. For example, on how to use a certain function. The search bar is not restricted to the information available in the EMR, but can access external information on the internet, via search engines such as "Google" (https://www.google.com/).

7.4.1.10. Patient Management: Guidelines 24, 25 and 26

Patient appointment scheduling is made easier to manage, more accessible and visible by the various features available in the Calendar UI (Appendix F14). Appendix F14 presents a Calendar UI whose view may be personalised for different optometrists. Colour is used to differentiate the optometrists, and autosave features are available to ensure the schedules are always updated. Patient appointment times may also be adjusted with the scale feature which allows time periods per appointment to be chosen, such as "15 minutes", "30 minutes". Patient information such as personal details or prescription information is also available to view and edit, allowing optometrists to manage their patients (Appendices F3, F6 and F13). These functions and features demonstrate Guideline 24.

Guidelines 25 and 26 are demonstrated in Appendix F6, illustrating a form for easy input and capturing of patient details. A "Hobbies", "Medical Aid" section, comprehensive contact details as well as provision for profile pictures are provided for. Drop down lists are also used which enable easier form input, as well as having multiple selection options ("Hobbies"). The "Hobbies" list also has a filtering feature which helps in easy navigation (Guideline 7).

7.4.1.11. Patient Examination: Guidelines 27, 28, 29, 30, 31 and 32

Appendices F15 and F16 demonstrate Guideline 27, providing for the ability to display information from the pre-testing machines. The selectable options are all displayed and

accessible via one UI. Comment boxes are available for each test respectively, and there is provision for uploading test images and results in various formats ("pdf", "jpeg", "doc").

Guideline 28 is demonstrated in Appendix F17, illustrating the blood pressure "Pre-Test" UI. Patient longitudinal data is available in the form of a chart, and custom filtering and organisation of results is provided for ("Sort by" drop list). This longitudinal data is also illustrated in Appendices F3, F4, F11 and F16 (chart icon). Guideline 29 is met, displayed in Appendix F3 and F10 with the provision of eye images for annotation, as well as comment boxes. Appendix F18 demonstrates Guideline 30, integrating the main optometric or "Visual Charts". Guideline 31 is demonstrated via Appendices F19 and F20. UI layouts are customisable and appropriate keyboard entry is available for the data type entry (e.g. numerical, text). Some entry fields have pre-loaded options in the form of drop lists, such as in Appendix F19, which illustrates a patient form with selectable options of common complaints. Guideline 32 is demonstrated via Appendices F3, F4 and F20. The "Optometric Examination", the "Prescription" process are separated via tabs. Information regarding each eye is separated for easy distinction (Appendices F4 and F10), and a print option for prescription printing is available (Print icons in Appendices F4 and F20). Option lists are also available displaying variety of glasses (Appendices F20 and F21). Validation checks to ensure correct input of information are also available (Appendices F9 and F10).

7.4.1.12 Patient Education: Guidelines 33 and 34

Appendices F22, F23 and F24 demonstrate Guideline 33. During consultations, optometrists are able to educate their patients, with the provision of educational materials (print material and videos) and search functionality, within their EMR. Optometrists often considered that the interaction with EMRs during consultations would take up valuable patient "one-on-one" time, making patients feel uneasy and neglected due to this lack of attention. The provision of these patient-specific after-care emails/reports helped to build upon patient relationships, and was favourably considered. Many Optometry practices have websites with general information around diagnoses and after-care knowledge, but are not specifically tailored to their patients. These guidelines aid with ensuring patients are provided with direct care during and after appointments. To meet Guideline 34 by providing features for after-care patient education (take-home/post-consultation), an email option with a pre-set, adjustable template is available in the EMR. This is also considered to aid in maintaining patient relationships. For example, appointment reminders and instructions on how to care for patients after they leave the practice alludes a sense of their optometrist "remembering" the patients, and caring for them. This essentially helps maintain trust, strengthens and builds relationships. Within the email,

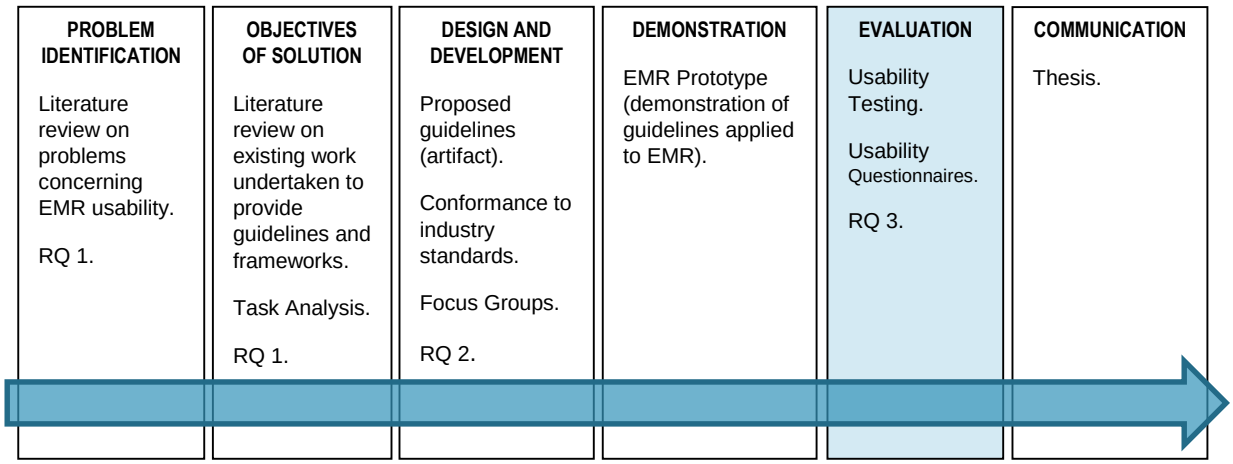
information relating to the patient consultation is included; such as the patient name, salutations, next appointment reminder, prescription attachment, information related to their glasses and educational information regarding their diagnoses. A “Pre-Email” (Appendix F12) option is used to sort through and select the information the optometrist requires to send to their patient after the appointment. Upon selection of the information, this is then set out into the email which is sent to the patients. Further addressing Guideline 34 are also Appendices F22, F23 and F24, with the email option for patients, additional patient experience information and frequently asked questions, as well as provision to print the educational material/reports for their take-away. Furthermore, there is also provision to search for additional educational material externally (Appendix F24).

Section 7.4 elaborates on how the proposed UID guidelines may be translated and applied to create an Optometry EMR prototype. The literature reviewed in Chapters 3 and 4 assisted in guiding the UI design in terms of the rules for layouts and general look and feel of the prototype. Chapters 5 and 6 further assisted in terms of generating the functional requirements that inform the EMR prototype design. This functionality ought to enable the users to complete the common tasks they normally carry out, and should endeavour to overcome the challenges users experienced when completing more infrequent tasks.

7.5 Conclusion

The developed set of UID guidelines were presented in this chapter, which was made possible via the input combined from previous chapters. The EMR prototype successfully demonstrated the proposed set of UID guidelines, which will be subjected to Usability Testing (UT) (evaluation) in the proceeding chapter to verify and test its use in practise. This will assess the quality, utility and efficacy of the proposed guidelines. The UI prototype reflects the applicability of the proposed guidelines, and the artifact (guidelines) are to be primarily evaluated. Chapter 8 next introduces UT as part of the guideline evaluation process. It also aims to obtain insight into the users’ satisfaction whilst using the prototype contextually in practise.

Chapter 8: Guideline Evaluation



This chapter contributes towards step five of the DSRPM, "Evaluation" of the proposed UID guidelines via Usability Testing (UT) of a prototype Optometry EMR. It also aims to answer RQ 3: "How do the user interface design guidelines affect the usability of EMRs in Optometry?" This chapter aims to not only evaluate the guidelines which have been applied to an Optometry EMR prototype, but also to gain insight into the users' satisfaction whilst using the prototype contextually in practise.

This chapter starts off exploring the importance of evaluation and its link to link to Design Science Research (DSR). Thereon, the rationale for UT is covered, as well as the method and procedures followed for this study. The various scenarios/test cases are discussed, as well as the post-test surveys and feedback. All the results and feedback are reflected upon, and refinements to the guidelines are presented and discussed. The chapter concludes with a discussion of the overall findings, influence on the guidelines, and success of the guidelines (via the UT).

8.1 Evaluation and Design Science Research

Referring to the Evaluation Framework (Venable, et al., 2012) in Chapter 2 (Table 2.2), the evaluation of an artifact may be described by a "2 x 2 framework" (Table 8.1) of the strategies for evaluation in DSR (Venable, et al., 2012). Technical artifacts do not require human use once instantiated, whereas socio-technical artifacts are ones that humans need to interact with in order to provide their utility (Venable, et al., 2012). As discussed in Chapter 2, this research produces a process artifact that is socio-technical, thus steering the evaluation process to the

"Ex-Post" and "Naturalistic" quadrant of the DSR Evaluation Strategy Selection Framework (Table 8.1) (Pries-Heje, et al., 2008; Venable, et al., 2012).

Table 8.1 DSR Evaluation Method Selection Framework (Venable, et al., 2012)

DSR Evaluation Method Selection Framework	Ex Ante	Ex Post
Naturalistic		• Participant Observation • Survey
Artificial		

Naturalistic evaluation discovers the performance of a solution technology within its real environment, using tangible situations and people to engender greater face validity. Proceeding the construction, acquiring and/or implementation of an IS artifact, "Ex-Post" evaluation occurs, which concerns instantiated artifacts (Pries-Heje, et al., 2008; Venable, et al., 2012). The placement within this specific quadrant can be attributed to the use of UT of the EMR UIs demonstrating the guidelines, by optometrists in their "real environments" or practices. Participant observation as well as surveys will also contribute towards the evaluation process (Venable, et al., 2012). The surveys using the System Usability Scale (SUS) Questionnaire (Appendix D) and Post Study System Usability Questionnaire (PSSUQ) (Appendix E) were chosen to conduct the surveys as they help measure the meaning of concepts, such as learnability, ease of use and user satisfaction for example, and also to derive the attitude towards these concepts. This supports the goal of the evaluation method (Venable, et al., 2012) as it will help to assess the extent to which the guidelines produce a successful and usable EMR.

In ensuring the efficiency, effectiveness, satisfaction and rigour of the process, as well as in the artifact, four evaluation process steps were considered that helped guide this chapter (Venable, et al., 2016). These are Step 1: Explicate the goals; Step 2: Choose a strategy or strategies for evaluation; Step 3: Determine the properties to evaluate and Step 4: Design the individual evaluation episode.

- **Step 1. Explicate the goals:** The goals are to evaluate and establish whether or not the application of the UID guidelines (established from Chapters 3-7) to the EMR prototype could in reality, aid in creating a more usable EMR that is better in comparison. Apart from the utility of the guidelines (effected from the EMR prototype), the goal is to also rigorously determine the effectiveness, efficiency, and satisfaction of the prototype, and thus the guidelines (which is the artifact).
- **Step 2. Choose a strategy or strategies for evaluation:** There are four main evaluation strategies (Venable et al., 2016): Quick and Simple, Human Risk and Effectiveness,

Technical Risk and Efficacy, and Purely Technical Artifact strategy, with Table 8.2 below illustrating the differences between each one. The strategy most suited for this research, and hence chosen for evaluation was the "Quick and Simple Technique" (proposed for small and simple designed artifacts where the social, technical risk and uncertainty is low) (Venable, et al., 2016). The artifact is considered to have a low social risk, technical risk and uncertainty. This strategy performs few evaluation episodes, where one iteration is considered adequate to reach project summative conclusions (Venable, et al., 2016). This research utilised one iteration with the "Quick and Simple Technique" (Venable, et al., 2016), as there is a limited time period to perform the evaluation results and reach project conclusions. UT (participant observation and surveys, SUS Questionnaire and PSSUQ, via the UT) were also used.

Table 8.2 Circumstances For Selecting A Relevant DSR Evaluation Strategy (Venable, et al., 2016)

DSR Evaluation Strategies	Circumstance Selection Criteria
Quick and Simple	If small and simple construction of design, with low social and technical risk and uncertainty.
Human Risk and Effectiveness	If the major design risk is social or user oriented and/or If it is relatively cheap to evaluate with real users in their real context and/or If a critical goal of the evaluation is to rigorously establish that the utility/benefit will continue in real situations and over the long run.
Technical Risk and Efficacy	If the major design risk is technically oriented and/or If it is prohibitively expensive to evaluate with real users and real systems in the real setting and/or If a critical goal of the evaluation is to rigorously establish that the utility/benefit is due to the artifact, not something else.
Purely Technical Artifact	If artifact is purely technical (no social aspects) or aspects use will be well in future and not today.

- **Step 3**. **Determine the properties to evaluate:** The properties to evaluate were mainly guided by the workflows observed (Task Analyses (TAs)). The properties included verbal feedback; learnability; user satisfaction (and overall system user satisfaction); ease of use; information quality; system usefulness; and interface quality (Lewis, 1995; Brooke, 1996). The activities involved during the critical-user interaction (patient-physician appointment) were tested.
- **Step 4. Design the individual evaluation episode:** Seven scenarios for testing and evaluation were created. These scenarios were designed by creating user tests based on the

activities observed during the patient-physician appointment. User evaluation then followed, based on the scenarios.

8.2 Rationale for Usability Testing

The efforts of this chapter help validate the researcher's application of the proposed set of UID guidelines. In UT, representative users (optometrists) are observed whilst they perform tasks with hardware or software systems (the EMR prototype whose design is informed by the artifact/guidelines). The testing evaluates the artifact by testing it with these representative users (the optometrists), who also evaluate it. The UT employed in this research is "Validation" (Kuniavsky, 2003), as it aims to support that features of the EMR UI are indeed usable late in the development process. UTs allow for the fast revelation of information regarding how people make use of software, and aid researchers in the identification of usability challenges. UTs are structured interviews that are focused on particular features in an interface prototype (Kuniavsky, 2003). It is advantageous in that it reveals design imperfections and other challenges that participants may face when using the EMR prototype, during the tests. It allows the researcher to probe participants concerning these challenges, which enable for a greater perspective into their interaction with a prototype. The ISO 9241-11 standard (ISO 9241-11, 2018) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness**,** efficiency and satisfaction in a specified context of use". Thus, usability is not a single, one-dimensional property, but rather an amalgamation of factors (Misfud, 2015). This research employs UT to verify whether the application of the proposed UID guidelines could aid in creating a usable Optometry EMR prototype, which is easier to use, understand, friendlier and less tedious, i.e. a greater product that better suits optometrists' needs.

The UT enabled the participants to carry out similar activities to those revealed during the TAs; in order to identify any possible usability challenges with the guidelines. The UT also helped to gain perspective into the challenges that participants met when performing EMR tasks, and took into consideration their comments regarding features they liked and disliked.
This research's primary objective of the UT is:

- To evaluate and establish whether or not the application of the UID guidelines (established from Chapters 3-7) to the EMR prototype could in reality, aid in creating a more usable EMR that is better suited to optometrists.

This objective links to the sub-research question three (Chapter 1.6), “How do the user interface design features affect the usability of EMRs in Optometry?”, and thus also to the main research question.

8.2.1 Expert Reviews

Expert reviews were not used in this research for a few reasons. Firstly, there was great variability when it came to what was being considered “experts” as heuristics evaluators (Hermawati and Lawson, 2016). A distinct definition of what constitutes as experts with respect to usability and specific domains is needed. The criteria for determining what constituted usability experts was unclear, i.e. whether it was based on formal educational training/qualification or professions (Hermawati and Lawson, 2016). The threat also arises if evaluators involved in an evaluation do not share the same level of expertise. Domain specific guidelines often misses some of the usability problems that are identified by general heuristics. This likely results from evaluators' tendency to ignore them as they are seen to be less problematic in comparison to other problems. This is especially true when bias views arise from having experts of varying levels of experience, or from different expertise fields (Hermawati and Lawson, 2016).

Additionally, Expert Reviews do not necessarily involve the users (Quinones and Rusu, 2017), which UT contrarily does. UT requires representative users for the evaluation, and not all expert reviewers may be users. This research considers a user centred approach, and thus requires the (representative) users (Optometrists) to be involved in the entire research process, including the evaluation. The Optometrists are also considered as the experts in their field, having the most interaction with their EMRs and domain specific knowledge/expertise in Optometry. Sourcing Expert Reviewers that have this required expertise for the specialist Optometric field is challenging, and thus Expert Reviewers of varying levels of expertise would have to be used, from different fields. This may be disadvantageous in that their varying backgrounds or domain knowledge may induce bias evaluations of the guidelines (some may be perceived differently that others by some evaluators). Furthermore, consensus may present as challenging amongst themselves, and thus force agreement upon higher level guidelines as compared to the domain specific, or Optometric EMR ones which are of utmost importance in this research. Thus, the initial problem of their being high level guidelines and a dearth of

domain-specialist ones would arise again; which this research sets out to address in the first place.

The entire research process followed, as well as the authorities referred to for the creation of guidelines, have been according to experts in their fields (Nielsen, 1995; Shneiderman, 2004; Smelcer, et al., 2009; Middleton, et al., 2013; Tognazzini, 2014), as well as the health domain (Zhang and Walji, 2011). Expert Reviews require evaluators to have experience and sufficient knowledge to evaluate the product interfaces, which is challenging in a niche medical environment such as Optometry. Evaluators may not understand the tasks performed by the EMR, so it can be challenging to identify usability problems. Furthermore, some usability problems that are identified by the evaluators are identified without directly providing an idea of how to solve it (there is a lack of systematic way to create solutions to the problems encountered) (Quinones and Rusu, 2017). Consequently, UT was the preferred option for the evaluation of the artifact.

8.3 Method

8.3.1 Participants

Kuniavsky (2003) and Tullis and Albert (2008) both recommend that between six to eight participants ought to be used for UT. This is because it is believed that the most imperative usability findings will be observed by at least six participants. According to Nielsen (1993), however, more than eighty percent of usability problems may be found by using only five participants. Sauro (2013) also supports the use of five participants, stating that "Five is often a magic number for early-phase usability studies". Thus, five participants were recruited for this study. Five was deemed to be sufficient as the workflows are generally standardised in Optometry, with a few minor, insignificant variations (WCO, 2019), as observed in the TAs (Chapter 5). Additionally, finding more optometrists proved to be a challenge, as many had busy schedules, unable to take the time off and avail themselves. The participants (Table 8.3) chosen for the testing were from the Eastern Cape in South Africa, and they were optometrists with prior exposure to, or experience using an EMR. Of these five, three were the same optometrists partaking in the TAs and FGs. This was in order to verify whether their challenges faced were actually addressed and relieved. The other two new participants were to ensure that the guidelines, demonstrated via the prototype were fit for purpose, and not just addressing the specific optometrists' challenges. This variation ensured for the most accurate results obtained.

Table 8.3 Usability Testing Population Sample

Optometrists (Participants)	Previously Participated in TA and FG	Age Group (Years)	Gender
P1	Yes	20-29	F
P2	Yes	30-39	M
P3	Yes	30-39	M
P4	No	40-49	M
P5	No	50-59	M

n=5

8.3.2 Procedure

8.3.2.1 Testing Setup

For the UT, a mobile station was used which could conveniently be set up at any desired location. Constituting the station was a monitor which served as the participants' display, which connected to a laptop via an HD cable and mirrored its display (the prototype EMR, running on Axure RP 9 (https://www.axure.com/)). The monitor was accompanied by a keyboard and mouse for interactions by the participants, and a webcam was attached to the monitor which connected to the laptop. A video and audio recording software called Camtasia 2019.0 (https://www.techsmith.com/video-editor.html) was installed onto the laptop, allowing for the participants undergoing the given tasks (user tests/scenarios), to be fully recorded and saved. The laptop was controlled by the researcher, who ran Camtasia from it, and was able to observe the participants. Since the medium fidelity prototype still lacked some functionality (for example, the "Email" option would not really send to the recipient), certain features were simulated in order for users to understand how the EMR would function.

A "think aloud" method was employed during the testing which encouraged the participants to talk out loud and explain what they were doing as they were executing their tasks (Kuniavsky, 2003). In order to help determine users' expectations and identify what aspects of the EMR were confusing or unideal, they were encouraged to speak about what they were looking at, thinking, and doing at each stage during the tasks.

8.3.2.2 Prototype Testing

Pilot Test

To ensure that there was sufficient time for the session, and tend to any logistical or technical problems, a pilot test of the scenarios was completed prior to the UT. The pilot test helped to ensure that the questions and scenarios were sensible and feasible, and that the interfaces were all working properly. In general, it helped ensure that whole testing/evaluation process ran smoothly.

Usability Testing

Each UT session was held separately, and lasted for one hour. Upon the participants' arrival, they were greeted and asked to sign consent forms (Chapter 1.8). They were then redirected to their testing area, and Camtasia was activated. Participants were given the scenario instructions, asked to think aloud during the whole session and were always observed. A "think aloud" method was employed during the testing, which encouraged the participants to talk out loud and explain what they were doing as they were executing their tasks (Kuniavsky, 2003). In order to help determine users' expectations and identify what aspects of the EMR were confusing or unideal, they were encouraged to speak about what they were looking at, thinking, and doing at each stage during the tasks. The participants were instructed to complete the scenarios, and then asked about their impressions of the EMR prototype (before the tests began), and for feedback after. They were additionally required to complete post-task evaluation, Likert questionnaires which incorporates the System Usability Scale (SUS) (Brooke, 1996) and a Post Study System Usability Questionnaire (PSSUQ) (Lewis, 1995).

8.3.2.3 Post Test and Surveys

Open ended questions were asked after the testing to clear up any ambiguities, which explored areas around the guidelines and interfaces, as well as the general testing session. The optometrists were then given some time to ask questions if they were uncertain about anything (Kuniavsky, 2003). The proposed guidelines (Table 7.2) were discussed with the optometrists, and more feedback or comments, which may have related to these guidelines from their session was encouraged to further establish the linkages with the UIs, and test the guidelines most effectively. Proceeding these aforementioned tasks, the SUS Questionnaire and PSSUQ were both administered to the participants.

For the surveys, several standardised usability questionnaires were studied (Lewis, 1995, Brooke, 1996, Ahlem, et al., 2016; Rotolo, et al., 2017). The SUS Questionnaire and PSSUQ were the two most "universal" ones found to be best suited for this research, regarded as being "best-known post-study questionnaires" (Ahlem, et al., 2016). The degree of "global reliability" considers the measure of internal reliability on a scale of zero (completely unreliable) to one (perfectly reliable) (Ahlem, et al., 2016). The PSSUQ items are appropriate "for a UT situation" (Lewis, 1995) and in terms of the usability criteria (ISO 9241-11, 2018), the PSSUQ covers all three elements of Effectiveness, Efficiency and Satisfaction, and the SUS Questionnaire mainly covers Efficiency and Satisfaction. However, the SUS questionnaire partially covers satisfaction, whereas the PSSUQ covers it more comprehensively. SUS measures the ease of use, learnability, user satisfaction and gives an overall usability score (out

of one hundred). The PSSUQ measures the overall user satisfaction with their systems, system usefulness, information quality and interface quality (Lewis, 1995; Brooke, 1996). Complementing each other for the best evaluation, the SUS Questionnaire and PSSUQ were both consequently utilised.

The SUS questionnaire was administered to each participant after the testing to obtain usability feedback on the guidelines and the interfaces. The questionnaire requires a score to be given for each question, and additionally allows for the addition of any comments and open ended feedback (Brooke, 1996). SUS produces reliable results from the repeatability of the responses of users, and the validity of the questionnaire is effectively presented through the variety of questions related to system usability, such as the need for training, support, and complexity (Sauro, 2011). SUS has been used to test an array of devices and is independent of the technology it is tested on (Sauro, 2011). The SUS scale ranges from one (Strongly Disagree) to five (Strongly Agree). According to Bangor, et al. (2008), products which are at least acceptable have SUS scores above seventy (70), with better products scoring in the high seventies (70's) to upper eighties (80's). The greater the participants'/users' scores, the higher the overall usability satisfaction with the EMR is. Supporting this range, Thomas (2015) stated that eighty point three (80.3) or higher is an A (excellent, recommendable to others), sixty-eight (68) is a C (improvements are needed, but passes as mediocre), and fifty-one (51) is an F (dismal). These figures have a maximum of one hundred (100) and minimum of zero (0).

Alongside the SUS questionnaire, the PSSUQ was administered to the participants (Lewis, 1995) to attain a greater knowledge around users' overall experience and satisfaction of the prototype and guidelines. PSSUQ is longer than SUS, being a nineteen (19) item "instrument for assessing user satisfaction with system usability" (Lewis, 1995; Fruhling and Sang, 2005). The items also assess system characteristics such as ease of use, ease of learning, simplicity, effectiveness, information, and the user interface (UI). The answering scale has a Likert scale, and ranges from one (Strongly Agree) to seven (Strongly Disagree), instead of one to five (like SUS). This allowed for the participants to give more nuanced responses to each question. PSSUQ was designed specifically for scenario-based usability studies, and thus favourable in UT (Lewis, 1995; Rotolo, 2017), and it is also highly suited for research information systems (Ahlem, et al., 2016). For the scores/results, the lower the response, the higher the subject's usability satisfaction with their system) (Lewis, 1995). PSSUQ has three sub-scores, derived from subsets of the questions, which reflect system usefulness, information quality, and interface quality. In conjunction, these two questionnaires help quantify the usability and user

satisfaction when their scores are calculated, and from any qualitative responses. They are also scored and evaluated similarly, despite their numerical ranges and questions varying.

8.4 Scenarios

In order to develop the most suitable scenarios to test, common tasks observed during the TA's (Chapter 5) were considered for the testing. These were part of the optometrists' actual workflows in practise (Chapter 5), thus guiding the development of the scenarios. To allow for participants to acquire context within which they needed to complete tasks, the scenarios used were also part of the critical user interaction and patient-appointment scope (Chapter 5). To allow for sufficient time for task completion and to discuss users' feedback (Kuniavsky, 2003) within the one hour period, seven scenarios of the EMR were chosen to be tested. The task designs aimed to be feasible, realistic and detailed so as to allow for their completion well within the stipulated period of one hour. The seven scenarios (Table 8.4) were all created on some of the most frequented tasks that were discovered during the TAs (Chapter 5), as well as some tasks that users had problems with. The tasks chosen ensured that the main features available on the UIs were interacted with and tested, and that they closely matched the actual tasks or activities the optometrists did in practise (workflows). The tasks ultimately helped to determine whether the guidelines that were created, added to the usability of an EMR system.

Table 8.4 Usability Testing Scenarios

Scenarios	Instructions
1. The optometrist checks their calendar to view their day's schedule and appointments.	• Select the upcoming appointment, patient "Dina Nathoo".
2. Appointment with patient.	• Navigate to view "Dina Nathoo's" profile to confirm she is currently on medical aid, "Mento Medical Aid". • Edit her profile to change her medical aid option to "Disco Medical Aid". • Submit and save the changes.
3. Viewing and recording of Pre-Test readings and patient history.	• Check the patient's "Pre-Tests" images under "Fundus Photographer". • View the "Blood Pressure" history chart. • Enter a blood pressure reading.
4. Patient examination, visual charts and recording of details.	• "Visual Chart" tests: Open and test with "Snellen Chart". • Record the values from the "Snellen Chart" test into the patient record. • View the "Snellen Chart" historical data. • Check if Dina Nathoo has "Macular Degeneration" running in her family.
5. Prescribe glasses and prescription process.	• Record relevant details for the "Prescription"
6. Educate patient on conditions and provide for after-care education.	• Educate the patient (Dina Nathoo) on the condition, "Astigmatism", using the print and video resources. • Search for additional information on "Astigmatism" using the in-built search functionality. • Include "Astigmatism" in the email report to Dina Nathoo.

7. Pre-Email and Email to patient (also aiding in after-care support).	• Check that the desired "Pre-Email" to include in the final one to the patient is selected. • Check and send the final email report to the patient.

8.5 Results and Discussion

8.5.1 User feedback

Scenario 1: *The optometrist checks their calendar to view their day's schedule and appointments.*

The participants favourably noted the use of the calendar's appointment time scale, namely the 15 minute appointment slot option, *"I see you've put them in 15 minute slots, great"* (Participant 1) and *"I think that's quite nice"* (Participant 2). This validates Guideline 24 (especially 24 d) under "Patient Management" (Chapter 7, Table, 7.1), in that the appointment scheduling is made easier to manage, customisable and more accessible.

Scenario 2: *Appointment with patient.*

All the participants had slight difficulty in locating patient "Dina Nathoo's" profile, due to the profile icon not adequately displaying its affordance as a selectable option or button. A suggestion was to increase its prominence and affordance, such as via the increase of size, colour or shadow effect; *"Enlarge the interactive area…Make it all interactive"* (Participant 2), which supports Guidelines 21 and 22. Participants 1 and 4 took some time in trying to edit the patient's profile before finding the "Edit" button. This was attributed to the initial, natural learning curve of systems, *"Need time to learn the system"* (Participant 1); *"Yes I'm just not used to the system...As you get used to the system its straight forward actually, hey, like most programmes"* (Participant 4).

Participant 5 initially navigated towards the "Medical Aid" button, thinking the profile information was within that page. In most EMRs observed, medical aid information is often linked to the billing aspects of the systems. This simple action reinforces the existence of the challenge trying to be overcome; where current Optometry EMRs are more *"business administration systems"*, than medical record systems. Participant 5 commented that the scenario was otherwise *"Pretty easy for someone like me who doesn't use computers a lot…it wasn't complicated once I kind of just knew"*. This reflects the easy learnability and positive usability of the prototype, whose design is based on the Guidelines in Table 7.2. For example, this could be attributed to the "Design Simplicity" guidelines, as well as Guideline 14; "Build on existing interface design patterns from optometrists' past experiences". The use of common

labels and UI layouts on other websites/programs helped reduce the amount of learning optometrists need to do. Participant 2 was impressed with the information within the UIs, stating "*Yoh! This is pretty comprehensive for a mock-up".* Upon selection of the patient's name on the calendar, the UI showing that patient's examination loaded. This UI allowed for the optometrists to access the patient's profile. Participant 3 suggested that this profile UI load before the examination UI, and rather have their orders swopped instead to allow for easy editing. The rest of the participants, however, did not indicate any change to the order needed, as the main examination UI loading first was found to be most time efficient and task orientated, matching their workflows (Guideline 3, Table 7.2).

Scenario 3: Viewing and recording of Pre-Test readings and patient history.

Participant 1 appreciated the integrated display of all the Fundus Photography pictures, as well as the comment box available (supporting Guideline 2b). Participants 1, 3, 4 and 5 had difficulty finding the blood pressure history chart that was represented via an icon, but soon located it when seeing the tooltip, and thus approving Guideline 23a (Table 7.2). Participant 4 especially required some assistance in navigating to the location of the icon, which was attributed to the expected, initial learning curve. The blood pressure readings were accompanied by an informative range box, providing information on the respective readings as entered and informed optometrists of any abnormal readings. This alert measure was favoured by the optometrists. Participant 2 added that when entering blood pressure readings, the current free-text area could rather be a hidden option that appeared upon demand. Instead, a list of ranges could be made available for easy selection. Participant 3 similarly suggested an alternative input method could be the addition of two input blocks to represent the systolic and diastolic readings as fractions, *"I think that's probably all you need".* All the participants greatly appreciated the integration of the Pre-Tests*, "Yeah, absolutely... "You can have everything in one place"* (Participant 1); *"I mean, that's the ideal"* (Participant 2); *"It would change my entire life… That's the biggest thing that all of us want"* (Participant 5). This supports Guideline 27 (Table 7.2).

Participant 1 commented on how one platform to access Pre-Tests right through to the patient longitudinal history was helpful and *"Great!"* supporting Guideline 28 (Table 7.2). Participant 3 appreciated the Pre-Test integration, commenting that, *"It's nice to have it in digital format in one place…that's always been the biggest problem with electronic patient records; the machines don't talk to each other because they're all different brands. They all have different software"*. However, machines all operating with one software would only be implementable once there are standards for data transfer. Having all the Pre-Test images and material in one

compatible format would be *"The holy grail"*, according to Participant 3. Participant 4 said, *"I think it's fantastic that it's all in one place hey…you can look at it all together"*, again meeting Guideline 27 (Table 7.2).

The participants also highly valued the provision of the longitudinal history feature; *"What I really liked about that was the fact that you can access your history!"* (Participant 1); *"…ya stuff over time…for education as well, is really great"* (Participant 3). Participant 5 valued this access to longitudinal history, complaining that in their current EMR system, *"The biggest single issue for us is change"*, and not being able to view this change in their patient histories *"…sequentially"*, and added that, *"…it's too complicated"*; *"If you could get that for us, it would change my life!"* The "Patient Examination" Guidelines were validated from this scenario, but most notably Guidelines 27 and 28 (Table 7.2).

Scenario 4: Patient examination, visual charts and recording of details.

Due to the nature of the application's input boxes, double clicking on them was required to initiate entry to overwrite any information. The participants were unaware of this, and perhaps needed an aid in the form of a tooltip upon hovering over the input area. Participant 1 reassured, *"…just because I didn't know it"*. The participants consequently struggled to initially enter the details into the Snellen Chart text box, and needed assistance. This emphasises the need for "Help and Reference Documentation" (Table 7.2), especially referring to Guideline 23 (Table 7.2). Participants 2, 3 and 5 indicated the possibility of rather including a list of numbers to choose from, or a drop-down list for the Snellen Chart capturing. However, due to the various formats of entering this information (feet vs metres, decimals vs fractions) the free-form text box was the most suitable option. The option of customising a certain, or preferred input method by an optometrist could perhaps be implemented for the Visual Acuity information.

Locating and viewing the patient's Snellen Chart history was conducted with ease, attributed to the fact that the icon was now familiar by its consistent use in the UIs, as well as with the aid of the tooltip and animation upon hovering over it, *"Now I know what it means"* (Participant 5). This supports Guidelines 7, 9b and 23b (Table 7.2). The addition of this Snellen Chart longitudinal data/history (as well as for the other charts and Pre-Tests) was again greatly valued as a visual aid and reference point. This helped with task continuity (Guideline 11), as well as meeting Guidelines 28 and 30 (Table 7.2). This meant that the optometrists would be able to better track changes in their patients' eye health over time, keeping records of it all as well as viewing possible trends. Participants 2 and 3 suggested that the Snellen Chart History should have a close or exit button of some sort, as they were unaware that it actually closed

automatically after a period of time. This supports Guidelines 1 and 2, regarding "System Status and Feedback" (Table 7.2).

Participant 3 commented on the Visual Acuity input boxes layout, suggesting that the actual order of layout is normally preferred to be in the way the attending optometrist sees the patients' eyes, *"…on how you look at the patient"*, i.e., right, left and then both eyes. The current layout displayed the left, right and both eyes. Participant 5 suggested that the General Ocular Information be presented above the Visual Information. This was so that patients' chief complaints could be recorded first, and then perhaps any secondary complains, as compared to recording the visual acuity information before, *"…you think, what is the main reason?...And address it"*. Participant 3 similarly proposed rearranging the patient examination UI, moving General Ocular Information to the top of the page, so that the flow displays the patient's case history first. The case history is normally asked first, which may influence the optometrist's notes and prescription or diagnoses process. This relates to Guideline 6, regarding customisation of the UI, Guidelines 31 and 32, relating to the increased efficiency of input (e.g. recordings) and features during the Optometric examination, as well as prescription process (Table 7.2). Participant 3 suggested that the term "Case History" replace "General Ocular History" relating to Guideline 5, supporting the EMRs' need for appropriate dialogue or terminology for optometrists (Table 7.2). As all the necessary information was available within the UI, Participants 1, 2 and 4 did not mind the current layout, as the transition from viewing and testing the different Visual Charts to the recording of the Visual Acuity information was smooth.

The integration of the projectable Visual Charts was greatly valued, with Participant 1 commenting, *"That's perfect"*, and *"I've never used ones like this with picture examples...I quite like that"* (Participant 2). This supports Guideline 30 (Table 7.2), regarding the integration of Visual Charts/Optometric Charts. Participant 4 commented on the convenience and, *"It's nice to have it all in one place"*, but was concerned that if the system ever crashed then information would be lost. They suggested having a separate Visual Chart system as a backup that was independent of the EMR. Under the Visual Information area, Participant 1 suggested that only the "*Snellen Chart"* fields be visible for example, and the rest hidden with an option for viewing and editing as needed, *"Like a drop-down chart…"* and *"…just to make it simpler"*. The "Patient Examination" guidelines are supported, namely Guideline 30 (Table 7.2).

Recovery when exiting a window was easy, with quick navigation back to the desired page, meeting Guideline 11 (Table 7.2). Participant 2 suggested that the Visual Charts have more interactive functionalities, such as highlighting certain lines on them when in use, or only showing individual letters at a time. The order of viewing them upon projection could also be customised, or randomised, which is *"Quite important"*, according to Participant 2.

In searching for the Macular degeneration information, Participant 1 erroneously exited the UI, but quickly recovered and seamlessly navigated back to the correct UI. This efficient recovery was possibly attributed to the simple design (Guidelines 21) and easy navigation (Guideline 7, Table 7.2), with Participant 1 commenting that the overall task execution was not difficult and *"Straight forward"*. This relates to Guidelines 3 and 20 (Table 7.2). Overall, this scenario relates to various categories; the guidelines under "Design Simplicity", "Efficiency", "Patient Examination" and "Patient Management" (Table 7.2).

Scenario 5: Prescribe glasses and prescription process.

Participants 1 and 2 noted the ease of capturing the information (meeting Guidelines 25, 31 and 32, Table 7.2), although Participant 2 commented on being more familiar with using a blank UI to enter every detail free-text. Participants 4 and 5 required assistance in locating the Prescription pane, admitting to them needing to pay more attention to the features on the screen. Meeting Guideline 32 (Table 7.2), Participant 5 appreciated the tabbed option, or separation of the Prescription to the Optometric Examination, as the prescriptions were often used by multiple parties, for example, for dispensing reasons, *"...a lot of people want to access it"*. This separation thus allowed for the optometrists to keep their clinical notes separated and confidential. The use of passwords could perhaps further secure the confidentiality of the clinical notes. Participant 5 suggested alternatively including the Prescription within the Optometric Examination UI, and providing an export option, *"Tick box to export"*, and even more ideally, *"automatically exportable"*. The other participants however, did not mind the current layout.

The drop-down lists included in the Prescription UI, as well as other UIs made selecting options faster than manually entering information, meeting Guidelines 31 and 32 (Table 7.2). Four commented that not all the information shown under Subjective Refraction was required, as the prism information was *"Not always used"* (Participant 1); *"You don't prescribe prisms that often…maybe once a week"* (Participant 1); *"I think that's extra stuff that's not necessary"* (Participant 3). It was suggested that the prism information could be hidden with the option of viewing and editing it when needed, which could help in simplifying the UI further. The

"Cognitive Load", Guideline 16 and "Design Simplicity" Guideline 20, could be more so applied here; reducing any UI clutter and removing redundant information, hiding the prism information.

The "Save as Final RX" option was favoured by Participants 1, 2, 3 and 5 as it saved an extra step of re-entering the same information in the Final Refraction part of the prescription process, *"That's a good button"* (Participant 3). This meets Guideline 11, relating to features to ensure task continuity and recovery, as well as the "Efficiency" Guideline 18, referring to the use of accelerators (Table 7.2). Participant 3 added that instead of just having the "Save as Final RX option", there could also be a "Copy to Final RX" option. This would duplicate the Subjective Refraction information to the Final Refraction boxes for adjustment if needed, saving time of re-entering the information. Participant 2 suggested that a *"Retinoscopy"* or *"Starting Refraction"* prescription box could also be added, and a *"Dispensing"* option for the lenses be added. This dispensing part was, however, out of the scope for this research and may be considered for future research. The order would be the *"Retinoscopy/Starting Refraction"* (manually checking patients' eyes), *"Subjective Refraction"* (taking into account the patients' comments), and then the *"Final Refraction"*. Participant 4 was impressed with the prescription process. Participant 5 suggested that often the refraction sections *"influence"* the *"Glasses Information"* (glasses, lenses, frame types, coatings), and could perhaps be presented first instead of coming after the Glasses Information section. This relates to the customisation on the UI, met in Guidelines 6 and 31 (Table 7.2).

It was observed that after the various tasks, the optometrists automatically navigated to the save functionality, reaffirming its fixed placement at the top of the UIs. This scenario relates to the validation of various categories; the guidelines mainly under "Patient Examination" and "Efficiency" (Table 7.2).

Scenario 6: Educate patient on conditions and provide for after-care education.

Supplementary to the text and video material, Participant 1 suggested the addition of *"Simple pictures"* to the education feature as *"Quick illustrations"*; to compare results against normal eye conditions for example, *"Good and bad"*. The addition of videos to supplement the print material was well received by all the participants, successfully meeting Guideline 33 (Table 7.2). Participant 1 commented, *"Great!"*, and expressed appreciation that the "*Videos are short, which is amazing",* and that this would save patients' time whilst retaining their concentration. This would simultaneously increase the optometrists' efficiency. Participant 4 exclaimed that the addition to pictures and videos are ideal as people often learn a lot better

through various interactive mediums (meeting Guideline 33, Table 7.2), *"Especially for new patients. It's such a lovely tool hey"*, and *"This is spectacularly done!"*

As optometrists often interact with their EMRs during consultations, which may make patients feel neglected and uneasy (Miller and Sim, 2004; Smelcer, et al., 2009; American Medical Association, 2018), the provision of the educational features on the EMRs includes them in the technology's used, relieving some of their insecurities of feeling neglected. The patients feel more included and part of the whole process, feeling more aware and less uneasy (RO Staff, 2019). Participant 2 greatly valued the educational feature, commenting, *"This is really cool"*, and that the educational aspect was their *"...favourite part"*. Participant 3 remarked, *"Ya I think you've got it pretty spot on!"* Participant 5 especially liked the fact that the feature allowed for them to carry on with their work whilst educating patients, and possibly even *"Leaving the room"*; *"I love this, this is a fantastic option...This might just change my life!"* (Participant 5). Participant 5 added that often boredom from repetition of the educational information to patients is a challenge, "We do this over and over again, and so we often do it badly". The educational feature would thus also greatly help by not only reducing optometrists' cognitive loads (relating to "Cognitive Load" Guidelines in Table 7.2) and boredom, but also by providing education to patients that do not have access to the material remotely (illiterate, no email access, not computers, no books etc.)

The Add-Ons section was favoured to include the pictures as it would be an easy addition, and the short-video addition was more favoured for the Diagnoses section. Participant 2 erroneously exited the Educational UI, but navigated back effortlessly, attributed to the simple design and navigation. This meets Guidelines 7 and 11 (Table 7.2). Participant 2 suggested the educational links (video, print material and searched items) be editable, in order to add more links or and customise them. This would then also be able to be included into the emails to patients, providing more information. This option was considered useful, as well as the addition of *"Simple pictures"*, and added to the Guidelines (Guideline 33, Table 7.2).

Participant 3 noted the consistency and familiarity of the use of icons, *"These are standard"*; *"...that's pretty standard across anyone who's half computer literate"*, and how this impacted the ease of conducting tasks, and reducing the learning curve. This meets Guidelines 9 and 21 (Table 7.2). Participants 4 and 5 did not see the search bar at the top of the UI, and needed help finding it. Both participants also required some assistance in selection of the "Include in email" tick box. This was attributed to its small size, thus needing enlargement, and to an extent, their

attention to detail, *"…attention to detail"* (Participant 5). This relates to, and supports the need for Guidelines 21 and 22 (Table 7.2). This scenario largely relates to and validates the guidelines under "Patient Education".

Scenario 7: Pre-Email and Email to patient (also aiding in after-care support).

Participant 1 was unsure of what the purpose of the Pre-Email stage/UI was for, but quickly realised and appreciated the information filtering purpose of it, stating it was *"Really cool".* Alongside a tooltip currently accompanying the email icon, the name "Pre-Email" could possibly be reconsidered, or a more comprehensive explanation appear on the UI when loaded. Alternatively, the feature's tooltip could be adjusted to include with more help information. Participant 4 needed some help initially locating the Pre-Email UI, but thereon completed the scenario with ease, remarking that the feature was *"Very impressive"*. All the participants positively commented on how helpful the Pre-Email and Email stages were, and the fact that the templates saved a lot of their time, *"Something we've all been wanting for a while, and it's great!"* (Participant 5). This supports Guideline 34 (Table 7.2). They also favoured how the Email was personalised for each patient (meeting Guideline 6, Table 7.2), and created a more eloquent layout of the Pre-Email information. This was also considered to be helpful in ensuring the patients felt valued due to the templates' customisability. For example, the patients names being mentioned, the individual appointment reminders and the custom after-care provision related to their diagnoses. Participant 2 added that they greatly desired the template, meeting Guideline 15 (Table 7.2), *"Ya, a lot…"* when asked to comment on the pre-set Email template. Participant 3 remarked in support*, "No one's going to have time to write their own Email for every single patient, I'll be here till ten o'clock"*. This feature saves time and relates to the "Efficiency" Guidelines, namely Guideline 18 (Table 7.2).

Despite the current Email template already being customisable, Participant 2 further suggested the addition of more templates or customisations of them, such as some more formal, business-like, or possibly informal ones; in order to provide for greater variety. Guidelines, 15 and 34b were adjusted to reflect this (Table 7.2). Further supporting the "Patient Education" Guidelines 33 and 34 (Table 7.2), Participant 2 furthered that the Email feature was *"Really nice"*, and that *"…we'd be geared towards something like that these days*…" They further added that the *"Ideas were pretty sound"*, although some items could be refined further. This refinement was in relation to the level of detail and functionality of the EMR Prototype. For example, the addition of more templates for the "Email" UI and the "Snellen Chart" input from Scenario Four. Participant 3 suggested that the tick boxes be made bigger for easier selection, *"You've got a fast mouse speed it may be difficult to stop on there"*. Participant 3 liked the Pre-Email

UI as a filtering option for the final Email, stating, *"I quite like that you've got those tick boxes that you can include. That's pretty cool"*. This scenario greatly supports the guidelines under "Cognitive Load", especially Guideline 15 (Table 7.2). Patient Education is still a part of this email process, as patients may receive educational material relating to their appointment. Thus, the "Patient Education" guidelines (Table 7.2) are again met within this scenario. The participants especially commented on the simple navigation (meeting Guideline 7, Table 7.2) between the UIs, and easy learnability of the EMR prototype in general.

8.6 Overall Feedback and Comments (Post-Testing)

Section 8.5 discussed the scenarios and feedback, linking specific guidelines to them. This section further reflects on the post-testing, and scenarios' overall feedback. Upon seeing the prototype, the participants' initial impressions were all positive and impressed, *"Quite a nice little system hey"* (Participant 4); *"This is quite a nice one you've built"* (Participant 5). The participants commented on how helpful the tooltips were as help aids in navigation, as well as always being informed on their current tasks and what the features/icons represented; *"It's easy to identify the icons"* (Participant 1); *"The first time I didn't really know where to look"* (Participant 1); *"...pretty self-explanatory"* (Participant 3); *"I mean I knew what I needed to do but I just couldn't find where to go because I wasn't familiar with the system"* (Participant 4). Overall, this validates the Guidelines under "Help and Reference Documentation", "Consistency" and "Design Simplicity" (Chapter 7, Table 7.2). In terms of familiarity when compared to other electronic systems and UIs, as well as in understanding the terms and features used, all the participants felt well acquainted, *"...I mean the icons were pretty straight forward…and all else perfect"* (Participant 2). Participant 3 also commented on the familiar use of the icons, *"…they were fine. I think you've used universal ones"* (Participant 3). Participant 4 commented, *"No it was all familiar hey…all the icons are familiar, it was just to find them…"* This supports the "Real-World Conformance" guidelines (Table 7.2).

All the Participants felt in control of their actions and tasks, and not restricted within the UIs; *"It's very easy to go back to a lot of pages..."* (Participant 1); *"…very easy to jump from Pre-Tests to Email"* (Participant 1); *"I don't think I was ever sort of lost"* (Participant 2); *"I was in control, with a bit of guidance"* (Participant 4). This supports the guidelines under "Flexibility Of Control And Adaption" (Table 7.2). Participant 2, however, added *"That's not a bad thing",* but their current EMR is largely a *"Blank canvas"* and so has even fewer restrictions than the prototype. Thus, they felt slightly restricted, but still noted that *"It gives you more freedom than some of the others I've worked with".* In order to increase the efficiency, Participant 1 favoured the idea of shortcuts, encouraging even more to be added, *"Just to make*

it quicker when you're looking for something" (Participant 1). This relates to the guidelines under "Efficiency", encouraging their effect (Table 7.2).

The overall prototype design was positively regarded; *"Yeah, great"* (Participant 1), and consistent *"...pretty consistent"* (Participant 2); *"All consistently presented"* (Participant 4); *"...I mean I thought it was, mmm"*. (Participant 5). This supports the guidelines under "Consistency" (Table 7.2). Participant 2 added that they would prefer to have every page or UI as a tabbed option that enables everything to be *"...viewed at once"*; and not have to scroll and navigate to individual windows. This was considered to promote efficiency, *"Making it easy to switch between things quickly"* (Participant 2). Participant 3 also reflected this idea, suggesting the use of less pop-up windows to reduce clutter, unless they were for projection, like the Visual Charts and Educational UIs. Participant 3 further suggested everything be confined to one UI, with back buttons to return to previous pages, *"I think the pop-ups can get a bit cluttered…I would keep it all in one window"*. UI layout customisation options could accommodate for different users' preferences. These points relate to and support the guidelines under "Cognitive Load" (namely Guideline 16), and those under "Design Simplicity" (Table 7.2).

The UIs' design and layouts were considered easy to explore, learn and understand; *"They don't really need to do more than what they're doing now"* (Participant 1), and *"It's simple, but it's great, we wouldn't want to complicate it too much"* (Participant 1); *"...I'm not great with software in general…this is my first time looking at it but most of it was pretty easy to find"* (Participant 2). Participant 3 commented, *"Once you know what you're looking for its easy"; "...It's pretty straight forward"* (Participant 3). Participant 4 commented, *"Its very user friendly and it is uncluttered. There's lots of space, and it moves quite nicely from one screen to the next. It's efficient, it's quick, and it's not so cumbersome"*. Participant 4 also emphasised on the easy learnability of the prototype, *"If I can use it, anybody can use it, because I'm not a computer fundi…so I think its very user friendly".* They added that the system looked very stable. Participant 5 commented, *"I mean, pretty straight forward to be honest…"* These points reaffirm the guidelines under "Design Simplicity" (Table 7.2).

The templates and UI layouts were considered helpful and time-efficient by all the participants, *"Especially the Email thing"* (Participant 2); *"For me it's nice, ya"* (Participant 4). Especially relating to the Email template, Participant 4 remarked, *"...without a doubt. I thought that was an amazing facility hey, to almost go from how it captured your information and put it into a*

little story". Participant 5 favourable stated, *"Absolutely loved it"*. The "Cognitive Load" guidelines are thus supported, especially Guideline 15 (Table 7.2).

Participant 2 added that the text could be made larger, but the use of colour and contrasts were well done. Participant 3 resounded that the text be make larger, as well as the tick boxes. They furthered that the Sans-serif font *"Verdana"* was actually found to be one of the most easy on computer-users' eyes, and could be used in the EMR prototype alongside "Arial", or any commonly used Serif fonts for UIs. During the testing, however, the participants did not struggle to read the UIs' font, and considered it legible. This relates to Guideline 22, under "Design Simplicity" (Table 7.2). Serif fonts have traditionally been credited with increasing both the reading speed and readability of lengthy passages of text, as they assist the eye to travel across a line, particularly "if lines are long or have relatively open word spacing (as with some justified type)" (Strizver, 2019). For example, "Times New Roman". In recent years, however, it has been found that several "Sans serif typefaces exist that are more legible at any size than some serif designs" (Strizver, 2019). The use of accelerators such as keyboard shortcuts to increase efficiency was appreciated, *"Oh ya, absolutely wonderful"* (Participant 5). This supports Guideline 18 under "Efficiency" (Table 7.2), and the guideline was adjusted to include the addition of keyboard shortcuts.

The scenarios tested (Table 8.4) were confirmed by all the optometrists to closely match their taskflows in practice. Participant 2 reaffirmed this by double checking the scenario order on paper, later commenting, *"This would be almost pretty much exactly"*. Participants 4 and 5 reassured, *"Very closely"*, and *"Yes they would"* respectively. This supports the guidelines under "Real-World Conformance", namely Guideline 3 (Table 7.2).

In terms of recovering from mistakes and error-prevention, the participants felt that it was easy to quickly recover from any errors made, *"No, could be easily corrected hey, if you know what you're doing"* (Participant 4). Participant 4 also agreed the prototype was designed in a way conducive to avoid easily making mistakes, *"It was designed in a way to avoid mistakes".* The undo or redo of capturing information was easy to conduct. The recovery, although pertaining to navigation, was also evidenced in earlier scenarios when the participants exited a UI during a scenario, and effortlessly re-navigated back to their task. Participant 1 felt that *"It was pretty straight forward"* and that if one made a mistake*, "it was probably one that you entered, not from here"* (the system). Participant 3 commented, *"I think the only mistakes I was making was not understanding where your buttons were…but once I knew the layout…I knew it's there".* These points support the guidelines under "Error Mitigation And Recovery" (Table

7.2). Participant 5 reflected concerns of ensuring that the system ought to be stable to prevent any future data losses or crashes.

Patient management and capturing of information was positively regarded, with Participant 2 adding, *"Ya, it was fine!"* and *"You're incorporating the calendar here which is great!"* Participant 1 commented, *"Yes, very"*, and Participant 3 said, *"...simple enough, I'm happy"*. Participant 5 furthered that the information capturing was great, but would prefer the Visual Acuity information be captured via drop-down lists or some form of number or pre-set options, whose formats could be customised for each optometrist. Participant 4 reassured that the capturing of information, *"...was easy hey"*. They also favoured the use of drop-down lists which were *"Quick"*, and added that they liked the fact that everything included in the whole appointment process was included in one place. Participant 4 wondered if the prescription process had more details to record, such as information regarding cataracts for example. Upon showing them the different features available, they remarked, *"Ya it's all here, it's actually impressive this programme"*. Participant 2 commented that a blank note feature could be added to the calendar UI for optometrists to quickly add any notes or thoughts. This note feature was actually available, but was located on the optometrists' Favourites UI within the EMR prototype. Another feature suggested to possibly add to the calendar UI was a list showing which optometrists were on leave or absent/present. This notes feature could perhaps be added to the calendar UI. Within the EMR prototype, a "Calendar Reports" UI was available, with these accountability features. This UI however, was not explored much and included for interaction, as it was not part of the main scenarios. Participant 5 liked the customisability of the calendar views, with the options to individually display an optometrist's schedule, or view all of them in one UI, *"That's ideal…That'd be great!"* These points support the guidelines under "Patient Examination", as well as "Patient Management's" Guideline 25d (Table 7.2).
Including the feature for patient histories (longitudinal information) was greatly valued by all the optometrists, and considered a great upgrade to their current systems. This supports Guideline 28 under "Patient Examination" (Table 7.2). Participant 2 added that it *"...was very nice, I like the idea of having a profile where you can link whatever you want"*. The integration of the patient longitudinal history overall was considered helpful for future references and diagnoses, keeping track of progressions and viewing trends, *"The history is normally very helpful when you understand it…that history is crucial"* (Participant 4); *"The single most important thing in medicine and we don't do it because it's too complicated"* (Participant 5).
Participant 3 commented on the security, legal and ethical aspects of patient clinical information being editable once entered, after the examination. They further commented that entered information, such as prescription details or clinically sensitive information should not

be editable upon saving. The saved version should rather be available for reference if needed, and new details be submitted. This would prevent any unethical or illegal behaviour if an optometrist wanted to maliciously edit any erroneous prescriptions or misdiagnoses at a later stage, *"So you can't come back and change clinical records"*; "*Obviously the personal information is editable, but not your notes"*. Participant 3 suggested a modal prompt box warning optometrists of this finality upon entering and saving the prescription details, or clinically sensitive information. This relates to the guidelines under "Error Mitigation And Recovery" (Table 7.2).

8.7 Post Test Questionnaires

After administering the questionnaires, they were scored.

8.7.1 SUS Results

The SUS Questionnaire was used to collect data about whether participants found the EMR prototype to be usable or not, and what their overall satisfaction level was with it. Table 8.4 presents the frequency count of the SUS Questionnaire scores given for all the participants (scale of one to five), with the SUS questions accompanying it.

Table 8.4 Frequency Count of SUS Results

SUS Questions	Participant Score Frequency Count				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I think that I would like to use this system frequently.	0	0	0	1	4
2. I found the system unnecessarily complex.	2	3	0	0	0
3. I thought the system was easy to use.	0	0	0	1	4
4. I think that I would need the support of a technical person to be able to use this system.	2	2	0	1	0
5. I found the various functions in this system were well integrated.	0	0	0	3	2
6. I thought there was too much inconsistency in this system.	4	1	0	0	0
7. I would imagine that most people would learn to use this system very quickly.	0	0	0	1	4
8. I found the system very cumbersome to use.	4	1	0	0	0
9. I felt very confident using the system.	0	0	0	4	1
10. I needed to learn a lot of things before I could get going with this system.	2	2	1	0	0

8.7.1.1 Overall SUS Score

The overall SUS score was calculated as 88.0/100 ± 6.22 (Brooke, 1996). This deems the EMR Prototype (and thus the artifact) as: "A"; Recommendable to others, and very usable with a greatly positive user satisfaction (Brooke, 1996). Overall there was an encouraging response from the participants regarding the ease of use, learnability, and user satisfaction of the EMR. Thus UID Guidelines (Table 7.2) informing the EMR prototype may be considered successful in designing usable and satisfactory systems.

8.7.1.2 Ease of Use

Questions 2, 3, 5, 8, and 9 all referred to the ease of use of the EMR prototype. The scores reflect the prototype as very easy to use (Table 8.4). With additional support from the comments and overall feedback from the scenarios, these results indicate that the EMR was usable, simple, and straightforward to use. It was also designed in a manner that allowed participants to feel fairly confident using it. This confidence level was high, but probably not at its peak due to participants operating and viewing the EMR for the first time (Participants 4 and 5, Table 8.4). The learning curve for the EMR was short, as participants did comment that once they knew how to use the features, they would remember the actions involved when navigating and completing certain steps for the scenarios. Question 5 showed that participants found the different features and functions to be integrated well, suggesting that the EMR flow was good, and that all necessary functionality was suitably included into the prototype.

8.7.1.3 Learnability

Questions 4, 7, and 10's (Table 8.4) purpose was to attain a sense of how easy the system was to learn. The scores reflect the learnability to be positive, and fairly easy (Table 8.3), and that all participants, or users of varying levels of technical expertise should be able to easily learn how to operate the system independently and relatively fast. One participant's score for Question 4 indicated that they would probably require the support of a technical person. This may be attributed to their lack of experience with EMRs, despite the easy learnability. Additionally, yet not generalising to all elderly generations, this participant, 4, fell within an older age group than Participants 1-3 (Table 8.3). The introduction of technology and EMRs have been more recent and was not as common amongst the elder generations of optometrists, hence possibly being a factor in the score given. This participant also admitted to not being good with using technology in general.

8.7.1.4 User Satisfaction

Questions 1 and 6 referred to users' overall satisfaction with the system, and their positive or negative impressions of it. The results showed that participants would be inclined to frequently operate the system, finding it useful and satisfying (Table 8.4).

8.7.2 PSSUQ Results

To calculate the PSSUQ scores, average the scores from the appropriate items to obtain the scale and subscale scores (Lewis, 1995). Low scores are better than high ones due to the anchors used in the seven-point scales. If a participant/user does not answer an item or marks "N/A," then average the remaining item scores (Lewis, 1995).

- Overall user satisfaction with their system (OVERALL): Calculated by taking the average of questions 1-19.
- System usefulness (SYSUSE): Calculated by taking the average of questions 1-8.
- Information quality (INFOQUAL): Calculated by taking the average of questions 9-15.
- Interface quality (INTERQUAL): Calculated by taking the average of questions 16-18.

Table 8.5 displays the PSSUQ Frequency Count for the participants (P1-P5). Figure 8.1 shows the PSSUQ Sub-Score Results, relating to the system characteristics of Overall User Satisfaction, System Usefulness, Information Quality and Interface Quality. The explanations relating to their varying scores are also explained in the sectioned followed below (8.7.2.1 - 8.7.2.4).

Table 8.5 PSSUQ Frequency Count

	Participant Score Frequency Count						
	Strongly Agree to Strongly Disagree						
PSSUQ	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Overall, I am satisfied with how easy it is to use this system	2	2	1	0	0	0	0
2. It was simple to use this system	2	3	0	0	0	0	0
3. I could effectively complete the tasks and scenarios using this system	2	3	0	0	0	0	0
4. I was able to complete the tasks and scenarios quickly using this system	3	1	1	0	0	0	0
5. I was able to efficiently complete the tasks and scenarios using this system	1	3	1	0	0	0	0
6. I felt comfortable using this system	2	2	1	0	0	0	0
7. It was easy to learn to use this system	4	1	0	0	0	0	0
8. I believe I could become productive quickly using this system	4	1	0	0	0	0	0
9. The system gave error messages that clearly told me how to fix problems	0	0	3	0	1	0	0
10. Whenever I made a mistake using the system, I could recover easily and quickly	2	0	2	1	0	0	0
11. The information (such as on-line help, on-screen messages, and other documentation) provided with this system was clear	2	2	0	1	0	0	0
12. It was easy to find the information I needed	3	2	0	0	0	0	0
13. The information provided for the system was easy to understand	3	2	0	0	0	0	0
14. The information was effective in helping me complete the tasks and scenarios	2	2	1	0	0	0	0
15. The organization of information on the system screens was clear	3	1	1	0	0	0	0
16. The interface of this system was pleasant	2	2	1	0	0	0	0
17. I liked using the interface of this system	3	2	0	0	0	0	0
18. This system has all the functions and capabilities I expect it to have	1	3	1	0	0	0	0
19. Overall, I am satisfied with this system	3	2	0	0	0	0	0

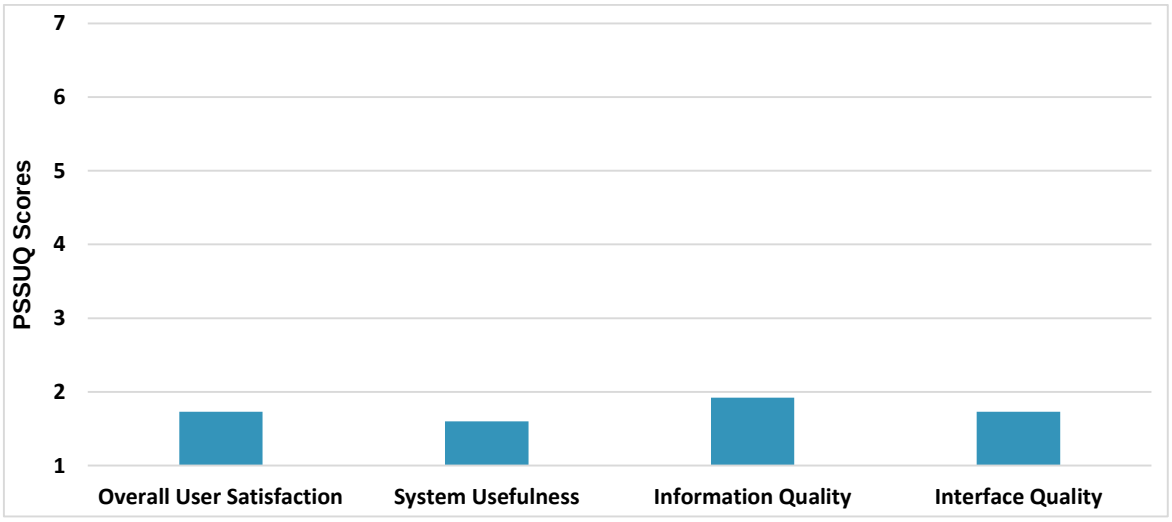


Figure 8.1 PSSUQ Sub-Score Results

****Lower scores are better than higher scores.**

8.7.2.1 Overall User Satisfaction

Questions' 1 to 19 (Table 8.5) average referred to the overall user satisfaction with the EMR system. The scores revealed that the participants were content with the system, with a total average of 1.73 (average value is represented by the "1.73" value) ± 0.85 (standard deviation is represented by the "0.85") (Figure 8.1). Participant 4's score was higher than the others, having admitted to being especially slow in learning how to use technology in general.

8.7.2.2 System Usefulness

Questions' 1 to 8 (Table 8.5) average concerned the system usefulness. The participants' scores indicate that system was found to be very useful, with an average of 1.60 ± 0.67 (Figure 8.1). In terms of completing some tasks/scenarios (Questions 3, 4 and 5, Table 8.5), some of the participants initially took slightly more time, attributed to the learning curve and getting used to the EMR layout.

8.7.2.3 Information Quality

Questions' 9 to 15 (Table 8.5) average related to the information quality. The scores indicate that the information quality was well regarded with Participants 1, 2 and 3. Participants 4 and 5 had higher scores as they took longer in learning how to use the system features. Additionally, some participants would have preferred the system to have more detailed error messages if mistakes were made. The overall total average of 1.92 ± 1.09 (Figure 8.1) indicates a fairly good information quality.

8.7.2.4 Interface Quality

Questions' 16 to 18 (Table 8.5) average indicated the interface quality, whose scores reveal a high quality, with an average of 1.73 ± 0.7. The participants found the interfaces pleasant, and liked interacting with the system.

The overall SUS and PSSUQ results all indicate the system to be very positive, usable and satisfactory. The task completions, and the positive comments and feedback support this. Thus, the guidelines, which informed the EMR prototype may be considered positively, and hence validated. It was interesting to note that both Participants 4 and 5 who were new to the study and also happened to be older than the other participants (Table 8.3), struggled slightly more when initially interacting with the UIs. They admitted to being less *"tech-savvy"* or computer literate, and thus required a greater learning curve and assistance. As aforementioned, the introduction of technology and EMRs have been more recent and were not as common amongst the elder generations of optometrists, hence possibly being a factor in the scores given. They

still, however, agreed on the easy learnability and navigation of the EMR prototype. As they admitted to being less *"tech-savvy",* it was reassuring to view their high usability scores and positive comments for the testing session, and hence the guidelines. The participants, namely 4 and 5, felt more inclined to explore the different features on the EMR, as it appeared more user friendly to a novice user. The results show that a simple UI, with adequate functionality for users to successfully perform desired tasks, and well-defined Information Architecture (IA) may aid in improving the usability of the EMR and user satisfaction of using the EMR.

8.8 Refinement of the Guidelines

Based on the scenarios and participant interactions with the EMR prototype, it was noted that the affordance of interactive areas or buttons/features ought to be made prominent enough as to avoid oversight. For example, the patient profile icon in Scenario 4 was not easily discoverable. On-screen elements such as text boxes, as well as fonts/text should be made large enough to afford good legibility, and to again avoid oversight or eye-strain. They ought to be generally proportionate to the UIs. The font "Verdana" which is easy on the eye is a possible suggestion to be used in the UIs, despite it being a San-serif font. This relates to Guidelines 21 and 22 under "Design Simplicity" (Table 7.2). For blood pressure readings, a suggestion was to use a range list or input-blocks, which represent fractions, whose layouts may be customised. This is already covered by "Patient Examination" Guideline 31 (Table 7.2). Input-method options for Visual Acuity (VA) information could possibly be customisable, i.e. options for selecting drop-down lists, text area or ranges. There could be provision to also select desired units and formats (feet, metres, decimals, fractions). This already is covered by Guideline 31 (Table 7.2). In terms of the presentation of this VA information, input was suggested to be shown from the optometrist's perspective, i.e., Right, Left and then both eyes' details. This relates to "Real-World Conformance", Guidelines 3 and 4 (Table 7.2). The Visual Chart input boxes were proposed to be expandable-hidden options, and only displaying one at a time, e.g. Snellen Chart input boxes. This is supported by the "Flexibility Of Control And Customisation", Guideline 6, as well as "Cognitive Load", Guideline 16 (Table 7.2).

Regarding the prescription process and capturing the Refraction details, information pertaining to the unfrequented Prisms was suggested by some participants to be hidden options, available on demand. This would de-clutter the screen and decrease "Cognitive Load" as indicated by Guideline 16 (Table 7.2). The other participants, however, did not mind the current layout. The Optometric Examination and Prescription notes ought to become un-editable once saving

for ethical and security reasons. A warning/alert message appearing upon saving the information which notifies optometrists could be added. This links to "Patient Examination" Guideline 32, as well as to "Error Mitigation And Recovery", Guideline 10 (Table 7.2).

For the Calendar UI, there could be the addition of a feature allowing for insertion of quick notes, or an independent, minimisable/expandable text-area. The quick notes feature was available within the EMR, but on the "Favourites" UI instead. This could be moved to the calendar UI. This relates to "Flexibility Of Control And Customisation", Guideline 6, and "Efficiency", Guideline 18 (Table 7.2). These aforementioned suggestions or additions to the guidelines (Table 7.2) may link to more than one category or guideline due to their nature. Consequently, their most relatable guidelines have been linked to them, despite the possibility of over-laps. Table 7.2 was re-visited with these aforementioned considerations, and enabled for the presentation of a final set of EMR UID Guidelines for Optometry (Table 9.1), reflecting these changes. From this chapter, the main refinements are:

It was suggested that more templates be included, and that they have greater provision for customisation. For example, the addition of more formal, business-like, or possibly informal templates; in order to provide for greater variety. Guidelines 15 and 34b (Table 7.2) were updated in Table 9.1, including the words "customisable", "formal" and "informal formats" in bold:

Guideline 15: Provide pre-set templates; a) Provide **customisable**, pre-set templates for frequented and standard tasks; ▪ E.g. Prescription templates. Email report templates **(formal, informal formats)**.
Guideline 34: Provide features for after-care patient education (take-home/post-consultation); b) Offer a variety of templates that are pre-set **and customisable**; ▪ E.g. **Informal, and formal formats**.

The use of accelerators was greatly appreciated, and a suggestion was to include keyboard shortcuts. As such, Guideline 18 (Table 7.2) was updated to include this (Table 9.1):

Guideline 18: Use accelerators to enable optometrists to conduct tasks more efficiently; a) Use of shortcuts **(i.e. keyboard shortcuts)** to direct optometrists to most frequent tasks.

The font, "Verdana" was noted to be especially to be suitable for easy reading on UIs. Thus, Guideline 22b (Table 7.2) was adjusted to include it in the final Table 9.1:

Guideline 22: Font sizes should be large enough to ensure good legibility, and styles should be professional; a) The use of styles ought to be professional and clear, and suitable to the context or UI information; ▪ E.g. Use of **San-Serif** fonts that are easier to read, as compared to Serif fonts depending on the font used (i.e. **Verdana**).

For the Calendar UI, a suggestion the addition of "quick notes", or an independent, minimisable/expandable text-area. As such, Guideline 24 (Table 7.2) was updated to include (Table 9.1):

Guideline 24: Provide appointment scheduling that is easy to manage, accessible and visible;
i) Include functionality for the easy addition of customisable notes or text areas on the Calendar UI;
- **E.g. Sticky notes.**

Security, legal and ethical aspects of patient clinical information being editable once entered after the examination was a concern. To address this, it was suggested that information such as prescription details or clinically sensitive information should not be editable upon saving. The saved version should rather be available for reference if needed, and new details be submitted. Guideline 32 (Table 7.2) was updated, and elaborated to include (Table 9.1):

Guideline 32: Provide features allowing for more efficient prescription entry (which is a more specific part of the optometric examination);
f) Include options to enable for the limiting of editing prescriptions and clinically sensitive information, upon entry and saving by attending optometrists.
- **E.g. A warning/alert message appearing upon saving the information which notifies optometrists could be added. Make the previous versions available for viewing, but not editable.**

Educational material ought to have greater provision for customisation and editing. Guideline 33 (Table 7.2) was updated to include the words, "editable/customisable" and "pictures" (Table 9.1):

Guideline 33: Provide links to educational material for patient education during a consultation;
a) Include **editable/customisable** educational videos, **pictures** and print materials for references to associated eye conditions.

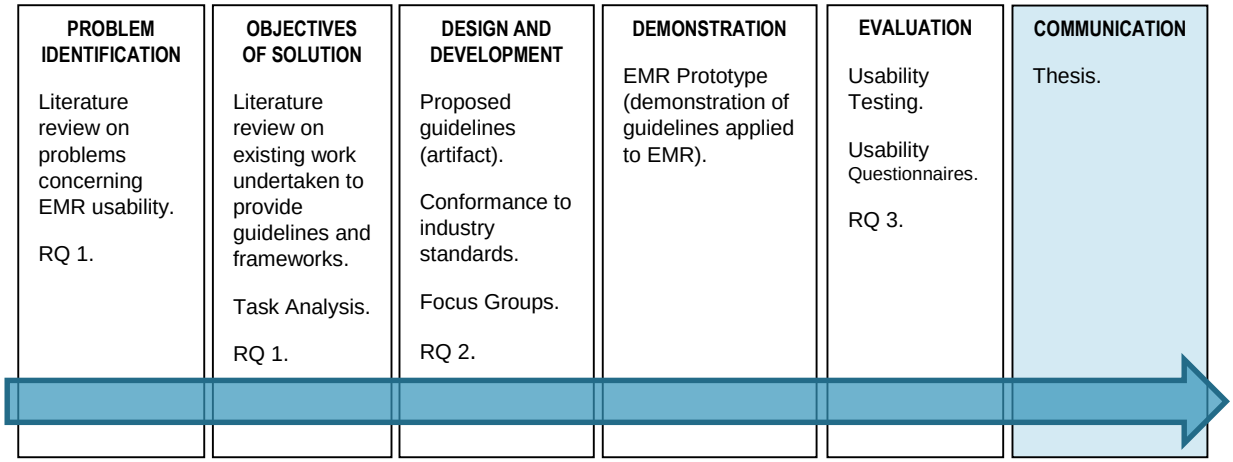
8.9 Conclusion

To test the proposed UID guidelines for EMRs used in Optometry (Chapter 7) via an EMR prototype, UT was employed. UT also enabled for an appreciation of the users' acceptance and satisfaction of the guidelines, as well as their effect on the users. In achieving this, the UT gathered information pertaining to users' past experiences with their EMRs, and applied it through given the tasks to complete on the EMR prototype. This permitted for the researcher to explore the challenges users faced or discovered when conducting EMR tasks, in effort to better inform the set of EMR UID guidelines. Informed by the literature review, TA and Focus Groups (FGs), Chapter 7 amalgamated the information and preliminary UID guidelines to create a more concrete set of EMR UID guidelines for Optometry. This set was then used to inform a prototype for testing in this chapter, 8. This chapter focused on evaluating the set of EMR UID guidelines, by means of subjecting typical user representatives (optometrist) to conduct tasks on a prototype EMR, which effected these guidelines. Additionally, the SUS

Questionnaire and PSSUQ was administered to evaluate and quantify the usability and satisfaction of the users.

By adhering to the UID guidelines, as well underlying usability principles during the process of the EMR prototype design and testing, it was established that the participants were satisfied, and had enjoyable interactions. Furthermore approving the UID guidelines, the UIs were also shown to be usable. As per the feedback and comments, it is a clear indication that the Proposed Guidelines (Table 7.2) have been effectively used to inform the EMR prototype. The scenarios were set out in order to test all the guidelines, whether directly or indirectly, and the overall results were positive, validating them via the testing of the EMR. In terms of adjustments/additions to the guidelines, not many arose, and the specific refinements were covered in Section 8.8. Points included provision for greater customisability and options for allowing optometrists to efficiently capture patient details, e.g. more drop-down lists, input as fractions, conversion of units from feet to metres etc. This was especially noted for the "Blood Pressure" and "Visual Acuity" recording process. During the prescription process, the "Prism" information was to be less prominent on-screen, and to rather become a hidden option. The font "Verdana" was suggested to be suitable for easy reading on UIs. Options for custom, quick notes on the calendar UI was suggested. The Optometric Examination and prescription notes ought to become un-editable once saved for ethical and security reasons. A warning/alert message appearing upon saving the information, which notifies optometrists could be added. Last, but not least, an option for the inclusion of a glasses dispensing feature arose, which was out of this scope for this research. This was considered as a possibility for future research. As users all have varying levels of technological competence and EMR experience, the need for designing systems with good usability in mind is essential to ensure that all users are supported. This was evident in the older participants' interactions with the EMR prototype; which was found to be slightly more challenging than with the younger participants, who have more EMR experience despite having fewer years of experience practising Optometry. Thus the guidelines ought to encourage and promote good usability, and were successful in doing so. The next chapter, Chapter 9, presents the final conclusions of the thesis, and reflects upon the entire process. The contributions are discussed, as well as future research areas.

Chapter 9: Conclusion



This chapter concludes the thesis, and contributes towards Step 6 of the Design Science Research Process Model (DSRP) model, which relates to the communication of the User Interface Design (UID) guidelines for electronic EMRs in Optometry. With reference to the research questions, the outcome of the research is briefly summarised and communicated. This chapter reflects on the research process used, as well as the contribution made, and ends with suggestions for future research. The contributions for this research include the user interface (UI) guidelines for Electronic Medical Records (EMRs) used in Optometry.

9.1 Research Overview

The benefits of Electronic Health Records (EHRs) and EMRs as e-health systems replacing the paper-based recording system was acknowledged, as well as their accompanying advantages and disadvantages. From these EHRs/EMRs, many usability challenges arose as barriers to effective adoption by physicians (Chapters 3 and 4). UID challenges were identified as major problems that hindered physicians' workflows and contributed towards poor usability. As such, interaction design heuristics (Nielsen, 1993), UID and usability guidelines pertaining to both EHRs and EMRs from literature (Zhang and Walji, 2011; Payne, et al., 2015), to address these problems were explored, as well as within the Optometry environment. Within the niche field of Optometry, physicians experienced hindered workflows as a result of poor EMR UID and usability, of which EMR guidelines to improve these challenges are scarce. This was confirmed via literature reviews and personal communication with optometrists, first discussed in Chapter 1. Hence, the need for this research arose, aiming to create UID guidelines for EMRs in Optometry (Table 9.1) which would improve the optometrists' EMR usability.

The main research question was successfully answered to produce a set of UID Guidelines for EMRs in Optometry (Table 9.1). Design Science Research (DSR) was chosen as a suitable approach, since it is a "problem-solving paradigm" (Hevner, et al., 2004) which aims to produce design artifacts that may be used to contribute towards research and provide solutions to real world problems. The phased DSRPM of Peffers, et al. (2006) was used to guide this research, which looked at the UID and accompanying usability problems of EMRs in Optometry. Task Analysis (TA) was used to observe and understand the optometrists' workflows and their interactions with their EMRs during patient appointments, also identifying EMR problem areas. To address these problems, Focus Groups (FGs) were used to brainstorm solutions in the form of EMR UID features that optometrists' desired to improve their usability. After the creation of the Proposed Guidelines for the UID of EMRs in Optometry (Table 7.2), they were subjected to evaluation. The guidelines informed the UID of an EMR prototype, which was successfully demonstrated to optometrists during Usability Testing (UT) sessions. The results showed the guidelines as successful, and were usable, effective, efficient and of good quality. From the results, a revised, "Final EMR UID Guidelines for Optometry" (Table 9.1) was created and is the main deliverable of this research.

9.2 Achievement of Research Objectives

The main research objective was to create a set of UID guidelines for EMRs in Optometry, to improve optometrists' usability.

The main research objective was achieved by answering the main research question:

What user interface design (UID) features should be incorporated into guidelines to enhance the usability of EMRs in Optometry?

The main research question was informed by three sub questions:

RQ1: What user interface design problems are associated with EHR and EMRs?

This was primarily addressed in Chapters 3, 4 and 5, which entailed literature reviews focusing on EHR and EMR usability issues that pertain to the UIDs, as well as TA (Chapter 5), which further helped by observing optometrists' workflows and identifying problems with their Optometry systems (EMRs). A table of categories (Table 3.1) was formed, which helped categorise the final set of guidelines (Table 9.1). Some of the general EHR and EMR problems included the lack of training and support, lack of intuitive designs, lack of customisation, incomplete information, poor system feedback, information density and the lack of verification and validation measures for entries. From Chapter 5, the Optometry environment was explored via a TA, allowing for the tasks conducted and practises followed by optometrists to be understood, with an insight into the specific challenges encountered; such as poor provision for

data entry into forms, lack of integration with pre-testing machinery, lack of provision for patient education and after-care (Table 5.2). As UID problems with Optometry EMRs were identified, some features to address these issues were briefly brought up during the TAs, thus contributing towards answering RQ 2, however, to a limited extent.

RQ2: What user interface design features should EMRs for Optometry contain?

The scope was limited to the critical user interaction with the EMRs, which was the patient-physician appointment period (Chapter 4.1.1). Chapter 6's FGs aim was finding the UID features that EMRs for Optometry should contain. The FGs allowed for brainstorming sessions to discover possible design features to address the EMR UID challenges faced and were presented in Table 6.5.

RQ3: How do the user interface design guidelines contribute to the usability of EMRs in Optometry?

The EMR prototype was developed to demonstrate the use of the guidelines (Chapter 7). The prototype's interface was then evaluated via UT and usability surveys (SUS Questionnaire and PSSUQ) (Chapter 8), to determine the usability and satisfaction. This assessment's outcome was used to evaluate the guidelines, which was thereon updated. The overall results deemed the guidelines as successful, thus confirming their utility, quality and efficacy. In terms of contributing towards the usability of EMRs in Optometry, the guidelines are able to inform the design of EMR UIs, providing features (Chapter 1.5) that improve the optometrists' usability and overall satisfaction (Chapter 8). The EMRs interface was usable, useful and satisfying, enabling the optometrists to carry out their tasks with effectiveness, efficiency and satisfaction.

Table 9.1 Final EMR UID Guidelines For Optometry

SYSTEM STATUS AND FEEDBACK • Guideline 1: Provide appropriate and timely feedback for optometrist actions and system events; a) Provide indication of system response to actions; ▪ E.g. Button depressions, colour changes. b) Have clear closure to inform optometrists of their task completion; ▪ E.g. Task success messages, icons. c) Include visual and/or auditory feedback to optometrists. ▪ E.g. Sounds accompanying appointment notifications. • Guideline 2: Ensure that the optometrist is always aware of the system's status; a) Keep optometrists aware of their task progress, from the beginning through the end; ▪ E.g. Progress indicators, notification banners, icons, informational text-boxes, alerts.
REAL-WORLD CONFORMANCE • Guideline 3: Provide support for tasks and functions to closely match optometrists workflows; b) Optometric workflows ought to be seamlessly accommodated in the UI design with adequate support. ▪ E.g. Input fields for patient information includes all the necessary fields required, in the correct order. • Guideline 4: Elements should match to their real-world functions (in functionality and design); a) Human interface objects ought to conform to standard methods of (direct) manipulation; ▪ E.g. Buttons being pressed, sliders dragged, and include standard resulting behaviours. b) Use of metaphors (skeuomorphism) and affordance; ▪ E.g. Glasses or lens icons could represent the prescriptions. Red colour signalling errors. Buttons should look like they can be clicked on. Sliders dragged. Envelopes representing emails. Hidden affordance to simplify the visual complexity of design, like drop down menus/lists. • Guideline 5: Dialogue should be appropriate for optometrist profession;

a) Clear and easily understood wording should be used.
b) Familiar optometric and related medical terminology should be used;
- E.g. Glaucoma, lenses, visual acuity, ocular.
- E.g. Snomed-CT and ICD-10 Codes provide standardised, multilingual vocabulary of clinical jargon that is used by physicians and other health care providers for the electronic exchange of medical health information.

FLEXIBILITY OF CONTROL AND CUSTOMISATION

- Guideline 6: Allow customisation of the UI;
  a) Provide functionality for optometrists to customise the layout of the UIs according to their preferences;
  - E.g. Allowing optometrists to re-arrange pre-test options on the UI according to their frequency of use.
  - E.g. A "Favourites" tab or separate section could be provided as a personal page for optometrists.

  b) Provide optometrists with a sense of autonomy, yet include boundaries, which also help reassure them;
  E.g. Choice of shortcuts.
  - E.g. Ability to alter settings but not those integral to system functioning.
- Guideline 7: Navigation should be easy;
  a) The UIs should be explorable, with features being easily identified and visible (but unobtrusive) on the UI, without much searching for;
  - E.g. Easily accessible patient profiles via an icon or button.

  b) Provide visual elements to speed up navigation, as well as in serving as reliable landmarks to reassure optometrists of a sense of "home";
  - E.g. A logo on the UIs that navigates optometrists to the home screen when selected. Magnifying glass indicating a search feature.

  c) Provide features enabling actions to be undone, reversible or saved;
  - E.g. Undo, redo, cancel, exit, back/return, auto save buttons/backup.

CONSISTENCY

- Guideline 8: Use consistent wording;
  a) Wording and labels used should be consistent, descriptive and clear;
  - E.g. If Hypotension is the term used for low blood pressure, use it throughout. Use of "Next" used consistently, instead of using it interchangeably with "Proceed".

  b) Features should perform the same actions when used or selected;
  - E.g. The patient profile button when selected should always navigate the optometrist to the same patient UI. Print button should always print the reports.

  c) Labels should be simple, clear, and well-defined so that optometrists are able to orientate themselves through the various UIs;
  - E.g. Clear and simple UI titles.
  - E.g. Correct semantics for words accompanying buttons (icons).
- Guideline 9: Keep UI elements consistent unless to highlight element differences;
  a) Elements acting differently ought to look different (Induced Consistency);
  - E.g. UIs with consistently behaving features and functions should be visually consistent and act the same.
  - E.g. UIs with modifications should highlight the changes.

  b) Button/element positioning and placement ought to be consistent, allowing for quick navigation;
  - E.g. Provide sufficient spacing between buttons/elements.
  - E.g. Use the left side of the UI to place smaller, less prominent buttons, and the right for more important and larger ones. Frequently used ones are generally positioned more centrally on the UI.

ERROR MITIGATION AND RECOVERY

- Guideline 10: Minimise the risks of human-errors;
  a) Provide verification and validation measures for input;
  - E.g. Confirmatory messages. Ranges for test values (protective restraints), like Intraocular Pressure Test recordings (IOP): 1-40, and then 45+. Email fields requiring appropriate formats.
- Guideline 11: Provide features to ensure task continuity and recovery;
  a) Allow for the use of state, whereby the systems remember and identify the optometrists, and deliver to them the content, functionality or experience that matches their role;
  - E.g. Remember certain colours and shapes.
  - E.g. Previously entered information is saved and presented for selection.
  - E.g. Auto save, backup, undo, redo, cancel and exit buttons.
- Guideline 12: Provide informative error messages (or success of actions);
  a) State which error occurred and give constructive help.
  b) Use language that is descriptive, user-friendly, clear and simple.
  - E.g. An error message for a pre-test, warning that a figure greater than what is provided as an upper limit cannot be used, and to select a lesser value.

COGNITIVE LOAD

- Guideline 13: Provide for predictive text functionality;
  - E.g. Glau- for Glaucoma, IOP- Intraocular Pressure. Patient names on the patient list.
- Guideline 14: Build on existing interface design patterns from optometrists' past experiences;

a) Use common labels and UI layouts on other websites/programs to reduce the amount of learning optometrists need to do;
   - E.g. Exit buttons on the top right of the UI. Default menu items at the top of the UIs.
- Guideline 15: Provide pre-set templates;
  a) Provide customisable, pre-set templates for frequented and standard tasks;
     - E.g. Prescription templates. Email report templates (formal, informal formats).
- Guideline 16: Avoid visual clutter;
  a) Ensure elements are readily available in plain sight, and easily accessible on the UIs for explorability;
     - E.g. Menu bar displaying the various options available like gallery, practice details.
  b) Use information hierarchies for determining relevance, and only show controls or features that are appropriate for the task being undertaken;
     - E.g. When writing prescriptions, optometrists should be presented with all the information influencing the prescriptive process, and not irrelevant options such as UI theme settings.
  c) Use chunking, or grouping of similar elements;
     - E.g. Information pertaining to lenses are grouped on a portion of the UI.
  d) Provide buttons or elements where possible to minimise interactions;
     - E.g. Tick boxes, radio buttons.

EFFICIENCY

- Guideline 17: Menus should be well organised;
  a) Menus should have a well-structured information architecture (IA), for correct presentation to optometrists, to allow for easy task accomplishment, and to locate what they need quickly;
     - E.g. Well-defined menu and icon labels.
     - E.g. Most frequented items should appear first on the menu list.
     - E.g. Simple, shallow levelled menus (hierarchical structures) for easy navigation.
- Guideline 18: Use accelerators to enable optometrists to conduct tasks more efficiently;
  a) Use of shortcuts (such as keyboard ones) to direct optometrists to most frequented tasks;
     - E.g. A patient icon/button navigating the optometrist directly to patient lists, or to tests.
  b) Use of defaults for more frequented options;
     - E.g. Commonly selected test readings which automatically display value ranges: 120/80 as the starting default value for blood pressure, with 120 allowing for up and down correction, as with 80.
     - E.g. Showing the default eye pressure readings as 12-22 mm Hg, or 15 mm Hg as within the normal range.

DESIGN SIMPLICITY

- Guideline 19: Use colour intuitively, serving as a visual aid (the use of an interface should not depend *solely* on colour schemes.);
  a) Use colour to differentiate tasks or activities;
     - E.g. Green indicating lens availability. Black indicating lens are out of stock.
  b) Ensure the colours used are consistent in the UIs, balanced and well contrasting;
     - E.g. Black against white, as compared to purple against another similar shade of purple.
  c) Keep colours consistent with those in the real world, and account for the visually impaired/colour-blind individuals;
     - E.g. Red for danger or caution, green for success.
  d) Use colours and appealing designs to draw attention to buttons and features as required.
     - E.g. Proceed/next button highlights when the next step in the prescriptive process is being undertaken.
- Guideline 20: The UI should be minimalistic in design, easy to learn and use;
  a) Ensure the interface layout is simple, intuitive, and uncluttered;
     - E.g. UI layouts ought to present information and features symmetrically.
     - E.g. UID and layouts should be flexible to user customisations.
     - E.g. Designs should be visually attractive, with balance between simplicity and functionality.
     - E.g. Use adequate spacing for elements.
- Guideline 21: Ensure buttons or elements allow for easy operation and navigation;
  a) Avoid redundant buttons or latent elements, keeping their numbers minimal;
     - E.g. Buttons or elements that do not serve a purpose. Radio buttons that cannot be selected. Underlined text indicating a link that does not work.
  b) Provide shortcut buttons for frequently used functions;
     - E.g. Pre-tests button. Calendar button.
  c) Buttons or elements should clearly communicate the content they represent;
     - E.g. A floppy disk to represent save. A printer icon to represent print.
  d) Buttons/elements should be of proportional size to the UI, as well as on based on their prominence.
     - E.g. An important element such as a pre-test button should be more prominent than a button relating to theme settings or colour changes.
- Guideline 22: Font sizes should be large enough to ensure good legibility, and styles should be professional;
  a) The use at least 12 point or a large enough font to ensure good legibility.
  b) The use of styles ought to be professional and clear, and suitable to the context or UI information;

- E.g. Use of San-Serif fonts that are easier to read, as compared to Serif fonts depending on the font used (i.e. Verdana).

HELP AND REFERENCE DOCUMENTATION

- Guideline 23: Provide adequate help functionality on how to use the systems, which enable for optometrists' efficient task conduction;
  a) Allow for optometrists to access the information required for easy discoverability of information related to their tasks, or on how to conduct certain tasks;
  - E.g. Search features that locate information from a repository of information (internal, or external such as Google).

  b) Include tooltip help associated with elements or on the UI;
  - E.g. A message informing optometrists on the function of an icon when hovering over it. "Creates new patient profiles", or "Edit" message appears when hovering over a patient icon.

PATIENT MANAGEMENT

- Guideline 24: Provide appointment scheduling that is easy to manage, accessible and visible;
  a) Use colour differentiation to associate optometrists to their respective appointments;
  b) Include features that allow for optometrists to customise their views on the appointment schedules;
  - E.g. Patient summary view. Individual optometrist's schedule.

  c) Ensure the schedule/calendar is always refreshed and updated;
  - E.g. Auto save features, backup.

  d) Allow for optometrists to select their preferred/customised patient appointment times;
  - E.g. 15 minutes, 30 minutes.

  e) Include automated reminders for appointments;
  f) Ensure alerts and notifications are effectual yet not desensitising (if they constantly or frequently appear);
  g) Include options to adjust the timings and settings of appointment alerts or notifications;
  h) Allow optometrists to view their patients' appointment information and prescriptions;
  - E.g. Informational boxes attached to patient profiles with information such as lens delivery dates to practice, the lens types, or frame types, collection dates of prescription glasses etc.

  i) Include functionality for the easy addition of customisable notes or text areas on the Calendar UI;
  - E.g. Sticky notes.

- Guideline 25: Provide forms for capturing new patient profiles and details;
  a) Include a "Hobbies" section so that optometrists may be better informed when prescribing lenses;
  b) Include the option for including patient profile pictures for better identification purposes;
  c) Include patient demographics and contact details;
  d) Include options that allow for easier input or selection of form information;
  - E.g. Tick boxes, lists.

- Guideline 26: Allow for relevant medical aid information to be accessed and displayed;
  a) Include medical aid details displaying the various options available to patients;
  - E.g. Name of medical aid, member option, prescription limits.

PATIENT EXAMINATION

- Guideline 27: Provide for the ability to display information from pre-testing machines;
  a) Display the various pre-tests for easy selection;
  - E.g. Selectable buttons or icons that represent each pre-test/test option, like the Fundus photographer tests, Vertometer tests.

  b) Include a comments box for free-text entry relative to each test;
  c) Include features to enable uploading of test results or images, in various formats;
  - E.g. Upload buttons on the prescription UI to include Fundus Photographer test images, or blood pressure readings.
  - E.g. Pdf, jpeg, .doc, etc.

- Guideline 28: Provide for the visualisation of patient longitudinal data;
  a) Allow for the viewing of patient results over time;
  - E.g. Displaying all the saved Fundus Photography images of a patient over time, alongside each other for easy comparison.

  b) Enable for custom filtering and organisation of results;
  - E.g. Date, time, size, name.

- Guideline 29: Provide eye-images for annotation;
  a) Provide eye images or diagrams to allow for optometrists to annotate;
  - E.g. Insert annotated callouts on eye images.

  b) Include provision for free form text below the eyes images.

- Guideline 30: Integrate the visual/optometric charts (main standardised ones);
  a) Allow for the selection of the various charts from the interface for display;
  - E.g. Snellen, Landolt, ETDRS and Tumbling E Charts.

- Guideline 31: Provide features to increase the efficiency of information input during the optometric examination;
  a) Include layouts which are able to be customised;
  - E.g. Prescription pane could be customised, or the generic layout could be used.

b) Include pre-loaded options for some entry-fields;
   - E.g. Provide a list of options regarding patient reasons for visiting, or a list of possible common complaints.
- Guideline 32: Provide features allowing for more efficient prescription entry (which is a more specific part of the optometric examination);
  a) Include a separate section on the UI, or a new UI for the prescription entry;
  b) Ensure validation checks for correct input of information;
     - E.g. Error message or hazard signs for out-of-range figures.
  c) Differentiate via spacing, the right and left eye.
  d) Include a print option for the prescriptions.
  e) Include an options list showing the varieties of glasses or lenses available;
     - E.g. Polarised lenses, fixed tints, photo chromatic lenses.
  f) Include options to enable for the limiting of editing prescriptions and clinically sensitive information, upon entry and saving by attending optometrists.
     - E.g. A warning/alert message appearing upon saving the information which notifies optometrists could be added. Make the previous versions available for viewing, but not editable.

PATIENT EDUCATION

- Guideline 33: Provide links to educational material for patient education during a consultation;
  a) Include editable/customisable educational videos, pictures and print materials for references to associated eye conditions;
     - E.g. Videos on the dangers of Glaucoma. Print material on the types of astigmatism.
  b) Allow search functionality to easily and quickly locate the educational material;
     - E.g. Search bar.
- Guideline 34: Provide features for after-care patient education (take-home/post-consultation);
  a) Offer an email option with information relating to the patient consultation;
     - E.g. Include a pre-set template. Include the patient name, salutations, next appointment reminder, prescription attachment, educational information regarding their diagnoses, and a link to new products or information related to them.
  b) Offer a variety of templates that are pre-set, yet customisable;
     - E.g. Informal, formal formats.
  c) Include information relating to glasses;
     - E.g. Printed reports. Email summaries available to send to patients regarding their appointment.
  d) Provide a search facility that may provide information regarding eye related conditions;
     - E.g. A UI presenting the optometrist with information regarding searched-for conditions, Glaucoma.

9.3 Research Contribution

9.3.1 Theoretical

DSR stresses the importance of contributing towards the knowledge base (March and Smith, 1995; Hevner, 2007), and Gregor and Hevner (2013) present a framework which includes four types of contributions resulting from conducting DSR (Figure 2.1). This research was positioned towards the “Improvement” quadrant, making a contribution to the prescriptive (“How”) knowledge base in the form of guidelines (artifact) (Gregor and Hevner, 2013). Upon the artifact’s subjection to evaluation (Chapter 8), there was also contribution towards descriptive (“What”) knowledge. This was in the form of extended comprehension around the usability and UIDs of EMRs used in Optometry, thus expanding the knowledge base (Gregor and Hevner, 2013).

Confirming their value via application in this research, this study reflected on the work, theories and frameworks of many authorities, such as those relating to the UID and usability of systems (Nielsen, 1993; Shneiderman, 2004; Rogers, et al., 2011; Tognazzini, 2014), as well as usability concerning EHRs/EMRs (Belden, et al., 2009; Zhang and Walji, 2011; Middleton, et al., 2013). These works were then built upon, with more contextual relevance to EMRs within the niche medical environment of Optometry, enabling for the creation of the guidelines. Reflecting the contextual applicability, the TURF Framework (Zhang and Walji, 2011) was referred to (Chapter 4), which is a unified framework of EMR/EHR usability, giving usability principles for the health domain. The categories (Table 3.1) developed for the grouping of the guidelines referred to these aforementioned, numerous authorities, built upon them, and thus further support existing works. Additionally, the categories and guidelines were applied within the context of EMRs in Optometry, making them more contextually applicable for this research. It may therefore be considered that the current theory was **expanded** upon, and "Improved" (Gregor and Hevner, 2013).

Figure 9.1 below is an example of some guidelines illustrating the theoretical contributions. The category (E.g. "Patient Management") and guideline (E.g. "Guideline 1") itself serve as the theoretical contribution.

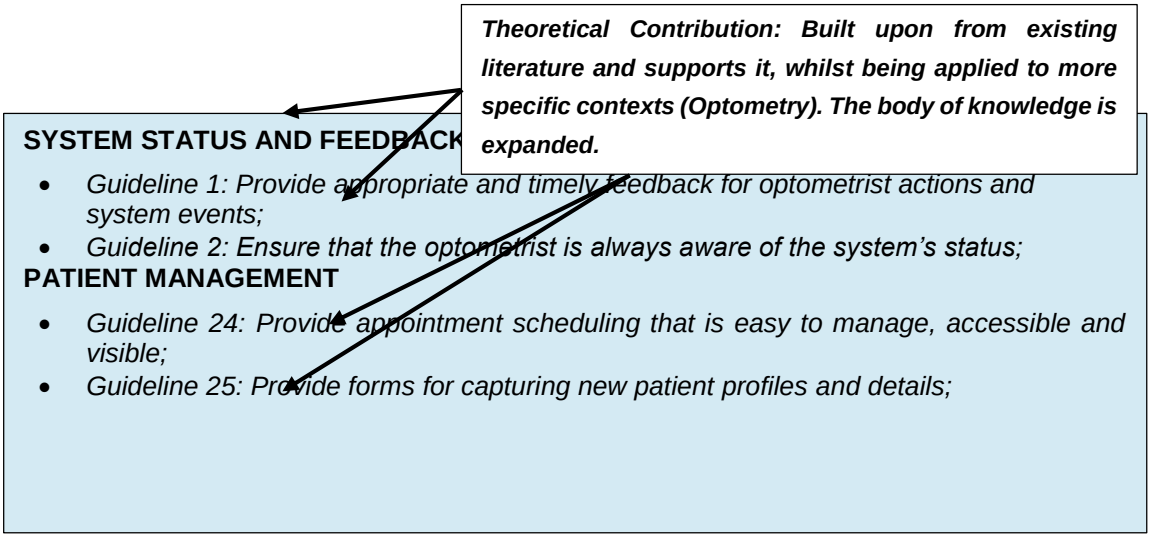


Figure 9.1 Guidelines Illustrating Theoretical Contribution

Apart from expanding the knowledge base, there were **additional contributions** as well, which allowed for the development of the artifact (Hevner, et al., 2004; Gregor and Hevner, 2013). From the TAs and FGs, new guidelines arose, falling under the categories of "Patient Management", "Patient Examination" and "Patient Education". These guidelines were more patient-centric than the others, and highlight the importance of the patient-physician relationships. The "Patient Management" and "Patient Education" guidelines especially related to the patient-physician relationship, and add to the UID of the niche medical environment by highlighting the importance of guidelines that point to the patient-physician relationship. As such, when developing UID guidelines for specialist medical EMRs, the patient-physician relationship aspects need to be considered and build into the EMR UID.

From the "Patient Management" guidelines (Table 9.1), optometrists are able to manage appointments more easily with the EMR's calendar and appointment booking features. Patients therefore have less waiting times and a more efficient experience. Additionally, these "Patient Management" guidelines also provide for easier capturing of patient information. The information required is also more personalised, such as including a "Hobbies" section, and the inclusion of patient profile pictures. This enables for the optometrists (and patients) to capture details more easily, and for the optometrists to more easily profile and identify their patients. The patient profiles are more comprehensive and allow the optometrists to quickly remember unique details pertaining to each patient, "refreshing their memory", and thus making the patient feel valued.

From the "Patient Education" guidelines, optometrists were able to educate their patients with material within their EMRs' and search for additional information needed. Patients are thus able to receive information relating to their eye-health not only from their consultation, but via print material and interactive videos, which adds to their understanding and enriches their overall experience and improves their health outcome. Interaction with EMRs during consultations was often feared by optometrists to take up valuable patient "one-on-one" time, making their patients feel neglected due to this lack of attention. Involving patients with the EMR via video material for example, may enable them to feel less neglected, and trusting more in the technology and overall process. After-care features were also available, providing for patients' continued care proceeding their appointments. Provision of the patient-specific and customisable after-care emails/reports helps to build upon patient relationships, making the patients feel valued upon their leave. For example, personalised appointment reminders and instructions on how to care for themselves after they leave the practice alludes a sense of their optometrist "remembering" the patients, and caring for them. This essentially helps maintain

trust, loyalty, strengthens and builds relationships. The final guidelines (Table 9.1) are intended to improve the optometrists' usability of their EMRs, and enable for their workflows to run more efficiently, which was confirmed in Chapter 8. It must be remembered, however, that the patients' perspectives also form part of the optometrists' workflows/practises and overall experiences.

From this theoretical contribution, some beneficiaries may include research in the health informatics, Optometry, usability and UID fields.

9.3.2 Practical

Table 7.2 presents the Proposed EMR UID Guidelines for Optometry used to inform the prototype, which was shown as successful, and providing practical suggestions for their implementation. Table 9.1 presents the revised, Final EMR UID Guidelines For Optometry, with the reflected changes from the evaluation (Chapter 8). The guidelines can be used to create usable EMRs for Optometry that enhance the usability as well as positively influence the overall satisfaction. Figure 9.2 illustrates an example of some guidelines' practical contributions. The practical contribution may be considered as the specific application of features accompanying the guideline. The guidelines are considered successful, easily interpretable, and thus may be used by system designers to develop EMRs in Optometry. In addition, their potential may also be harnessed when used by usability engineers to evaluate the usability of EMRs in Optometry.

The benefits of creating the guidelines rather than just an EMR per se, are that the guidelines are more transferrable, i.e., able to be adapted to various environments in Optometry, achieving the same purpose of enhancing Optometrists' usability. The guidelines are adjustable in nature as compared to EMR systems, provide more customisability and thus able to be adapted as needed. Some of the concepts could be applied to guidelines for other specialist EMRs. For example, providing for greater customisability, or for more system visibility and feedback (Table 9.1).

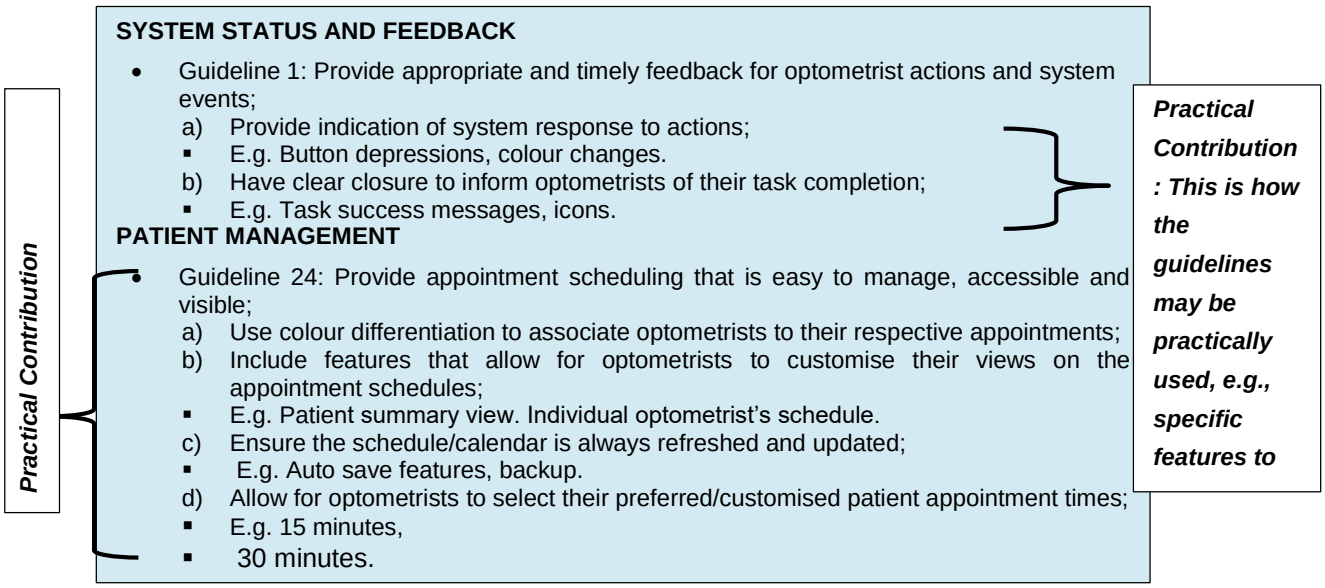


Figure 9.2 Guidelines Illustrating Practical Contribution

9.4 Limitations

The focus of this research is not on all aspects of EMR usability, but "rather on those that are part of critical user interactions" (Lowry, et al., 2012). The scope therefore narrows to the interactions of the optometrists with the EMR during patient visits; from the time the patients check in to the end of their visit, and primarily concentrates on the physicians' interactions rather than the patients', as the optometrists are the main EMR users. Thus, other EMR components such as administrative functions (billing, orders, stock) are not focused on, which may have contributed to a greater system usability.

During the TAs, FGs and UT, the numbers of participants employed were limited (maximum of six participants). This was often due to their time constraints, not wanting to partake in the research, or being too far away and thus inaccessible. Additionally, observations during the TAs sessions for example, needed to be done in person. The optometrists were all from the Eastern Cape in South Africa, due to restraints from resources, travelling costs and the availability of optometrists willing to participate. More participants from different locations may have allowed for a greater variation in the results obtained. Another limitation is that this research explored the private sector of Optometry. The franchises and larger corporate environments were difficult to enter, due to intellectual property constraints. Exploring these environments may have presented additional insights.

9.5 Future Research

A greater focus on the user experience (UX) could be considered for future research, particularly the patient-physician relationships. As the importance of the patient-physician relationship arose during the course of this research, future considerations could be on building upon these relationships, exploring ways on improving it, and not just focusing on data efficiency. Aspects around patient management, education and after-care could be further studied. Patient care ought to be central to the EHRs/EMRs' function, and the patient's role in a medical appointment should be enhanced by the EHR/EMR. Patient involvement in clinical care is central to patient-centred care (Epstein and Street, 2007) and has been shown to result in better physician understanding of the patient (Street and Haidet, 2011), and an enhanced patient commitment to treatment (Parchman, et al., 2010). Future research may also extend to explore other niche medical domains, following this research's methods, how the guidelines (Table 9.1) can be used in other specialist domains, and if the guidelines can be tailored to them. Additionally, franchises and the public sector of Optometry could be researched, as compared to just the private sector. EMRs with greater functionality for dispensing features may also be considered for future research.

9.6 Concluding Remarks

This research aimed to develop a set of UID guidelines for EMRs in Optometry. The DSRPM helped to structure this thesis following different research methods, with the chapters including: A literature review concerning UID; EHR/EMR usability; TA; FGs; and UT. The UID guidelines presented were specific to EMRs for Optometry, whose validation was accredited via UT in Chapter 8. Through this entire research journey, the main research question was thus answered with the objective being achieved as well as contributions made to EMR UID in Optometry. The rigorous methods employed ensure that the guidelines created can be used by other researchers to build on, and create usable UIs for future EMRs in Optometry, and contribute towards a greater, overall user satisfaction. The methods used may also similarly apply to other niche medical fields, whose EMRs, if challenged, may also be addressed.

References

Ackoff, R. L., 1974. *Systems, messes and interactive planning*. Redesigning the future: Systems Approach to Societal Problems. The Social Engagement of Social Science, Volume 3: A Tavistock Anthology-The Socio-Ecological Perspective.

Adams, A., Cox, A. L., 2008. Questionnaires, in-depth interviews and focus groups. Cairns, P & Cox, A. L. *Research Methods for Human Computer Interaction*. Cambridge, UK: Cambridge University Press, pp.17-34.

Ahmed, A., Chandra, S., Herasevich, V., Gajic, O., Pickering, B. W., 2011. The Effect of Two Different Electronic Health Record User Interfaces on Intensive Care Provider Task Load, Errors of Cognition, and Performance. *Critical Care Medicine*, 39(7), pp.1626-1634.

Ajami, S., Bhageri-Tadiet, T., 2013. Barriers for Adopting Electronic Health Records (EHRs) by Physicians. Acta Informatica *Medica,* 21(2), pp.129-134.

Alben, L., 1996. Quality of Experience: Defining the Criteria for Effective Interaction Design. *Interactions*, 3(3), pp.11-15.

Al-Sa'di, A., Parry, D., 2017. Successful User Centred Design for Tablet PC, A Conceptual Framework. *Human IT*, 13(3), pp.89–114.

American Medical Informatics Association (AMIA)., 2017. *Discovering Health Insights.* Accelerating Health Transformation. [Online] Available at: https://www.amia.org/about-amia/mission-and-history [Accessed 14 May 2018].

American Medical Association (AMA)., 2018. *Improving Care: Priorities to Improve Electronic Health Record Usability. Executive Summary.* [Online] Available at: https://www.ama-assn.org/sites/ama-assn.org/files/corp/media-browser/member/about-ama/ehr-priorities.pdf [Accessed 15 April 2019].

Arhippainen, L., Tahti, M., 2003. Empirical Evaluation of User Experience in Two Adaptive Mobile Application Prototypes. *Proceedings of 2nd International Conference on Mobile and Ubiquitous Multimedia*, 2003. Norrkoping, Sweden, pp.27-34.

Armijo, D., McDonnell , C., Werner, K., 2009. Electronic Health Record Usability: Evaluation and Use Case Framework. *AHRQ Publication,* No. 09(10)-0091-1-EF(10), pp.2-57.

ASAHP., 2018. *What is Allied Health?* Association of Schools of Allied Health Professions (ASAHP). [Online] Available at: http://www.asahp.org/what-is/ [Accessed 30 March 2018].

Ash, J. S., Berg, M., Coiera, E., 2004. Some Unintended Consequences if Information Technology in Health Care: The Nature of Patient Care Information System-related Errors. *Journal of the American Medical Informatics Association,* 11(2), pp.104–112.

Bangor, A., Kortum, P.,T., Miller, J. T., 2008. An Empirical Evaluation of the System Usability Scale. *International Journal of Human-Computer Interaction*, 24(6), pp.574-594.

Bates, D., Kuperman, G. J., Wang, S., Gandhi, T., Kittler, A., Volk, L., Spurr, C., Khorasani, R., Tanasijevic, M., Middleton, B., 2003. Ten Commandments for Effective Clinical Decision Support: Making the Practice of Evidence-based Medicine a Reality. *Journal of the American Medical Informatics Association,* 10(6), pp.523–530.

Belden, J. L., Grayson, R., Barnes, J., 2009. Defining and Testing EMR Usability: Principles and Proposed Methods of EMR Usability Evaluation and Rating. *Healthcare Information and Management Systems Society (HIMSS),* June, pp.1-40.

Benda, N. C., Meadors, M. L., Hettinger, A. Z., Ratwani, R. M., 2016. Emergency physician task switching increases with the introduction of a commercial electronic health record. *Annals of Emergency Medicine*, 67(6), pp.741-746.

Bevan, N., 2008. *UX, Usability and ISO Standards*. Professional Usability Services. [Online] Available at: http://www.cs.tut.fi/ihte/CHI08_workshop/papers/Bevan_UXEM_CHI08_06April08.pdf [Accessed 14 July 2018].

Beymer, D., Russel, D., Orton, P., 2008. An eye tracking study of how font size and type influence online reading. *BCS-HCI '08 Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction*, 2, pp.15-18

Black, N. J., Lockett, A., Winklhofer, H., Ennew, C., 2001. The Adoption of Internet Financial Services: a Qualitative Study. *International Journal of Retail & Distribution Management*, 29(8), pp.390- 398.
Blumenthal, D., Tavenner, M., 2010. The "meaningful use" regulation for electronic health records. *New England Journal of Medicine*, 363, pp.501-504.
Boland, M. V., 2010. Meaningful Use of Electronic Health Records in Ophthalmology. American Academy of Ophthalmology. *Ophthalmology*, 117, pp.2239-2240.
Boonstra, A., Broekhuis, M., 2010. Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy interventions. *BMC Health Services Research*, 10(1), p.23.
Brandtner, P., Helfert, M., Auingera, A., Gaubingera, K., 2015. Conducting focus group research in a design science project: Application in developing a process model for the front end of innovation. *Systems, Signs & Actions: An International Journal on Information Technology, Action, Communication and Work practices*, 9(1), pp.26-55.
Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in Psychology*, 3(2), pp.77-101.
Brooke, J. 1996. A quick and dirty usability scale. *Usability evaluation in industry*, 189(194), p.4-7.
Bruno, F., Muzzupappa, M., 2010. Product interface design: A participatory approach based on virtual reality. *International Journal of Human-Computer Studies*, 68(5), pp.254-269.
Bruseberg, A., McDonagh-Philp, D., 2001. New Product Development by Eliciting User Experience and Aspirations. *International Journal of Human-Computer Studies*, 55, pp.435-452.
Carlsson, S. A. 2006. Towards an information systems design research framework: A critical realist perspective. In: *Proceedings of the First International Conference on Design Science Research in Information Systems and Technology*, Claremont, CA, pp.192-212.
Carroll, J. M., 2013. Human Computer Interaction. Soegaard, M. & Dam, R. F. *The Encyclopaedia of Human-Computer Interaction*, 2nd ed. Aarhus, Denmark: The Interaction Design Foundation.
Carvalho, C. J., Borycki, E. M., Kushniruk, A., 2009. Ensuring the Safety of Health Information Systems: Using Heuristics for Patient Safety. *Healthcare Quarterly*, 12, pp.49-54.
Castillo, V., Martínez-García, A., Pulido, J., 2010. A Knowledge-Based Taxonomy of Critical Factors for Adopting Electronic Health Record Systems by Physicians: A Systematic Literature Review. *BMC Medical Informatics and Decision-Making*, 10(1), p.60.
Chang, D., Dooley, L., Tuovinen, J. E., 2002. Gestalt Theory in Visual Screen Design- A New Look at an Old Subject. *Selected Papers from the 7th World Conference on Computers in Education (WCCE'01), Copenhagen. Computers in Education 2001: Australian Topics*. Melbourne: Australian Computer Society, 8, pp.5-12.
Charles, D., Gabriel, M., Searcy, T., 2015. Adoption of Electronic Health Record Systems among U.S. Non- Federal Acute Care Hospitals: 2008-2014. *ONC Data Bried*, 1(23).
Checkland, P., Scholes, J., 1990. Soft Systems Methodology in Practice. *J. Wiley, Chichester*.
Chiang, M. F., Boland, M. V., Brewer, A., Epley, K. D., Horton, M. B., Lim, M. C., McCannel, C. A., Patel, S. J., Silverstone, D. E., Wedemeyer, L., Lum, F., 2011. Special Requirements for Electronic Health Records in Ophthalmology. *Ophthalmology*, 118(8), pp.1681-1687.
Cho, I., Kim, E., Choi, W. H., Staggers, N., 2016. Comparing usability testing outcomes and functions of six electronic nursing record systems. *International Journal of Biomedical Informatics*, 88, pp.78-85.
Chou, B., Warren, J., Parker, A., 2011. *EMRs: Their Benefits and Their Bugs.* Review of Optometry. [Online] Available at: https://www.reviewofoptometry.com/article/emrs-their-benefitsand-their-bugs [Accessed November 2019].
Cleveroad., 2019. Building a Custom HER System: Practical Examples, Cost, Compliance, and Features. [Online] Available at: https://www.cleveroad.com/blog/ehr-software-development [Accessed 1 March 2020].
CMS.gov., 2017. *Certified EHR Technology: Certified Electronic Health Record Technology (CEHRT)*. Centres for Medicare and Medicaid Services. [Online] Available at: https://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Certification.html [Accessed 24 March 2018].

Coffey, C., Wurster, L.A., Groner, J., Hoffman, J., Hendren, V., Nuss, K., Haley, K., Gerberick, J., Malehorn, B., Covert, J., 2015. A Comparison of Paper Documentation to Electronic Documentation for Trauma Resuscitations at a Level I Pediatric Trauma Center. *MEDLINE,* 41, pp.52-56.

Coyette, A., Kieffer, S., Vanderdonckt, J., 2007. Multi-fidelity prototyping of user interfaces. *Human Computer Interaction – INTERACT 2007.* Springer Berlin Heidelberg, 1, pp.150-164.

Craig, D., Farrell, G., 2010. Designing a physician-friendly interface for an electronic medical record system*. Proceedings of the Third International Conference on Health Informatics*. Spain. 2010. Healthinf. 1, pp.324-329.

Dabasia, P. L., Edgar, D. F., Garway-Heath, D. F., Lawrenson, J. G., 2014. A survey of current and anticipated use of standard and specialist equipment by UK optometrists. *Ophthalmic and amp; Physiological Optics*, 34, pp.592-613.

DeBry, P., 2001. Considerations for Choosing an Electronic Medical Record for an Ophthalmology Practice. *Archives of Ophthalmology*, 119(4), pp.590-596.

Deloitte., 2014. *Health care as a share of GDP: South Africa- Deloitte US.* 2015 health care outlook South Africa. [Online] Available at: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-2015-health-care-outlook-south-africa.pdf [Accessed 15 May 2018].

Dillon, A., 2001. Beyond Usability: Process, Outcome and Affect in human computer interactions. Canadian Journal of Information and Library Science, 26(4), pp.57-69.

Dix, A., 2009. Human-Computer Interaction. Encyclopedia of Database Systems. *Interacting with Computers.* Oxford University Press, Inc. New York, NY, USA, 22(1), pp.13-27.

DJSResearch, 2018. *Mini* Groups. DJSResearch. [Online] Available at: https://www.djsresearch.co.uk/glossary/item/Mini-Groups [Accessed 15 December 2018].

Drechsler, A., Hevner, A., 2016. A Four-Cycle Model of IS Design Science Research: Capturing the Dynamic Nature of IS Artifact Design. Parsons, J., Tuunanen, T., Venable, J. R., Helfert, M., Donnellan, B., Kenneally, J (EDs). *Breakthroughs and Emerging Insights from Ongoing Design Science Projects: Research-in-progress papers and poster presentations from the 11th International Conference on Design Science Research in Information Systems and Technology (DESRIST) 2016.*St. John, Canada*.* Pp.1-8.

Drew, M. R., Falcone B., Baccus W. L, 2018. What Does the System Usability Scale (SUS) Measure? Design, User Experience, and Usability: Theory and Practice. *7th International Conference, DUXU 2018, Held as Part of HCI International 2018*, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part I.

Edlow, R. C., Markus, G. R., 2008. State of the Profession: 2008. *Optometry- Journal of American Optometric Association,* 79(6), pp.337-343.

Edwards, P. J., Moloney, K. P., Jacko, J. A., and Sainfort, F., 2008. Evaluating usability of a commercial electronic health record: A case study. *International Journal of Human-Computer Studies*, 66, pp.718-728.

Elmansy, R., 2018. *Characteristics of Human-Centered Design*. Designorate. [Online] Available at: http://www.designorate.com/characteristics-of-human-centered-design/ [Accessed 13 July 2018].

Epstein, R. M., Street, R. L, Jr., 2007. Patient-centered communication in cancer care: promoting healing and reducing suffering. *Bethesda, MD: National Cancer Institute*. Report No.: NIH Publication No. 07-6225.

Freitas, G., 2018. *User Testing vs Usability Testing.* Strategy, Design and Development. Commonplaces Interactive. [Online] Available at: https://www.commonplaces.com/blog/user-testing-vs-usability-testing/ [Accessed 17 July 2018].

Fruhling, A., Sang, L., 2005. Assessing the Reliability, Validity and Adaptability of PSSUQ. *A Conference on a Human Scale. 11th Americas Conference on Information Systems.* Omaha, Nebraska, USA. August 11-14, 2005. AMCIS.

Fusch, P. L., Ness, L. R., 2015. Are We There Yet? Data Saturation in Qualitative Research. *The Qualitative Report.* Minnesota, USA. 20(9), pp.1408-1416.

Galitz, W. O., 2007. The Essential Guide to User Interface Design*: An Introduction to GUI Design Principles and Techniques*. 3rd ed. Indianapolis, Indiana: John Wiley & Sons.

Garets, D., Davis, M., 2006. Electronic Health Records vs. Electronic Medical Records: Yes, There is a Difference. *HIMSS ANALYTICS*. Chicago: Health Information Management Systems Society.
Garrett, J. J., 2011. *The Elements of User Experience: User-Centered Design for the Web and Beyond.* 2nd ed. California: New Riders.
Gkatzidou, V., Hone, K., Sutcliffe, L., Gibbs, J., Sadiq, S. T., Szczepura, A., Sonnenberg, P., Estcourt, C., 2015. User Interface design for mobile-based sexual health interventions for young people: Design recommendations from a qualitative study on an online Chlamydia clinical care pathway. *BMC Medical Informatics and decision Making.* 15(1), p.72.
Goldstein, M. K., Hoffman, B. B., Coleman, R. W., Shankar, R. D., O'Connor, M., Martins, S., Advani, A., Musen, M. A., 2002. Patient Safety in Guideline-Based Decision Support for Hypertension Management: ATHENA DSS. *Journal of the American Medical Informatics Association: JAMIA,* 9(6), pp.11-16.
Goodman, E., Kuniavsky, M., Moed, A., 2012. *Observing the User Experience.* A Practitioner's Guide to User Experience. 2nd Edition. San Francisco, CA: Morgan Kaufmann Publishers.
Gregg, D., Kulkarni, U., Vinze, A., 2001. Understanding the Philosophical Underpinnings of Software Engineering Research in Information Systems. *Information Systems Frontiers. Springer Link,* 3(2), pp.169-183.
Gregor, S., Hevner, A. R., 2013. Positioning and presenting design science research for maximum impact. *MIS quarterly*, 37(2), pp.337-356.
Grudin, J., 1989. The Case against User Interface Consistency. *Communications of ACM*, 32(10), pp.1164-1173.
Hampton-Smith, S., 2017. *The Designer's Guide to Gestalt Theory.* Graphic Design: Creative Bloq. [Online] Available at: https://www.creativebloq.com/graphic-design/gestalt-theory-10134960 [Accessed 10 May 2018].
Hassenzahl, M., Tractinsky, N., 2006. User experience - a research agenda. *Behaviour & Information Technology*, 25(2), pp.91-97.
Haux, R., 2005. Health Information Systems: Past, Present and Future. *International Journal of Medical Informatics*, 75(3-4), pp.268-281.
Hayrinen, K., Saranto, K., Nyakanen, P., 2008. Definition, structure, content, use and impacts of electronic health records: A review of the research literature. *International Journal of Medical Informatics*,(5), pp.291-304.
Hedges, L., 2019. *EHR vs. EMR- What's the Difference?* Software Advice. [Online] Available at: https://www.softwareadvice.com/resources/ehr-vs-emr-whats-difference/ [Accessed 6 November 2019].
Heeks, R., 2005. Health Information Systems: Failure, Success and Improvisation. *International Journal of Medical Informatics*, 75(2), pp.125-137.
Heidarian, A., Mason, D., 2013. Health Information Technology Adoption In New Zealand Optometric Practices. *Clinical and Experimental Optometry*, 96(6), pp.557-565.
Helfert, M., Donnellan, B., Ostrowski, L., 2012. The case for design science utility and quality - Evaluation of design science artifact within the sustainable ICT capability maturity framework. *Systems, Signs & Actions: An International Journal on Information Technology Action, Communication and Workpractices*, 6(1), pp.46–66.
Henning, G., 2012. *Global ICT Trends in Health.* DocPlayer. [Online] Available at: http://docplayer.net/8878349-Global-ict-trends-in-health-presented-by-gerrit-henning-ceo-amethst-pty-ltd.html [Accessed 16 May 2018].
Heo, J., Ham, D. H., Park, S., Song, C., Yoon, W. C., 2009. A Framework for Evaluating the Usability of Mobile Phones based on Multi-level, Hierarchical Model of Usability Factors. *Interacting with Computers*, 21(4), pp.263-275.
Hermawati, S., Lawson, G., 2016. *Establishing usability heuristics for heuristics evaluation in a specific domain: Is there a consensus?* ScienceDirect. [Online] Available at: https://www.sciencedirect.com/science/article/pii/S0003687015301162 [Accessed 15 April 2019].
Hevner, A. R., 2007. A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*, 19(2), p.4.

Hevner, A.R., March, S. T., Park, J., Ram, S., 2004. Design Science in Information Systems Research. *MIS Quarterly*, 28(1), pp.75-105.
Hevner, A., Chatterjee, S., 2010. Design Science Research in Information Systems. *Design Research in Information Systems*, pp.9-22, Springer.
HPCSA., 2014. *Professional Boards: Overview*. Health Professions Council of South Africa. [Online] Available at: <http://www.hpcsa.co.za/board_overview.php> [Accessed 1 April 2014].

Huang, H., Lai, H. H., 2008. Factors influencing the usability of icons in the LCD touchscreen. *Science Direct*, 29(4), pp.339-344.
Hwang, K., 2016. Nielsen's Usability Heuristics Applied to Electronic Health Records. *Verywell*. [Online] Available at: https://www.verywell.com/nielsens-usability-heuristics-applied-1739137 [Accessed 14 May 2017].
Hyppönen, H., Reponen, J., Lääveri, T., Kaipio, J., 2013. User experiences with different regional health information exchange systems in Finland. *International Journal of Medical Informatics*, 83(1), pp.1-18.
IMSANZ (International Medicine Society of Australia and New Zealand)., 2018. *What is a General Physician?* IMSANZ. [Online] Available at: https://www.imsanz.org.au/about-us/what-is-a-general-physician [Accessed 15 March 2018].
ISO (International Organisation for Standardisation)., 2018. *ISO: 9241-11: 2018.* Ergonomics of human-system interaction -- Part 11: Usability: Definitions and concepts. Geneva: International Organisation for Standardisation.
ISO (International Organisation for Standardisation)., 2019. *ISO: 9241-210: 2019*. Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. Geneva: International Organisation for Standardisation.
Jens, S., 2011. *Special Edition EHR Consideration for Today's O.D.* Optometric Management. [Online] Available at: https://www.optometricmanagement.com/supplements/2011/october-2011/adapting-to-the-changing-landscape-of-optometry/font-color-000000-special-edition-2011-font-(8) [Accessed 18 August 2018].
Johnson, J., 2014. *Designing With The Mind In Mind.* 2nd ed. Elsevier: Morgan Kaufman.
Jokela, T., Koivumaa, J., Pirkola, J., Salminen, P., Kantola, N., 2006. Methods for Quantitative Usability Requirements: a Case Study on the Development of the User Interface of a Mobile Phone. *Personal and Ubiquitous Computing*, 10, pp.345-355.
Kearns, M., 2014. *8 usability traits that define the ideal EHR*. [Online] Available at: http://www.medicalpracticeinsider.com/best-practices/8-usability-traits-defineideal-ehr [Accessed 14 May 2018].
Kelder, J., Marshall, P., Perry, A., 2005. Constructionism with a Twist of Pragmatism: A Suitable Cocktail for Information Systems Research. *16th Australasian Conference on Information Systems Social Constructionism and Pragmatism in IS.* Association for Information Systems AIS Electronic Library (AISeL). ACIS 2005 Proceedings. 29 Nov-2 Dec 2005. Sydney, Australia.
Kendall, K. E., Kendall, J. E., 2013. *Systems Analysis and Design*. 9th ed. Cloth, New Jersey: Prentice Hall.
Kent State University., 2019. *Human-Centered Vs. User-Centered UX Design.* User Experience Design. [Online] Available at: https://onlinedegrees.kent.edu/ischool/user-experience-design/community/human-centered-vs-user-centered-design [Accessed 24 August 2019].
Khorasani, R., Hentel, K., Darer, J., Langlots, C., Ip, I. K., Manaker, S., Cardella, J., Min, R., Seltzer, S., 2014. Ten Commandments for Effective Clinical Decision Support for Imaging: Enabling Evidence-Based Practice to Improve Quality and Reduce Waste. *Health Care Policy and Quality*, 203(5), pp.945-51.
Kildal, J., Paasovaara, S., Aaltonen, V., 2012. Kinetic Device: Designing Interactions with a Deformable Mobile Interface. *Proceedings from CHI '12 Extended Abstracts on Human Factors In Computing Systems.* Austin, Texas, USA. May 5-10, 2012. ACM. New York, NY, USA. Pp.1871-1876.
Knottnerus, J.A., 1991. Medical decision making by general practitioners and specialists. *Family Practice*, 8(4), pp.305-307.

Kohli, R., Tan, S. S., 2016. Electronic Health Records: How Can IS Researchers Contribute To Transforming Healthcare? *MIS Quarterly*, 40(3), pp.553-57.
Krueger, R. A., Casey, M. A., 2009. *Focus Groups: A Practical Guide for Applied Research*. 4th edition. CA: Sage, Publishing.
Kruse, C. S., Kothman, K., Anerobi, K., Abanaka, L., 2016. Adoption Factors of the Electronic Health Record: A Systematic review. *JMIR Medical Informatics*, 4(2):e19.
Kumar, A., Maskara, R., Maskara, S., Chiang, I., 2014. Conceptualization and application of an approach for designing healthcare software interfaces. *Journal of Biomedical Informatics*, 49, pp.171-186.
Kuniavsky, M., 2003. *Observing the User Experience: A Practitioners Guide to User Research*. San Francisco: Morgan Kaufmann Publishers.
Lazar, J., Feng, J. H., Hochheiser, H., 2010. R*esearch Methods in Human-Computer Interaction.* Chichester, UK: John Wiley & Sons Inc.
Levy, M., Hirschheim, R., 2012. Removing The Positivist Straight Jacket From Information Systems Design Science Research. *ECIS 2012 - Proceedings of the 20th European Conference on Information Systems.* Association for Information Systems AIS Electronic Library (AISeL).
Lewis, J. R., 1995. IBM Computer Usability Satisfaction Questionnaires: Psychometric Evaluation and Instructions for Use. *International Journal of Human-Computer Interaction*, 7(1), pp.57-78.
Linder, J. A., Schnipper, L. J., Tsurikova, R., Melnikas, A. J., Volk, A. L., Middleton, B., 2006. Barriers to Electronic Health Record Use during Patient Visits. *Journal of the American Informatics Association 2006 Symposium Proceedings*, pp.499-503.
Love, S., 2005. *Understanding Mobile Human-Computer Interaction*. Burlington, MA: Elsevier Ltd.
Lowry, S. Z., Quinn, M. T., Ramaiah, M., 2012. *Human Factors Guide to Enhance EHR Usability of Critical User Interactions when Supporting Pediatric Patient Care.* NIST Interagency/Internal Report (NISTIR)-7865.
Lowry, S. Z., Ramaiah, M., Patterson, E. S., Brick, D., Gurses, A. P, Ozok, A., Simmons, D., Gibbons, M. C., 2014. *Integrating Electronic Health Records into Clinical Workflow: An Application of Human Factors Modelling Method to Ambulatory Care*. NIST Interagency/Internal Report (NISTIR)-7988.
Ludwick, D. A., Doucette, J., 2009. Adopting electronic medical records in primary care: Lessons learned from health information systems implementation experience in seven countries. *International Journal of Medical Informatics*, 78, pp.22-31.
Luna, D. R., Rizzato Lede, D. A., Otero, C. M., Risk, M. R., Gonzalez, F., de Quiros, B., 2017. User-centered design improves the usability of drug-drug interaction alerts: Experimental comparison of interfaces. *Journal of Biomedical Informatics*, 66, pp.204-213.
Maasen, H., 2008. *UX Design-Planning Not One Man Show.* [Online] Available at: http://boxesandarrows.com/ux-design-planning-not-one-man-show/ [Accessed 1May 2018].
Macintosh, 2013. *OS X Human Interface Guidelines: The Philosophy of UI Design: Fundamental Principles.* [Online] Available at: https://developer.apple.com/library/mac/documentation/UserExperience/Conceptual/OSXHIGuidelines/index.html#//apple_ref/doc/uid/20000957-CH3-SW1 [Accessed 3 May 2018].
Maguire, M., Bevan, N., 2002. User Requirements Analysis. *Proceedings of IFIP 17th World Computer Congress*, 25-30 August 2002, Montreal, Canada. Kluwer Academic Publishers, pp.133-148.
March, S., Smith, G., 1995. Design and Natural Science Research on Information Technology. *Decision Support Systems*, 15(4), pp.251-266.
Mason, R. O., Mitroff, I. I., 1973. A program for research on management information systems. *Management Science*, 9(5), pp.475-48.
McVeigh, F. L., Tarbett, A. K., Betts, A. M., Boal, T. R., 2008. Efficiency of automation and electronic health records in optometric practice. *Optometry*, 79(1), pp.43-49.
McVeigh, K. H., Newton-Dame, R., Perlman, S., Chernov, C., Thorpe, L., Singer, J., Greene, C., 2013. *Developing an Electronic Health Record-Based Population Health Surveillance System*. New York: New York City Department of Health and Mental Hygiene.

Medjobnetwork.com, 2016. *Mitigating Burnout & Improving EHR Usability with Physician Feedback.* [Online] Available at: http://content.medjobnetwork.com/blog/2016/08/mitigating-burnout-improvingehr-usability-with-physician-feedback/ [Accessed 14 May 2018].

Meinert, D. B., 2005. *Resistance to Electronic Medical Records (EMRs): A Barrier to Improved Quality of Care.* Issues in Informing Science and Information Technology. [Online] Available at: http://proceedings.informingscience.org/InSITE2005/I41f100Mein.pdf [Accessed 2 May 2018].

Middleton, B., Bloomrosen, M., Dente, M. A., Hashmay, B., Koppel, R., Overhage, J. M., Payne, T. H., Rosenbloom, S. T., Weaver, C., Zhang, J., 2013. *Enhancing Patient Safety and Quality of Care by Improving the Usability of Electronic Health Record Systems: Recommendations from AMIA.* Journal of the American Informatics Association, 20(1), pp.e2-e8.

Miller, R. H., Sim, I., 2004. Physicians' Use Of Electronic Medical Records: Barriers And Solutions. *Health Affairs*, April, 23(2), pp.116-126.

Misfud, J., 2015. *Usability Metrics – A Guide To Quantify The Usability Of Any System.* UsabilityGeek. [Online] Available at: https://usabilitygeek.com/usability-metrics-a-guide-to-quantify-system-usability/ [Accessed 8 November 2018].

Moores, T. T., 2012. Towards an integrated model of IT acceptance in healthcare. *Decision Support Systems*, 53(3), pp.507-516.

Morgan, D., 2011. *Are We Too Limited on Group Size? What About 2 or 3 Person "Mini-Groups"?* MethodSpace. [Online] Available at: https://www.methodspace.com/are-we-too-limited-on-group-size-what-about-2-or-3-person-mini-groups/ [Accessed 15 December 2018].

Morrissey, J., 2005. This time they really mean it. *Modern Healthcare*, 35(7), pp.42-43, 46-50.

Morville, P., 2004. *User Experience Design*. Semantic Studios. [Online] Available at: http://semanticstudios.com/publications/semantics/000029.php [Accessed 1 May 2018].

Mosaly, P. R., Mazur, L., Hoyle, L., Marks, L. B., 2015. Usability Evaluation of Electronic Medical Record System With Radiation Oncologist Using Subjective and Objective Measures. *Proceedings of the American Society for Radiation Oncology 57th Annual Meeting ASTRO's 57th Annual Meeting*, 93(3), p.E387.

Murphy, L. A., 2012. *The State of EHR in Optometry*. Optometrists are steadily adopting electronic health records. Is it time to pick up the pace? Optometric Management. [Online] Available at: https://www.optometricmanagement.com/issues/2012/january-2012/the-state-of-ehr-in-optometry [Accessed 18 August 2018].

Myint, J., Edgar, D. F., Kotecha, A., Murdoch, I. E., Lawrenson, J. G., 2011. A national survey of diagnostic tests reported by UK community optometrists for the detection of chronic open angle glaucoma. *Ophthalmic Physiological Optics*, 31(4), pp.353-359.

Ng, V., Tilliss, J., 2018. *Balancing Aesthetics and Usability in Medical user Interface Design: 9 Key Trends.* Emergo. [Online] Available at: https://www.emergobyul.com/blog/2018/07/balancing-aesthetics-and-usability-medical-user-interface-design-9-key-trends [Accesses 19 September 2018].

Nielsen, J. 1993. *Usability Engineering*. San Francisco, CA: Morgan Kaufmann Publishers.

Nielsen, J., 1995. *10 Usability Heuristics for User Interface Design*. Nielsen Norman Group. [Online] Available at: https://www.nngroup.com/articles/ten-usability-heuristics/ [Accessed 2 May 2018].

Nielsen, J., 2012. Usability 101: Introduction to Usability. *Nielsen Norman Group,* Volume 1.

Noraziani, K., Ain, A.N., Azhim, M.Z., Eslami, S.R., Drak, B., Ezat, S. and Akma, S.N., 2013. An Overview of Electronic Medical Record Implementation in Healthcare System: Lesson to Learn. *World of Applied Sciences Journal*, 25(2), pp.323-332.

Nunamaker, J. F., Chen, M., 1990. Systems Development in Information Systems Research. In System Sciences IEEE. *Proceedings of the Twenty-Third Annual Hawaii International Conference*, 3, pp.89-106.

Nwiabu, N., Adeyanju, I., 2012. User Centred Design Approach to Situation Awareness. *International Journal of Computer Applications*, 49(17), pp.26-30.

ONCHT., 2010. Health information technology: initial set of standard, implementation specifications, and certification criteria for electronic health record technology. Final rule. Office of the National Coordinator for Health Information Technology, Department of Health and Human Services. *Federal Register,* 75(8), pp.2013-2047.

Padilla, M. A., Stefano, D. F., 2009. *A Snapshot of Optometry Around the World*. Review of Optometry. [Online] Available at: https://www.reviewofoptometry.com/article/a-snapshot-of-optometry-around-the-world [Accessed 6 November 2019].

Pandit, R. R., Boland, M. V., 2013. The Impact of an Electronic Health Record Transition on a Glaucoma Subspecialty Practice. American Academy of Ophthalmology. *Ophthalmology,* 120(4), pp.753-760.

Parchman, M. L., Zeber, J. E,. Palmer, R. F., 2010. Participatory decision making, patient activation, medication adherence, and intermediate clinical outcomes in type 2 diabetes: a STARNet study. *Annals of Family Medicine,* 8(5), pp.410–417.

Pare, G., Raymond, G., Oritz de Guinea, A., Poba-Nzaou, P., Trudel, M., Marsan, J., Micheneau, T., 2014. *Barriers to organizational adoption of EMR systems in family physician practices: A mixed-methods study in Canada*. International Journal of Medical Informatics, 2 June, Volume 83, pp.548-558.

Parush, A., Lorenco-Levin, M., Campbell, C., 2014. *Dual Patient – Healthcare Provider Experience Mapping and Implications for Information Technology Deployment and Clinic Layout*. In: V. Duffy and N. Lightner, eds. 2014. Advances in Human Aspects of Healthcare. Published Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics. Massachusetts: AHFE Conference 2014.

Patel, V. L., Kushniruk, A.W., 1998. Interface design for health care environments: The role of cognitive science. *Proceedings of the AMIA 1998 Annual Symposium,* pp.29-37.

Payne, T. H., Corley, S., Cullen, T. A, Gandhi, T. K, Harrington, L., Kuperman, G. L., Mattinson, J. E., McCallie, D. P., McDonald, C. J., Tang, P. C., Tierney, W. M., Weaver, C., Weir, C. R., Zaroukian, M. H., 2015. Report of the AMIA EHR-2020 Task Force on the status and future direction of EHRs. *Journal of the American Informatics Association,* 22(5), pp.1102–1110.

Peffers, K., Tuuanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V., Bragge, J., 2006. The Design Science Research Process: A Model for Producing and Presenting Information Systems Research. In: *Proceedings of the First International Conference on Design Science Research in Information Systems and Technology*, 24-25 February, Claremont, CA, pp.86-106.

Peffers, K., Tuunanen, T., Rothenberger, M. A., Chatterjee, S., 2007. A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, 24(3), pp.45-77.

Peute, L. W., Driest, K. F., Marcilly, R., Bras da Costa, S., Beuscart-Zephir, M., Jaspers, M. W. M., 2013. A Framework for Reporting on Human Factor/Usability Studies of Health Information Technologies. *Context-Sensitive Health Informatics: Human and Sociotechnical Approaches*, 194, pp.54-60.

Pickwell, D., 1987. World Optometry. *Ophthalmic and Physiological Optics*, 7(2), pp.115-119.

Pirkkalainen, H., 2015. Dealing with emergent design science research projects in IS. *At the Vanguard of Design Science: First Impressions and Early Findings from Ongoing Research Research-in-Progress Papers and Poster Presentations from the 10th International Conference, DESRIST 2015*. Dublin, Ireland, 20-22 May. DESRIST 2015.

Poissant, L., Pereira, J., Tam, R., 2005. The Impact of Electronic Health Records on Time Efficiency of Physicians and Nurses: A Systematic Review. *Journal of the American Medical Informatics Association,* 12(5), pp.505-516.

Prestopnik, N., 2013. *Design Science in Human-Computer Interaction: A Model and Three Examples.* Ph.D. School of Information Studies, Syracuse University.

Pries-Heje, J., Baskerville, R., Venable, J. R., 2008. Strategies for Design Science Research Evaluation. *Proceedings of the 16th European Conference on Information Systems (ECIS),* 87.

Purao, S., 2013. Truth or Dare: The Ontology Question in Design Science Research. *Journal of Database Management*, 24(3), pp.1-16.

Quesenbery, W., 2001. *What does Usability Mean: Looking beyond 'Ease of Use'.* WQusability. [Online] Available at: http://www.wqusability.com/articles/more-than-ease-of-use.html [Accessed 5 May 2018].

Quinones, D., Rusu, C., 2017. How to develop usability heuristics: A systematic literature review. *Computer Standards and Interfaces,* 53, pp.89-122.

Ratwani, R. M., Fairbanks, R. J., Hettinger, A. Z., Benda, N. C., 2015. Electronic health record usability: analysis of the user-centred design processes of eleven electronic health record vendors. *Journal of the American Medical Informatics Association,* 22(6), pp.1179-1182.

Ratwani, R. M., 2017. Electronic Health Records and Improved Patient Care: Opportunities for Applied Psychology. *Association for Psychological Science,* 26(4), pp.359-365.

Reed, P., Holdaway, K., Isensee, S., Buie, E., Fox, J., Williams, J., Lund, A., 1999. User interface guidelines and standards: progress, issues, and prospects. *Interacting with Computers,* 12(2), pp.119-142.

Rittel, H., Webber, M., 1984. *Planning problems are wicked problems.* N.Cross (Ed.). Developments in Design Methodology. Chichester, UK: John Wiley & Sons, pp.135-144.

RO Staff., 2019. *Yes, Patient Educational Videos Do Work.* Review of Optometry. [Online] Available at: https://www.reviewofoptometry.com/article/yes-patient-education-videos-do-work [Accessed 5 November 2019].

Rogers, Y., Sharp, H., Preece, J., 2011. *Interaction design: beyond human-computer interaction.* Beyond Human-Computer Interaction. 3rd ed. United Kingdom, John Wiley & Sons Ltd.

Roman, L. C., Ancker, J. S., Johnson, S. B., Senathirajah, Y., 2017. Navigation in the electronic health record: A review of the safety and usability literature. *Journal of Biomedical Informatics,* 67, pp.69-79.

Rose, A. F., Schnipper, J. L., Park, E. R., Poon, E. G., Li, Q., Middleton, B., 2005. Using Qualitative Studies to Improve the Usability of an EMR. *Journal of Biomedical Informatics*, 38, pp.51-60.

Rosenbloom, S. T., Crow, A. N., Blackford, J. U., Johnson, K. B., 2007. Cognitive factors influencing perceptions of clinical documentation tools. *Journal of Biomedical Informatics,* 40, pp.106-113.

Rotolo, T., 2017. *SUS and PSSUQ: Quantifying user experiences*.TryMyUIBlog. [Online] Available at: https://www.trymyui.com/blog/2017/02/24/sus-pssuq-website-usability-surveys/ [Accessed 25 May 2019].

Saffer, D., 2009. *Designing for Interaction: Creating Smart Applications and Clever Devices*. 2nd ed. Berkeley: New Riders.

Saleem, J. J., Patterson, E.S., Mitlitello, L., Render, M. L., Orshansky, G., Asch, S. M., 2005. *Exploring Barriers and Facilitators to the Use of Computerized Clinician reminders*. Journal of the American Medical Informatics Association. [Online] Available at: https://academic.oup.com/jamia/article/12/4/438/927335 [Accessed 14 May 2018].

Saleem, J. J., Russ, A. L., Justice, C. F., Hagg, H., Ebright, P. R., Woodbridge, A., Doebbeling, B. N., 2009. Exploring the persistence of paper with the electronic health record. *International Journal of Medical Informatics,* 12(4), pp.438-447.

Saunders, M., Lewis, P., Thornhill, A. 2009. *Research Methods for* B*usiness Students*. Essex, England: Prentice Hall.

Sauro, J., 2011. *Measuring Usability with the System Usability Scale (SUS).* Measuring Usability. [Online] Available at: http://www.measuringusability.com/sus.php [Accessed 23 August 2018].

Sauro, J., 2013. 10 Things to Know About the System Usability Scale (SUS). Measuring Usability. [Online] Available at: https://measuringu.com/10-things-sus/ [Accessed 10 October 2018].

Schlossman, D., Schumacher, R. M., 2014. *HIMSS EHR Usability Pain Point Survey Results 2014.* [Online] Available at: http://www.himss.org/sites/himssorg/files/FileDownloads/Physician%20Webinar%20Series%202013-2014%20Schlossman%20&%20Schumacher.pdf [Accessed 15 May 2018].

Scholl, J., Syed-Abdul, S., Ahmed, L. A., 2011. A case study of an EMR system at a large hospital in India: Challenges and strategies for successful adoption. *Journal of Biomedical Informatics,* 44(6), pp.958-967.

Schumacher, R. M., 2010. Commentary: Electronic Health Records and Human Performance. *Journal of Oncology Practice,* 6(3), pp.125-126.

Schumacher, R. M., 2010. Electronic Health Records: Physicians' Perspective on Usability. *54th Human Factors and Ergonomics Society Annual Meeting 2010, HFES 2010,* 2, pp.816-820.

Senathirajah, Y., Kaufman, D., Bakken, S., 2014. The clinician in the driver's seat: Part 2 – intelligent uses of space in a drag/drop user-composable electronic health record. *Journal of Biomedical Information,* 52, pp.177-188.

Shneiderman, B., 2004. Designing For Fun: How Can We Design User Interfaces To Be More Fun? *Interactions-Funology*, 11(5), pp.48-50.
Shneiderman, B., 2011. Tragic Errors: Usability and Electronic Health Records. *Interactions*, 18(6), pp.60-63.
Simon, H. A., 1996. *Sciences of the Artificial. Cambridge*, MA: MIT Press.
Sittig, D. F., Kuperman, G. J., Fiskio, J., 1999. Evaluating Physician Satisfaction Regarding User Interactions with an Electronic Medical Record System. *AMIA Annual Symposium*, 8280, pp.400-404.
Smelcer, J. B., Miller-Jacobs, H., Kantrovich, L., 2009. Usability of Electronic Medical Records. *Journal of Usability Studies*, 4(2), pp.70-84.
SAOA., 2019. *About SAOA.* South African Optometric Association. [Online] Available at: https://www.saoa.co.za/About [Accessed 6 November 2019].
Stockbridge, L., Mughal, A., 2007. *Experience Lab: Design Guidelines/Mobile Phones*. Serco. [Online] Available at: http://www.serco.com/Images/Mobile%20Phone%20Design%20Guidelines%20(Jun%20 07)tcm3-32584.pdf [Accessed 19 May 2019].
Stolee, P., McKillop, I., McMurray, J., Strong, J. G., Jones, D. A., Hildebrand, J. M., 2011. Eye-T: Information technology adoption and use in Canada's optometry practices. *Journal of American Optometric Society*, 83(3), pp.166-174.
Street, R. L, Jr., Haidet, P., 2011. How well do doctors know their patients? Factors affecting physician understanding of patients' health beliefs. *Journal of General Internal Medicine*, 26(1), pp.21-27.
Strizver, I., 2019. *Fontology: Serif vs. Sans for Text in Print.* Fonts.com. [Online] Available at: https://www.fonts.com/content/learning/fontology/level-1/type-anatomy/serif-vs-sans-for-text-in-print [Accessed 17 June 2019].
Subramanya, S. R., Yi, B. K., 2008. Enhancing the User Experience in Mobile Phones. *IEEE Computer Society Press*, 40(12), pp.114-117.
Tang, P. C., Ash, J. S., Bates, D. W., Overhage, J. M., Sands, D. Z., 2006. Personal health records: Definitions, benefits, and strategies for overcoming barriers to adoption. *Journal of the American Medical Informatics Association*, 13(2), pp.121-126.
Taylor, B., Kermode, S., Roberts, K., 2007. *Research in Nursing and Health Care: Evidence for Practice*. 3rd ed. Australia: Thompson.
The Pew Charitable Trusts., 2016. *How to Improve Electronic Health Record Usability and Patient Safety*. [Online] Available at: https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2016/09/how-to-improve-electronic-health-record-usability-and-patient-safety [Accessed 1 May 2018].
Thomas, N., 2015. *How To Use The System Usability Scale (SUS) To Evaluate The Usability of Your Website.* UsabilityGeek. [Online] Available at: https://usabilitygeek.com/how-to-use-the-system-usability-scale-sus-to-evaluate-the-usability-of-your-website/ [Accessed 7 November 2018].
Thomas, V., Remy, C., Bates, O., 2017. The Limits of HCD: Reimagining the Anthropocentricity of ISO 9241-210. *Proceedings of the 2017 Workshop on Computing Within Limits*. Santa Barbara, California. June 22–24, 2017, Santa Barbara. 1, pp.85-92.
Tognazzini, B., 2014. *First Principles of Interaction Design: Revised and Expanded*. Interaction Design Solutions for the Real World. [Online] Available at: http://asktog.com/atc/principles-of-interaction-design/#visibleInterfaces [Accessed 2 May 2018].
Tremblay, M. C., Hevner, A. R., Berndt, D. J., 2010. Focus Groups for Artifact Refinement and Evaluation in Design Research. *Communications of the Association for Information Systems*, 26(27), pp.599-618.
Tullis, T., Albert, B., 2008. *Measuring the User Experience: Collecting, Analysing, and Presenting Usability Metrics.* Burlington, MA: Morgan Kaufmann Publishers.
Tutty, M. A., Carlasare, L. E., Lloyd, S., Sinsky, C. A., 2019. The complex case of EHRs: examining the factors impacting the EHR user experience. *Journal of the American Medical Informatics Association*, 26(7), pp.673-677.
Usability-BoK., 2012. *Contextual Inquiry.* Usability Body of Knowledge. [Online] Available at: http://usabilitybok.org/contextual-inquiry [Accessed: 21 June 2018].

Usability.gov., 2018. *Information Architecture Basics*. [Online] Available at: https://www.usability.gov/what-and-why/information-architecture.html [Accessed 8 May 2018].
Vaishnavi, V., Kuechler, B., 2004. *Design Science Research in Information Systems.* Association for Information Systems. [Online] Available at: http://desrist.org/desrist/content/design-science-research-in-information-systems.pdf [Accessed 16 November 2018].
Vaishnavi, V., Kuechler, W., 2015. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. Florida, New York: Taylor & Francis Group.
Van Kleef, E., van Trijp, H. C. M., Luning, P., 2005. Consumer Research in the Early Stages of New Product Development: A Critical Review of Methods and Techniques. *Food Quality and Preference*, 16, pp.181-201.
Vaughn, V. M., Linder, J. A., 2018. *Thoughtless design of the electronic health record drives overuse, but purposeful design can nudge improved patient care.* BMJ Quality and Safety Online First. [Online] Available at: https://qualitysafety.bmj.com/content/qhc/early/2018/03/24/bmjqs-2017-007578.full.pdf [Accessed 20 August 2018].
Venable, J., Pries-Heje, J., Baskerville, R., 2012. A Comprehensive Framework for Evaluation in Design Science Research. In: *International Conference on Design Science Research in Information Systems*. Berlin, Heidelberg: Springer, pp.423-438.
Venable, J., Pries-Heje, J., Baskerville, R., 2016. FEDS: a Framework for Evaluation in Design Science Research. *European Journal of Information Systems*, 25(1), pp.77-89.
Viitanen, J., Hyppönen, H., Laaveri, T., Vanska, J., Reponen, J., Winblad, I., 2011. National questionnaire study on clinical ICT systems proofs: Physicians suffer from poor usability. *International Journal of Medical Informatics*, 80(10), pp.708-725.
Wachter, R., Goldsmith, J., 2018. *To Combat Physician Burnout and Improve care, Fix the Electronic Health Record.* Harvard Business Review Technology. [Online] Available at: https://hbr.org/2018/03/to-combat-physician-burnout-and-improve-care-fix-the-electronic-health-record [Accessed 16 November 2019].
WCO., 2019. *Country Members.* World Council of Optometry. [Online] Available at: https://worldcouncilofoptometry.info/country-members/ [Accessed 6 November 2019].
Weaver, K., Olsen, J. K., 2006. Understanding paradigms used for nursing research. *Journal of Advanced Nursing*, 53(4), pp.459-469.
Weber, S., 2010. *Design Science Research: Paradigm or Approach?* AMCIS 2010 Proceedings. [Online] Available at: http://aisel.aisnet.org/amcis2010/214 [Accessed 25 April 2018].
Whetton, S., 2005. *Health Informatics: A socio-technical perspective.* New York: Oxford University Press.
Wickens, C.D., Lee, J.D., Liu, Y., Gordon-Becker, S., 2004. *An Introduction to Human Factors Engineering*. 2nd ed. Upper Saddle River, NJ: Pearson Prentice Hall.
Wiklund, M. E., 1998. *Making Medical Device Interfaces More User-Friendly*. Medical Device and Diagnostic Industry. [Online] Available at: https://www.mddionline.com/making-medical-device-interfaces-more-user-friendly [Accessed 18 September 2018].
Wiklund, M. E., Kendler, J., Hochberg, L., Weinger, M., 2015. *Technical Basis for User Interface Design of Health IT.* NIST GCR 15-996. [Online] Available at: http://dx.doi.org/10.6028/NIST.GCR.15-996 [Accessed 3 August 2018].
Wilbanks, B. A., Moss, J., 2018. Evidence-Based Guidelines for Interface Design for Data Entry in Electronic Health Records. *Informatics, Nursing*, 36(1), pp.35-44.
Woo, H. E., Pfeffer, M. A., 2013. *Clinical Vignette. A Brief Introduction To Electronic Health Records And Associated Terminology.* Proceedings of UCLA Healthcare, 17. [Online] Available at: https://proceedings.med.ucla.edu/wp-content/uploads/2016/11/A-Brief-Introduction-To-Electronic-Health-Records-edited.pdf [Accessed 26 March 2018].
World Health Organisation (WHO)., 2012. *National eHealth Strategy Toolkit: Overview.* World Geneva: Health Organisation and International Telecommunication Union. [Online] Available at: https://www.who.int/ehealth/publications/overview.pdf [Accessed 29 July 2019].
World Health Organisation (WHO)., 2019. *The World Council of Optometry (WCO).* Global Health Workforce Alliance. [Online] Available at: https://www.who.int/workforcealliance/countries/en/ [Accessed 29 October 2019].

Wright, G., O'Mahony, D., Cilliers, L., 2017. *Electronic Health Information Systems For Public Health Care On South Africa: A Review Of Current Operational Systems.* Journal of Health Informatics in Africa.

Xu, L., Wen, D., Zhang, X., Lei, J., 2016. *Assessing and comparing the usability of Chinese EHRs used in two Peking University hospitals to EHRs used in the US: A method of RUA.* International Journal of Medical Informatics, 89, pp.32-42.

Zahabi, M., Kaber, D.B., 2015. Usability and Safety in Electronic Medical Records Interface Design: A Review of Recent Literature and Guideline Formulation. *Human Factors*, 57(5), pp.805-34.

Zaroukian, M. H., 2013. *Assessing and Advancing EHR Usability*. Healthcare Information and Management Systems Society. Amsterdam: Europe. 31 October-1 November 2013. Amsterdam: HIMSS.

Zhang, J., Walji, M. F., 2011. TURF: Toward a unified framework of EHR usability. *Journal of Biomedical Informatics*, 44, pp.1056-1067.

Zheng, K, Padman R, Johnson M. P., Diamond, H. S., 2009. An interface-driven analysis of user interactions with an electronic health records system. *Journal of American Medical Informatics Association*, 16(2), pp.228-237.

Appendices

Appendix A. Consent Form

RHODES UNIVERSITY

INFORMED CONSENT FORM

Department of Information Systems

Research Project Title:	**Guidelines for the User Interface Design of Electronic Medical Records in Optometry.**
Principal Investigator(s):	**Dina Nathoo.**

Participation Information
• I understand the purpose of the research study and my involvement in it • I understand the risks of participating in this research study • I understand the benefits of participating in this research study • I understand that I may withdraw from the research study at any stage without any penalty • I understand that participation in this study is done on a voluntary basis • I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential • I understand that I will receive no payment for participating in this study

Information Explanation
The above information was explained to me by: Dina Nathoo
The above information was explained to me in: ☐English ☐Afrikaans ☐isiXhosa ☐isiZulu ☐Other:

and I am in command of this language **OR**, it was comprehensibly translated to me by: [name of translator]

Voluntary Consent		
I, [leave space for full name of participant], hereby voluntarily consent to participate in the above-mentioned research.		
Signature:	**OR**, right hand thumb print Witness signature:	Date: / /

Investigator Declaration	
I, Dina Nathoo, declare that I have explained all the participant information to the participant and have truthfully answered all questions ask me by the participant.	
Signature: 	Date: / /

Translator Declaration	
I, [full name of translator], declare that I translated a factually correct version of: 1. all the contents of this document 2. all questions posed by the participant 3. all answers given by the investigator In addition, I declare that all information acquired by me regarding this research will be kept confidential.	
Signature	Date: / /

Appendix B. Demographics Questionnaire

RHODES UNIVERSITY

Department of Information Systems

User Profile Survey

Instructions: Please answer each question unless stated otherwise. All answers will be considered as confidential.

DATE:

NAME/CODE:

Demographic Questions

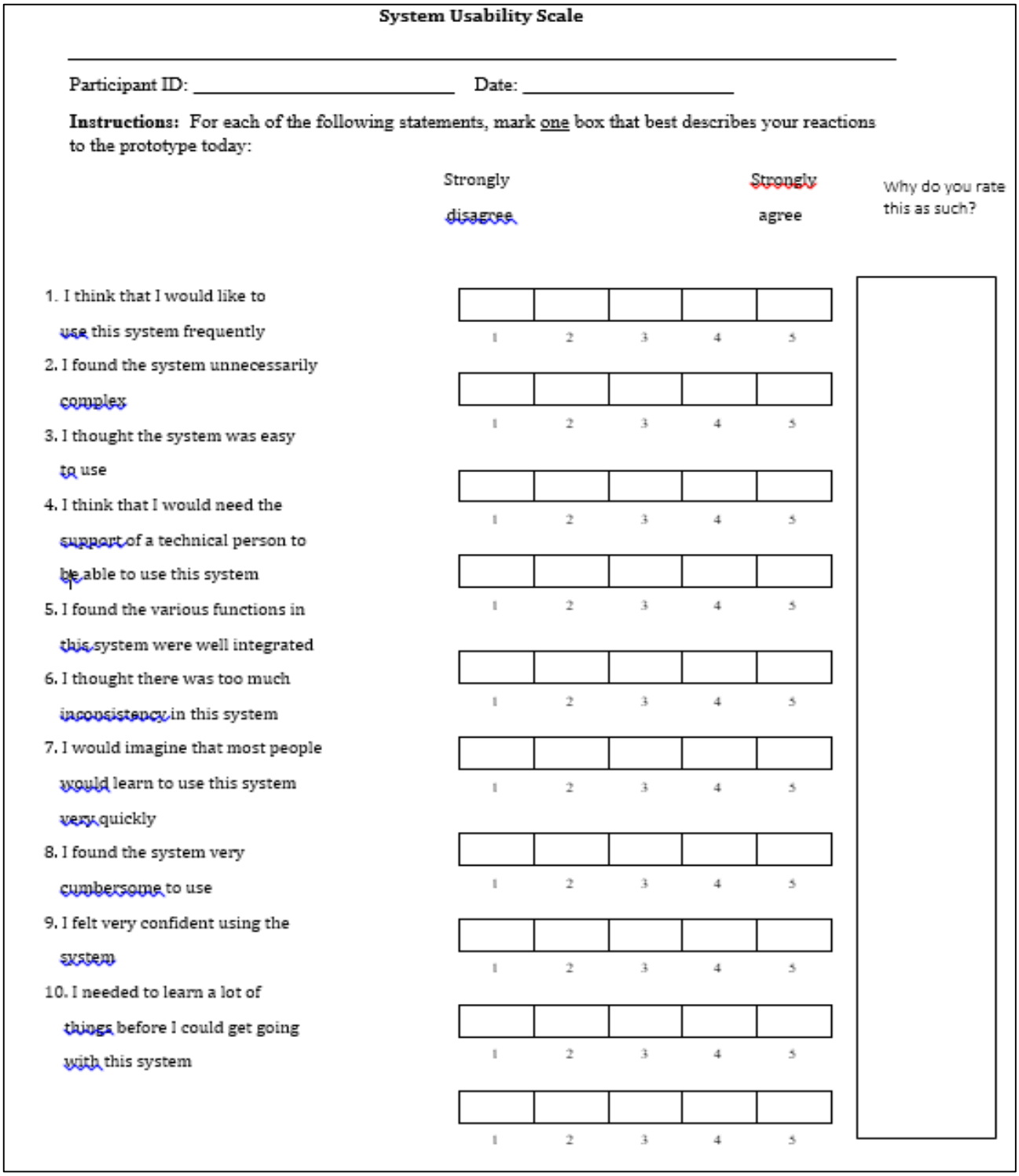
1. Are you currently practising or retired? *Currently Practising <> Retired <>*
2. How long have you been in practise for*? 6-12 months <> 1 year-8years <> 9 years+ <>*
3. Have you had any exposure to or interacted with a form of Electronic Medical Records (EMR)? *Yes <> No <>*
4. How long has this experience with EMRs been for? *6-12 months <> 1 year-8years <> 9 years+ <>*
5. How many patients do you typically see a day? *1-5 <> 5-10 <> 10-15 <> 15-20 <> 20-25 <> 25+*
6. How long is a typical patient appointment? *5-15 min <> 15-25min <> 30-60min <> 60min + <>*
7. How long do you spend interacting with the EMR per appointment? *¼ <> ½ <> ¾ <> full appointment <>*
8. Do you generally have to finish adding notes to the EMR after the patient leaves, or are you able to complete it all during the appointment? *During Appointment <> After Appointment <>*
9. What is your current satisfaction level with your EMR? *Greatly Dissatisfied, Help! <> Somewhat Satisfied <> Greatly Satisfied <> Excellent System, no changes needed! <>*
10. What is your gender? *Male <> Female <> Other <>*
11. What age group to you fall in? *Under 20 years <> 20-29 <> 30-39<> 40-49<> 50-59<> 60+ <>*

End of questions. Thank-you for your time.

Appendix C. Task Analysis Follow-up Discussion Questions

1. What features or functionalities did you find valuable with the current EMR (UIs)?
2. What features or functionalities did you find problematic with the current EMR (UIs)?
3. Are there any specific attributes you desire or wish to be removed?
4. Are there any specific attributes you desire or wish to be added?
5. How do you feel when you have interacted with the UIs on this EMR? (UX)?
6. Do you have any concerns with use of the EMR? E.g., will this data be saved the next time I log onto a patient's profile etc.?
7. Which tasks have alternate pathways to be conducted?
8. Why do you choose the pathway you do, over the others?
9. What would you describe as the ideal EMR (and UIs) that you could use in your practice that would really be beneficial to optometrists all over the globe?
10. Would you consider the UIs as easy to learn?
11. Would you consider the UIs as easy to use?
12. Would you consider the UIs as error-tolerant?
13. Would you consider the UIs as being able to fully support your workflows and tasks at hand, both routine and specialist?
14. What advice can you give others about using the EMR?
15. During the time you have been working with this EMR, are there ways of working smart or accomplishing more with less that you have found especially useful?
16. Can you think of a time when you realised you would have to change the way you were working with the EMR? Follow-up probes: to avoid medical errors? To improve communication with patients?
17. Were there times when you had to rely on experience to avoid being led astray by the EMR? Probe: can you give me an example?
18. Do you spend additional time before or after appointments, entering information about a patient, and if so, could you give an estimate?
19. Would you like to add anything?

Appendix D. System Usability Scale (SUS) Questionnaire



System Usability Scale

Participant ID: _____ Date: _____

Instructions: For each of the following statements, mark one box that best describes your reactions to the prototype today:

	Strongly disagree				Strongly agree	Why do you rate this as such?
1. I think that I would like to use this system frequently	1	2	3	4	5	
2. I found the system unnecessarily complex	1	2	3	4	5	
3. I thought the system was easy to use	1	2	3	4	5	
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5	
5. I found the various functions in this system were well integrated	1	2	3	4	5	
6. I thought there was too much inconsistency in this system	1	2	3	4	5	
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5	
8. I found the system very cumbersome to use	1	2	3	4	5	
9. I felt very confident using the system	1	2	3	4	5	
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5	

Appendix E. Post Study System Usability Questionnaire (PSSUQ)

Post Study System Usability Questionnaire (PSSUQ)

Instructions: For each of the following statements, circle a number (1-7) after the sentence that best describes your reactions to the prototype today:

1. Overall, I am satisfied with how easy it is to use this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

2. It was simple to use this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

3. I could effectively complete the tasks and scenarios using this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

4. I was able to complete the tasks and scenarios quickly using this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

5. I was able to efficiently complete the tasks and scenarios using this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

6. I felt comfortable using this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

7. It was easy to learn to use this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

8. I believe I could become productive quickly using this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

9. The system gave error messages that clearly told me how to fix problems.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

10. Whenever I made a mistake using the system, I could recover easily and quickly.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

11. The information (such as on-line help, on-screen messages and other documentation) provided with this system was clear.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

12. It was easy to find the information I needed.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

13. The information provided for the system was easy to understand.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

14. The information was effective in helping me complete the tasks and scenarios.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

15. The organization of information on the system screens was clear.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

Note: The interface includes those items that you use to interact with the system. For example, some components of the interface are the keyboard, the mouse, the screens (including their use of graphics and language).

16. The interface of this system was pleasant.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

17. I liked using the interface of this system.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

18. This system has all the functions and capabilities I expect it to have.

STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

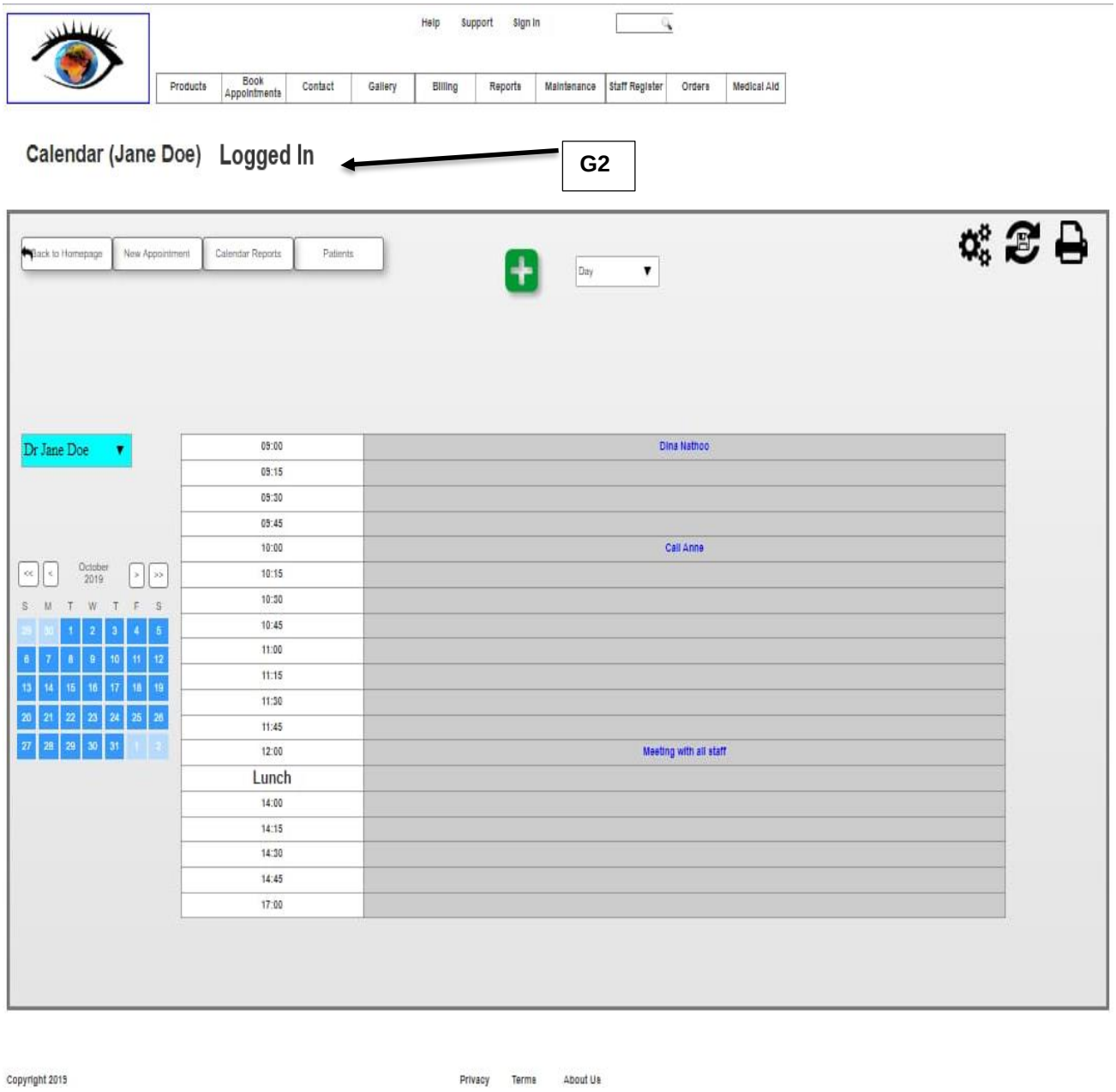
COMMENTS:

19. Overall, I am satisfied with this system.

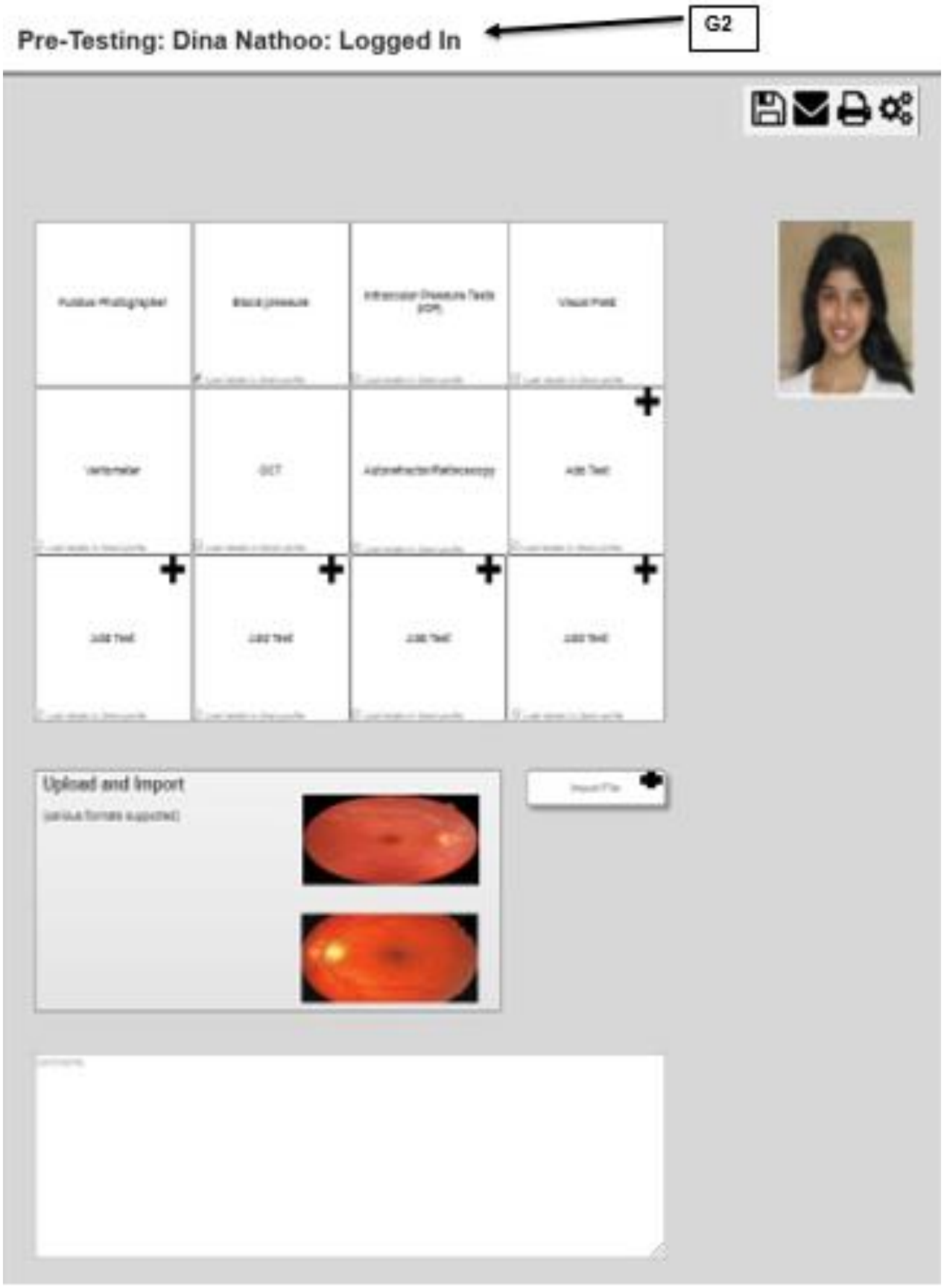
STRONGLY AGREE 1 2 3 4 5 6 7 STRONGLY DISAGREE

COMMENTS:

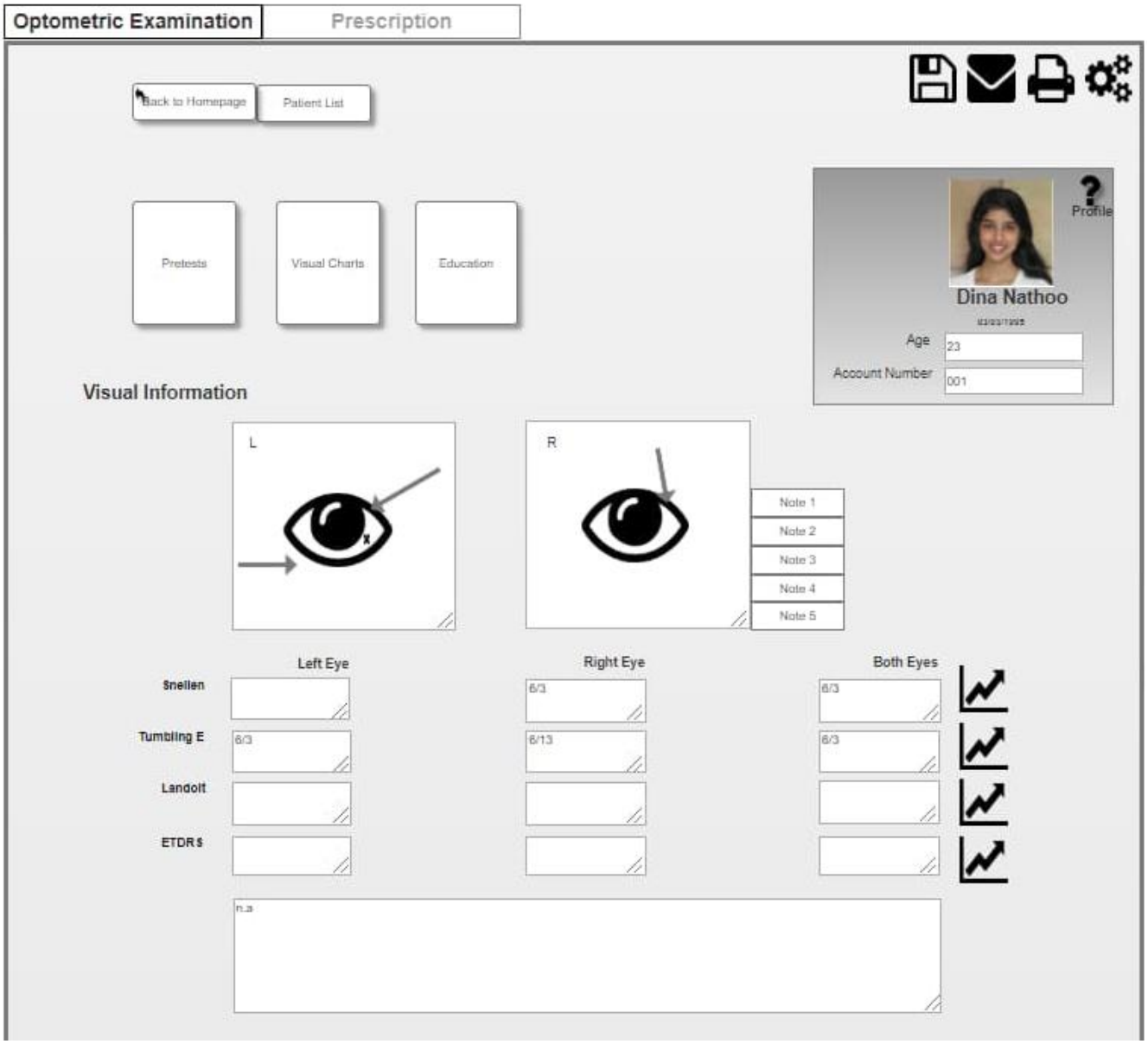
Appendix F1. S1: Patient Arrival and Appointment Management- Calendar UI



Appendix F2. S2: Pre-Testing/Pre-Screening-Pre-Testing UI



Appendix F3. S3 Optometric Examination/Health Process- Optometric Examination UI



General Ocular Information

Ocular Medical History

	NO	YES	?	RELATIONSHIP TO YOU (Family members with any)
Glaucoma	◉	○	○	Daughter, Father, etc.
Cataract	○	◉	○	Grandmother
Macular Deneration	○	◉	○	Father
Eye Injury	◉	○	○	Daughter, Father, etc.
Retinal Detachment/Disease	◉	○	○	Daughter, Father, etc.
Other Eye Injury	◉	○	○	Daughter, Father, etc.
Blindness	◉	○	○	Daughter, Father, etc.
Crossed Eyes	◉	○	○	Daughter, Father, etc.
Lazy Eye	◉	○	○	Daughter, Father, etc.
Dry Eye	◉	○	○	Daughter, Father, etc.
Diabetes	◉	○	○	Daughter, Father, etc.
High Blood Pressure	○	◉	○	Grandmother
Cancer	○	◉	○	Grandfather
Thyroid Disorder	◉	○	○	Daughter, Father, etc.
Lupus	◉	○	○	Daughter, Father, etc.
Other:	◉	○	○	Daughter, Father, etc.

n.a

Optometrist Attending: Dr Jane Doe

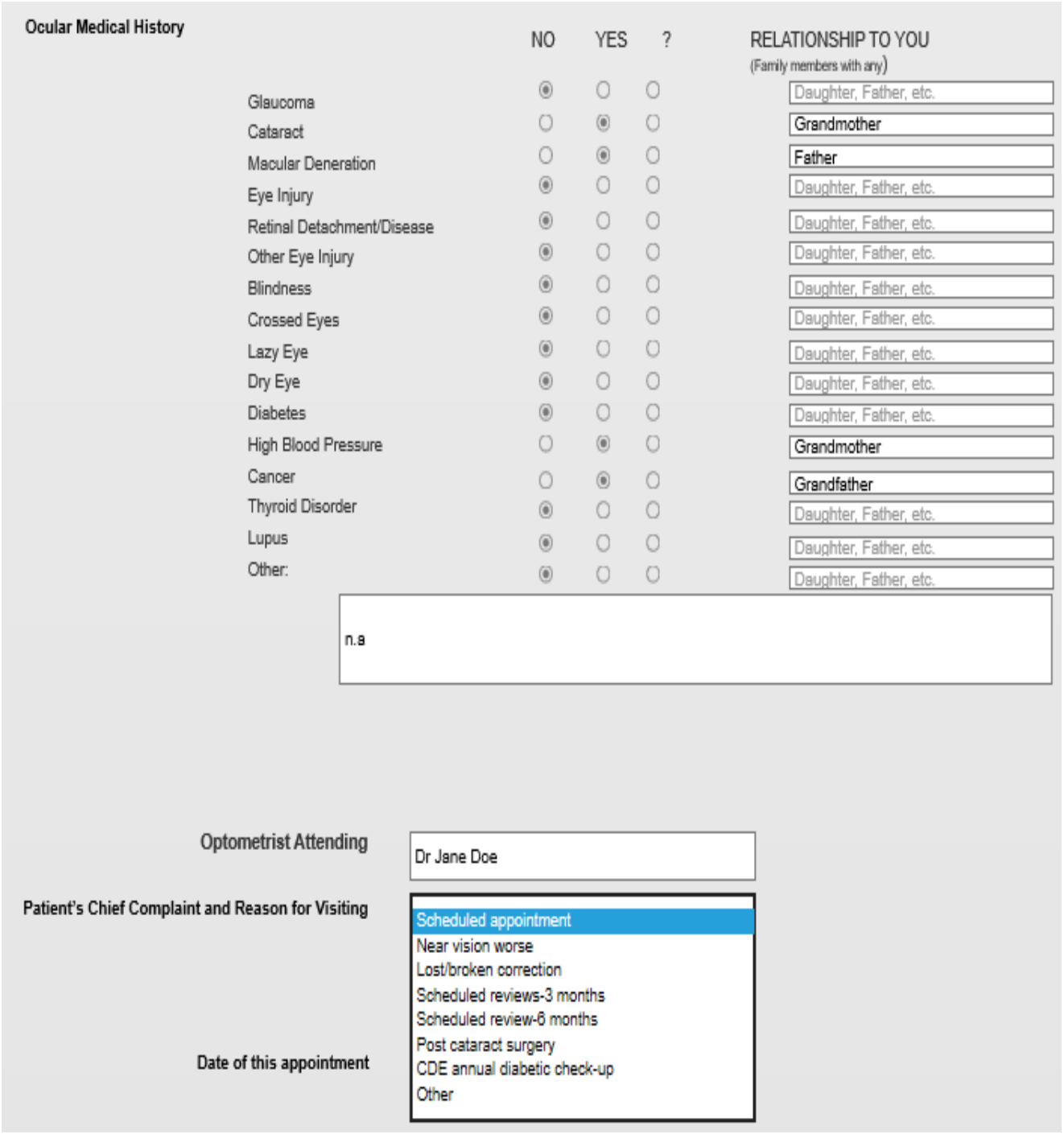
Patient's Chief Complaint and Reason for Visiting: Scheduled appointment ▼

General checkup.

Date of this appointment: yyyy/mm/dd

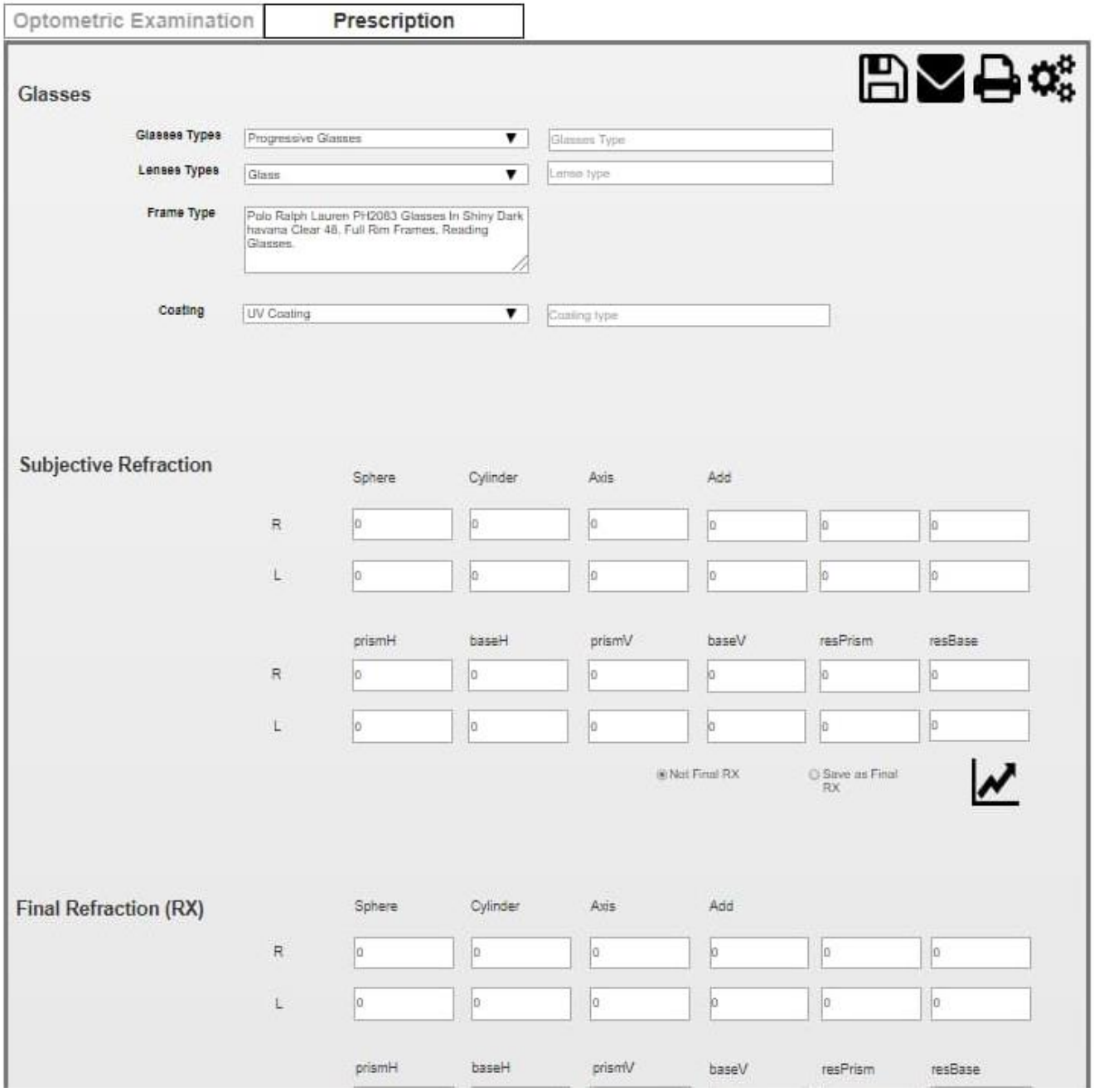
Chronic Medication: n.a

Previous Prescription information: n.a



Zoomed in screenshot of Appendix F3.

Appendix F4. S3 Optometric Examination/Health Process- Prescription UI



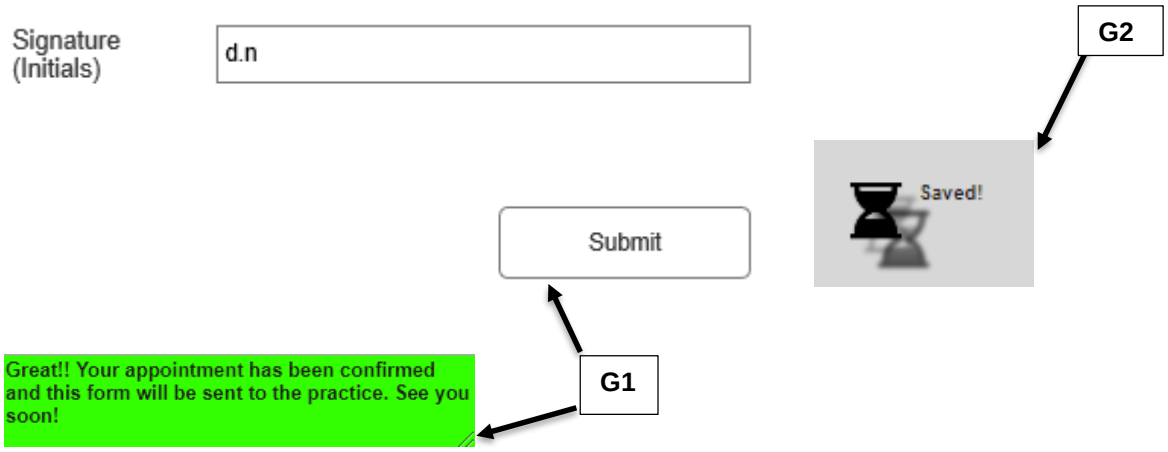
Final Refraction (RX)

	Sphere	Cylinder	Axis	Add		
R	0	0	0	0	0	0
L	0	0	0	0	0	0

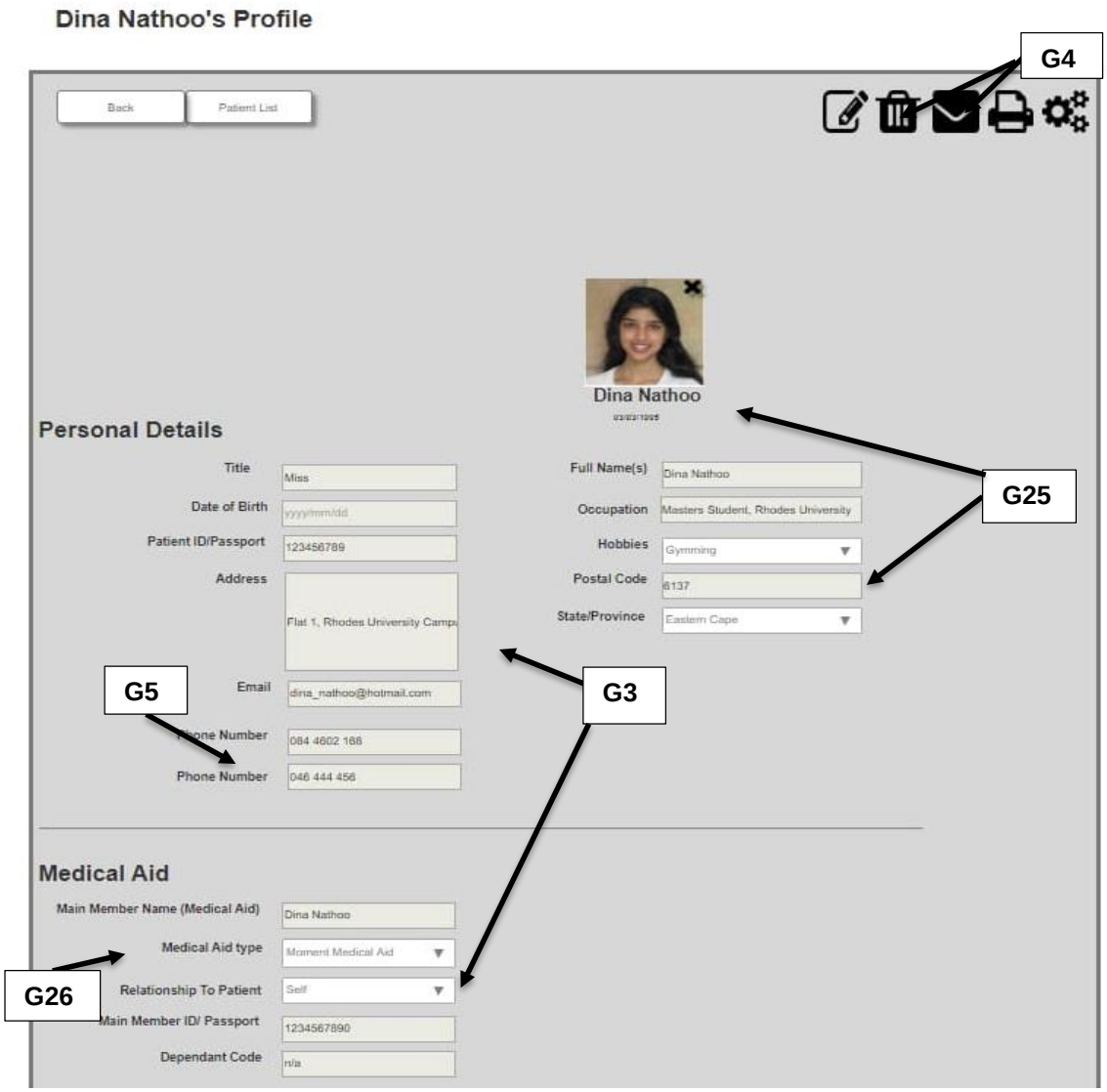
	prismH	baseH	prismV	baseV	resPrism	resBase
R	0	0	0	0	0	0
L	0	0	0	0	0	0

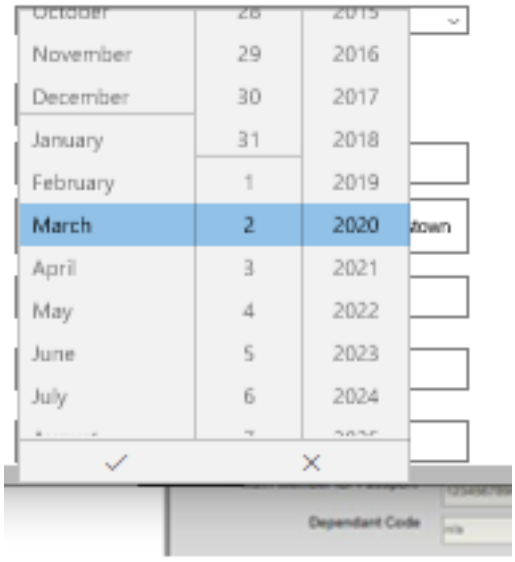
Astigmatism. Legally blind.

Appendix F5. Appointment Booking: Patient Form after Submit Button is Selected



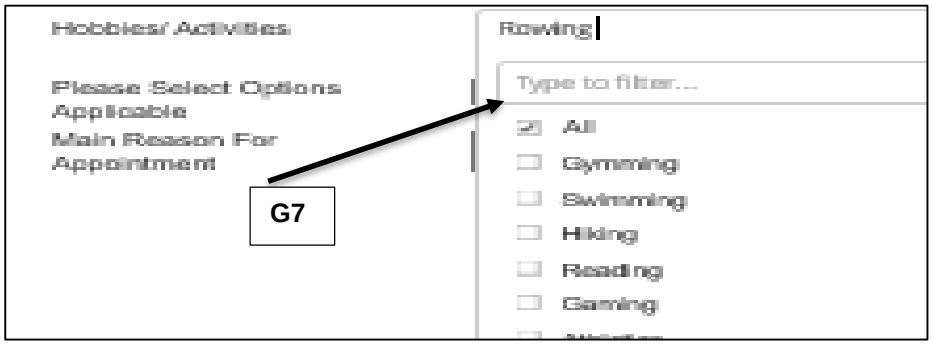
Appendix F6. Patient Profile: Top Half of UI





Date of Birth field: Easy date selector to prevent any erroneous entries and for easy usability. This also helps with Efficiency (Table 9.1).

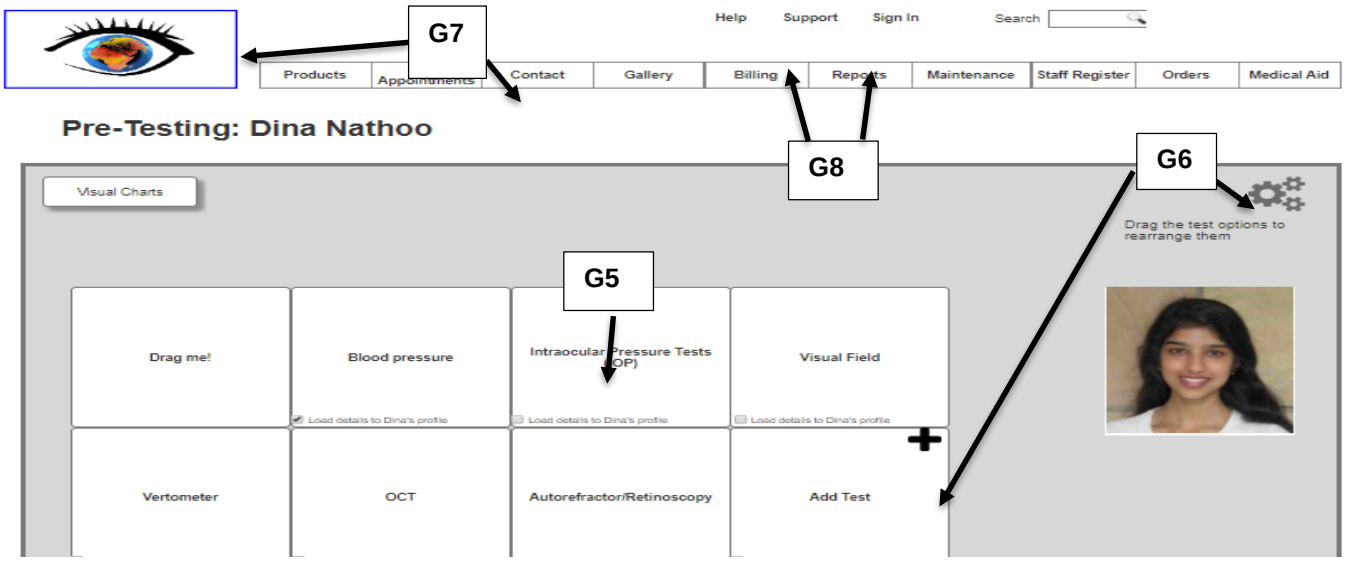
Title field: Drop-down optionality for title selection, aiding in usability (Table 9.1).



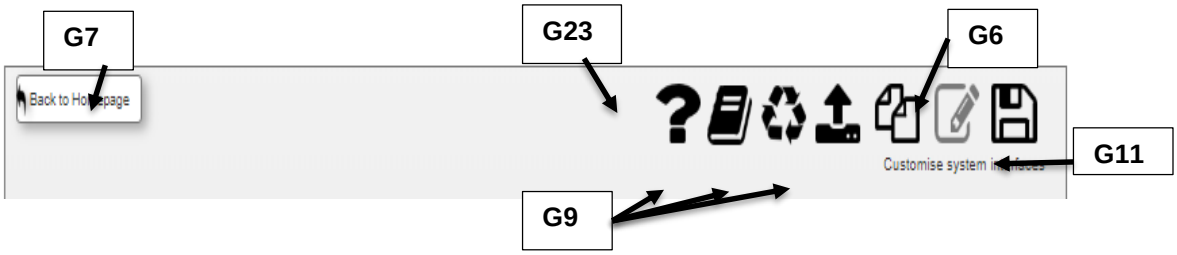
Hobbies field: Drop-down optionality for multiple selections as well as a filtering option for easy navigation and searching of results.

Zoomed in screenshots of Appendix F6.

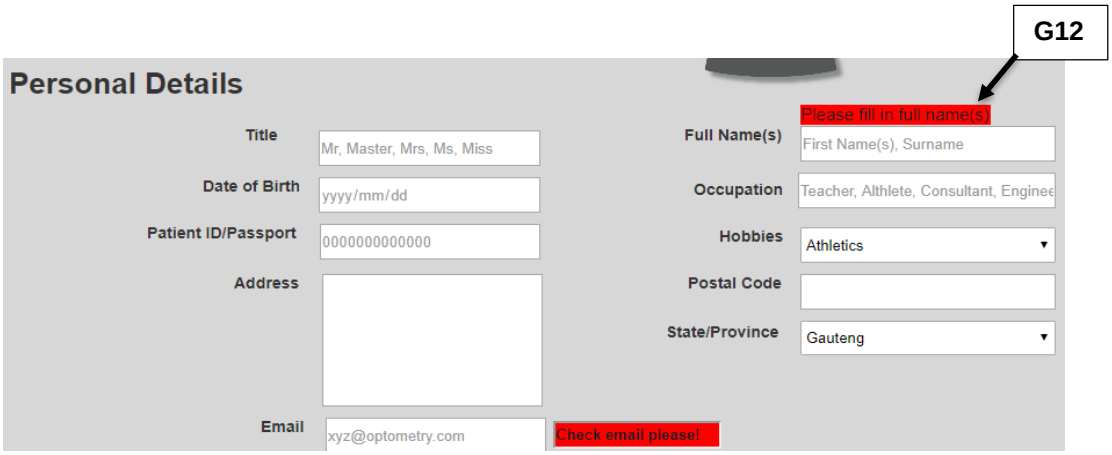
Appendix F7. Pre-Testing: Customisation

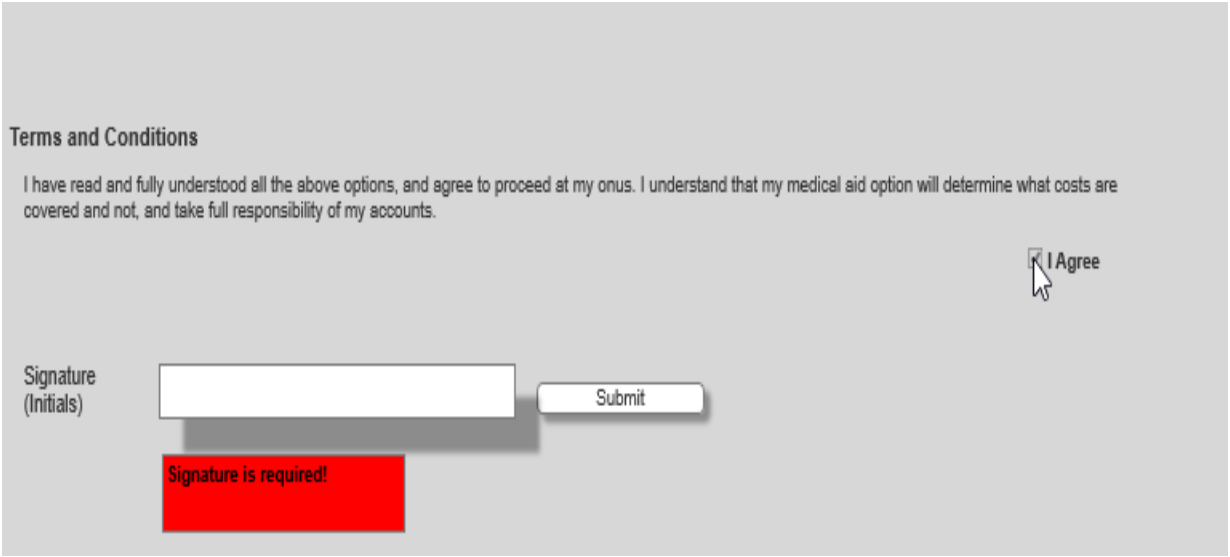


Appendix F8. Customisation Feature When Hovering Mouse (1), and Back Button (2)

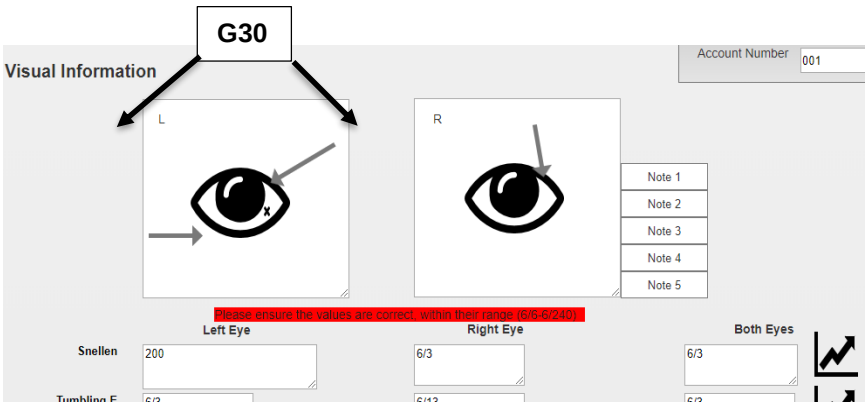


Appendix F9. New Patient Form





Appendix F10.Patient Ocular Information

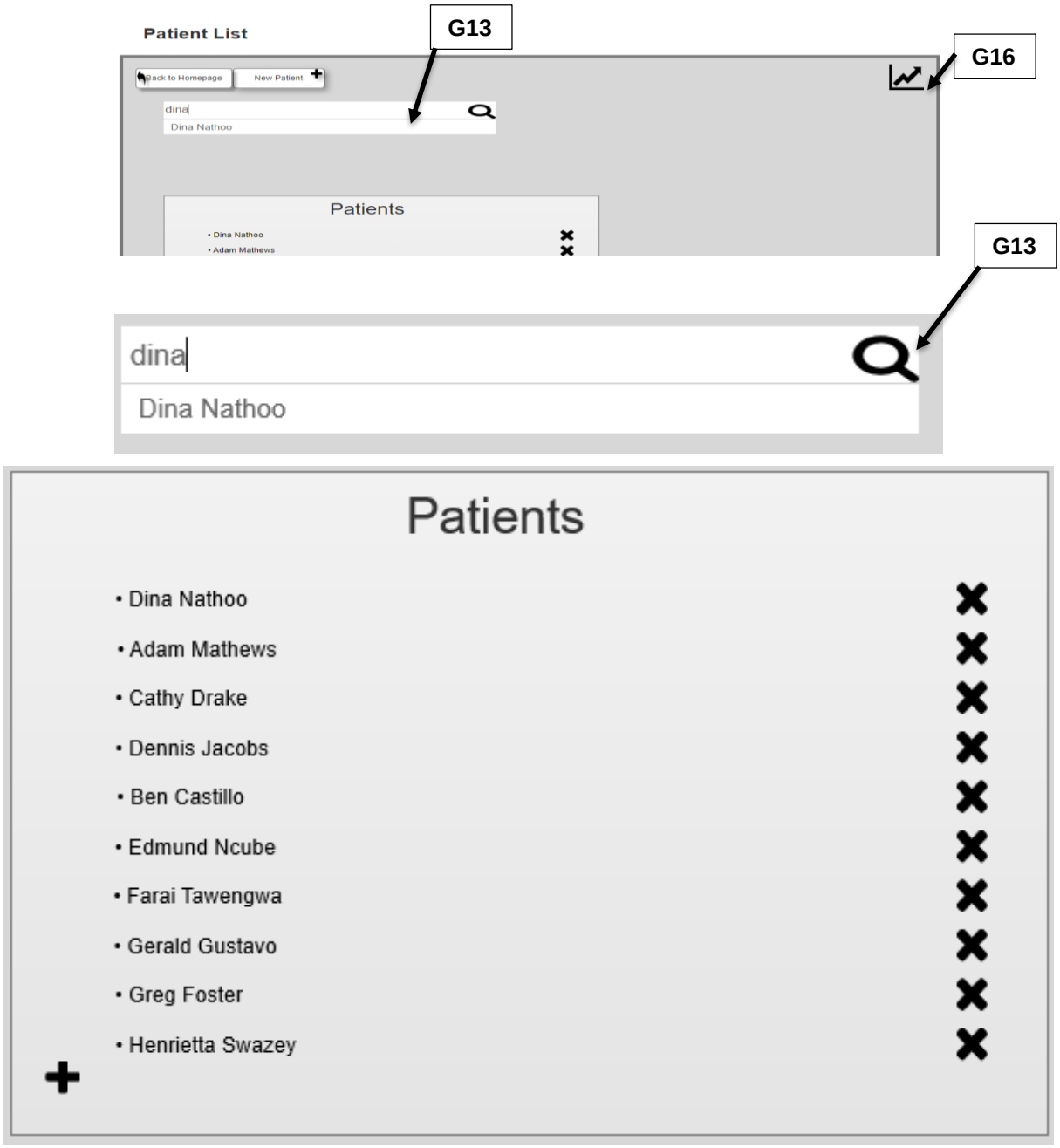


G10

This is the correct range and format

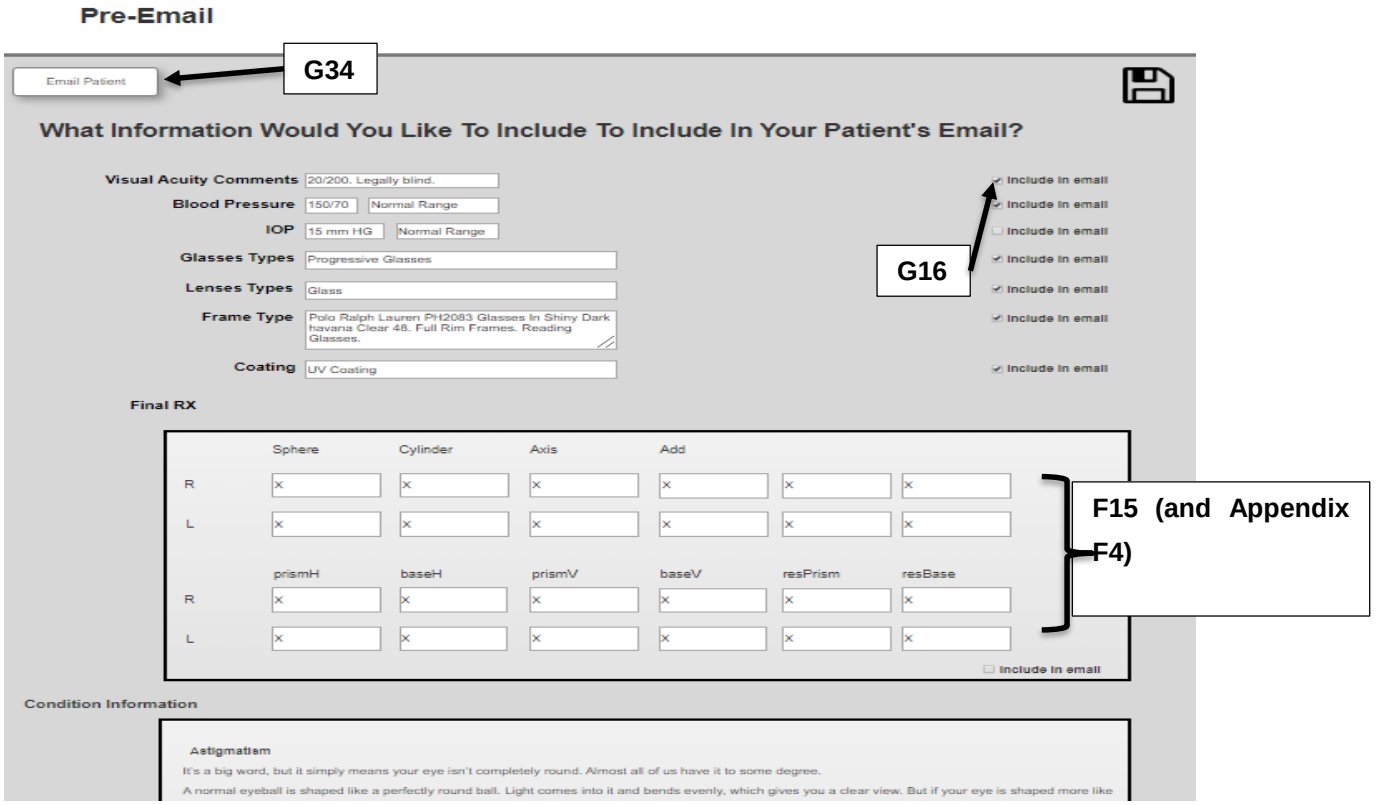
Pease ensure values are correct, within their ranges (6/6 -6/240)

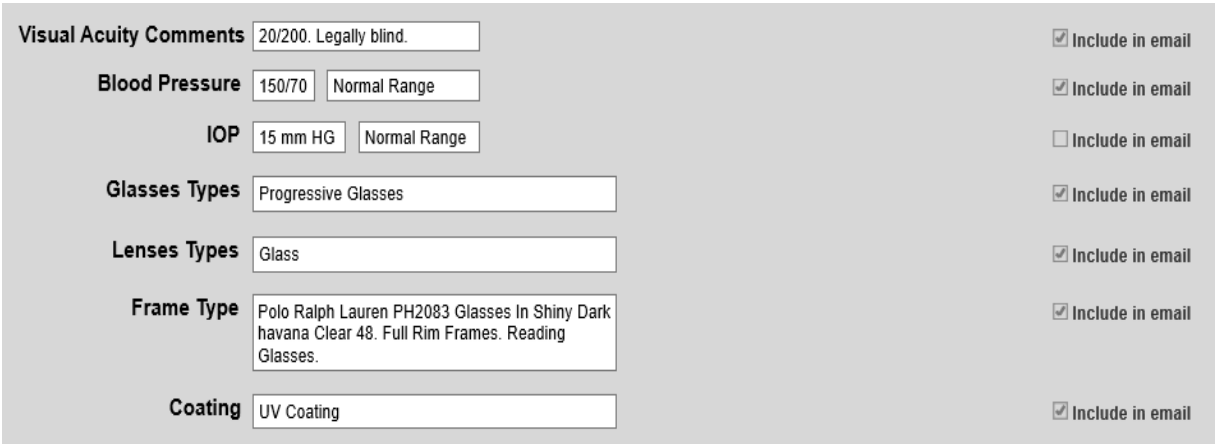
Appendix F11. Patient List



Zoomed in screenshots of Appendix F11.

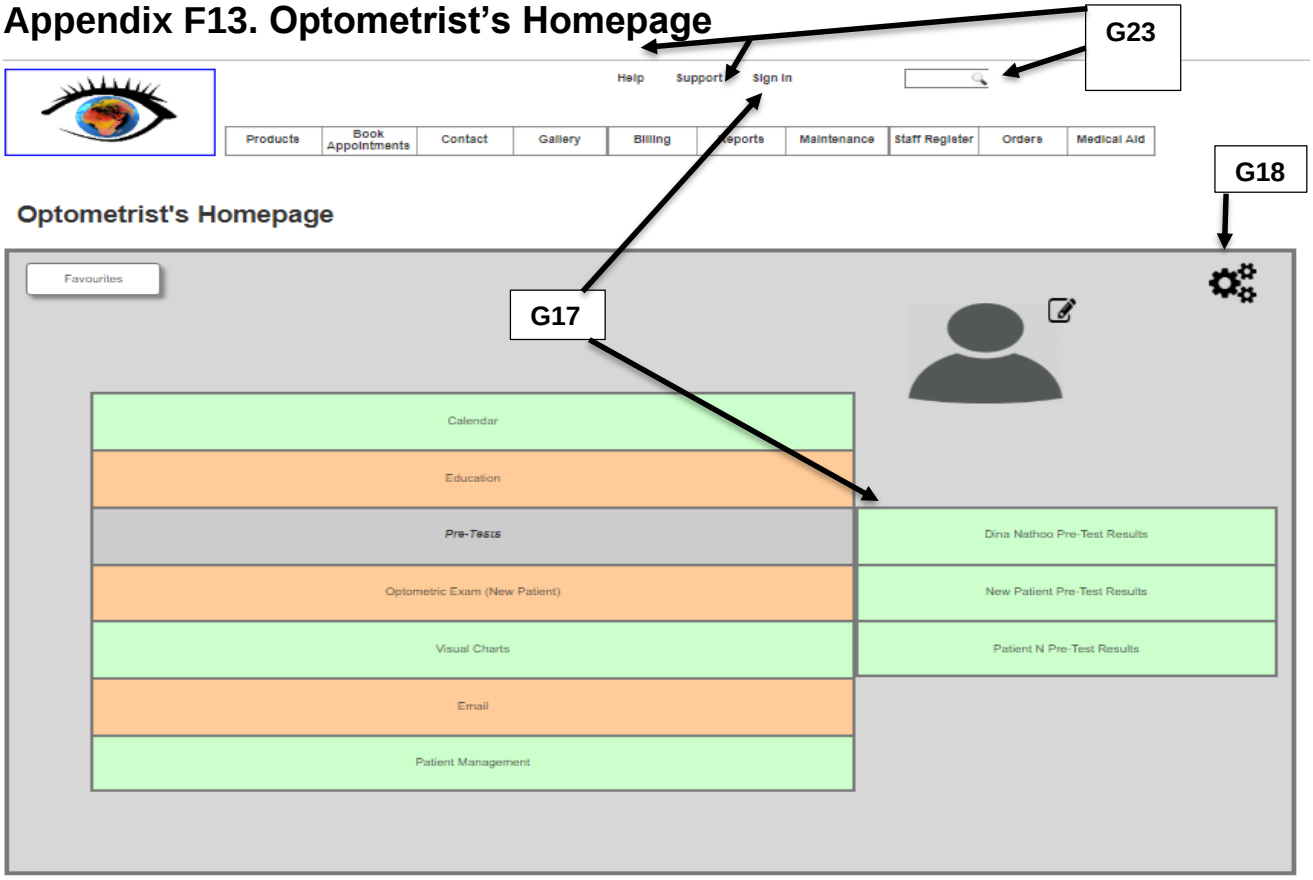
Appendix F12. Pre-Email



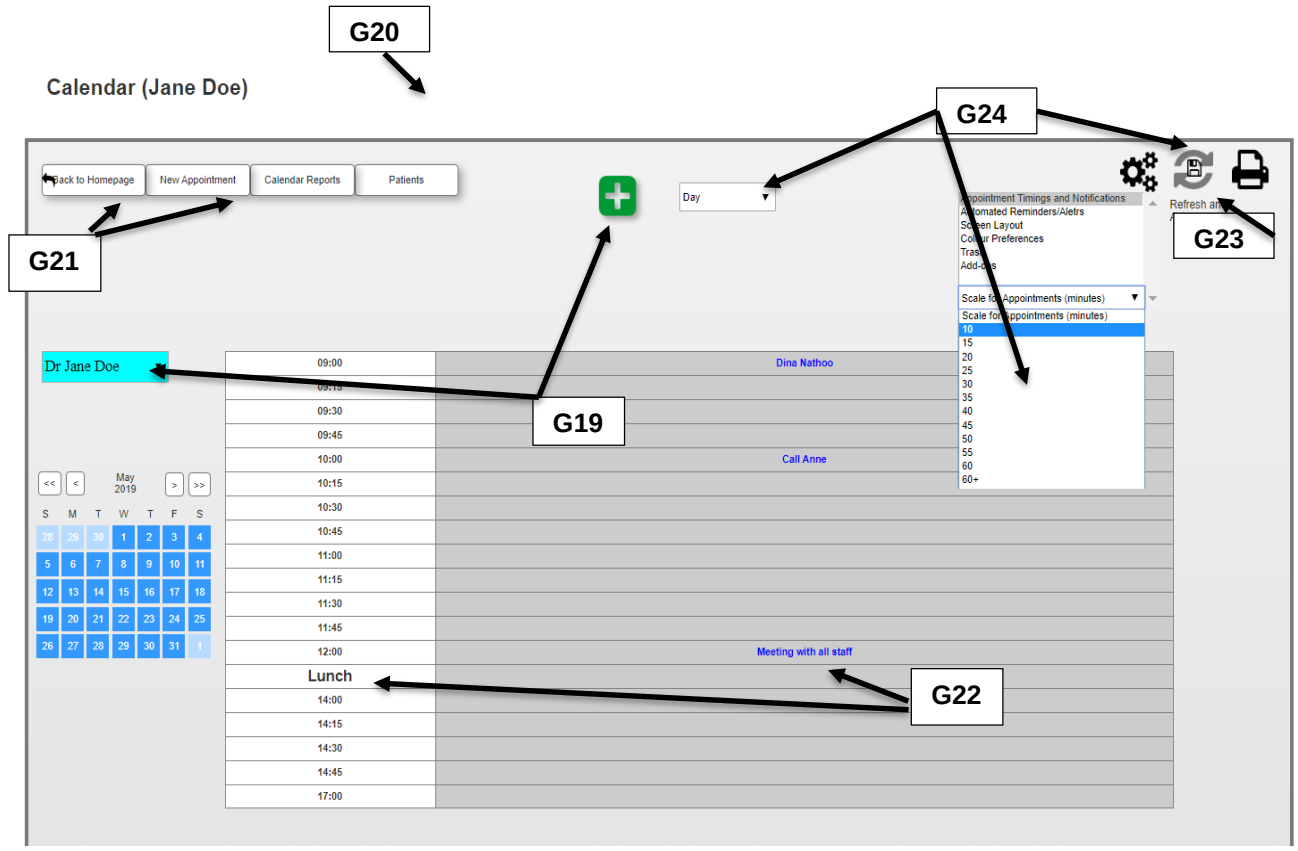


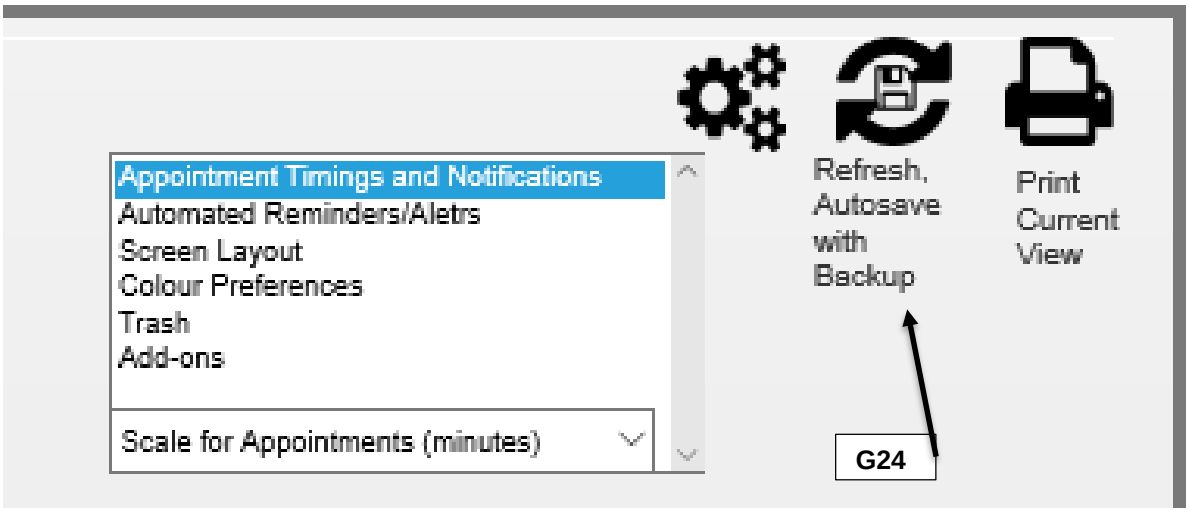
Zoomed in screenshot of Appendix F12.

Appendix F13. Optometrist's Homepage



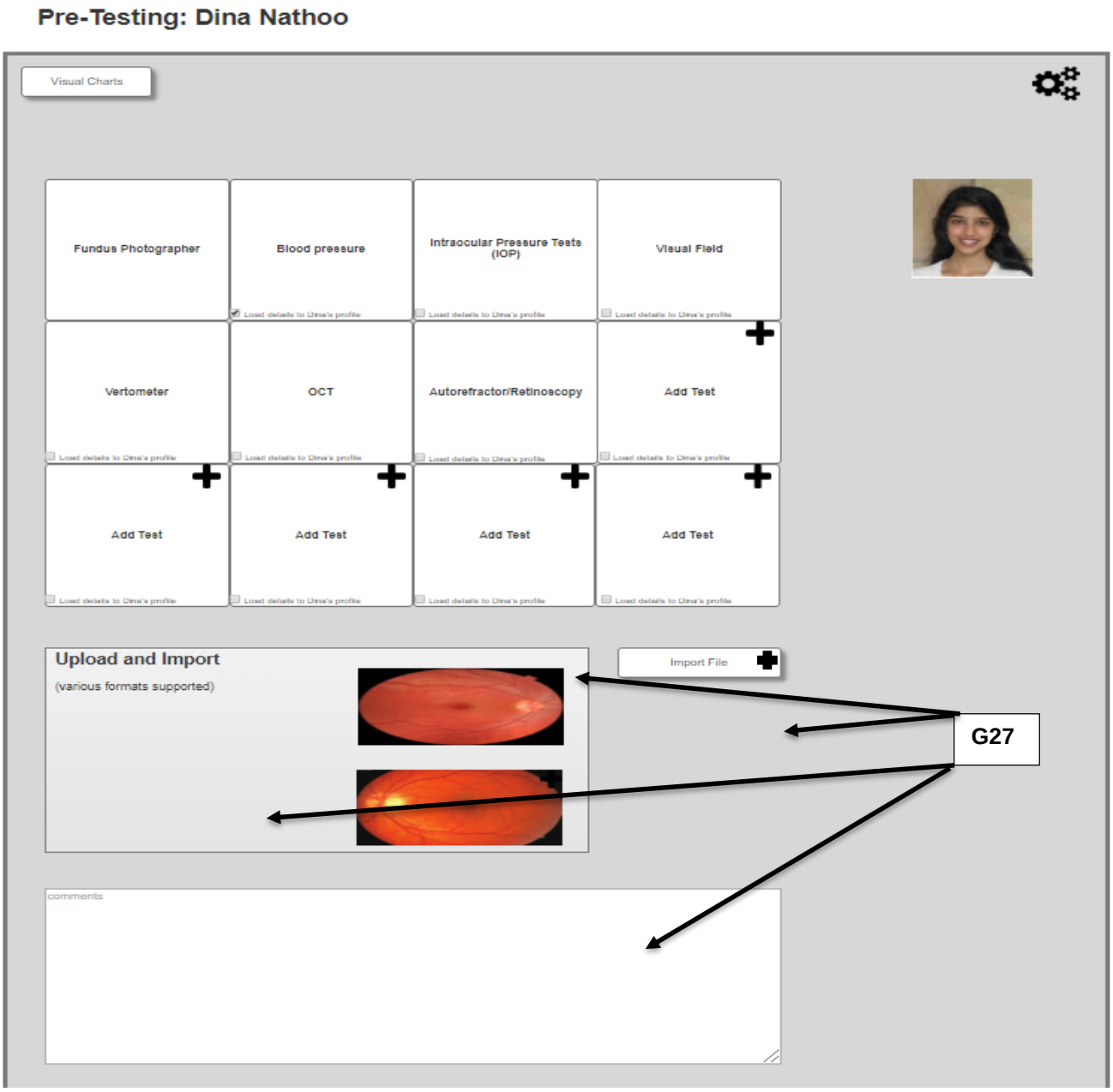
Appendix F14. Calendar: Dr Jane Doe's View



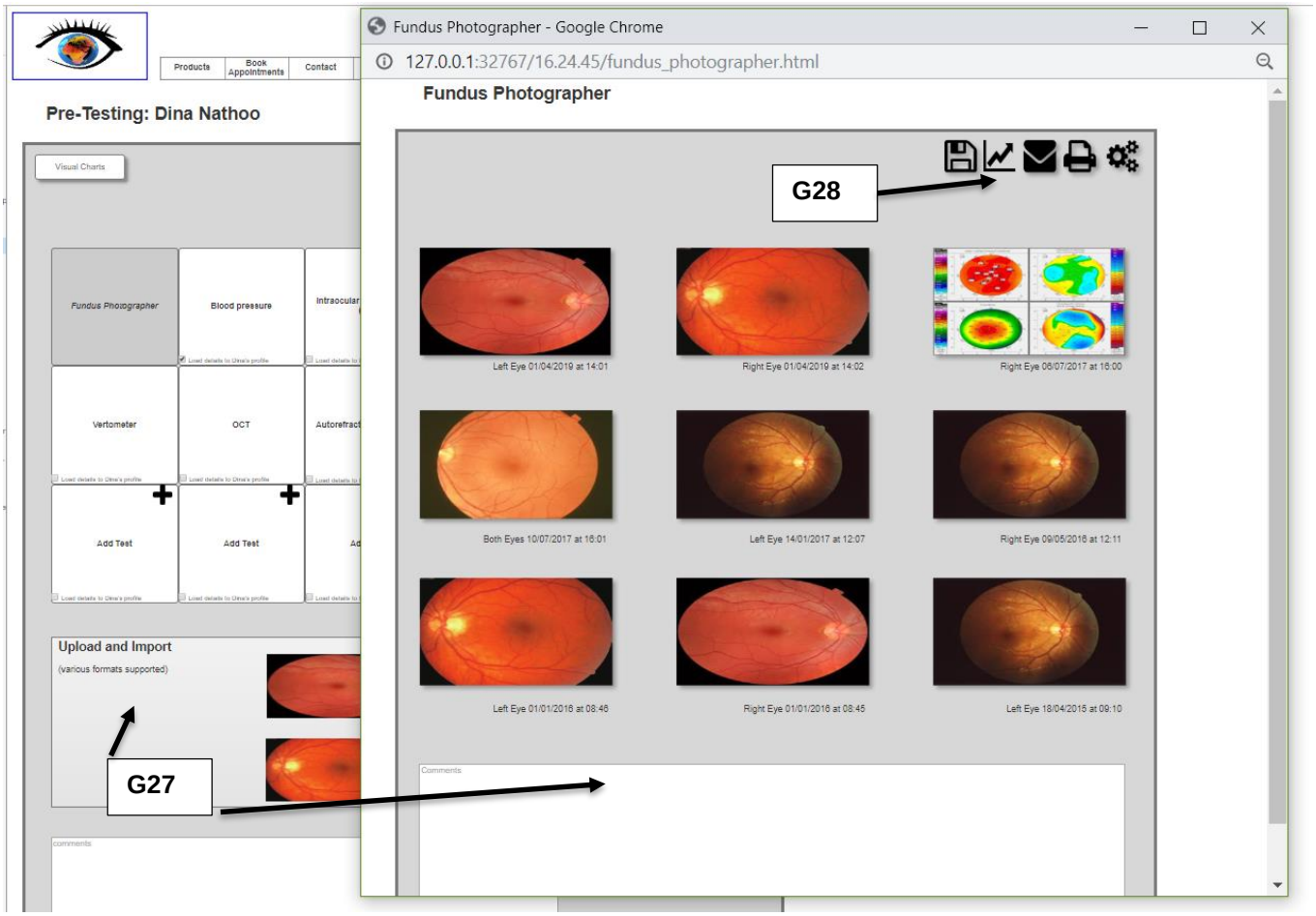


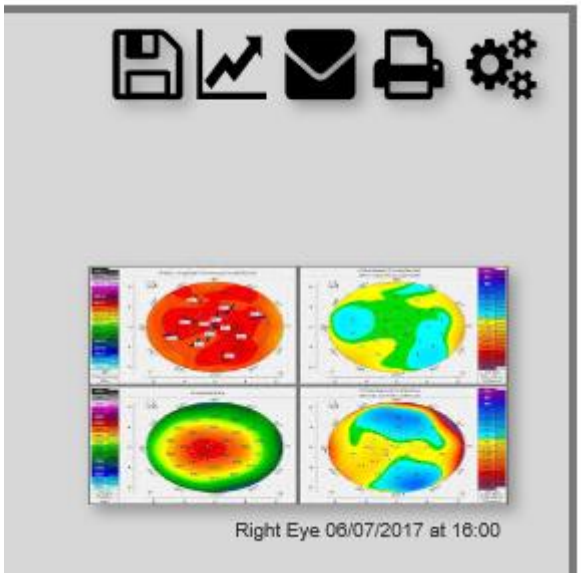
Zoomed in screenshot of Appendix F14.

Appendix F15. Pre-Tests



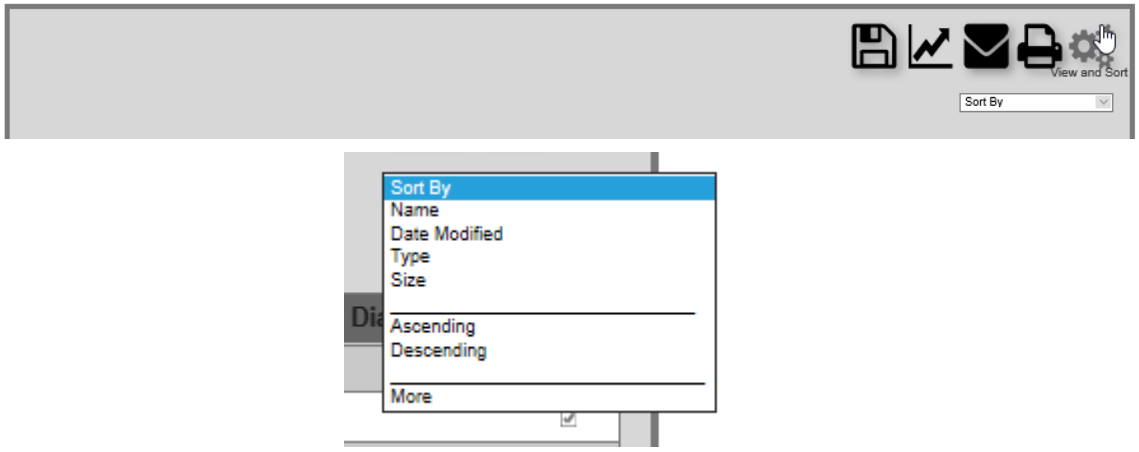
Appendix F16. Pre-Tests: Fundus Photography Selected





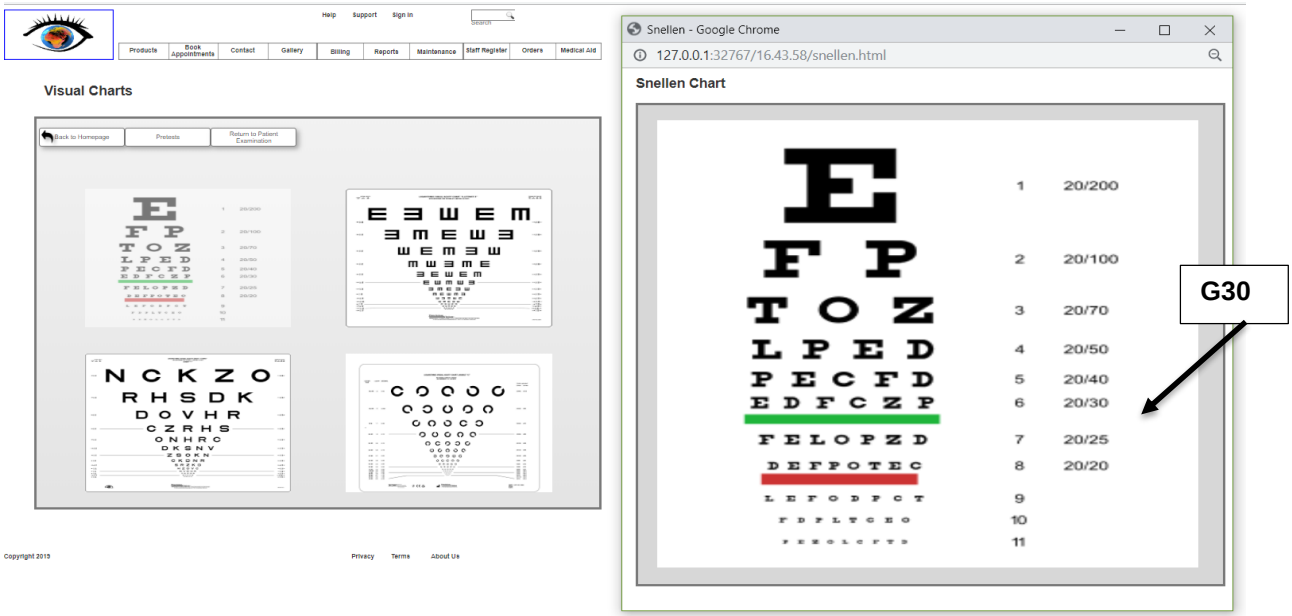
Zoomed in screenshot of Appendix F16. Timestamp is shown for each test.

Appendix F17. Pre-Tests: Blood Pressure Selected. Longitudinal History

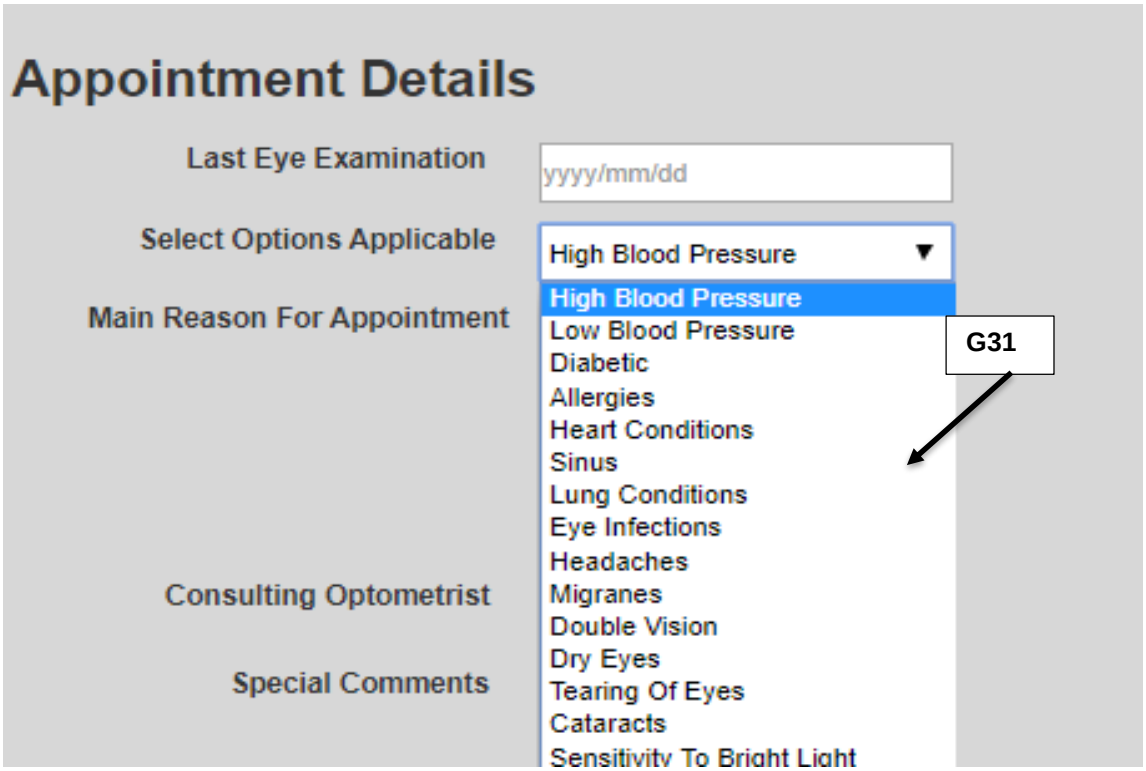


Zoomed in screenshot of Appendix F17.

Appendix F18. Visual Charts: Snellen Chart Selected

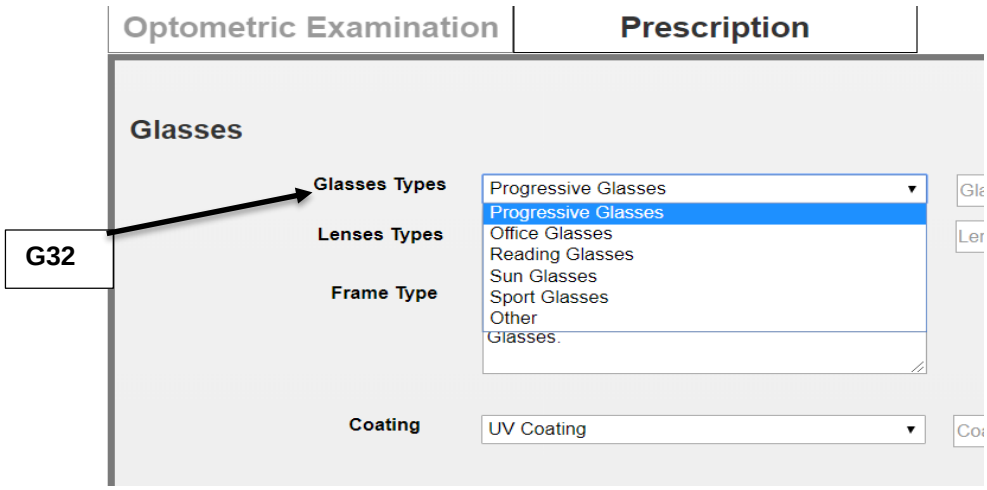


Appendix F19. Patient Form: Selectable Options of Common Complaints

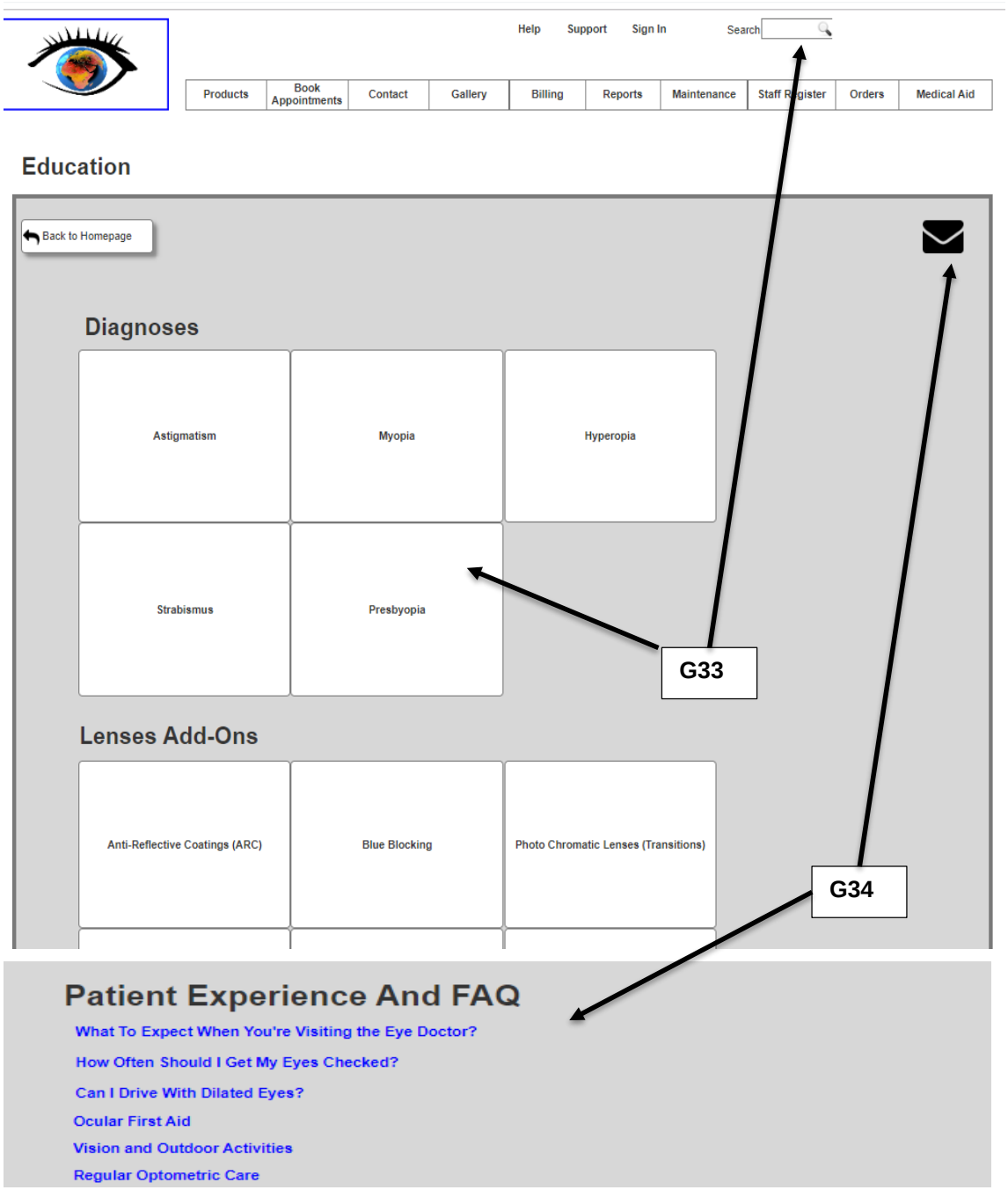


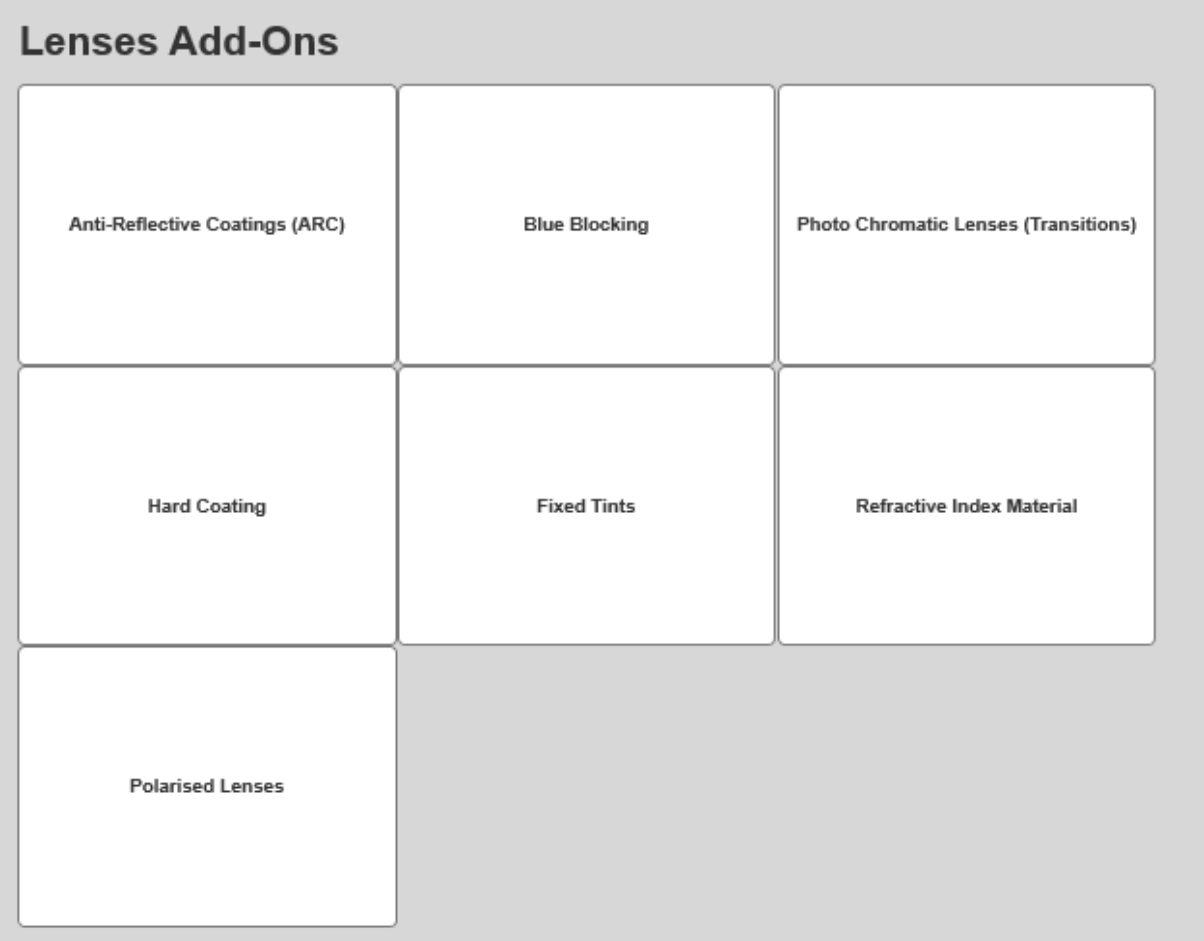
Appendix F20. Patient Ocular Information UI: Customisable Prescription UI

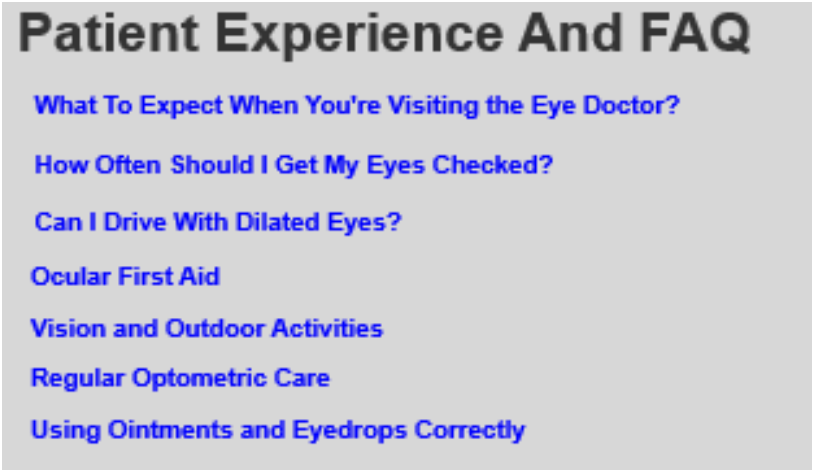
Appendix F21. Prescriptions: Glasses Types List Favourites



Appendix F22. Education

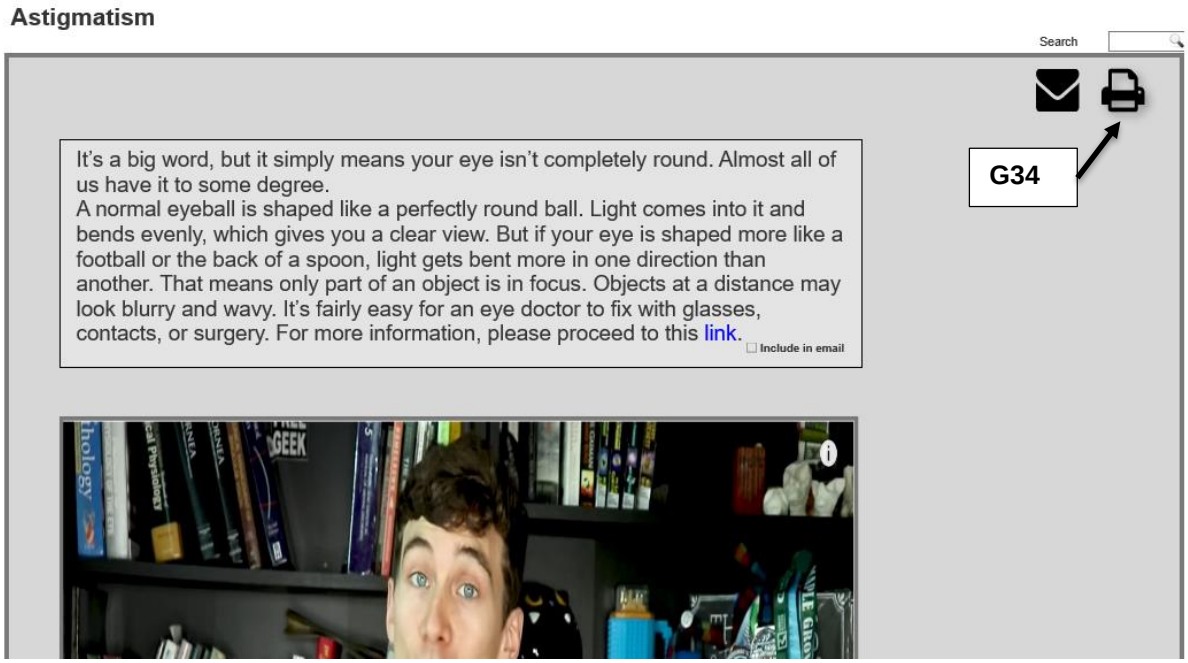




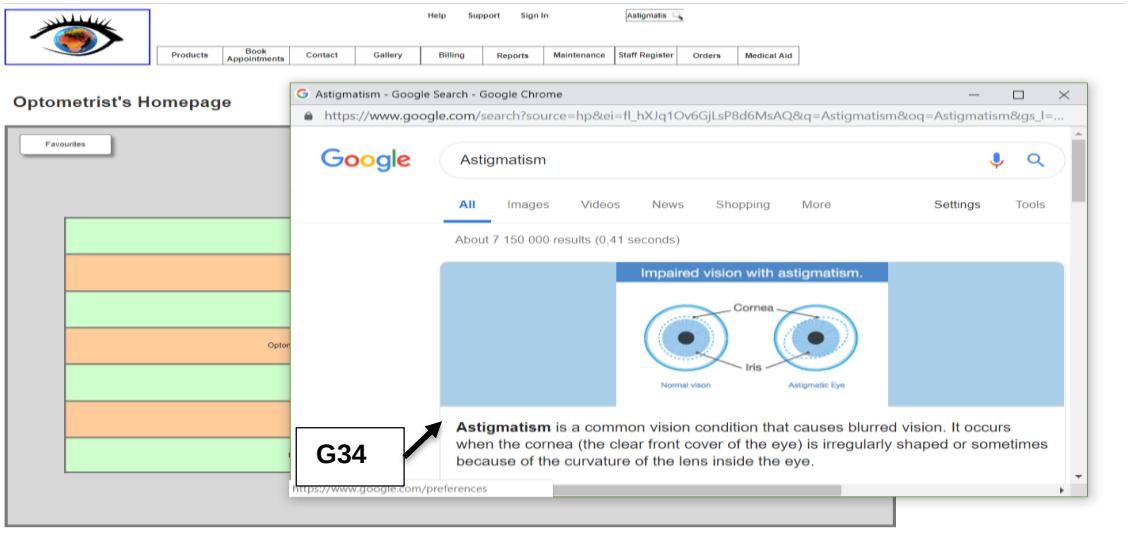


Zoomed in screenshots of Appendix F22.

Appendix F23. Astigmatism Education



Appendix F24. Astigmatism Searched for Externally Via Google Search Engine



Appendix F25. Favourites Page (From Optometrist's Homepage)