Usability of Digital Health Technologies

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A thesis submitted for the degree of
Doctor of Philosophy

Trinity 2024

Acknowledgements

Thank you to my supervisory team, Prof Mike English, Prof Jim Warren, Prof Elizabeth Borycki and Prof Andre Kushniruk. Both Mike and Jim have been mentors to me throughout my career, and I will always be grateful for their support and advice on all aspects of academic life over many years.

In 2019, Jim introduced me to Elizabeth and Andre. We planned the DPhil at the MEDINFO conference in Lyon, France, on an excursion to view the ancient artefacts at the Lugdunum Museum. Thankfully, our conference workshop outlining the idea of using human-computer interaction modelling to improve the evidence base of digital health technologies was well received by the MEDINFO participants. Returning to Oxford, Mike approved the idea and has kindly supported me through the hurdles of finishing my DPhil alongside my other responsibilities.

I would also like to thank my family: my partner Meriel, my children Bridget and Edward, and my parents for their support over the last few years as I juggled various academic and professional roles.

Abstract

Background

Motivated by the mixed outcomes of previous digital health initiatives, such as the National Programme for IT and the adoption of US-based electronic health record (EHR) systems, this thesis investigates how the usability of NHS digital systems could be improved through the development of modernised user interface (UI) guidelines and how quantitative usability modelling could be used to evaluate and improve the design of digital health technologies.

Method

The Design Science Research framework was used, spanning six stages: problem identification, objective definition, artefact development, demonstration, evaluation, and communication. EHR usability problems were identified by analysing the Certified Health IT Product List (CHPL) database of usability tests. The objective was defined through a document review of the existing NHS usability guidelines, which informed the development of novel UI design artefacts demonstrating how existing usability guidelines could be feasibly modernised. Human-computer interaction (HCI) modelling was used to evaluate the artefacts, and the results have been communicated through peer-reviewed journal articles, conference presentations, and this thesis.

Results

The CHPL analysis showed significant variability in the usability performance of EHR systems, establishing the need for improved usability guidelines. The document analysis of the NHS Common User Interface (CUI) and Design System (DS) guidelines provided the information needed to create updated UI design artefacts by integrating the CUI guidelines with the modern technology stack and design principles from the NHS DS. HCI modelling showed how different designs performed and provided a foundation for scientifically validated usability improvements without reliance on human-subject experiments.

Conclusion

This thesis contributes evidence for variability in the usability of existing EHR systems, proposes technically feasible updated design artefacts for two safety-critical components of EHR systems, the Patient Banner and Patient Name Input, and demonstrates how HCI modelling can be integrated into the Human-Centred Design process of designing evidence-based digital health technologies.

Declaration of Authorship

This thesis is my own work unless otherwise stated in the text. Quoted text from sources is shown in single-line spacing.

The text from this thesis has been used in the following publications where I am first author:

Chapters 1, 2 and 6

Paton, C., Kushniruk, A. W., Borycki, E. M., English, M., & Warren, J. (2021). Improving the Usability and Safety of Digital Health Systems: The Role of Predictive Human-Computer Interaction Modeling. Journal of Medical Internet Research, 23(5), e25281.

Chapters 4 and 5

Paton, C., Borycki, E. M., Warren, J., Kushniruk, A. W., & English, M. (2024). HCI-modelling for improving the clinical usability of digital health technologies. Methods, 227, 60–77.

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Chapter 1

Introduction

In this first chapter, I describe the background to my research: how the NHS introduced digital health technologies (DHTs) such as Electronic Health Record (EHR) systems, first through the National Programme for IT (NPfIT) and then via the introduction of systems developed through a large-scale government funding programme in the United States of America. I describe the clinical usability challenges reported in the recent literature associated with these systems and the importance of ensuring good usability for safe and efficient healthcare services. I outline the NHS Common User Interface (CUI) project developed during NPfIT and the newer NHS Design System (DS) that is now used to guide how the NHS designs DHTs for new digital services. I will make a case for better usability guidelines for EHR systems and explain how the NHS CUI and the NHS DS could be combined to develop and scientifically evaluate new guidelines using Human-Computer Interaction (HCI) modelling. Finally, I describe this DPhil project's overall aim and specific research questions and the sub-aim of exploring the feasibility of HCI modelling as a method of cost-effectively generating quantitative data on the usability of digital health technologies such as EHRs.

1.1 Adoption of EHR Systems in the NHS

Government initiatives have been a significant driver of digital health, particularly in countries with socialised healthcare systems, such as the UK. For example, from 2002 to 2011, the UK government spent £14 billion on digital health initiatives under the National Programme for Health IT [26, 15, 56, 12]. Similarly, the Obama administration in the US oversaw the implementation of the HITECH Act, created by President George Bush II, which allocated stimulus funds after the 2008 global financial crisis for investment of more than $20 billion subsidising and incentivising hospitals and individual doctors to begin to adopt new DHTs [28, 1, 3]. As I will describe below, these two programmes have shaped the current EHR landscape in the UK, including the present challenges with clinical usability and patient safety.

1.1.1 National Programme for IT

The National Programme for IT (NPfIT, pronounced N-P-Fit) was an ambitious initiative launched in 2002 by the Tony Blair administration to modernise the NHS in England. The primary objective was to create a single, centrally-mandated electronic care record for patients, complemented by various modern IT services and infrastructure across the NHS. This initiative aimed to safely and efficiently improve patient information sharing among hospitals, GP surgeries, and other healthcare providers.

The Programme comprised several core elements designed to achieve its goals. Among these were the "Choose and Book" system [25], to allow patients to book hospital appointments electronically, and the Electronic Prescription Service (EPS) [32], which aimed to facilitate the electronic transfer of prescriptions from GPs to pharmacies. The NHS Care Records Service (NHS CRS) was established to create and maintain centralised electronic patient records. The Programme also created NHSmail, a secure email service for NHS staff, and a Picture Archiving and Communications System (PACS) for storing and sharing radiological images electronically. The NHS Spine provided the "backbone" for secure information exchange, supporting services like the Personal Demographics Service (PDS) and Summary Care Record (SCR).

A national EHR system called Lorenzo was initially envisioned as an integral part of NPfIT. It was designed to create a comprehensive electronic health records system to improve patient care through access to information, streamlined clinical processes, and enhanced data accuracy. Despite its ambitious goals, the development and deployment of Lorenzo faced numerous challenges, including technical difficulties, project delays, and escalating costs. Frequent changes in project scope and the complexity of meeting the diverse needs of various NHS trusts further complicated its implementation [56, 26].

NPfIT encountered many other challenges and faced significant criticism over its implementation. The National Audit Office report on NPfIT describes how it suffered from severe cost overruns, with costs far exceeding initial estimates and substantial delays that plagued the rollout of systems [56]. The report also shows how the ambitious scope and complexity of NPfIT made it challenging to manage and implement effectively. Issues with contractors and suppliers further contributed to the delays and failures in delivering critical components of the system. Importantly for this thesis, the report notes how there was resistance from healthcare professionals, who often found the usability and functionality of the new systems lacking.

Ultimately, NPfIT was dismantled in stages beginning in 2011, following several critical reviews and reports highlighting its shortcomings. The Programme was deemed overly ambitious, and many components were abandoned or significantly restructured. Despite its failure, NPfIT did lead to some important advancements in the NHS's IT infrastructure, and the lessons learned from this initiative have informed subsequent health IT projects in the UK. One crucial but often overlooked aspect of NPfIT was the creation of the NHS Common User Interface (NHS-CUI), a significant focus of this DPhil project, described in more detail in the section on the usability of EHR systems below.

1.1.2 The HITECH Act

Arguably, the HITECH Act was the most significant influence on the recent growth of DHTs in the UK despite being a USA-based initiative [28]. After the Global Financial Crisis, the US government created nearly $700 billion of new money to provide economic stimulus. Through the HITECH Act, $20 billion of this funding was directed toward digitising hospitals and clinics. In return for receiving payments for purchasing EHR software and computer equipment, doctors and hospitals promised to use them to improve the care of patients in a "meaningful" way. The phrase "Meaningful Use" has become widely used to discuss how digital systems should improve patient care, demonstrating the legislation's significance in influencing the digital health technology landscape internationally [40]. Providers would need to meet various clinical objectives in terms of using the systems not just for collecting billing and insurance-related data but also to digitise medical notes, blood test results, and other clinical activities. This stimulus accelerated the growth of several US-based digital health companies, which have now become leading EHR suppliers worldwide [28]. Entrepreneurs and investors also established new companies to fill the gaps and offer new digital health solutions. This US-based stimulus has had ripples around the world, with many countries, including the UK, now adopting the major US EHR vendors for large government and private sector hospitals and clinics.

1.1.3 UK adoption of US EHRs

Post-NPfIT, the NHS adopted a new approach to DHT adoption, allowing individual NHS trusts to purchase EHR systems without central guidance. As the previous decade of the NPfIT had limited the development of UK-based EHR systems, most trusts either did not adopt EHR systems at all or, if they had sufficient funding, purchased systems initially funded through the HITECH Act. This development means most UK hospitals that have any EHR system now have US-designed systems [58]. Most of the world has followed this line of development, and the systems initially funded by the US government are now in place worldwide. So, when we consider the evidence for the usability of EHRs used in the NHS, we can look to the usability assessments made by the US government as part of the conditions for receiving stimulus funding. These assessments are described in further detail below.

1.2 Usability of DHTs

As digital health technologies such as EHRs have proliferated in the healthcare sector, driven by the central government funding described in the previous section, reports of problems caused by poor usability have also increased. A recent Mayo Clinic study [53] surveyed clinicians using the System Usability Scale (SUS) and gave the Electronic Health Record system they used a rating of "F", below such systems as Microsoft Word (C) and far below modern user-focused systems such as

Table 1.1: International EHR Usability Guidelines

ONC SED	EHR Usability Certification (examined in Chapter 3)
NISTIR 7804-1	Guidelines for evaluating and testing EHR systems
NISTIR 7741	Guidelines for improving EHR usability
ISO 9241-210	Guidelines for Human-Centred Design
ISO 9241-11	Usability definitions and concepts
HIMSS UXMM	EHR Usability Maturity Model

Amazon (B) and Google Search (A). There are also concerns emerging that poor usability may contribute to patient harm with DHTs increasingly mentioned in adverse event reports [34, 62].

1.2.1 Guidelines for Improving EHR Usability

The US government both anticipated and responded to the need to ensure that government-funded Electronic Health Records systems would be monitored for usability problems and supported by guidelines. Therefore, they provided funding for several projects aimed at improving the usability of digital health technologies, which I describe below. I also describe how international organisations such as ISO and HIMSS have actively promoted the usability of EHRs (see Table 1.1).

1.2.1.1 Office of the National Coordinator for Health Information Technology (ONC)

The Office of the National Coordinator for Health Information Technology (ONC) is a federal entity within the U.S. Department of Health and Human Services, established by the HITECH Act in 2009 to promote the adoption and meaningful use of health IT, enhance healthcare quality and efficiency, and provide guidance for interoperable health IT systems nationwide [28]. The ONC has developed national health IT policies, set standards and certification criteria for EHR systems, and promoted interoperability to aid information exchange across different health IT platforms. The ONC also has a remit to improve the usability and safety of health IT systems by providing resources and guidance to support their adoption and effective use by healthcare providers. The ONC's Safety Enhanced Design (SED) Certification mandates that EHR vendors adhere to specific usability standards and engage in user-centred design processes [71]. The goal is to ensure that EHR systems are safe, effective, and tailored to users' needs. Under the rationale described above (that the NHS has now adopted US-based EHR systems), in Chapter 3, I will analyse SED data from the Certified Health IT Product List (CHPL) to understand the current levels of usability of the major EHR systems widely used in the UK. Recently, the ONC also developed a new "Change Package" for improving EHR usability that gives general guidance for identifying and addressing usability problems with EHR systems [61].

1.2.1.2 National Institute of Standards and Technology (NIST)

Outside of the remit of the HITECH Act, the National Institute of Standards and Technology (NIST) has also been involved in advancing the usability and safety of healthcare systems, including Electronic Health Records (EHRs), through several projects. NIST's primary area of work has been producing guidelines and best practices to ensure that EHR systems are user-friendly and meet the practical needs of healthcare providers. A key document in this endeavour is NISTIR 7804-1, "Technical Evaluation, Testing, and Validation of the Usability of Electronic Health Records," which provides empirically-based guidelines for evaluating and testing EHR systems [50]. This report outlines specific methodologies for improving the usability of EHR systems, emphasising identifying and resolving potential issues that could impact user experience and patient safety. In addition to NISTIR

7804-1, NIST produced the NISTIR 7741 guideline, "NIST Guide to the Processes Approach for Improving the Usability of Electronic Health Records" [72]. This guide advocates for a process-oriented approach to usability enhancement and gives structured methodologies for continuous EHR design and implementation improvement. It emphasises the importance of user-centred design and iterative testing so that EHR systems are tailored to the real-world needs of healthcare providers. Beyond these specific documents, NIST's broader projects, such as its work on cybersecurity frameworks and interoperability standards, also contribute to healthcare systems' overall usability and safety.

1.2.1.3 International Organisation for Standardisation (ISO)

The International Organisation for Standardisation (ISO) has also been involved in setting global standards that enhance the usability and accessibility of IT systems, including Electronic Health Records (EHRs). The key standards in this area are ISO 9241-210, titled "Ergonomics of Human-System Interaction - Human-Centered Design for Interactive Systems" [38] and ISO 9241-11, titled "Ergonomics of human-system interaction Part 11: Usability: Definitions and concepts" [39]. These standards describe principles and activities that guide the design of user-friendly and accessible IT systems and define the process of standardised usability testing. They focus on the importance of incorporating human-centred design processes, which involve understanding the users, their tasks, and the environments in which they operate.

1.2.1.4 Healthcare Information and Management Systems Society (HIMSS)

In 2015, HIMSS produced the Usability Maturity Model (UXMM), a framework designed to help organisations assess and enhance the usability of their health IT

Table 1.2: NHS Usability Guidelines and Regulations

NHS Common User Interface	Specific guidelines for EHR design (see Chapter 4)
NHS Design System	Design guidelines for patient-facing NHS websites such as NHS.uk (see Chapter 4)
Digital Technology Acceptance Criteria (DTAC)	Criteria to assess DHTs for NHS adoption (including usability)
National Institute for Health and Care Excellence (NICE) Evidence Standards Framework (ESF)	Evaluation guidelines for DHTs including usability and human-centred design

systems [75]. This model offered a structured approach for evaluating the current state of EHR usability within an organisation and identifying areas for improvement. However, this UXMM appears to have now been deprecated, as it is not currently available through the HIMSS website.

1.2.2 NHS Usability Initiatives

The NHS has undertaken two significant work programmes relating to the usability of DHTs. The first, the NHS Common User Interface (NHS-CUI) project, was part of NPfIT, and the second, the NHS Design System (NHS-DS), was developed by NHS Digital after the closure of NPfIT as part of work supporting patients to access NHS services online. These two initiatives form the core background for this DPhil project and are described below.

1.2.2.1 The NHS Common User Interface (CUI) project

The NHS commissioned Microsoft to develop the NHS Common User Interface (CUI) project as part of the National Programme for IT (NPfIT)[37, 15]. It aimed to standardise user interface design and functionality across various NHS IT systems, including the new Lorenzo EHR system developed through the programme[37]. Specific goals of the CUI project were to enhance usability, improve user experience, and ensure consistency in how healthcare professionals interacted with different software applications. By establishing standardised design guidelines and interface elements, the NHS CUI sought to reduce training time for staff, minimise user errors, and streamline workflows within the healthcare system. The NHS intended this standardisation to facilitate better data entry, retrieval, and sharing, ultimately supporting the broader goals of the NPfIT in improving patient care and operational efficiency within the NHS. The development of the CUI followed industry best practices and included questionnaires, focus groups and subject matter experts but did not include larger-scale quantitative evaluations. The CUI guidelines were developed into a set of government-approved standards and guidelines, but these were not mandated, so developers could opt not to adopt them. In 2019, the CUI was officially deprecated by the NHS[19]. In the document review in Chapter 4, I go into specific detail of the CUI standards that relate to the objectives of this DPhil.

1.2.2.2 NHS Design System

The NHS Design System is a set of guidelines, principles, and tools created by NHS Digital (now merged into NHS England) to help design and develop consistent, user-friendly, and accessible digital services for the NHS[16]. The system aims to ensure that all NHS digital products, such as websites and mobile applications (apps), offer a cohesive experience for users, including patients, healthcare professionals, and the general public. NHS Digital aimed to provide a unified design approach, demonstrating a solid and recognisable brand while making digital interactions straightforward and intuitive.

The basis of the NHS Design System is a set of guidelines and principles covering various aspects of design, including typography, colour usage, layout, and imagery. These guidelines ensure that all digital services reflect the NHS brand and are visually consistent. The principles emphasise simplicity, clarity, and human-centred design to create aesthetically pleasing interfaces that are intuitive and easy to navigate. This focus on human-centred design aimed to ensure that digital products meet the needs and expectations of their users.

The system includes a library of reusable components and design patterns, such as buttons, forms, navigation menus, and alerts. These components are pre-designed and tested to work across different devices and screen sizes to promote efficiency and consistency in the design process. Design patterns offer best practices for common design problems, ensuring that solutions are practical and consistent across the NHS digital landscape. This modular approach allows designers and developers to build digital products more quickly and reliably, using elements that are known to work well together.

The NHS Design System also focused on accessibility. The guidelines aim to ensure that digital services are usable by people with various disabilities, including visual, auditory, cognitive, and motor impairments. The NHS-DS adheres to the Web Content Accessibility Guidelines (WCAG), and the NHS Digital team designed the components and patterns with accessibility in mind.

In line with industry best practices for human-centred design, user research and testing were encouraged throughout the design process to understand user needs and behaviours. This user-centred approach aimed to ensure that the NHS tailors digital services to users' needs. NHS Digital uses feedback from user testing to improve and refine the design system continuously. The NHS Digital website also provides a wide range of documentation and support resources to help designers and developers implement the guidelines and components effectively. This documentation includes information on using the design system and specifications for each component. This documentation is reviewed in detail in Chapter 4, particularly as it relates to the specific aims of this DPhil described below.

1.2.2.3 Integrating Usability into NHS Digital Health Guidelines and Regulations

In the UK, the Digital Technology Assessment Criteria (DTAC) and the NICE Evidence Standards Framework (ESF) aim to improve the adoption and regulation of digital technologies, such as EHR systems. NHS organisations use these frameworks to determine whether or not the IT systems they are considering implementing meet the required standards for safety and effectiveness. Software developers can also use them to guide the development process and ensure that the systems they create will be acceptable for use in the NHS. Not surprisingly, usability is addressed in both systems (albeit not through specific UI guidelines), and they provide a baseline set of regulatory standards and guidelines that can be followed.

1.2.2.4 Digital Technology Assessment Criteria (DTAC)

The NHS Digital Technology Assessment Criteria (DTAC) is a standardised framework designed to evaluate digital health technologies, ensuring they meet the necessary standards for safe and effective use within the NHS[17]. The DTAC framework assesses technologies across five key areas: Clinical Safety, Data Protection, Technical Security, Interoperability, and Usability and Accessibility:

- The **Clinical Safety** section of the DTAC aims to ensure that digital technologies do not pose risks to patient safety and comply with established clinical safety standards. This involves testing and validation to confirm that the technology can be used in clinical settings without compromising patient care based on the NICE Evidence Standards Framework (ESF) described below.

- The **Data Protection** section evaluates compliance with data protection regulations, ensuring that patient data is handled securely and responsibly following legal and ethical standards.

- The **Technical Assurance** section assesses the technology's measures to protect against cyber threats and unauthorised access to maintain the integrity and confidentiality of patient information.

- The **Interoperability** section provides guidance to support the integration and exchange of information with other NHS systems. This is important for creating a cohesive healthcare ecosystem where patient information can be easily shared across different platforms and services, enhancing the continuity and quality of care.

- The **Usability and Accessibility** section of DTAC states that technologies must be designed with a user-centred approach, involving user feedback and iterative testing to refine the user interface. To be usable by individuals with disabilities, technologies should also comply with standards such as the Web Content Accessibility Guidelines (WCAG) [7].

1.2.2.5 National Institute for Health and Care Excellence (NICE) Evidence Standards Framework (ESF)

Developed collaboratively by NICE, NHS England, NHS Digital, Public Health England, and DigitalHealth.London, the NICE Evidence Standards Framework (ESF) for Digital Health Technologies (DHTs) outlines the evidence requirements for DHTs to support their adoption and commissioning within the UK health and social care system[60]. Usability in the ESF is primarily addressed in **Section C: Evidence Standards Tables**, which outlines specific requirements for user-centred design, ease of use, accessibility, support for clinical workflows, and error reduction. Technologies must be designed with the end-user in mind, incorporating feedback and iterative testing to refine the interface. They should feature intuitive navigation, comply with accessibility standards like the WCAG, and integrate seamlessly into clinical workflows to support efficient healthcare delivery. Additionally, the design should minimise user errors and provide clear guidance for correcting mistakes.

1.2.2.6 The Need for Evidence-based Design Guidelines for Digital Health Technologies

The Common User Interface and the NHS Design System provide a reasonable basis for design guidelines for future systems, and the DTAC and the NICE ESF both encourage the adoption of user-centred design principles in developing software that the NHS will use. The CUI is outdated (and now deprecated) but provides guidelines for common EHR user interface (UI) elements. The NHS Design system is modern but focuses on web components and mobile apps that are predominantly patient-focused. Neither system has a strong quantitative evidence base, as evaluations have predominantly been in the form of interviews and focus groups with clinical users rather than quantitative evaluations or clinical usability trials. This is at odds with how other technologies, such as drugs and medical devices, are evaluated in healthcare. As digital health technologies become more integrated into clinical workflows, particularly with the introduction of clinical decision support systems, software suppliers will need better-evidenced design guidelines to ensure maximal patient safety and clinical usability. The current guidelines and regulations described above (both internationally and for the UK NHS) provide a good basis for future guidelines and regulation, and the qualitative user research that has been done to create the guidelines (particularly the NHS Design System) ensured that user needs and preferences have been addressed. However, the CUI is the only guideline that specifies EHR UI elements in detail. Unfortunately, it has now been deprecated and requires updating to a modern technology stack. In addition, these specific EHR UI elements that the CUI describes should be evaluated using rigorous quantitative methodologies in a similar way to how we evaluate other interventions in healthcare to ensure that they are quantifiably safe and effective.

1.3 Research Aims

To address the current lack of up-to-date and evidence-based EHR UI guidelines as described above, this DPhil aims to extend the NHS Design System, which has a good base of qualitative user research and a modern technology stack, to include UI components for EHR systems based on the guidance in the NHS Common User Interface (CUI), specifically, the **Patient Name Input** and the **Patient Banner**, and to quantitatively evaluate them leading to the development of a scientific evidence-base for EHR UI designs. I have chosen to focus the "design artefacts" on the Patient Name Input and the Patient Banner as these are core components of an EHR system and are important for ensuring patient safety and workflow efficiency. If patient names are entered incorrectly due to working memory overload, then serious medical errors could result from lost communication or misidentification of patients. Similarly, clinicians use the patient banner continuously to ensure that the correct information is displayed about the patient and that new data is recorded for the correct patient. Inefficiencies in the designs of these components would mean significant delays in patient care due to their frequency of use and importance in the overall design of the EHR system. Many additional components of EHR systems are defined in the NHS-CUI, but it is beyond the scope of this DPhil project to define all of them. However, if the approach used here is feasible and effective, additional future work could be undertaken to develop and scientifically evaluate designs for all existing components and to develop new ones, creating a comprehensive evidence base for EHR UI designs.

A further sub-aim is to assess whether HCI modelling as a research method is feasible for providing quantitative evidence of the safety and efficiency of the new designs without the need to conduct expensive empirical testing. If HCI modelling is feasible, then there is significant potential for improving the scientific process of evidence generation for the usability of digital health technologies. The potential for HCI modelling is described in detail in Chapter 2, and I will discuss this topic further in Chapter 6.

1.3.1 Research Questions

To achieve these aims, I will answer the following five research questions:

1. Does the CHPL database show significant variation in the time it takes to complete clinical tasks in the different Electronic Health Record (EHR) systems used in the National Health Service (NHS)?

2. How do the NHS Common User Interface (CUI) guidelines specify the design of EHR systems, focusing on the Patient Name Input and the Patient Banner?

3. How should the NHS CUI guidelines be implemented within a modern web technology stack to adhere to the NHS Design System guidance?

4. How long does it take to view and input data, and does working memory become overloaded when using newly developed Patient Name Input and Patient Banner designs that adhere to the NHS CUI and NHS Design System guidelines?

5. Is Human-Computer Interaction (HCI) modelling feasible for evaluating UI designs in terms of efficiency and working memory load, and could it be used to develop evidence-based UI guidelines for Digital Health Technologies such as EHRs?

In the next chapter, I will describe the overall methodological framework of Design Science Research (DSR) that I will use to answer these questions using various methods and tools, including HCI modelling. Following this, Chapter 3 will provide the first results chapter, where I present the results of my analysis of the Certified Health IT Product List (CHPL) database of usability test results. In Chapter 4, I review the documentation describing the CUI and NHS Design System to determine how the new Patient Banner and Patient Name Input artefacts should be designed. Then, in Chapter 5, I demonstrate the design artefacts and quantitatively evaluate them using HCI modelling. Finally, in Chapter 6, I discuss the results of my DPhil and the implications for digital health regulation and future research.

Chapter 2

Methodological Overview

2.1 Introduction

This methodological overview chapter discusses the background and rationale for the methodological framework I used for this DPhil, Design Science Research. For each stage of the DSR process, I give an overview of the specific methods used and link the DSR Stages to the research questions described in Chapter 1.

2.2 Researching Digital Technologies in Healthcare

The computer systems that we use in healthcare often serve critical life-saving functions: Electronic Health Records (EHRs) provide immediate access to information about patients that form a key part of diagnostic and treatment decisions, and automated pharmacy dispensing systems must operate flawlessly to avoid the consequences of harmful drug interactions or giving patients medications to which they are allergic. However, these systems are often designed and implemented without scientific studies. We do not provide patients novel drugs that have not been extensively tested through rigorous scientific processes; however, we currently allow the use of information technology that has only been through relatively superficial evaluations, and often primarily to ensure that systems benefit (or at least do not harm) the financial side of the healthcare enterprise rather than evaluating the impact these systems have on patient health outcomes. The reasons for this are historical and complex. For many years, there was no scientific paradigm into which the study of information systems would fit [73, 74]. They are complex artefacts created by human minds rather than physical substances like drugs or mechanical medical devices. Computer software is also ephemeral: code developed by programmers is compiled, copied, executed, and influences the real world through human-computer interaction. If IT systems were stable hardware devices like prosthetic hips or mechanical heart valves, studying their properties, benefits, and side effects would be more straightforward before implementing them in the healthcare system. However, they are difficult to grasp, continuously updating and changing, and subject to the needs of various stakeholders.

Many scientists have tried to solve this issue by applying methodologies used in other areas of healthcare to the challenges of evaluating digital health technologies, but these are fraught with problems. The randomised controlled trial (RCT) is the "gold-standard" approach to evaluating whether a new therapy or diagnostic test works as it can control for unknown confounders and enable a fair test[22]. However, digital technologies quickly change, and if an unknown system is subject to a fair test but is then quickly changed (as software often is), then a new RCT may need to be conducted. Although this may be the ideal solution, it is impractical and far too expensive for most digital health technologies[55]. Qualitative methodologists study digital technologies as social phenomena to be studied through social science techniques, interviewing users and stakeholders and building grounded theories of how technologies work[4, 27, 2]. These approaches provide valuable data on system design and implementation but may sometimes fail to generalise beyond the context in which they are studied. It can be very difficult to use these methods to describe the mechanisms of how digital technologies affect the world through human-computer interaction in the same way that we understand how a drug or medical device works.

2.3 Design Science Research

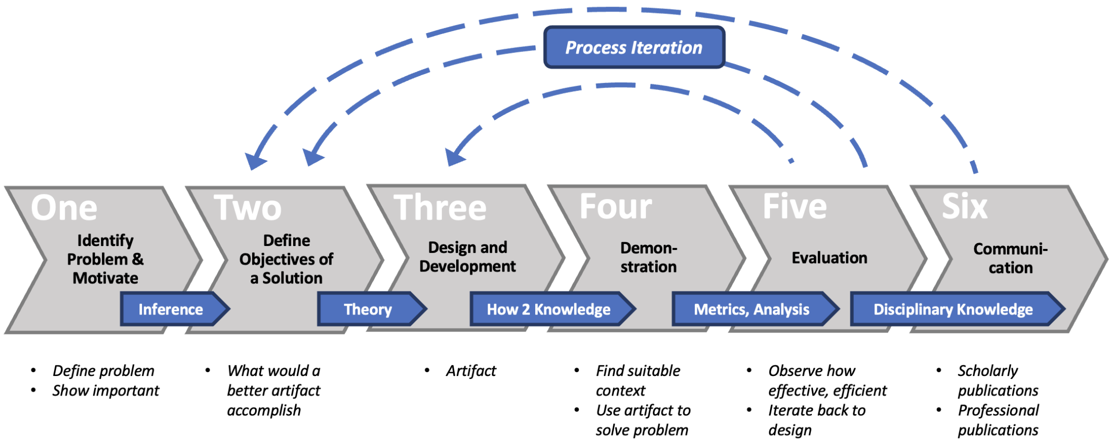

Figure 2.1: The Six Stages of Design Science Research (modified from Peffers et al., 2007

Although far from solved, in the field of Information Science, the challenge of how to design and evaluate digital technologies has adopted an approach called Design Science Research (DSR) to address the "wicked problem" of developing an understanding of how information systems exert an effect on the world[31, 30]. The epistemological foundations of DSR come from the philosophical field of Pragmatism and align with the hypothetico-deductive approach developed by the philosopher Karl Popper[68], which is commonly used in medical research. The scientific aim remains to test falsifiable hypotheses to progress generalisable scientific theories. However, the DSR framework enables pragmatic approaches, adjusting the methods to suit the particular technology and context best. Particularly relevant for research into information systems, DSR emphasises the production of artefacts that can be implemented into real-world use as part of the scientific process[66].

The DSR research question reflects the meta-requirements of the project - why are we developing this software? This can be approached through requirements engineering, qualitative research, and analysis of existing data sets, but it must still be framed in a scientific hypothetico-deductive format. The question is answered by building a design artefact such as a prototype system, algorithm or model, then subjecting the prototype to evaluation. The design artefact should be grounded in the existing theories and knowledge base and tested through evaluation. At this stage, it is important to fully document the processes by which the artefact is brought into existence, as these are critical to fully understanding whether or not the research question can be answered in a generalisable way. The evaluation can be done using various methods depending on the form of the artefact and the question to be answered. Finally, the evaluation results are used to develop or refine generalisable theories for future work. These theories in DSR often take the form of design guidelines, standards, models and frameworks.

In Marcus Vitruvius Pollio's De Architectura[67], he states that good building design demonstrates *utilitas* (utility), *firmitas* (strength) and *venustas* (beauty/delight). The same applies to software in healthcare; forfeiting these three essential elements can decrease utility, cause medical errors, and result in weak technical infrastructure, leading to system outages and cyber-attacks. This is not to mention the depression and burnout caused by frustrating and overcrowded user interfaces that are often the polar opposite of "delightful" to use. The DSR approach combines scientific rigour with sound software development principles to achieve software that echoes Vitruvius and is useful, reliable, and delights the user.

Peffers et al.[66] describe a 6-stage DSR methodology, which I follow in this thesis (Figure 2.1).

2.4 Stage 1: Identification of the Problem

This first stage in the DSR methodology identifies the problem we are interested in. To do this, I have analysed the Certified Health IT Product List (CHPL) database, which collates government-mandated usability test results for Electronic Health Records (EHR) systems. Although I am primarily interested in NHS systems (I am building on NHS usability guidelines), the CHPL, despite being a US government database, includes evaluations of many of the EHR systems used in the NHS for reasons described in the previous chapter. Stage 1 of the DSR process enables us to answer research question 1: **Is there significant variation in the time it takes to complete clinical tasks in the different EHR systems used in the NHS??**

2.4.1 Analysis of CHPL database (Chapter 3)

The CHPL database is an online resource hosted by the US government that gives access to the results of usability studies on electronic health records systems (EHRs) used in hospitals and clinics[11]. Companies must submit the results of usability tests to receive subsidies from the US government.

I downloaded the usability results dataset from the CHPL website, cleaned the data and conducted a quantitative analysis using the R programming language[36]. I developed a metric that provided a percentage score for how long it took test participants to complete tasks compared to a baseline expected time provided by the vendor, which allowed comparison across different vendors and systems in a standardised way. The results of the CHPL analysis are presented in Chapter 3.

2.5 Stage 2: Define Objectives

To define the objectives for the work, I conducted a document review to obtain the information necessary to build design artefacts that would demonstrate how the NHS-CUI guidelines could be developed using the NHS Design System guidelines and technology stack. Stage 2 of the DSR process enables us to answer Research Question 2: **How do the NHS Common User Interface guidelines specify the design of EHR systems, focusing on the Patient Name Input and the Patient Banner?**

2.5.1 Document Review (Chapter 4)

Most of the literature about digital health design guidelines is in the form of national and international policies and standards rather than academic research papers. I therefore used a document review methodology (READ) to review the relevant literature. READ, developed by Dalglish et al.[14], describes a four-step approach to reviewing documents: 1. Readying the materials; 2. Extracting data; 3. Analysing data; 4. Distilling the findings. Each phase is applied separately to the NHS CUI and the NHS Design System documentation to provide a comprehensive review for each framework.

The findings of the document review enabled me to define the research objective of integrating the two guidelines. In the DSR paradigm, the overall objective is the creation of new design artefacts that represent a new theory of how UI components aligning with the NHS CUI and the NHS Design System could be used to improve the usability of digital health technologies. HCI modelling will then be used to benchmark the performance and demonstrate a method of quantitatively improving the artefacts and updating the guidelines in an iterative scientific process.

2.6 Stage 3: Design and Development of Artefacts

Stage 3 of the DSR process involves designing and developing software artefacts that bring to life the ideas and concepts to be tested[66]. In Stage 3, I answer the third research question: How should the NHS CUI guidelines be implemented within a modern web technology stack to adhere to the NHS Design System guidance?

Stage 3 is described in Chapter 5, where I developed two sets of design artefacts. The first set of design artefacts used the NHS Common User Interface Guidelines alone and the second set of artefacts used the CUI and the NHS Design System guidelines. This enabled comparison using HCI modelling to show the benefits (or problems) of integrating the two guidelines.

The first set of artefacts, based on just the CUI, were developed in Visual Studio Code using HTML, CSS, and JavaScript. I used two approaches to combine the CUI and the NHS Design systems. I applied the NHS Frontend CSS to my existing HTML code for the patient banner to add the NHS DS "look and feel". The second approach was used for the NHS Prototype Kit [59], described in further detail in Chapter 5, to create the Patient Name Input and a version of the Patient Banner that more closely aligned to the Design System and used existing HTML and CSS components.

2.7 Stage 4 Demonstration of the Artefacts

Next, the artefacts need to be demonstrated (Stage 4 of the DSR process). For the HTML, CSS and JavaScript code I wrote to show the CUI and NHS DS designs, I used the Live Server built into Visual Studio Code and rendered the HTML and CSS in the Google Chrome browser. For code developed for the NHS Prototyping Kit, I ran the kit from the Terminal application and viewed the pages using Google Chrome. For each design artefact, I took screenshots to demonstrate how the artefacts worked, which are presented in detail in Chapter 5.

2.8 Stage 5: Evaluation of the Solution

In Stage 5, I answer the final two research questions:

- How long does it take to view and input data, and does working memory become overloaded when using newly developed Patient Name Input and Patient Banner designs that adhere to the NHS CUI and NHS Design System guidelines?
- Is Human-Computer Interaction (HCI) modelling feasible for evaluating UI designs in terms of efficiency and working memory load, and could it be used to develop evidence-based UI guidelines for Digital Health Technologies such as EHRs?

I have used Human-Computer Interaction (HCI) mathematical modelling to evaluate how using the CUI and NHS Design system impacts the usability of the Patient Banner and Patient Name Input components. HCI modelling provides quantitative data on task time and memory load while performing tasks. The use of mathematical modelling for evaluation is a sub-aim of this DPhil project. As discussed in this chapter's introduction and Chapter 6, the potential for HCI modelling in evaluating digital health technologies could accelerate and simplify the process of ensuring DHTs are safe and effective through a scientifically robust process, similar to how we evaluate drugs and medical devices in healthcare. In this section, I will therefore describe the history and process of HCI modelling in detail as it is an important element of this DPhil.

2.8.1 Human-Computer Interaction (HCI) Modelling

Mathematical modelling is a research methodology that can help us think about and test ideas without new experimental or observational studies. Using the results from previous scientific experiments, we can create a simulation of reality in a computer to answer questions. Mathematical modelling is used widely in healthcare and science, from simulating aircraft turbulence to modelling disease outbreaks. In Human-Computer Interaction, we can use a mathematical model of how humans interact with computers to test different user interface (and user input device) designs before creating them in the real world and testing them with real users[9, 64].

2.8.1.1 Predictive models

Over a period of many years, researchers have conducted a wide range of experiments on how humans perform various activities related to using a computer. This includes data on how quickly we can react to new information or how long it takes us to point at something accurately. The results of these experiments can often be described as reasonably simple relationships based on how quickly humans can (on average) move their hands and fingers or process information in their working memory. Researchers express these relationships in the form of equations or predictive models. They are predictive because if you input specific values, such as the distance from the mouse cursor to a button you want to click and the size of the button (the independent variables or predictor variables), the equation will output a time it takes an average human to move the cursor to the button (the dependent variable or outcome variable). The factors that go into the equation are derived from previous experiments that measured how long it took a sample of people to click on buttons at various sizes and distances. The results of these experiments can be plotted with the resulting graphs representing equations. Superficial relationships can be determined using a process of linear regression to generate simple predictive equations of the form y = mx +b, where the values of m and b are derived from the experimental results. m is the gradient of the line of best fit through a scatter plot of the results (using a method of measuring how far each point is from the line and finding the line that gives the "least squares" of the distances of each end) and b is where the line intersects with the y axis. With such an equation, we can predict the outcome (y) of a new independent variable (x) that we might want to know without running a new experiment. As described below, most HCI laws are more complex than simple linear regression but were developed using a similar approach with empirical data informing the development of a mathematical model that reflects the relationship between independent and dependent variables.

2.8.1.2 Fitts's Law

In 1954, Paul Fitts developed a model of the time required for rapid aimed movement as a function of target size and distance [23, 24, 8]:

$$MT = a + b \cdot \log_2 \left(\frac{D}{W} + 1 \right) \tag{2.1}$$

Where MT represents "movement time", D stands for distance (from the starting point), and W is the width of the target. The values of a and b are constants determined through empirical observation and linear regression and represent the intercept and the slope of the resultant linear equation that is particular to the circumstance or device used for pointing. The values of a and b will be different for different pointing devices, such as a light pen or a mouse. The value of $\log_2\left(\frac{D}{W}+1\right)$ is often called the "Index of Difficulty" or ID based on the distance and size of the target. There is an intuitive relationship between distance and size: if the size increases, the distance can also increase without increasing the overall ID.

Even though Fitts's Law, as the model became known, is not limited to activities on a computer screen (using a mouse or other pointer), the model works just as well on a computer as in the real world. In short, the model says that as a target gets smaller or further away, it becomes increasingly difficult to point to or touch it. The exact time it takes to hit the target depends on the target's size and the distance from the starting point. It encompasses the mental and physical limitations of humans and the usability of the device used for pointing.

2.8.1.3 Hick-Hyman Law

Another law derived from combining experimental psychology and information theory, the Hick-Hyman law for calculating choice reaction time, was invented around the same time as Fitts's law in the early 1950s[33, 35]. This is similarly a predictive equation/model in the form $RT = a + b \cdot \log_2(n)$ where RT is reaction time, and n represents the number of stimuli and responses in a one-to-one relationship (i.e., there is one possible response for each stimulus). Like Fitts's law, the values of the coefficients, a and b, are derived empirically. The Hick-Hyman law has been used

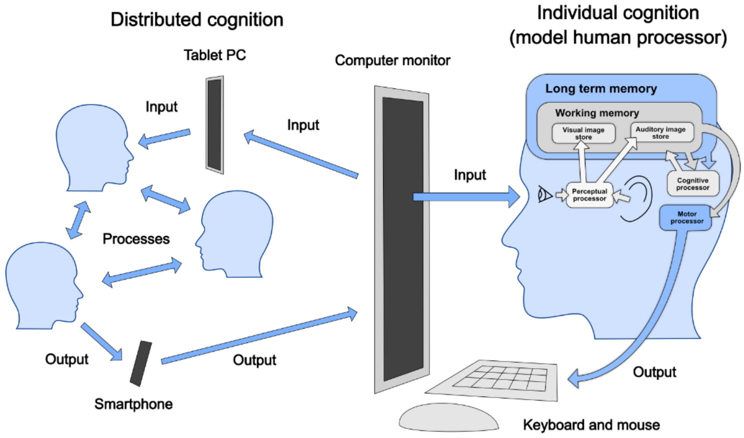

Figure 2.2: Model Human Processor

in computer menu design but has proven less valuable due to the need to account for movement or visual search, complicating the calculations.

2.8.1.4 The Model Human Processor

The Xero PARC Applied Information-Processing Psychology Project was led by three researchers, Stuart Card, Tom Moran and Allen Newell, to create an "applied psychology of HCI by conducting requisite basic research within a context of application". The research was published in a book called The Psychology of Human-Computer Interaction, which was published in 1983[9]. In the book, Card, Moran, and Newell propose a framework for describing how humans interact with computers called the "Model Human Processor", a simplified model of how humans perceive, process and use information in the form of motor responses. The model is a predictive mathematical model with experimentally (empirically) derived parameters representing how fast information can be perceived, stored, processed and used to complete the motor tasks involved in interacting with computers, such as typing on a computer keyboard.

The dependent variable in the MHP is the time taken to complete a task. Each task is broken down into subsystems, each with an associated cycle time. The primary subsystems are the cognitive, perceptual, and motor processors. There are also 'buffers' for each process where information is temporarily held, such as working memory, the visual image store and the auditory store. The cycle times for the subsystems involved in a task are then added up to give a total time for task completion (utilising buffers if necessary).

2.8.1.5 GOMS

The Goals, Operators, Methods and Selection rules (GOMS) model was developed by Card, Moran and Newell in the early 1980s to apply the MHP to computer systems in a systematic methodology[9, 41, 42]. GOMS uses the cycle and buffer times from MHP to show how long tasks take using a computer system. The "Goals" are the high-level tasks that need to be accomplished. "Operators" are the basic interactions, such as moving the mouse, clicking on a button or pressing a button on a keyboard. The "Methods" are the sequence of the operators strung together to describe how the user uses each operator to achieve the goal, such as typing a command or opening a file. The "Selection Rules" are included as there are often many ways of accomplishing a task on a computer, so the model can consist of various ways of completing the task, such as using a mouse or a keyboard shortcut. For example, here is a GOMS model for saving a document on a computer:

Goal: Save a document:

Method 1 (Using a mouse):

1. Move the mouse cursor to the "File" option on the main menu (1.2s)
2. Click on the word "File". (0.3s)
3. Move the mouse cursor to the word "Save" on the dropdown menu. (1.2s)

4. Click the mouse button on the word "Save". (0.3s)

Total time for Method 1 = 3.0 seconds.

Method 2 (Using a keyboard shortcut):

1. Press the “Ctrl” + “S” keys together. (0.5s)

Total time for Method 2 = 0.5 seconds.

Selection Rule: Use Method 2 if the user prefers keyboard shortcuts and knows the correct keypress combination. Otherwise, use Method 1.

The example can be abbreviated using shorthand as:

Goal: Save a document

- M1: Mouse File[1.2s]+Click[0.3s]+Mouse->Save[1.2s] + Click[0.3s] = 3.0s
- M2: “Ctrl+S”[0.5s] = 0.5s
- SR: Knows shortcut? Use M2. Else, M1

It is obvious that using a keyboard shortcut is quicker than using the mouse for the same task, but it is useful to know how much quicker to balance the trade-off of needing to learn the shortcut. Breaking down the steps into a structured method is also useful for refining the process. It enables us to ask questions like, "How much time would be saved if we replaced this sequence of steps with a new button or menu option?"

Since the original GOMS (often now called CMN-GOMS after its creators), several variants of GOMS have been proposed[41]. These include CPM-GOMS (Cognitive Perceptual Motor GOMS), developed by David Kieras and David Meyer, and NGOMSL, developed by William Kieras[42]. CPM-GOMS is based on the Cognitive Perceptual Motor (CPM) task framework, which adds parallel processing to the model to make it more realistic, as a user often reads while using the mouse or doing other tasks in parallel. Natural GOMS Language (NGOMSL) is a more structured and formal way of representing a formal GOMS model[45].

2.8.1.6 The Keystroke-Level Model (GOMS-KLM)

Card, Moran, and Newell created the Keystroke-Level Model to provide a more detailed and specific model that included keystroke timings for entering text. It was introduced in the textbook The Psychology of Human-Computer Interaction in 1983[9]. If we add KLM to the GOMS model above, we get:

Method 1 (Using the mouse):

- H - Hand on the mouse: 0.4s
- P - Move the mouse cursor to the "File" option: 1.2s
- B - Click on "File": 0.1s
- P - Move the mouse cursor to "Save": 1.2s
- B - Click on "Save": 0.1s

Total Time for Method 1: 3.0 seconds

Method 2 (Using a keyboard shortcut):

- H - Hand on the keyboard: 0.4s
- K - Press Ctrl: 0.2s
- K - Press S: 0.2s

Total Time for Method 2: 0.8 seconds

This shows how KLM adds more detail but also extra time to the model, making it more accurate with more information for changing the GUI for improved efficiency.

GOMS can be used without KLM (particularly for the decision rules), and KLM can be used without GOMS (for timings of a particular method). They can also be combined, as in the above example.

2.8.1.7 Cogulator

The software I have used to evaluate the new user interface designs is called Cogulator[21]. Cogulator is a relatively new tool for creating HCI models that was developed by the MITRE Corporation. Cogulator has been used in various industry and research contexts including nuclear safety [46] and aviation [80]. This software enables the creation of GOMS models by either typing in the model using a series of commands or tracking the user's mouse and keyboard interactions as they perform a task. Once the model has been entered, Cogulator presents quantitative results (such as task time and chunks of working memory used) and a swim lane graph to show how users use different cognitive and motor faculties as they go through the task. It also graphically shows how much working memory is used during the task. Figure 2.3 shows how the Cogulator user interface displays the sequence of tasks and the swimlane graph of cognitive load. Cogulator is described in further detail in Chapter 5, along with the results of the HCI modelling evaluations.

2.9 Stage 6: Communication

The final stage in the DSR framework is the communication of the research results. The results of this thesis have been communicated during the period of my

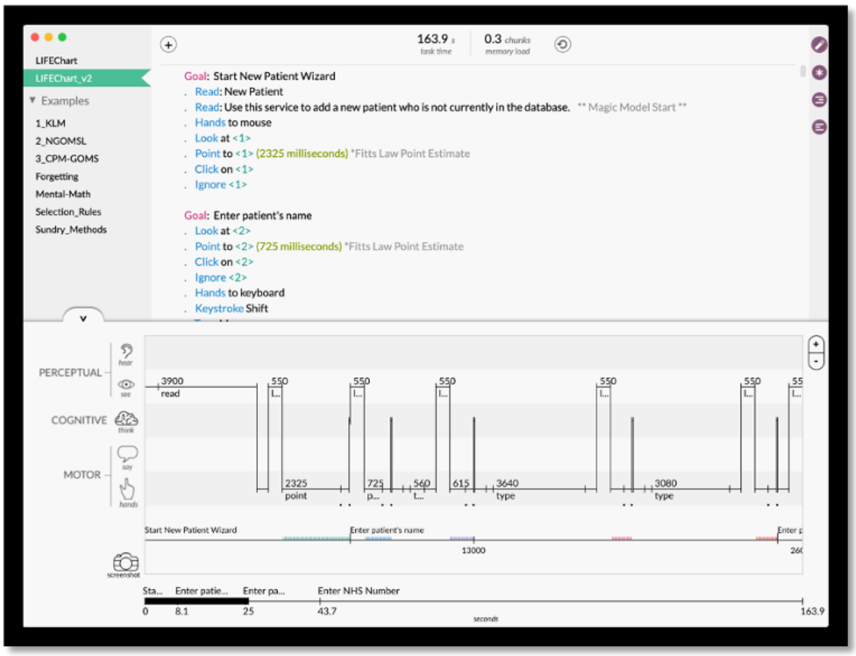

Figure 2.3: Screenshot of the Cogulator modelling application

DPhil. I have described the overall aim and HCI methodology in a workshop in 2019 at the International Medical Informatics Association (IMIA) MEDINFO conference. This workshop was then written up and expanded as an article published in JMIR in 2021[64]. I also described the research methodology in a presentation at the Health Informatics New Zealand (HINZ) 2022 conference. I published the results of the design system literature review in a paper in the IMIA Yearbook in 2022[65]. The CHPL analysis was presented at the 2024 HINZ Conference and will be submitted for journal publication. The results of the modelling studies and final design guidelines have been published in the journal Methods[63].

Chapter 3

Analysis of the Certified Health IT Product List Database

3.1 Introduction

In this first results chapter, I describe the results of my analysis of the Certified Health IT Product List (CHPL) database. As described in the Methods section below, my analysis focuses on the time it takes to complete tasks as a measure of overall health IT system usability. I developed a computed measure called Task Time Ratio (TTR) in order to make comparisons between different systems where different tasks were tested. By having a ratio of the time it took a test participant to complete a task to the optimum time it should have taken (according to the software developer), we can compare tasks across tests.

By analysing the results of usability tests of a broad range of EHR systems, I aimed to identify and quantify common usability problems with EHR systems, many of which are in use in the NHS. The UK has not developed a similar database for systems used in the NHS, and there has not been any other systematic testing of EHR systems that could offer comparable information. Therefore, the CHPL database is the best source of quantitative information on the usability of the wide range of EHR systems in use today, including those used in the NHS. The results of this study inform "Stage 1" of the Design Science Research framework, giving an understanding of the problem area of DHT usability and answering my first research question: **Does the CHPL database show significant variation in the time it takes to complete clinical tasks in the different Electronic Health Record (EHR) systems used in the National Health Service (NHS)?**

3.2 Background to the CHPL Database

Before 2008, hospitals and medical clinics in the USA predominantly used paper-based medical records to form a legal record of medical encounters and to provide an aide memoir for the doctor when they saw the same patient in a future visit. To gather data for billing and administrative purposes, the paper-based notes were reviewed by clinical coders who categorised diagnoses, tests and procedures so that insurance companies and the government could reimburse doctors. By supporting the adoption of new EHR systems, the government hoped that the data collected during clinical encounters could be used for more efficient and accurate billing and to improve the process of providing clinical care to patients. However, the government also acknowledged that introducing new technology into providing healthcare could have unintended adverse consequences. Borycki and Kushniruk describe technology-induced errors as errors "...that arise from a) the design and development of technology, b) the implementation and customization of a technology, and c) the interactions between the operation of a technology and the new work processes that arise from a technology's use"[49].

3.2.0.1 Safety-Enhanced Design

As described in Chapter 1, the US government enacted the HITECH Act [28] in 2009, together with a regulation system called "Safety-Enhanced Design" (SED) to mitigate technology-induced errors that the new EHR systems funded by HITECH might cause [71]. The regulation required vendors of EHR systems to conduct "Human-Centred Design" tests and report the results to a central government database called the Certified Health IT Product List (CHPL). The regulation states:

The regulations also specify the types of tasks that should be evaluated for each product, which are categorised as follows:

For this study, I aimed to evaluate the CHPL database to investigate the variability in task time across the different SED criteria and between various vendors and products.

3.2.1 Method

The CHPL dataset was extracted through the CHPL website in Comma Separated Value (CSV) format. The R programming language was used to clean and analyse the data.

3.2.1.1 Data Cleaning

Rows with NA values and implausible time values were removed (only rows with $>$ 0 seconds for *time_mean* or *time_optimum* were kept).

Due to how the data from the usability test are recorded in the CHPL dataset, each row represents a single user with individual demographic information (age, sex, experience, etc.). However, the mean time for each individual is recorded as the mean for the group of participants tested on each task (usually 10-15 participants).

§170.315 (g)(3) Safety-enhanced design—
(i) User-centered design processes must be applied to each capability technology includes that is specified in the following certification criteria: paragraphs (a)(1) through (9) and (14), (b)(2) and (3) of this section.
(ii) Number of test participants. A minimum of 10 test participants must be used for the testing of each capability identified in paragraph (g)(3)(i) of this section.
(iii) One of the following must be submitted on the user-centered design processed used:
A. Name, description and citation (URL and/or publication citation) for an industry or federal government standard.
B. Name the process(es), provide an outline of the process(es), a short description of the process(es), and an explanation of the reason(s) why use of any of the existing user-centered design standards was impractical.
(iv) The following information/sections from NISTIR 7742 must be submitted for each capability to which user-centered design processes were applied:
A. Name and product version; date and location of the test; test environment; description of the intended users; and total number of participants;
B. Description of participants, including: sex; age; education; occupation/role; professional experience; computer experience; and product experience;
C. Description of the user tasks that were tested and association of each task to corresponding certification criteria;
D. The specific metrics captured during the testing of each user task performed in (g)(3)(iv)(C) of this section, which must include:task success (%);task failures (%);task standard deviations (%);task performance time; and user satisfaction rating (based on a scale with 1 as very difficult and 5 as very easy) or an alternative acceptable user satisfaction measure;
E. Test results for each task using the metrics identified above in paragraph (g)(3)(iv)(D) of this section; and
F. Results and data analysis narrative, including: major test finding; effectiveness; efficiency; satisfaction; and areas for improvement. (v) Submit test scenarios used in summative usability testing.

Table 3.1: §170.315 (g)(3) Safety-enhanced design Regulations

Section	Description
§ 170.315 (a)(1)	Computerized Provider Order Entry (CPOE) – medications
§ 170.315 (a)(2)	CPOE – laboratory
§ 170.315 (a)(3)	CPOE – diagnostic imaging
§ 170.315 (a)(4)	Drug-drug, Drug-allergy Interaction Checks for CPOE
§ 170.315 (a)(5)	Demographics
§ 170.315 (a)(6)	Problem List
§ 170.315 (a)(7)	Medication List
§ 170.315 (a)(8)	Medication Allergy List
§ 170.315 (a)(9)	Clinical Decision Support
§ 170.315 (a)(14)	Implantable Device List
§ 170.315 (b)(2)	Clinical Information Reconciliation and Incorporation
§ 170.315 (b)(3)	Electronic Prescribing

Table 3.2: SED Task Categories

These mean values are then repeated for each user, resulting in duplicate rows (apart from demographic information). In this analysis, demographic information is not used; therefore, duplicated mean times were removed prior to comparison.

However, there remain duplication issues for some products. For some products, the same mean time is recorded for several different tasks. This seems to be because the developer has not conducted the error testing or user satisfaction surveys on the same tasks as the time to task completion. In the dataset, tasks used for testing errors or user satisfaction have their time data duplicated instead of omitted. To correct for this, I removed duplicates where time-related data appears duplicated even if the tasks are different, as some tasks are probably just for user satisfaction or error testing.

Many entries also had implausible values, such as 0 or -1 for task time (mean or optimal), so these rows were excluded from the analysis. Outliers were trimmed at 1.5 times the IQR.

3.2.1.2 Task-Time Ratio

With the large number of software developers represented in the database, I decided to focus my analysis on the top 20 developers included by the number of usability tasks tested. For each developer, I identified the range of products they had submitted data on to the CHPL database.

Although developers are required to categorise each usability task they assess, they do not have to test exactly the same tasks. This means individual task results cannot be directly compared across different products and developers. However, the mean time for each task is recorded alongside an "optimal" time for each task (the time it takes an expert user to complete the task). I defined a derived variable of "Task Time Ratio" (TTR), the ratio between the mean test user time and optimum expert user time for each task in the dataset. The 'optimum' expert time is the time expert users take to complete a task under ideal conditions. This value serves as a benchmark for comparing actual performance across products. However, it is important to note that task difficulty and product design variations may affect these comparisons. By calculating the TTR as the ratio between the recorded mean task time and the optimum time, the TTR can be compared across different products and vendors and between categories of tasks, even though these tasks and systems are different. A low TTR indicates that the test subjects take less time than expected to complete tasks, and a high TTR indicates that test subjects take more time than expected, indicating that there may be a problem with the design of the system.

3.2.2 Results

After cleaning to focus on tasks that included task time results, the CHPL dataset now contained the results of 5,777 tasks tested on 321 EHR vendors and 371 different products. For each product tested, the developer chose a series of usability tasks, such as searching for a patient or identifying a drug allergy, and asked at least 10 participants to complete each task.

Many vendors provided niche products that are not widely used, and their testing results varied considerably by product. Therefore, I aimed to limit my analysis to the top 20 vendors by overall number of usability tests conducted. This meant that I included vendors with multiple products that were more likely to be used in hospitals and clinics. Using 20 out of the 335 vendors in the CHPL also made it possible to make a more meaningful comparison in terms of the variability of the test results without the major vendors being drowned out by the results of smaller vendors.

3.2.2.1 Task Categories

Firstly, I grouped the overall usability tests for the top 20 vendors into the task categories defined in the SED regulations from Table 3.2 in Figure 3.1

3.2.2.2 Developers and Products

The top developer tested 253 tasks, and the developer with the smallest number of tests in the top 20 tested 36 tasks. I have anonymised the developers' and products' names. Figure 3.2 shows the range of tasks tested by each developer (developer names are hidden), including a breakdown of the tasks tested for each product that the developer sells.

3.2.2.3 Task-Time Ratio

The TTR ranged from 2.2 to 266.7 across all products, with a mean TTR of 134.9, a median TTR of 125.7, and an IQR of 83.3-175 (Table 3.3). Figure 3.3 shows the

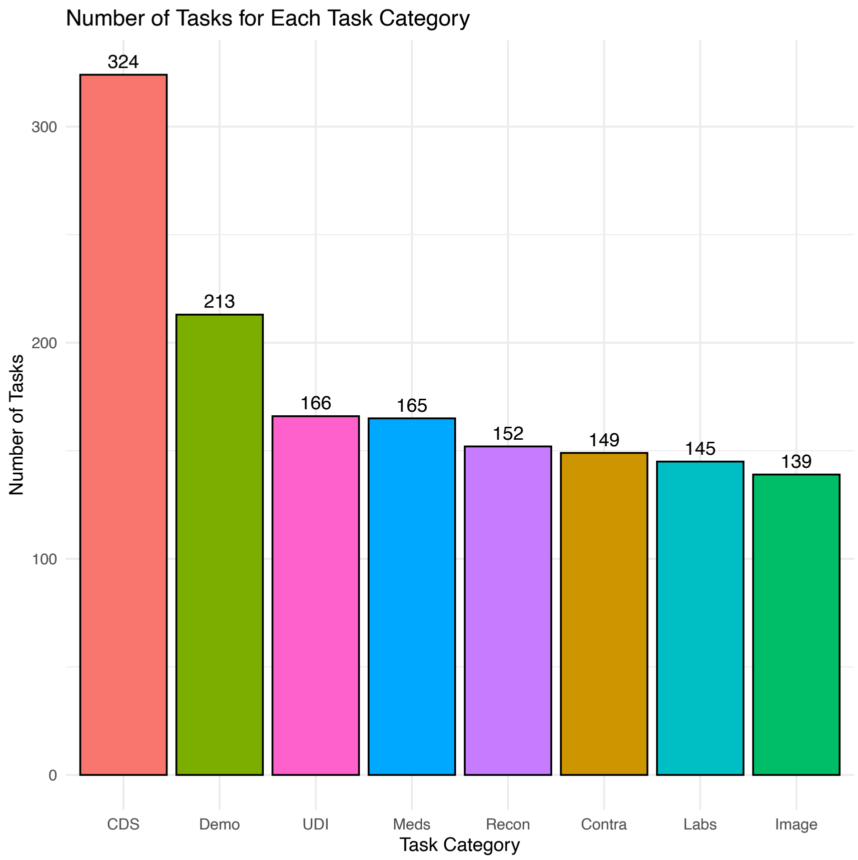

Figure 3.1: Distribution of tasks by SED Task Category. The x-axis shows each category for tasks defined by SED (from table 3.2). The y-axis shows the number of tasks tested for each task category.

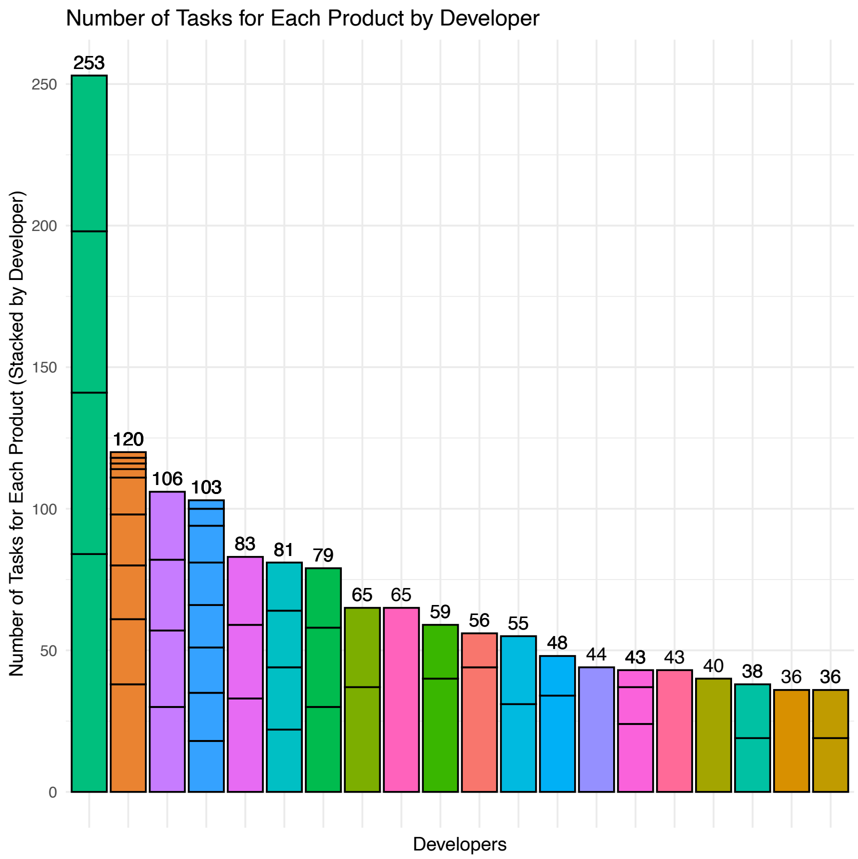

Figure 3.2: Number of Tasks Tested per Developer (vendor names hidden) for Top 20 Developers by Task Number. Each developer is represented by a stacked bar divided into each product (the stacks).

Min.	1st Quartile	Median	Mean	3rd Quartile	Max.
2.2	83.3	125.7	134.9	175.0	366.7

Table 3.3: TTR Summary Statistics

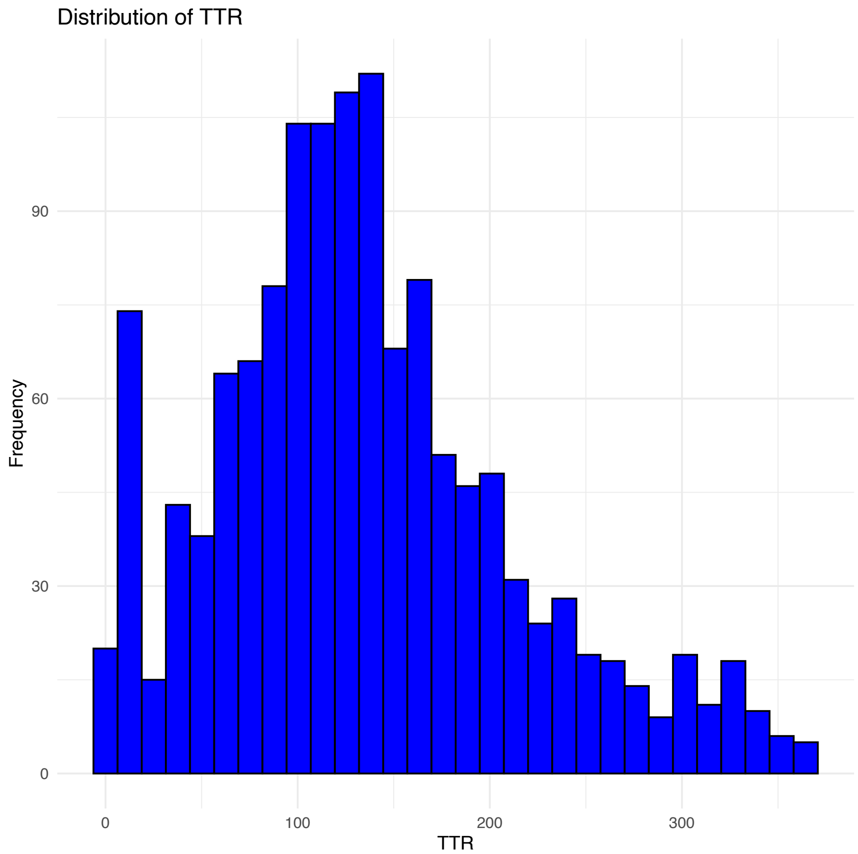

Figure 3.3: Histogram showing the distribution of TTR across all products

right-skewed distribution across all products, as indicated by the difference between the median TTR and mean TTR.

3.2.2.4 Task-Time Ratio for Task Categories

Figure 3.4 shows little variation in the TTR between different categories of tasks for the 20 developers selected (across all of their products), indicating that categories have similar levels of usability.

A one-way ANOVA was conducted to determine TTR's variation between task categories. The analysis (see Table 3.4) revealed no statistically significant vari-

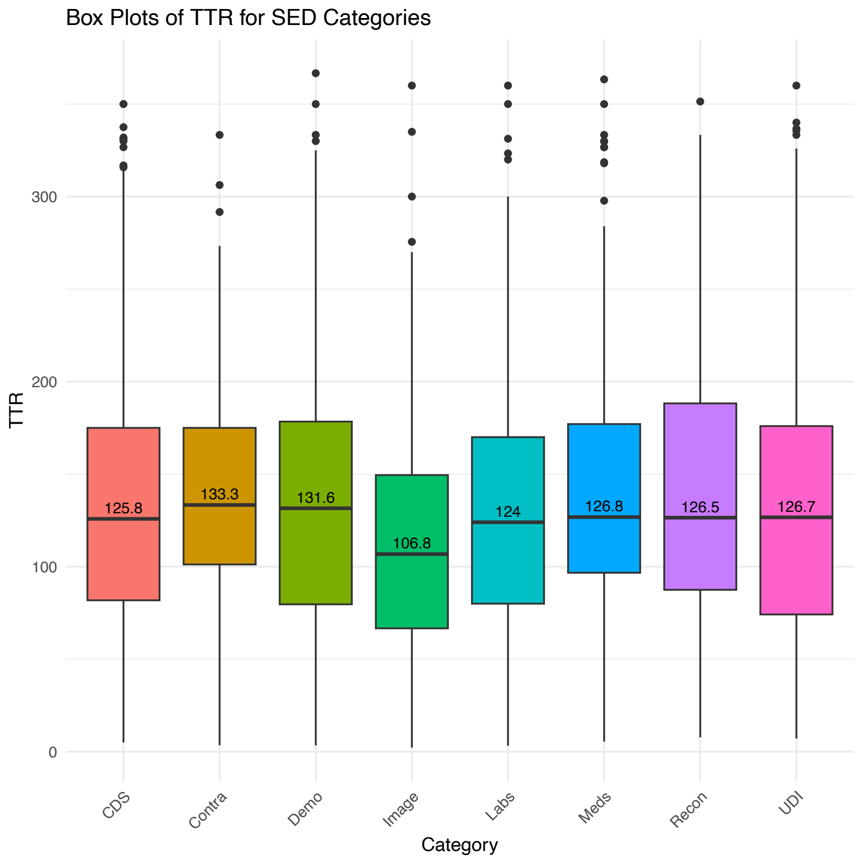

Figure 3.4: Plot of TTR by SED Task Categories showing median TTR, IQR and range with outliers

	Degrees of Freedom	Sum Squares	Mean Squares	$Fvalue$	$Pr(> F)$
Category	7	74552.2678	10650.324	1.78363091	0.08668886
Residuals	1323	7899828.68	5971.14791	NA	NA

Table 3.4: ANOVA results of TTR by Task Category

	Df	**Sum Sq**	**Mean Sq**	$Fvalue$	$Pr(> F)$
developer	19	3287539.51	173028.395	48.3993812	2.13E-136
Residuals	1311	4686841.44	3575.01254		

Table 3.5: ANOVA results of TTR between developer

ation (at the level of $p < 0.05$) in TTR across the task categories, $F(7, 1323) = 1.78, p = 0.087$. This suggests that task category according to the SED criteria is not a significant predictor of TTR in our dataset.

3.2.2.5 TTR By Developer

There is considerable overall variation in the TTR between the 20 software developers as can be seen in Fig 3.5, with a mean overall TTR for the 20 developers of 135 and some developers TTR being more than twice that of others.

A one-way ANOVA was conducted to determine the variation between developers in TTR. The analysis (see Table 3.5) revealed a statistically significant difference in TTR across the developer categories, $F(19, 1311) = 48.4, p < .001$.

It is interesting to note that some developers have a median TTR of less than 100. This indicates that the median test participant completed the task in less time than the "optimum" time, which seems implausible. It is likely, in these cases at least, that the optimum time is incorrect. Some developers have very large IQRs of TTR, indicating significant variation in performance between different tasks tested. If we are to take the testing results at face value (and believe that the "optimum" value is accurate for optimal task performance), the results of this analysis would

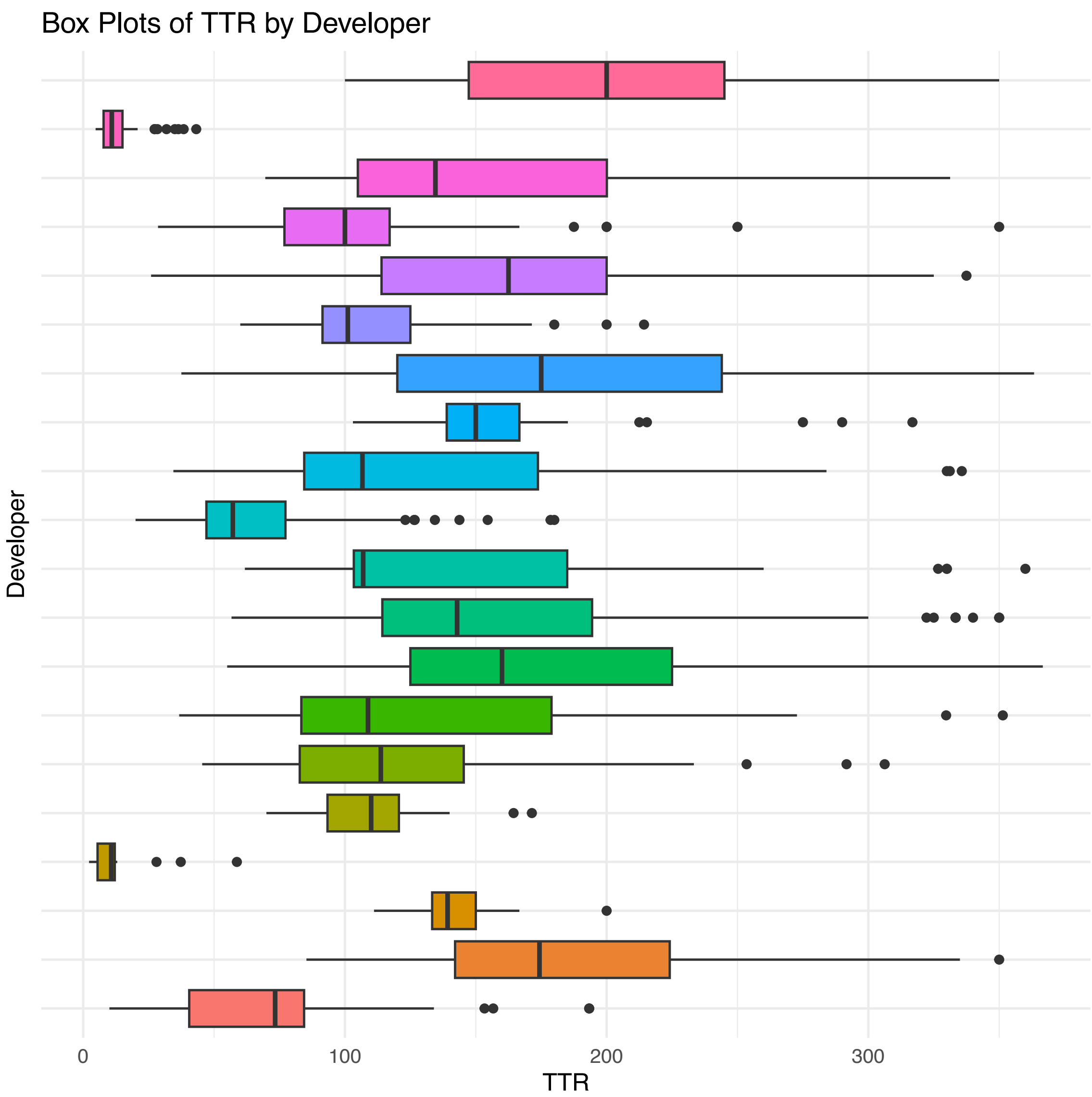

Figure 3.5: Boxplots of TTR by Developer (individual developer names are hidden). Each developer is represented by a different colour on the y-axis with the TTR on the x-axis.

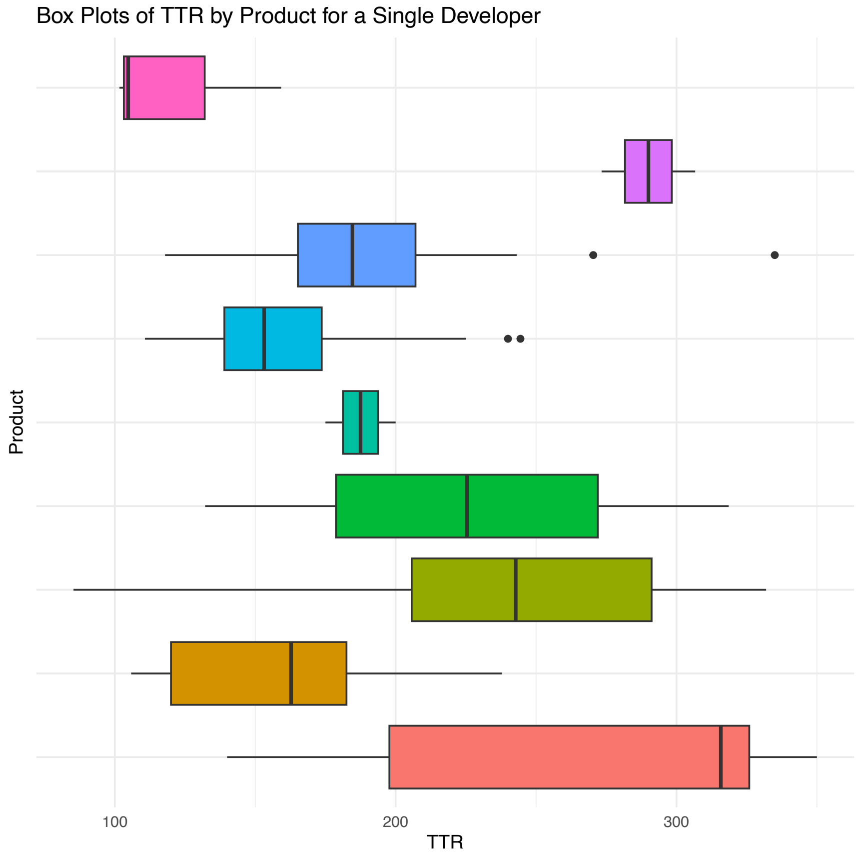

Figure 3.6: Boxplots of TTR by product from a single developer. The different products produced by a single vendor are represented by different coloured boxes on the y-axis with the TTR on the x-axis

indicate considerable variation in usability across different developers. However, it seems likely that much of the variation is due to a lack of standardisation of how "optimal time" should be recorded and the differences in the tasks tested between different developers.

3.2.2.6 TTR By Product

To investigate whether the difference in usability between developers is due more to the testing procedure rather than inherent usability problems, I looked for variation in TTR between products of the same developer (the top developer by number of tasks tested to give the largest n for analysis).

	Df	**Sum Sq**	**Mean Sq**	$Fvalue$	$Pr(>F)$
product	8	162282.071	20285.259	7.878	$4.48E-08$
Residuals	95	244626.808	2575.019		

Table 3.6: ANOVA results of TTR by product for a single developer

As shown in Figure 3.6, this developer had no TTR results under 100, indicating that the "optimal time" was plausible. This seems to suggest that the actual usability of the developer's products differs significantly.

A one-way ANOVA was conducted to determine the variation between products in TTR from the same developer. The analysis (see Table 3.6) revealed a statistically significant difference in TTR across the developer categories, $F(8, 95) = 7.9, p < .001$.

3.2.3 Discussion

The analysis of the CHPL dataset showed that there is statistically significant variation between software developers in the mean time for task completion for a usability test of a specified task (such as "Edit demographics for the patient"). There is also significant variation of TTR across different products from a single developer. Overall, this indicates that different products and vendors may have meaningful variations in how long it takes to complete tasks compared to how long it should take.

Higher TTRs may indicate inefficient task flows, which can contribute to clinician frustration or task errors and potentially impact patient safety. The findings in this chapter reveal significant variation in TTR across different EHR systems, underscoring the potential risks associated with inefficient task completion. Prolonged task times can increase cognitive load, contributing to user fatigue and errors in clinical workflows. This aligns with studies such as Howe et al. [34] and Lowry et al. [50], which highlight the connection between EHR usability issues, delays, and patient harm. Furthermore, Pacheco et al. [62] emphasise how inefficient task execution in EHR systems can exacerbate clinician burnout, further increasing the likelihood of errors and compromising patient safety. These findings stress the critical need to optimise TTR to enhance usability and safety in digital health technologies.

This analysis also raises the question of how well the CHPL does in terms of allowing product comparisons and regulating product use in terms of usability. The inclusion of products from developers with implausible optimal times in the dataset seems to indicate that some improvement may need to be made in the process of assessing that data before it is included in the CHPL. More research is needed to investigate the specific causes of implausible data in the dataset.

The TTR metric used here allows for a comparison between categories, developers, and products. However, it would be easier to compare the usability of different products if standardised tasks within the SED categories were set for developers to test. Healthcare organisations would find it easier to compare products if they could see how long it takes to complete standardised tasks across different products and developers.

The data on task time completion is a summary for each test (mean time for all participants in the test). Individual demographic information is provided for each participant, but the times are averaged. It would be better for overall meta-analysis if CHPL could provide the individual times for completing tests for each participant.

The products in the CHPL dataset are used by thousands of clinicians daily, impacting the care of millions of patients. Taken at face value, my analysis would indicate that the efficiency of healthcare services could be significantly improved if the usability of underperforming EHR products could be improved or if products with poor usability could be replaced with better products.

3.2.4 Limitations

Due to the inclusion of implausible values for both time to task completion (such as 0 or 1) and optimal time (such as times less than the mean time or even 0 or negative optimal times) in the raw data, it isn't easy to have confidence in the dataset as a whole (even after applying data cleaning techniques). There is likely some problem with how data from individual usability tests are included in the database and how it was prepared for export.

3.2.5 Conclusions

Despite the limitations in the quality of the data in the CHPL dataset analysed, it seems likely that many products in the USA healthcare system could be improved in terms of how quickly users complete tasks. The CHPL may be more useful for healthcare providers selecting systems if included products were required to pass a benchmark in terms of usability rather than just requiring that testing be performed.

Chapter 4

Document Review of the NHS Common User Interface Project and the NHS Design System Documentation

4.1 Introduction

In this second results chapter, I describe the results of my document review of the NHS Common User Interface (CUI) documentation and the NHS Design System (DS) documentation. As described in Chapter 2, this document review is part of Stage 2 of the Design Science Research Framework to define the project's objectives and aims to answer Research Question 2: **How do the NHS Common User Interface guidelines specify the design of EHR systems, focusing on the Patient Name Input and the Patient Banner?** and Research Question 3: **How should the NHS-CUI guidelines be implemented within a modern web technology stack to adhere to the NHS Design System guidance?**

There is very limited research published in the scientific literature about the methods used by the team at Microsoft to develop the CUI or by the NHS digital team to create the NHS Design system. However, using information gathered from the guideline documents themselves and from the NHS Digital "Design Matters" blog, I have summarised the overall research methods used by these teams during the development of the guidelines.

4.1.1 Research used to develop the Common User Interface

The documents reviewed showed that research that informed the design of the Patient Banner guidelines (ISB 1505) included a web survey of 65 clinicians about patient identification issues, another survey of 158 clinicians and administrative staff, 12 interviews with healthcare professionals, a patient safety assessment and a plenary discussion with 10 members of the CSA Design Steering Group.

The research that informed the development of the Patient Name Guideline (ISB 1506) are described briefly in the guideline and included a “desk-based” research project “looking at a range of information entry Web pages and clinical applications”, and a web-based survey with 41 respondents including NHS clinicians and administrative staff, independent software vendors, community pharmacists and NHS Connecting for Health. A patient safety assessment was also carried out.

The specific methods or results of this research are not described in the documents. For example, it is not described what the questions for the survey were or how the data were analysed. There was also no information on how the interviews were analysed. I was not able to identify any published research articles that were associated with this research. It is assumed that the research was performed internally at Microsoft while designing the guidelines and was never published.

However, the results of the research (the guidelines themselves) were described in detail in the documents and I was able to extract these and can therefore present the analysis in the results section of this chapter.

4.1.2 Qualitative Research used by NHS Digital

The NHS Design system has evolved over more than a decade. Although the NHS Digital team have published very little in the academic literature about the qualitative methods they used to develop the design system, they have kept a blog called "Design Matters" which shares information about how the system was developed and the user research undertaken to develop it. Below I summarise the research methods that were described within the NHS Design System web pages including the "Design Matters" blog posts:

4.1.2.1 1. User Research

The design team interviews patients, clinicians, and NHS staff to uncover how they experience digital services, allowing designers to ask follow-up questions and clarify user needs or frustrations in real time. By observing users (whether they're scheduling appointments online or navigating a mobile app in a clinic), the team learns the users' pain points and the "workarounds" people use. This helps ensure that any new design or feature addresses real, on-the-ground needs.

4.1.2.2 2. Iterative Feedback Loops

The NHS design teams often share early prototypes with a small group of real users. They gather qualitative feedback including information on what is confusing and what is helpful to quickly refine and iterate the design. The blog also highlights the importance of building relationships with user groups or "panels" over time. This allows for multiple rounds of qualitative input as new features or design patterns evolve.

4.1.2.3 3. Co-Design and Collaborative Workshops

Clinicians, nurses, administrative staff, and patients are brought together in collaborative sessions. They map out current user journeys, discuss "must-haves" and "nice-to-haves," and sketch rough interface ideas. This is aimed at creating a shared ownership of final solutions. The NHS design team emphasises the value of having developers, product managers, and policy experts participate in workshops. This cross-functional collaboration aims to ensure feasibility and alignment with NHS policies or technical constraints.

4.1.2.4 4. Context and Empathy

The team recognises that healthcare settings can be stressful or time-constrained. By conducting in-context interviews (for instance, in a GP surgery or a hospital), researchers better understand how design choices might impact a busy clinician's workflow or a patient's emotional state. The blog underscores that qualitative methods help the design team see beyond numbers (e.g., analytics dashboards) to the personal stories, frustrations, and motivations users have when interacting with NHS digital products.

4.1.2.5 5. Continuous Learning and Adaptation

Insights from qualitative research directly inform the NHS Design System's patterns and components. If multiple user interviews reveal confusion about a particular button label or form layout, the design team updates guidance accordingly. The blog mentions feedback from the wider NHS community (through GitHub, Slack channels, or email discussions). These conversations often include qualitative accounts of what's working, leading to iterative improvements in the system and associated apps.

These methods align closely with the Goal-Directed Design methodology developed by Cooper and colleagues [13]. This is not surprising as this approach is widely used in modern software development and, as described in the results of the document review below, the NHS Digital team's ambition was to bring a modern software design process to the NHS.

4.2 Methods

I used the document review methodology, READ, to review the relevant literature. READ, developed by Dalglish et al.[14], describes a four-step approach to reviewing documents: 1. Readying the materials; 2. Extracting data; 3. Analysing data; 4. Distilling the findings.

The documents were extracted from the project websites for the two initiatives. As the CUI has been deprecated, the copy of the CUI website that has been archived on the National Archives website was used to access the required documentation. The NHS Design System is fully documented on the NHS Service Manual website [16].

4.2.1 NHS Common User Interface Documentation Review

4.2.1.1 Reading Phase

The Reading phase involved examining the NHS Common User Interface (CUI) standards and guidelines archived by the UK government on the National Archives website to gain an initial understanding of the content. During this phase, the documents were read to capture the breadth and depth of the material covered. The primary focus was understanding the CUI standards' overall structure and how specific guidance is presented. This phase also included noting key sections and recurring themes within the documents. Following a review of the National Archives website for the CUI, the following two guidelines were chosen for data extraction: ISB 1505: Common User Interface - Patient Banner and ISB 1506: Common User Interface - Patient Name Input and Display.

4.2.1.2 Extraction Phase

In the Extraction phase, relevant information for building the design artefacts was systematically identified and extracted from the NHS CUI documentation in general and the ISB 1505 and ISB 1506 guidelines specifically. This involved highlighting relevant sections and guidance needed to develop the artefacts. The extraction focused on information relating to the Patient Name and Patient Banner guidelines, such as where information should be displayed, how names, dates and address information should be displayed and laid out and how interactive elements should function. As described in the previous section, I also extracted information on the qualitative methodologies used to develop the guidelines.

4.2.1.3 Analysis Phase

The Analysis phase focused on interpreting the extracted information to determine how it could be implemented using the technology stack used by the modern NHS design system (see below for details). This involved considering HTML and CSS's limitations while adhering as closely as possible to the guidance from the documentation.

4.2.1.4 Distillation Phase

The Distillation phase synthesised the findings from the guideline analysis in preparation for developing the new user interface designs. This final phase provided me with a structured plan for the development process where I could follow the guidelines closely without missing any specific instructions. The results of the distillation are presented in the Results section below.

4.2.1.5 NHS Design System Documentation Review

4.2.1.6 Reading Phase

The Reading phase involved reviewing the NHS Design System documentation to understand the framework, components, and overall structure. The documents were read comprehensively to identify core elements, such as design principles, component libraries, and user guidelines. The initial reading aimed to grasp the scope and intended use of the design system in its entirety.

4.2.1.7 Extraction Phase

Information from the NHS Design System documentation pertinent to creating the Patient Name Input and Patient Banner design artefacts was systematically identified and recorded during the Extraction phase. This involved extracting details about design components, usage guidelines, and best practices outlined in the document. Key elements related to visual design, accessibility, and consistency were highlighted to form the basis for further analysis.

4.2.1.8 Analysis Phase

The Analysis phase involved a detailed examination of the extracted information to determine how the relevant guidelines from the NHS design system could be applied to the CUI guidelines identified through the CUI document analysis.

4.2.1.9 Distillation Phase

In the Distillation phase, the final plan for integrating the NHS design system with the CUI guidelines was determined. This plan considered how each part of the CUI Patient Name and Patient Banner could be developed using the technology stack used for the NHS design system and following the NHS design system guidelines. The results of the distillation are presented in the Results section below.

4.3 Results

4.3.1 NHS Common User Interface (CUI)

As described in Chapter 1, the NHS Common User Interface (CUI) project was a component of the National Programme for IT (NPfIT), delivered by NHS Connecting for Health, an agency of the UK Department of Health that operated between April 2005 and March 2013. NPfIT was a large-scale £12.5 billion IT project that aimed to create a national electronic health record (EHR) for hospitals in the UK that would be connected to thousands of General Practice primary care providers across the country. The proposed system would also include electronic prescribing, appointment booking, medical imaging and performance management. Although the NPfIT ultimately fell short of delivering a national EHR [56], one of the projects that was successfully delivered was the Common User Interface guidelines.

The CUI guidelines were developed to provide "consistency in the display of common items and their layout on screens, driven by a desire to improve patient safety and to aid clinician effectiveness" [37].

The guidelines take the form of a series of Information Standards Board guideline documents with associated implementation guides. The full list of the Information Standards Board approved CUI guidelines is as follows:

- ISB 1500: Common User Interface - Address Input and Display
- ISB 1502: Common User Interface - Date and Time Input
- ISB 1503: Common User Interface - Date Display
- ISB 1504: Common User Interface - NHS Number Input and Display
- ISB 1505: Common User Interface - Patient Banner
- ISB 1506: Common User Interface - Patient Name Input and Display
- ISB 1507: Common User Interface - Sex and Current Gender Input and Display
- ISB 1508: Common User Interface - Telephone Number Input and Display
- ISB 1501: Common User Interface - Time Display

Several other guidelines were also developed as part of the CUI project, but they were not adopted as ISB standards. These included:

- Micro patient banner
- Patient list view
- Drug administration
- Medications list (with implementation guide)
- Medications line (with implementation guide)
- Search and prescribe
- Timeline view

There was also a project to provide recommendations on user interaction with SNOMED CT enabled interfaces. This resulted in a series of guidance documents listed below:

- Display of adverse drug reactions
- Recording adverse drug reaction risks
- Displaying graphs and tables
- Noting with graphics
- Terminology – Display standards for coded information
- Terminology – Elaboration
- Terminology – Disambiguation and error correction
- Terminology – Matching
- Terminology – Post coordination
- Display of clinical statements consultation document
- Noting using templates consultation document
- Truncation of clinical terms consultation document
- Clinical noting in forms – admissions clerking

Other guidance developed included:

- Handover requirements for systems and an introduction to design principles in handover:

- Handover requirements spreadsheet
- Introduction to handover presentation
- Introduction to handover

Consistent navigation guidance on icons, symbols and filtering, sorting and grouping:

- Filtering, sorting and grouping
- Icons and symbology
- Keyboard shortcuts
- Alert symbol design

An investigation into the use of abbreviations and acronyms:

- Abbreviations and acronyms in free text
- Abbreviations and acronyms

Early guidance and thinking on the decision support features:

- Care pathways conceptual modelling
- Decision support summary
- Decision support

I describe the ISB guidelines for the Patient Banner and the Patient Name Input and Display in the sections below. These two guidelines will be used to create the artefacts evaluated for this thesis.

4.3.2 NHS CUI Patient Banner Guidelines (ISB 1505)

The NHS CUI Patient Banner is described in the CUI documentation as "...an area within a clinical user interface (UI) that provides key information consistently and unambiguously, allowing patients to be accurately identified and matched with their associated records". This shows that the banner is a critical user interface element and essential for maintaining patient safety across systems and functions of EHR and CDS systems. Clinicians and administrative staff use the patient banner to match records with patients using key identifying information such as the name, address and date of birth. The clinical workflow most associated with using the banner is where a clinician or administrator is present with a patient in person or over the telephone. The clinician or administrator needs to confirm the correct records are being used, for example, by asking the patient to confirm information on the patient banner, such as hospital number, name, or date of birth. In the customer need overview in the documentation for the patient banner, it is stated that the National Patient Safety Agency (NPSA) report that mismatching errors form a significant part of the range of errors in healthcare. It is, therefore, essential that the layout of the patient banner is harmonised across systems to minimise the opportunity for errors to occur when matching patients. These types of errors include giving the patient the wrong treatment due to incorrect identification of the patient or failure to match the patient to the correct artefacts such as X-rays or specimens and samples.

In addition to matching, the patient banner's secondary aims are to "allow quick access to and display of other summary information, such as contact details and allergies, for a patient." It is also a communication tool and a secondary checking method staff use when managing patients.

Section 1.1.3 in the CUI documentation states that having a consistent layout for patient banners also facilitates the design and development of clinical systems.

The scope section of the patient banner guidance states that it is designed for user interfaces on desktop or laptop computers with a minimum display resolution of 1024 x 768 and a keyboard and pointing device (such as a trackpad or mouse). It should include a minimum number of items used to identify the patient, including Patient name (family name, given name and title), patient address, date of birth, patient age, date of death (only displayed for deceased patients), gender and NHS number. The scope of the design included the groupings and layout of items, labelling, location and shape of the banner itself, and the size of the banner, bearing in mind the space needed for the rest of the clinical application. There is a separate guidance for a minimal patient banner for mobile devices. The guidance doesn't note specific details such as font size, background and foreground text colour or any text input associated with the banner. The display of data elements should adhere to other guidance and depend on the patient banner guidance.

4.3.2.1 Patient Banner Zones 1 and 2

The patient banner is comprised of two zones: Zone 1 and Zone 2. By default, Zone 2 is collapsed but can be expanded to show additional information after the user clicks anywhere within the zone. The following screenshot shows the example layout of Zone 1 and Zone 2 from the official CUI guidelines:

The guidance with ID numbers and status are as follows:

The guidance states that the patient banner should only be present once a patient record has been selected and opened. It must reside within the context of an overall clinical application that provides access to information about the patient,

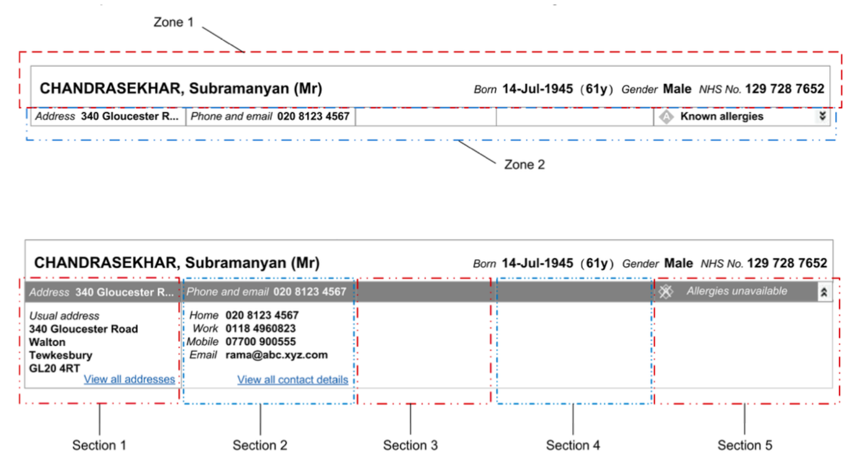

Figure 4.1: Zones 1 and 2 of the Patient Banner

Table 4.1: Patient Banner Zone 1 and Zone 2 Guidelines

ID	Guideline	Status
PAB-0001	The Patient Banner should consist of two zones, Zone 1 and Zone 2	Recommended
PAB-0073	The Patient Banner must include Zone 1	Mandatory
PAB-0002	Display information that facilitates patient identification in Zone 1	Mandatory
PAB-0074	The Patient Banner should include Zone 2	Recommended
PAB-0003	Display supplementary information that either supports patient identification or assists patient care in Zone 2	Mandatory
PAB-0004	Where Zone 2 is used, in the default display of the Patient Banner, show Zone 1 and Zone 2, with Zone 2 in the collapsed state	Mandatory
PAB-0005	Zone 2 consists of five sections	Mandatory
PAB-0075	Zone 2 must have expand and collapse capability	Mandatory
PAB-0006	All five sections in Zone 2 expand and collapse together	Mandatory
PAB-0007	Display a tooltip when the mouse is positioned over Zone 2 while Zone 2 is collapsed, stating that Zone 2 can be expanded	Mandatory
PAB-0008	The Patient Banner adheres to role-based access control, for example, do not display clinical information, such as allergy propensities, to non-clinical users	Mandatory

such as patient records and medications. An example position is shown in the following screenshot:

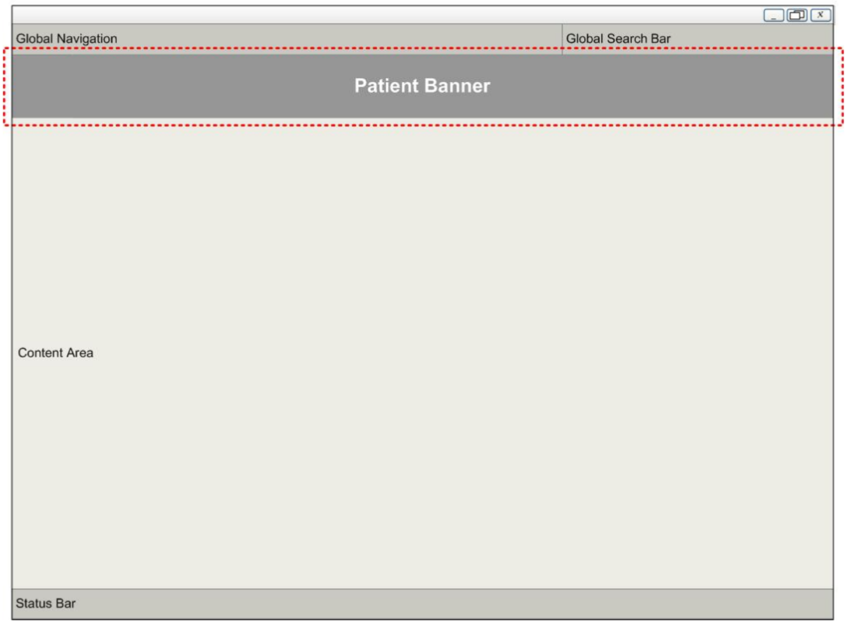

Figure 4.2: Position of Patient Banner

Specific guidelines for the display of the patient banner are shown in table 4.2. Note that the guidance states that the banner should not be displayed as a left-sided vertical column or at the bottom of the screen versus the top.

The rationale for placing the banner at the top horizontally of the screen is to ensure that the information is in a "permanent and prominent" position and supports most NHS users' natural reading pattern of top-to-bottom and left-to-right.

The guidelines for information groupings are listed in table 4.3.

The official patient banner guidelines also contain specific guidelines for labelling and values, displaying the patient's name, how to show a patient banner for a deceased patient, alignment of information within the banner, and guidelines for displaying allergy propensities.

Table 4.2: Patient Banner Display Guidelines

ID	Guideline	Status
PAB-0009	Display the Patient Banner at the top of the application window	Mandatory
PAB-0010	Display the Patient Banner across the width of the screen rather than vertically	Mandatory
PAB-0011	Display the Patient Banner in a fixed position, unmovable by the user	Mandatory
PAB-0012	Display the Patient Banner so that it occupies the full width of the application window	Mandatory
PAB-0013	Do not obscure the Patient Banner with other elements of the screen	Recommended
PAB-0014	Apply visual styling such as a thick border or distinguishing background colour, to the Patient Banner in contrast to other elements of the application's user interface	Mandatory
PAB-0015	Do not display the Patient Banner on screens that contain information relating to more than one patient	Recommended

4.3.3 NHS CUI Patient Name Input and Display Guidelines (ISB 1506)

The NHS CUI guidance for Patient Name Input and Display describes the rationale, guidelines and recommendations for the display and input of patient name data in a computer user interface. The display of the patient's name is included in the Patient Banner described above but there are two acceptable formats for accepting user input to create or edit the patient name a vertical "InForm" style for use within applications and an "InLine" style for use where inputting a name is the main objective of the form. The "InForm" style of patient name input shown in Figure 4.3 and the "InLine" style is shown in Figure 4.4.

The patient name is displayed in numerous other places on clinical applications in addition to the patient banner, and this guidance aims to standardise how this is displayed so that it is the same on the banner and in other applications and user interface elements.

Table 4.3: Information Grouping Guidelines

ID	Guideline	Status
PAB-0022	Display the elements of the patient name, date of birth, gender and NHS number in Zone 1	Mandatory
PAB-0023	Display the age of a living patient in Zone 1	Mandatory
PAB-0024	For a deceased patient, display the date of death and the age at death in Zone 1	Mandatory
PAB-0025	Display as much of the address as possible in a single line, in the title of the first section in Zone 2, displaying an ellipsis to show incomplete display of the address	Mandatory
PAB-0026	Display the full address including the postcode, in the first section of the expanded Zone 2	Mandatory
PAB-0027	Precede the full address with the label "Usual address", "Temporary address", or one of the types of temporary address, as appropriate, and as defined in the PDS	Mandatory
PAB-0028	Display as much of a single phone number as possible in a single line, in the title of the second section on Zone 2, displaying an ellipsis to show incomplete display of the phone number	Mandatory
PAB-0029	Display contact numbers and email addresses in the second section of the expanded Zone 2, in the following order: Home, Work, Mobile, Email	Mandatory
PAB-0030	Precede each contact number and email address with the label "Home", "Work", "Mobile", or "Email", as appropriate	Mandatory
PAB-0031	Optionally, display allergy propensity information in Zone 2 of the Patient Banner	Recommended
PAB-0032	Reserve the fifth section of Zone 2 for the display of optional allergy propensity information	Mandatory

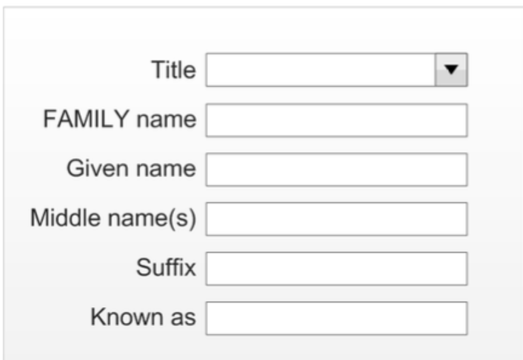

Figure 4.3: InForm Style Patient Name Input Control

Figure 4.4: InLine Style Patient Name Input

The NHS research that informed the development of the Patient Name Guidelines included a "desk-based" research project "looking at a range of information entry Web pages and clinical applications", and a web-based survey with 41 respondents including NHS clinicians and administrative staff, independent software vendors, community pharmacists and NHS Connecting for Health. A patient safety assessment was also carried out.

The patient name guidance aims to include enough information to distinguish the name for identification purposes. The correct format is shown in the figure below:

Figure 4.5: Patient Name Display Format

The guidelines follow the guidance and maximum field sizes in the NHS Connecting for Health Personal Demographics Service (PDS) and UK Government Data Standards Catalogue, the National ID card and clearly and uniquely identifies each of the name elements (family name (capitalised), given name (lowercase) and title (in parentheses)). It should be noted that the guidance acknowledges that using all capitals for the family name does decrease reading speed but this could be seen as an advantage as "the clinician will be more likely to interpret the name correctly, rather than make mistakes caused by false recognition".

The specific guidelines for the Patient Name field are listed in Table 4.4.

Table 4.4: Patient Name field guidelines

ID	**Guideline**	**Status**
NID-0001	The display must present the Family Name in all uppercase letters to clearly distinguish it from the Given Name.	Mandatory
NID-0002	The display must separate the Family Name and Given Name using a comma to further establish that the Family Name is being placed first.	Mandatory
NID-0003	The display must include parentheses around the Title to separate and distinguish it from the other name elements.	Mandatory
NID-0004	The display must present the name elements strictly in the order shown.	Mandatory
NID-0005	The display must present all data for each specified element (Family Name, Given Name and Title) of the Patient Name in full. Avoid truncation of information where possible.	Mandatory
NID-0006	The display must separate the presentation of Given Name and Title by a single space.	Mandatory
NID-0007	The display must present the Title element in title case, for example, Sir not SIR, Mr not MR.	Mandatory
NID-0008	The display must present a single pair of parentheses around the Title element, for example, (Mr).	Mandatory
NID-0009	The display must allow any free-text (up to 35 characters) to be presented in the Title element.	Mandatory
NID-0010	The display must, in accordance with the UK Government Data Standards Catalogue guidelines, omit a trailing full stop from the Title element (for example, 'Mr' not 'Mr.').	Mandatory
NID-0011	The display must allow the Family Name, Given Name and Title elements to present at least the maximum field sizes given in the NHS Connecting for Health Personal Demographics Service3 (PDS) FS 10.00, Issue 1A, 18th January 2005 (CDT D 0222).	Mandatory

NID-0012	The display must allow for the Family Name and Given Name elements to consist of multiple components. Components are constituent parts of the name element that combine with other parts to form the element as a whole. For example, the components of the name LIDMAN-SUN are LIDMAN and SUN and the components of Mary Jane are Mary and Jane. Components have the following features: Family Name components must consist of UPPERCASE alphabetic characters only, for example, SMITH. Multiple Family Name components must be separated by a hyphen or a single space, for example, LIDMAN-SUN-DEWAR or EVANS WEST. Given Name components must display in title case, for example, Nadejda. Multiple Given Name components must be separated by a hyphen or a single space, for example, Anne-Jorun, Nis Bank.	Mandatory
NID-0013	The display should allow word wrapping to occur in instances where the field length exceeds the width allocated to it on the form. If word wrapping occurs, it should be applied only at the end of a whole field element or at the end of a field element component, if it comprises multiple parts (for example, Middle name(s) field).	Recommended
NID-0062	By default, include a prompt in the input boxes to indicate to a user the information required	Recommended
NID-0063	Present the default prompt in an occluded form to prevent confusion with actual data input by a user	Recommended
NID-0064	Remove the default prompt when a user begins to input data	Mandatory

The storage standard for patient name is defined in the PDS as:

- Person Title (35 characters)
- Person Given name (40 characters)
- Person Family name (40 characters)

In terms of inputting the patient name data elements, the guidance defines the

UI for a patient input control with up to six constituent field with labels. These are: Title, Family Name, Given Name, Middle Name, Suffix and Preferred Name. Only Title, Family Name and Given Name are mandatory fields.

Each field has a separate input box with a maximum of 35 characters (the maximum for data storage) and a minimum width the same as the maximum length of pre-sets in the title drop down box (with an absolute minimum of 4 characters).

The specific guidelines for the Title field are show in Table 4.5.

Table 4.5: Title field guidance

ID	**Guideline**	**Status**
NID-0014	Input control must allow a maximum of 35 characters.	Mandatory
NID-0015	Minimum visual width of the input box must display four characters.	Mandatory
NID-0016	Suggested values are: 'Mr' 'Mrs' 'Ms' 'Dr' 'Rev' 'Sir' 'Lady' 'Lord' 'Dame' 'Other...'	Recommended
NID-0017	One value should allow the user to invoke free-text input mode (for example 'Other...' in the illustrations).	Recommended
NID-0018	Input box should contain a relevant prompt, for example, Mr.	Recommended
NID-0019	Input control should be in the form of a drop-down combo-box.	Recommended

The specific guidelines for the Family Name field are shown in Table 4.6.

For Given Name, they are shown in Table 4.7.

For Middle Names(s), the guidance is shown in Table 4.8.

For Suffixes, the guidance is shown in Table 4.9. For Preferred Name, the guidance is shown in Table 4.10.

Table 4.6: Family name field guidance

ID	Guideline	Status
NID-0020	Family Name input must be via a free-text entry box.	Mandatory
NID-0021	Family Name input box must accept a maximum of 35 characters.	Mandatory
NID-0022	Family Name input box should be capable of displaying a minimum of eight characters without occlusion.	Recommended
NID-0023	Family Name input box should optimally display 14 characters without occlusion.	Recommended
NID-0024	Family Name input box should contain a relevant prompt in its default state (for example, 'e.g. SMITH') in occluded form.	Recommended
NID-0025	When displaying a Family Name value, the characters should all be in uppercase.	Recommended

Table 4.7: Given name field guidance

ID	Guideline	Status
NID-0026	Given Name input must be via a free-text entry box.	Mandatory
NID-0027	Given Name input box must accept a maximum of 35 characters.	Mandatory
NID-0028	Given Name input box should be capable of displaying a minimum of eight characters without occlusion.	Recommended
NID-0029	Given Name input box should optimally display 14 characters without occlusion.	Recommended
NID-0030	Given Name input box should contain a relevant prompt in its default state (for example, 'e.g. John') in occluded form.	Recommended
NID-0031	When displaying a Given Name value the first character should be in uppercase.	Recommended

Table 4.8: Middle name field guidance

ID	Guideline	Status
NID-0032	Middle Name input must be via a free-text entry box.	Mandatory
NID-0033	Middle Name input box must accept a maximum of 100 characters.	Mandatory
NID-0034	Middle Name input box should be capable of displaying a minimum of eight characters without occlusion.	Recommended
NID-0035	Middle Name input box should optimally display 7 characters without occlusion.	Recommended
NID-0036	Middle Name input box should contain a relevant prompt in its default state (for example, 'e.g. David James') in occluded form.	Recommended

Table 4.9: Suffix field guidance

ID	Guideline	Status
NID-0037	Suffix input must be via a free-text entry box.	Mandatory
NID-0038	Suffix input box must accept a maximum of 35 characters.	Mandatory
NID-0039	Suffix input box should be capable of displaying a minimum of eight characters without occlusion.	Recommended
NID-0040	Suffix input box should optimally display 14 characters without occlusion.	Recommended
NID-0041	Suffix input box should contain a relevant prompt in its default state (for example, 'e.g. Junior') in occluded form.	Recommended

Table 4.10: Preferred name field guidance

ID	Guideline	Status
NID-0042	Preferred Name input must be via a free-text entry box.	Mandatory
NID-0043	Preferred Name input box must accept a maximum of 35 characters.	Mandatory
NID-0044	Preferred Name input box should be capable of displaying a minimum of eight characters without occlusion.	Recommended
NID-0045	Preferred Name input box should optimally display 14 characters without occlusion.	Recommended
NID-0046	Preferred Name input box should contain a relevant prompt in its default state (for example, 'e.g. Johnny-Boy') in occluded form.	Recommended

The guidelines for the InForm Input Design are shown in Table 4.11.

Table 4.11: InForm input design guidance

ID	Guideline	Status
NID-0047	InForm field controls must be aligned on the left edge of the input boxes.	Mandatory
NID-0048	InForm field controls (where they exist) must be placed underneath each other in the following order: • Title • Family Name • Given Name • Middle name(s) • Suffix • Known as	Mandatory

The guidelines for the InLine style design are the same as the InForm guidelines but they are arranged horizontally and should be wrappable, as shown in Fig 4.6 and Fig 4.7.

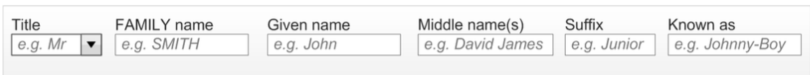

Figure 4.6: Inline Patient Name Input

If wrapping, it should wrap at whole fields and use sentence style left-align wrapping. The specific guidelines for InLine forms are shown in Table 4.12.

Figure 4.7: Wrapped Inline Patient Name Input

Table 4.12: InLine form guidance

ID	Guideline	Status
NID-0049	Ensure wrapping only occurs on whole fields.	Mandatory
NID-0050	Correct presentation order is: • Title • Family Name • Given Name • Middle name(s) • Suffix • Known as	Mandatory
NID-0051	InLine design choice should only be used when InForm has been considered undesirable.	Recommended

There is also a set of guidelines for instructional text for the input forms: Field labels, Table 4.13; Prompts, Table 4.14.

Table 4.13: Field label guidance

ID	Guideline	Status
NID-0052	Each field in a name input control must have an associated label.	Mandatory
NID-0053	Labels must be programmatically linked to their associated input field.	Mandatory
NID-0054	Label values should be: • Title: "Title" • Family Name: "Family Name" • Given Name: "Given Name" • Middle name: "Middle name(s)" • Suffix: "Suffix" • Preferred name: "Known as"	Recommended

Table 4.14: Prompt guidance

ID	Guideline	Status
NID-0055	Each field in a name input control should have an associated prompt.	Recommended
NID-0056	Prompts for Family Name should be capitalised.	Recommended
NID-0057	All prompts except Family Name should have sentence style capitalisation.	Recommended
NID-0058	Prompt values should be: • Title: "e.g. Mr" • Family Name: "e.g. SMITH" • Given Name: "e.g. John" • Middle name(s): "e.g. David James" • Suffix: "e.g. Junior" • Known as: "e.g. Johnny-Boy"	Recommended
NID-0059	Prompts should be lighter in weight and colour than the input text, and italicised.	Recommended

4.4 The NHS Design System

The National Health Service (NHS) design system is based on the United Kingdom (UK) government's GOV.UK Design System. The GOV.UK Design System was established following a strategic review of the “Directgov” website, which was then used to allow UK citizens and residents access to a limited number of government services. The review was carried out by Martha Lane Fox and recommended a sweeping overhaul of all UK government websites and centralisation of the teams that design and manage online services [6]. The result was a new ”Government Digital Service” (GDS) and a set of core design principles [10] based on Fox's success in developing commercial websites such as lastminute.com. These principles formed the basis of the GOV.UK design system and were subsequently adapted to create the

Table 4.15: Comparing the UK GDS and NHS Design Principles

Principle	GDS Principles	NHS Design Principles
1	Start with needs	Put people at the heart of everything you do
2	Do less	Design for the outcome
3	Design with Data	Be inclusive
4	Do the hard work to make it simple	Design for context
5	Iterate. Then, iterate again.	Design for trust
6	Build for inclusion	Test your assumptions
7	Understand context	Make, learn, iterate
8	Build digital services, not websites	Do the hard work to make it simple
9	Be consistent, not uniform	Make things open. It makes things better
10	Make things open: it makes things better	

NHS Design Principles (Table 4.15). Both design systems have developed similar design styles, components, and patterns using their respective principles. The NHS system, geared more towards healthcare services, has similar designs but clearly recognisable differences, such as the colour scheme used for the header banner (black for GOV.UK and NHS Blue for NHS).

The NHS Design system is now used across many NHS services, including the NHS website, NHS.uk receives over 50 million visits every month [57]. It allows users to look up information on their health conditions and access NHS services.

4.5 NHS Prototype Kit

The NHS Prototype Kit is a tool for aiding the design and development of digital services within the National Health Service (NHS) in the United Kingdom. This document review section examines the kit's components, its integration within broader NHS digital frameworks, and its implications for accessibility, user experience, and

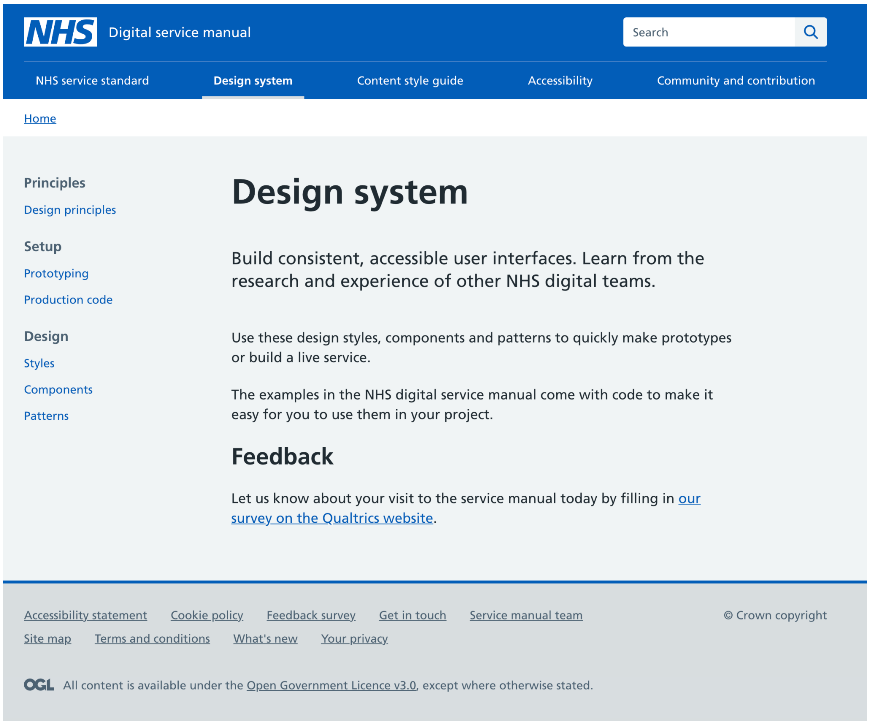

Figure 4.8: NHS Design System

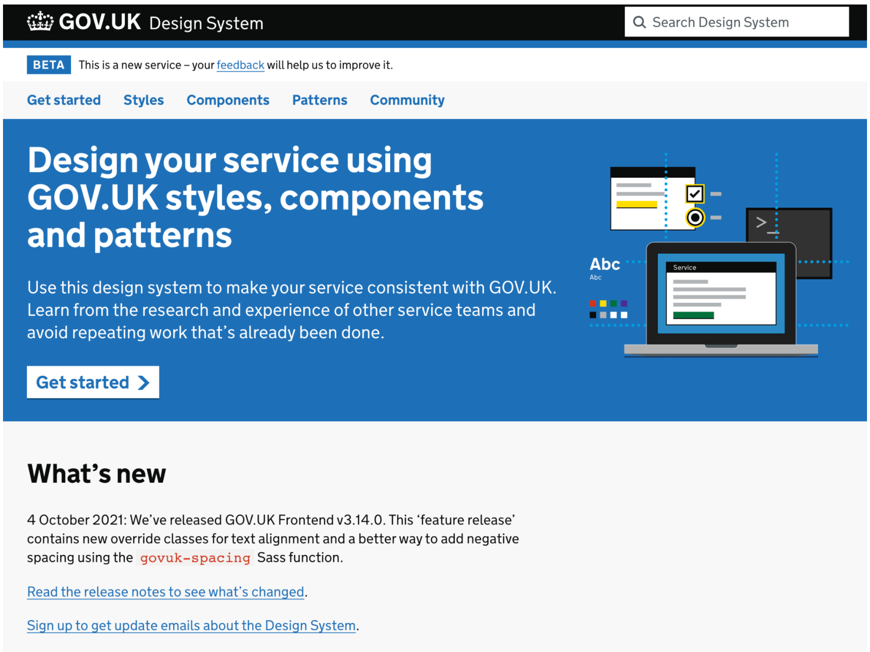

Figure 4.9: GOV.UK Design System

service consistency.

4.5.1 Installation

The installation process is documented on the Prototype Kit web pages [59]. Users need to download the kit from the website and then use the command line to install it on their computer. The kit is based on the Express framework, making it compatible with Node.js environments, a common setup in web development. Once the kit is installed, users can edit various template files to assemble the prototype, run it on a locally hosted Node.js server, and access it through their web browser.

4.5.2 Pre-Built Components and Templates

The NHS Prototype Kit has a library of pre-built components that maintain consistency across NHS digital services. These components are designed to adhere to the NHS Service Manual's standards for accessibility and usability. Table 4.16 shows the main pre-built components, their purpose and accessibility features.

These components are integrated into the NHS design system, ensuring that all digital services offer users a familiar and intuitive experience. The kit also provides customisable templates, which allow developers to rapidly prototype various page layouts, enabling an efficient development process.

4.5.3 Content Presentation and Navigation Elements

Navigation and content presentation are important aspects of any digital service, particularly in the healthcare sector, where users need quick and easy access to essential information. The NHS Prototype Kit includes several components to optimise navigation and content presentation. These elements are designed to ensure that all users, regardless of their familiarity with digital interfaces, can navigate

Table 4.16: Key Pre-Built Components

Component	Purpose	Accessibility Features
Text Input	Used for collecting text-based data from users, such as names or addresses.	Designed with appropriate labelling and focus states to aid users with visual impairments.
Date Input	Facilitates the entry of date information, formatted to prevent errors.	Ensures compatibility with screen readers and allows for easy keyboard navigation.
Checkboxes	Allows users to select multiple options from a list.	Includes accessible labels and is optimized for screen reader navigation.
Radio Buttons	Enables users to select a single option from a list.	Accessible via keyboard and screen readers, with clear visual indicators.
Error Messages	Displays error messages related to form inputs, guiding users to correct mistakes.	Positioned to ensure visibility, with screen reader support to announce errors.

NHS services. Table 4.17 show the navigation components, their functions and UX considerations.

4.5.4 Accessibility and Compliance

The NHS Prototyping Kit adheres to the Web Content Accessibility Guidelines (WCAG) 2.2. Accessibility is one of the kit's main purposes, and each component is designed to align with WCAG guidelines. Table 4.18 shows the accessibility features of several key components.

4.5.5 Interactive Prototyping and User Testing

The NHS Prototype Kit allows developers to create interactive prototypes. These prototypes can help with user testing, which is important for gathering feedback and refining the user experience before full-scale development. Table 4.19 shows

Table 4.17: Navigation and Content Presentation Components

Component	Function	User Experience Considerations
Breadcrumbs	Helps users understand their current location within a website and navigate back to previous pages.	Provides a clear and consistent method of navigation, reducing cognitive load.
Pagination	Enables the division of content across multiple pages, improving readability.	Ensures that content is presented in manageable chunks with clear navigation controls.
Care Cards	Used to present critical healthcare information in a prominent and easily digestible format.	Focuses attention on important messages, enhancing the delivery of important information.
Inset Text	Highlights supplementary information, ensuring that users do not overlook important details.	Positioned to be immediately noticeable yet unobtrusive to enhance content comprehension.
Back Link	Allows users to return to the previous page, simplifying navigation through the service.	Gives users an intuitive method to retrace their steps, reducing frustration.

Table 4.18: Accessibility Features in Key Components

Component	Accessibility Feature	Compliance
Error Summary	Aggregates all form errors in one place for easy user review.	Ensures that users can quickly identify and address errors, complying with WCAG guidelines.
Text Input	Includes ARIA labels and supports voice input for enhanced accessibility.	Meets WCAG requirements for accessible input fields, ensuring usability for diverse user groups.
Buttons	Designed with sufficient contrast and size for users with visual impairments.	Complies with WCAG criteria for visual accessibility, ensuring buttons are easily distinguishable.

how branching logic and data passing enable more complex and realistic prototypes to be developed using the kit.

Table 4.19: Features of Interactive Prototyping

Feature	Description	Benefit
Branching Logic	Allows prototypes to simulate different user paths based on inputs.	Enables testing of complex user journeys, ensuring that all possible interactions are considered.
Data Passing	Supports the transfer of data between pages in a prototype.	Facilitates the testing of multi-step processes, such as booking appointments or filling out forms

4.6 Summary

In this chapter, I described the results of the document review of the NHS CUI and the NHS Design System. These results can now be used to develop the design artefacts that integrate the two guidelines to produce EHR components that use the up-to-date technology stack and design guidelines of the NHS Design System and the specific guidelines for EHR components specified by the NHS CUI. In Chapter 5, I will demonstrate and evaluate the artefacts using HCI modelling.

Chapter 5

Artefact Evaluation

In this chapter, I use the document review results to produce design artefacts for the Patient Name Input and Patient Banner EHR components. As described in Chapter 2, I follow the NHS CUI guidelines as closely as possible and use the NHS design system technology stack and style guidelines. For the CUI-only artefacts, it was possible to replicate the CUI guidance precisely, but adhering to the NHS design system required some deviation to ensure the the design system's "look and feel" was followed. The resulting integrated artefacts are then compared to the CUI-only artefacts using HCI modelling to produce quantitative data on the difference in usability between following CUI stictly and integrating the CUI and the NHS Design System.

5.1 NHS Design System Technology Stack

The NHS Design system consists of HTML, CSS compiled from SASS, and JavaScript code. The code is well documented internally, but there is minimal official published documentation and no specific guidelines as seen with the NHS Common User Interface Project. To ensure the artefacts complied with the NHS Design System, the overall page structure, heading, navigation and styling were applied to an HTML page, and then the standard CUI code was included within the main page section (where the page content is normally placed). The compiled CSS for the design system was not modified and is linked to in the header of the HTML file:

<link rel="stylesheet" href="css/style.css">

External NHS Design System JavaScript (also unmodified) was also linked to at the end of the header section of the HTML code:

<script src="node_modules/nhsuk-frontend/dist/nhsuk.min.js" defer></script>

5.2 Artefact 1: The NHS CUI-only Patient Name Input

The first artefact (5.1) is the screen clinicians use to input or edit a patient's name in a DHT such as an EHR. This was created by following the Common User Interface (CUI) guidance described in Chapter 4 but does *not* adhere to the NHS Design System guidelines. The screen shows a drop-down selector and a series of user input boxes displayed in a standardised way according to the guidance. This was created using HTML and CSS.

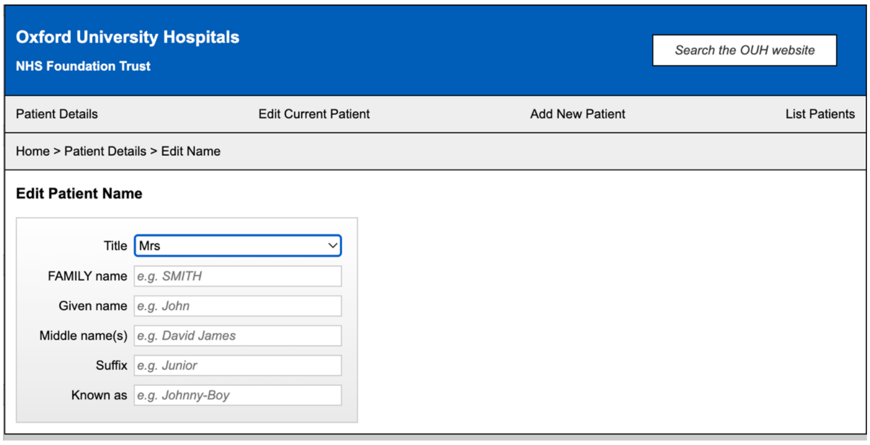

Figure 5.1: Artefact 1: The NHS CUI-only Patient Name Input

5.3 Artefact 2: Patient Name Input using the NHS Design System combined with the CUI

The next artefact (5.2) is the Patient Name Input, which follows the guidelines for both the NHS CUI and the NHS Design System. This was created using the NHS Prototype Kit, which uses JavaScript, HTML, and CSS and runs on a locally hosted Express server. This artefact demonstrates the difference between the CUI and NHS Design System, which follows the NHS Service Standard. The screens for adding patient details are separated into a single screen for each detail ("one thing per screen") and have a continue button. This input type is more standard for web-based UIs than desktop application UIs, where fields are often entered without requiring a continue or input button. The DS doesn't utilise a drop-down to select the title but allows the user to enter free text here.

5.4 Artefact 3: NHS CUI-only Patient Banner (Including Patient Name Display)

The next artefact shows the Patient Banner coded in HTML and CSS. This includes the patient name (displayed following the CUI guidelines but *not* using the NHS Design System guidelines) and other details as required by the Patient Banner CUI guidelines.

If the user clicks anywhere in "Zone 2", the banner expands to show the address, contact and allergy details:

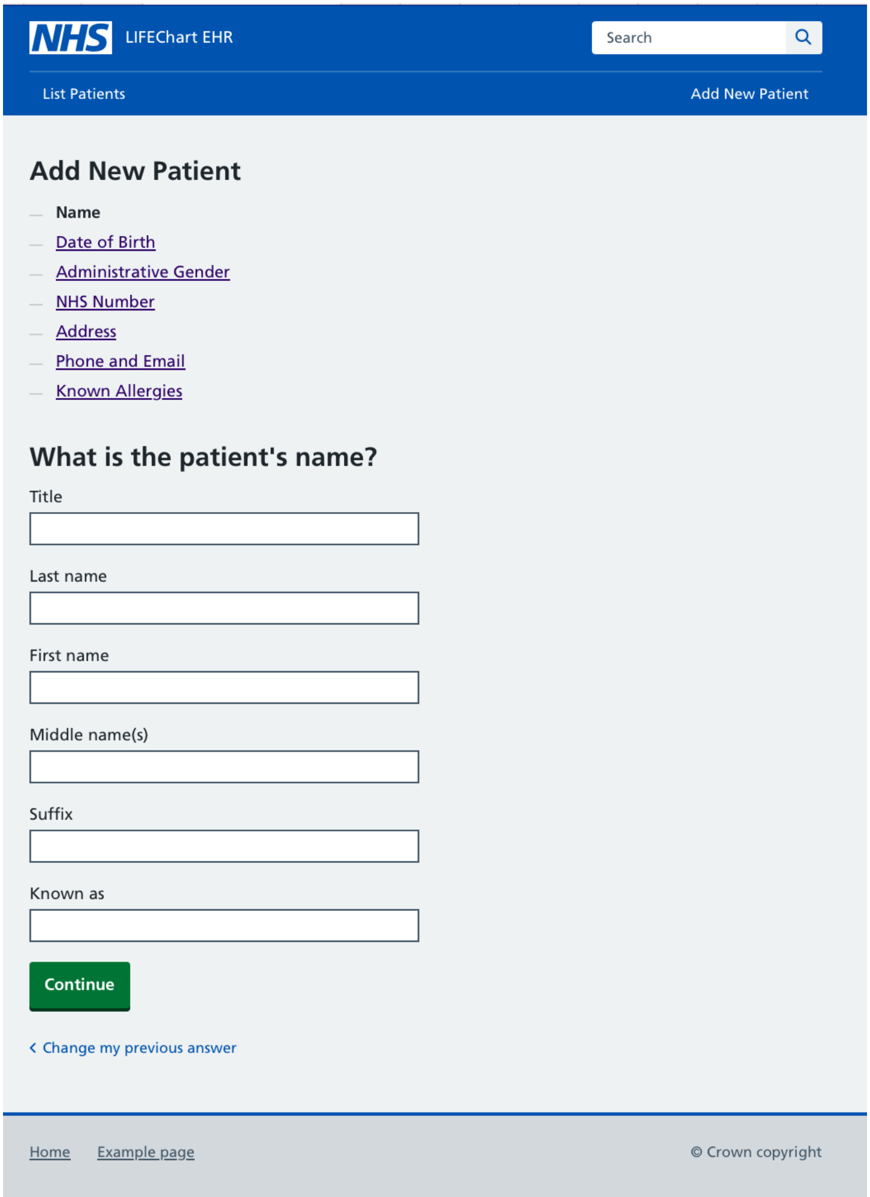

Figure 5.2: Artefact 2: Patient Name Input using the NHS Design System combined with the CUI

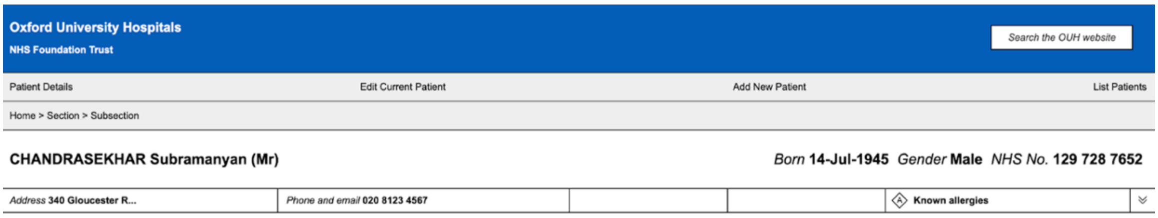

Figure 5.3: Artefact 3 (Unexpanded): NHS CUI-only Patient Banner (Including Patient Name Display

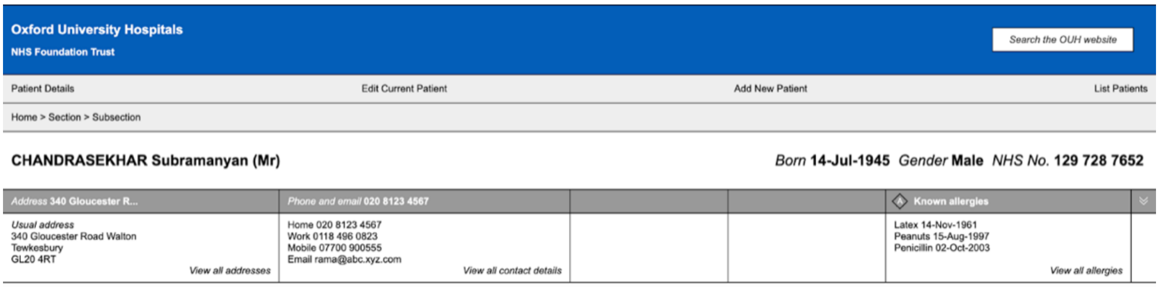

Figure 5.4: Artefact 3 (Expanded): NHS CUI-only Patient Banner (Including Patient Name Display)

5.5 Artefact 4: Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

Artefact 4 is the Patient Banner, which shows the Patient's Name and other details. It was created using HTML, CSS, and JavaScript in the same way as the CUI-only Patient Banner, but with the inclusion of the NHS Design System CSS to ensure the Banner follows the look and feel of the NHS Design System.

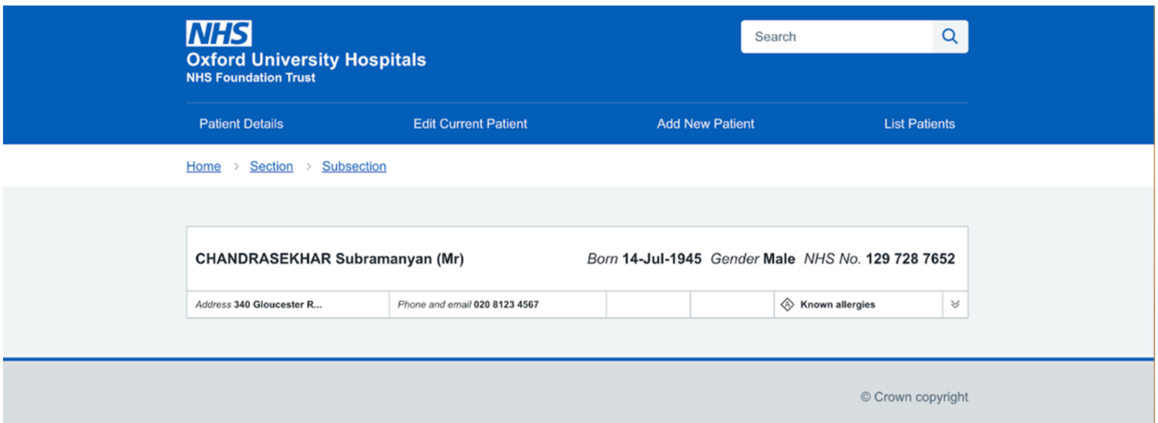

Figure 5.5: Artefact 4 (Unexpanded): Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

The NHS Design System specifies the HTML and CSS for the header section, search box, navigation, and general layout. This means the patient banner is much more central on the page, with space around it. This looks 'cleaner' but takes up more screen real estate. Figure 5.5 shows the banner before Zone 2 is clicked and Figure 5.6 shows the full banner expanded showing both Zone 1 and Zone 2 in full.

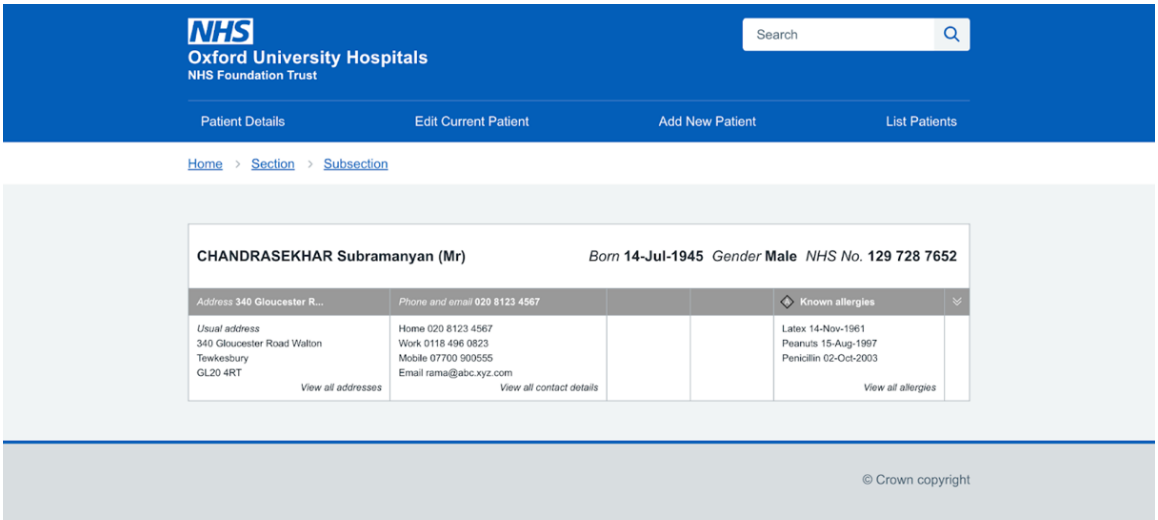

Figure 5.6: Artefact 4 (Expanded): Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

On a mobile screen 5.7, the NHS Design System compressed the menu into a button (top right), and the search icon (magnifying glass) needs to be clicked on before it can be used. Due to the specifications of the CUI, the patient banner does not fit onto a mobile screen. To overcome this issue, a new ‘mobile version’ of the patient banner guidelines was developed for mobile screens.

5.6 Artefact 5: Patient Banner using NHS Prototype Kit

As a further experiment, another artefact was created for the Patient Banner that aligns more closely with the NHS Design System but is less adherent to the CUI guidelines (Figures 5.8 and 5.9). This was created using the NHS Prototype Kit (described in Chapter 4). This artefact is more in line with the overall style of the

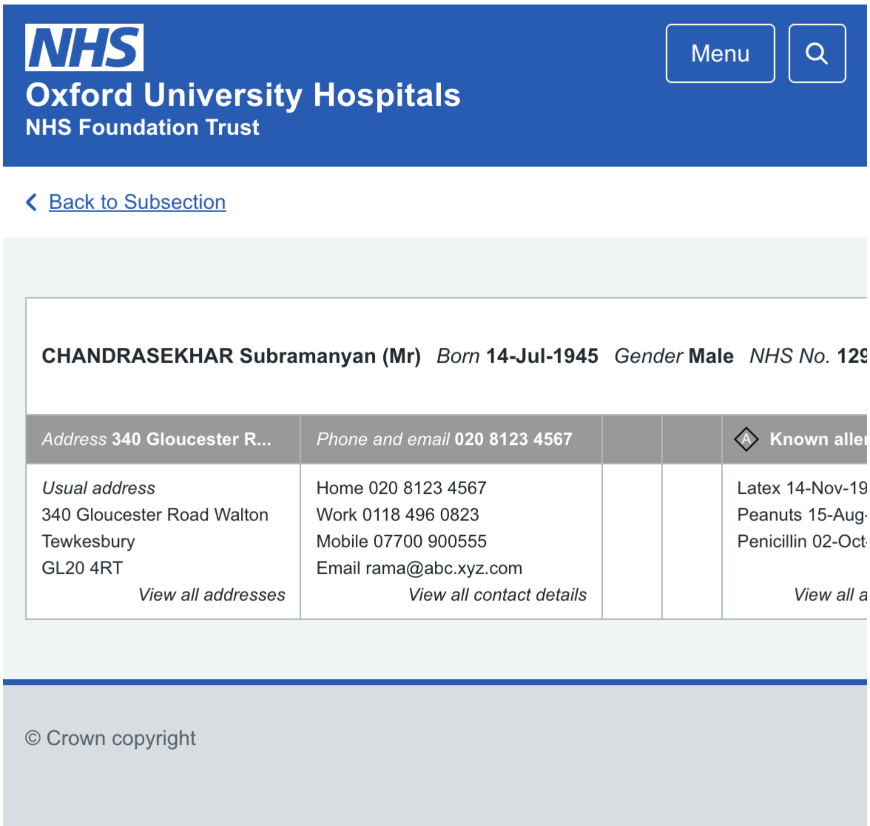

Figure 5.7: Artefact 4 (Expanded on mobile screen): Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

NHS DS and applies the expandable box components built into the prototyping kit. This would mean that this UI is more familiar to users of the DS and is, therefore, more aligned with the DS guidance than Artefact 4. The main difference is that each section of Zone 2 is expandable individually rather than having one-click expanding the entirety of Zone 2.

5.7 Evaluation: Human-Computer Interaction Modelling (HCI-Modelling)

I used the Cogulator software package to create HCI models (see Chapter 2) and derive time-to-task completion and cognitive load values. The time to task completion relates to the efficiency of the user interface, but it is also important that

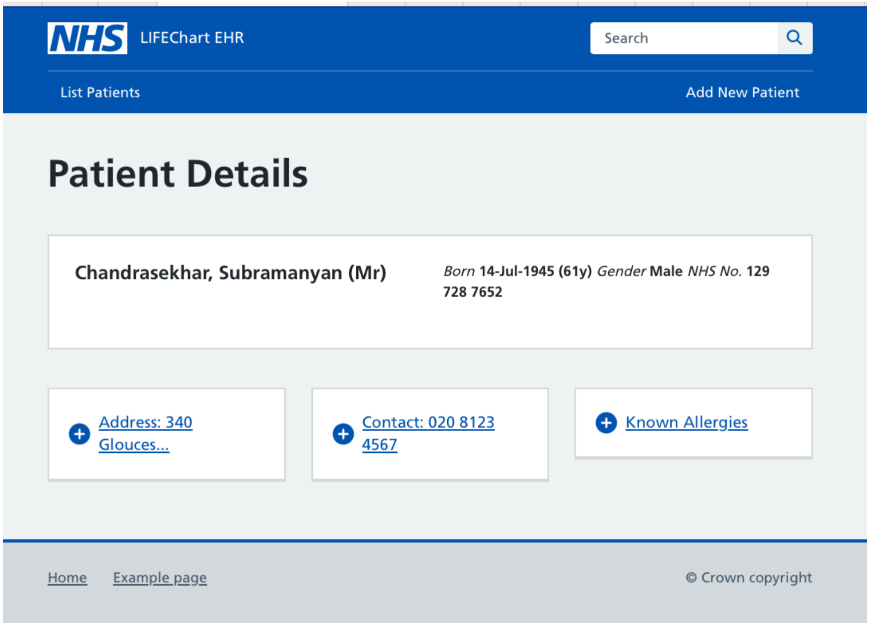

Figure 5.8: Artefact 5 (unexpanded): Patient Banner using NHS Prototyping Kit

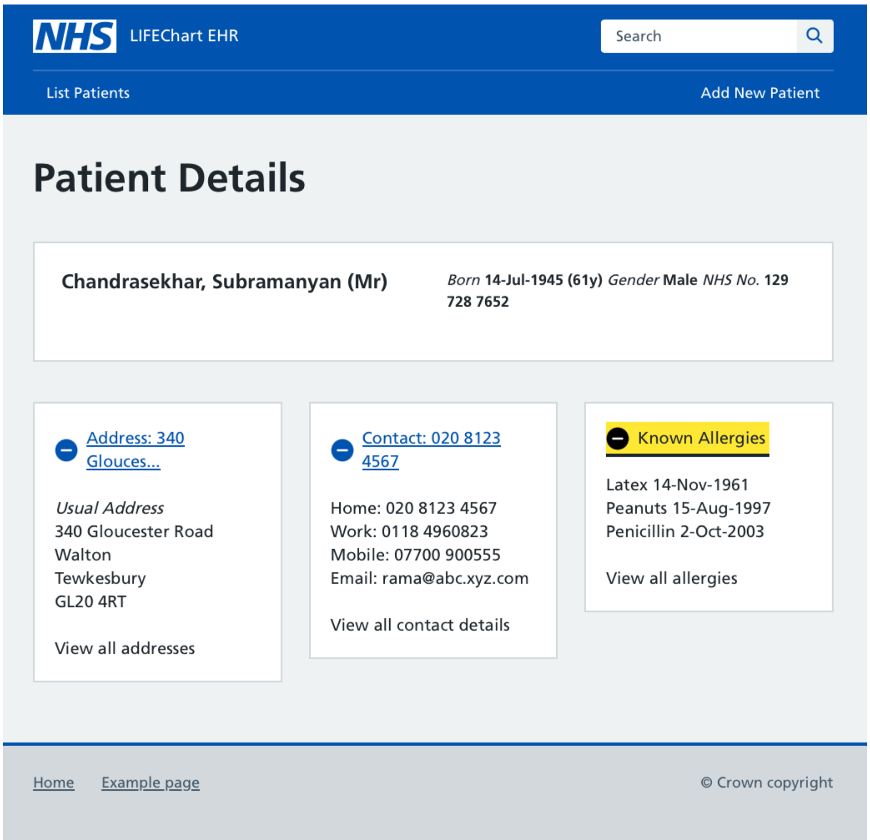

Figure 5.9: Artefact 5 (Expanded): Patient Banner using NHS Prototyping Kit

users can complete tasks efficiently without making errors. Cogulator also allows for the modelling of working memory by counting the number of 'chunks' of working memory used in each model at a particular time. By modelling the working memory capacity of users as they progress through tasks, we can model the potential for making errors by ensuring the user interface does not overload the working memory capacity of the model user.

5.7.1 Results

5.7.1.1 Artefact 1: The NHS CUI-only Patient Name Input

- **Task:** Complete the Patient Name Input with title, last name and first name.
- **Task time:** 18.5 seconds
- **Memory load:** 0.4 chunks
- **Max workload:** Low

Completing the patient name input using CUI rules is fast and doesn't significantly increase the working memory load. The Swimlane graph 5.10 shows how the model predicts users will move between perceptual, cognitive and motor tasks without overwhelming working memory. The compact nature of the UI means that it takes slightly less time to move the mouse and click on each field, and the lack of a final input button also reduces the time.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (2595 milliseconds) *Fitts Law Point Estimate
Click on <1>
Ignore <1>
Look at <2>
```

```
Point to <2> (495 milliseconds) *Fitts Law Point Estimate
Click on <2>
Ignore <2>
Look at <3>
Point to <3> (461 milliseconds) *Fitts Law Point Estimate
Click on <3>
Ignore <3>
Hands to keyboard
Keystroke Shift
Type Subramanyan
Hands to mouse
Look at <21>
Point to <21> (2190 milliseconds) *Fitts Law Point Estimate
Click on <21>
Ignore <21>
Hands to keyboard
Keystroke Shift
Type Chandrasekhar
```

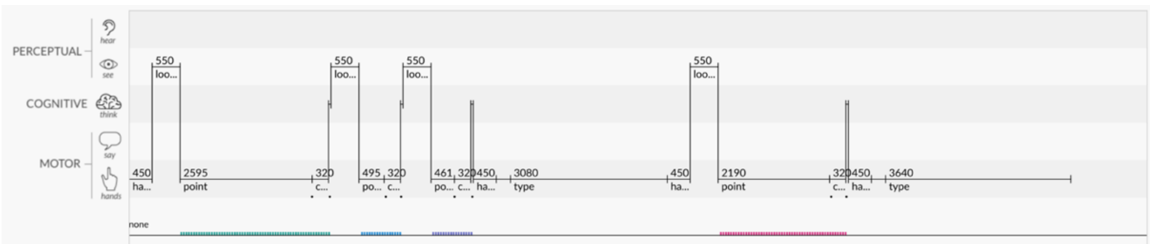

Figure 5.10: Artefact 1 Working Memory Swimlane Graph

5.7.1.2 Artefact 2: Patient Name Input using the NHS Design System combined with the CUI

- **Task:** Complete the Patient Name Input with title, last name and first name.
- **Task time:** 22 seconds
- **Memory load:** 0.4 chunks
- **Max workforce:** Low

Adding the DS guidance adds time but does not increase the working memory load as shown in Figure 5.11. The increased distance to the fields increases the time it takes to click on each field to enter the data, as does the extra click on the continue button.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (2226 milliseconds) *Fitts Law Point Estimate
Click on <1>
Ignore <1>
Hands to keyboard
Keystroke Shift
Type Mr
Hands to mouse
Look at <5>
Point to <5> (638 milliseconds) *Fitts Law Point Estimate
Click on <5>
Ignore <5>
Hands to keyboard
Keystroke Shift
Type Subramanya
Hands to mouse
Look at <17>
Point to <17> (547 milliseconds) *Fitts Law Point Estimate
Click on <17>
Ignore <17>
Hands to keyboard
Keystroke Shift
Type Chandrasekhar
Look at <18>
Hands to mouse
Point to <18> (1000 milliseconds) *Fitts Law Point Estimate
Click on <18>
Ignore <18>
Look at <19>
Point to <19> (1989 milliseconds) *Fitts Law Point Estimate
Click on <19>
Ignore <19>
```

5.7.1.3 Artefact 3: NHS CUI-only Patient Banner (Including Patient Name Display)

- **Task:** Expand and contract the patient banner to view more patient details

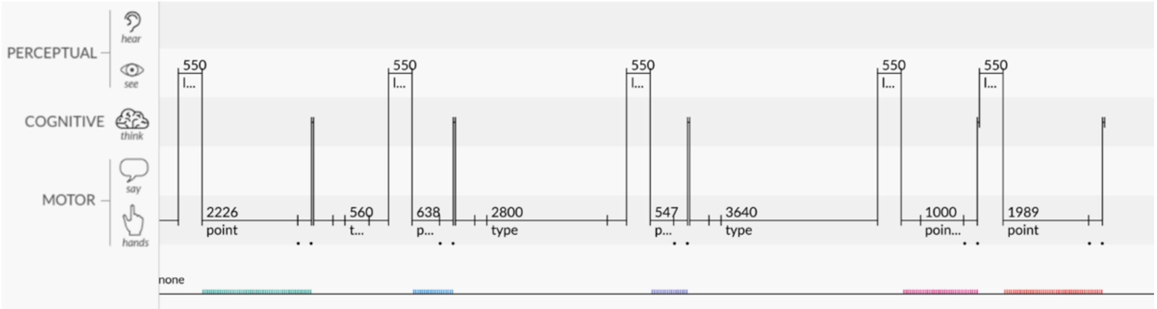

Figure 5.11: Artefact 2 Working Memory Swimlane Graph

- **Task time:** 6.3 seconds
- **Memory load:** 0.7 chunks
- **Max workforce:** Low

The CUI-only patient banner displaying the patient's name and other details is a relatively simple model, as the only interaction here is expanding and contracting the banner to view more details as shown in the model below and the swimlane graph in Figure 5.12. The CUI requirement to stretch the banner across the full length of the screen means the user has to move the mouse all the way across the screen to click on the down-chevrons. In fact, the whole of Zone 2 is clickable, but for creating this model, the chevrons were clicked on as it is not obvious that the whole of Zone 2 is clickable.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (1292 milliseconds) *Fitts Law Point Estimate
Click on <1>
Ignore <1>
Look at <2>
Point to <2> (2746 milliseconds) *Fitts Law Point Estimate
Click on <2>
Ignore <2>
```

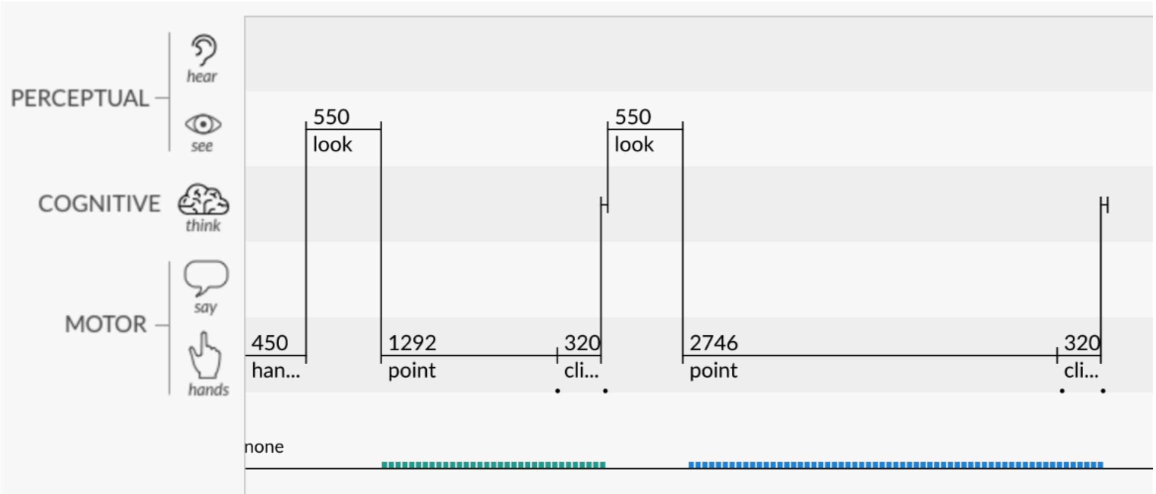

Figure 5.12: Artefact 3 Working Memory Swimlane Graph

5.7.1.4 Artefact 4: Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

- **Task:** Expand and contract the patient banner to view more patient details
- **Task time:** 5.2 seconds
- **Memory load:** 0.7 chunks
- **Max workload:** low

Adding the NHS Design System CSS to the design reduces the width of the patient banner, so it no longer stretches across the screen. This reduces the time it takes to click on the down chevrons to expand Zone 2 demonstrated in the swimline graph in Figure 5.13. However, this is against the CUI guidelines, so it creates a conflict between the layout styles of the two systems.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (2746 milliseconds) *Fitts Law Point Estimate
Click on <1>
```

```
Ignore <1>
Look at <2>
Point to <2> (200 milliseconds) *Fitts Law Point Estimate
Click on <2>
Ignore <2>
```

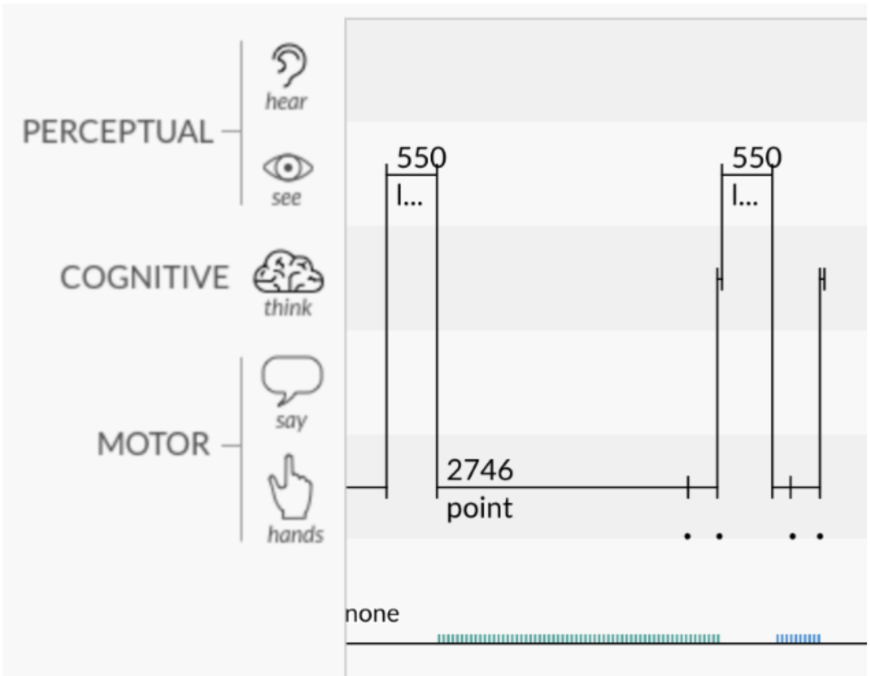

Figure 5.13: Artefact 4 Working Memory Swimlane Graph

5.7.1.5 Artefact 4 (mobile): Mobile screen size for Patient Name Display within the Patient Banner using the NHS Design System combined with the CUI

Task: Expand and contract the patient banner to view more patient details **Task time:** 5.8 seconds **Memory load:** 0.6 chunks **Max workload:** Low

Reducing the screen size to that of a mobile screen increases the task time and working memory load as the user has to scroll the screen horizontally. For real-world implementation, a different design would be used to show the details of a patient on a mobile screen. There is a separate CUI guideline for a mobile version of the patient banner with fewer details.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (1000 milliseconds) *Fitts Law Point Estimate
Click on <1>
Ignore <1>
Look at <2>
Point to <2> (1363 milliseconds) *Fitts Law Point Estimate
Click on <2>
Ignore <2>
Look at <3>
Point to <3> (200 milliseconds) *Fitts Law Point Estimate
Click on <3>
Ignore <3>
```

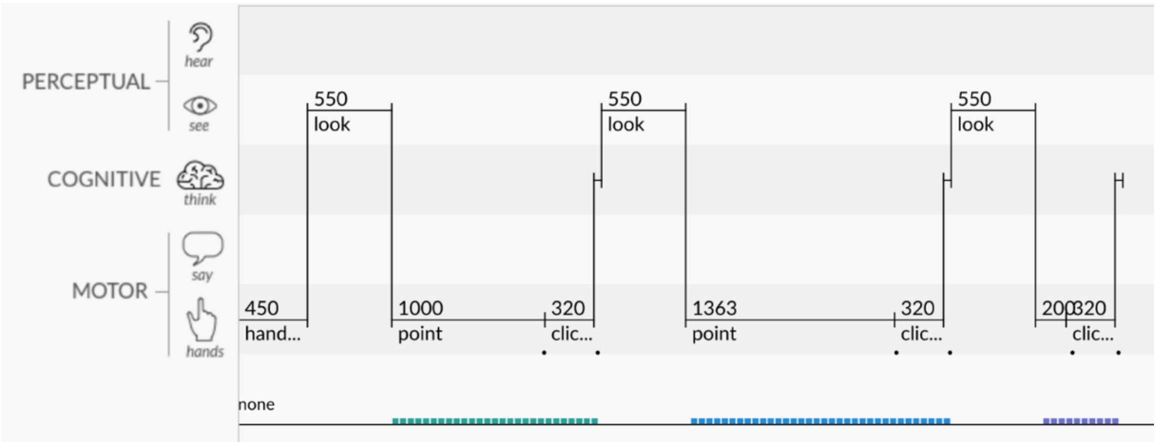

Figure 5.14: Artefact 4 (mobile): Working Memory Swimlane Graph

5.7.1.6 Artefact 5: Patient Banner using NHS Prototyping Kit

- **Task:** Expand and contract the patient banner to view more patient details
- **Task time:** 13.2 seconds
- **Memory load:** 0.7 chunks
- **Max workload:** low

If the prototype kit is used, the patient banner will have a more modern design that aligns with the rest of the NHS DS system components. The standard component expanding/collapsing box is aesthetically in line with the rest of the DS but adds two extra clicks as each box must be expanded individually as shown in the HCI model and in Figure 5.15. This significantly increases the time to complete the task of expanding the full Zone 2 details.

HCI Model

```
Hands to mouse
Look at <1>
Point to <1> (1980 milliseconds) *Fitts Law Point Estimate
Click on <1>
Ignore <1>
Look at <2>
Point to <2> (1289 milliseconds) *Fitts Law Point Estimate
Click on <2>
Ignore <2>
Look at <3>
Point to <3> (1263 milliseconds) *Fitts Law Point Estimate
Click on <3>
Ignore <3>
Look at <4>
Point to <4> (200 milliseconds) *Fitts Law Point Estimate
Click on <4>
Ignore <4>
Look at <5>
Point to <5> (1241 milliseconds) *Fitts Law Point Estimate
Click on <5>
Ignore <5>
Look at <6>
Point to <6> (1302 milliseconds) *Fitts Law Point Estimate
Click on <6>
Ignore <6>
```

5.7.1.7 Overall Results

Table 5.1 shows the overall modelling results, showing the differences between the time to task completion and working memory of the different artefacts.

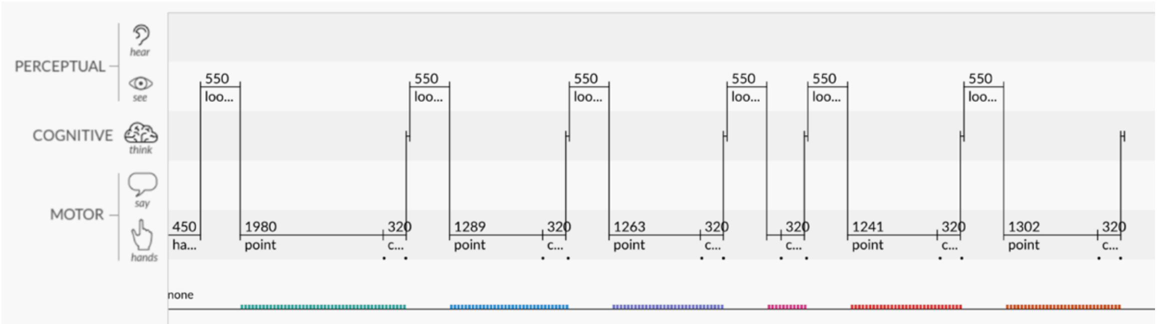

Figure 5.15: Artefact 5 Working Memory Swimlane Graph

Using the NHS Prototyping kit components rather than custom HTML increases the task time (22.0 vs 18.5 seconds and 13.2 vs 5.2 seconds) without significantly decreasing the workload. As the components in the prototype kit are designed to decrease workload, these results indicate that they are not required for this kind of UI. Using the DS CSS for the patient banner decreased the time to task completion due to the closer position of the expand/contract button, as the DS CSS made the width of the banner less than the full window size. This is a conflict between the DS and the CUI, as the CUI requires the patient banner to stretch across the full-screen width.

5.7.2 Discussion

In this chapter, I have demonstrated that the NHS Common User Interface Guidelines could be feasibly implemented in HTML and CSS and that they can also adhere to the NHS Design System guidelines for the Patient Banner and Patient Name Input. As shown in the screenshots of the artefacts, the two guideline systems are largely compatible with the components were developed.

Using HCI modelling as a methodology for evaluating the design artefacts, we can produce quantitative data on time to task completion and working memory use for each artefact. The results showed that working memory use was similar whether

Table 5.1: Overall Results of HCI Modelling

Arte-fact	Component	CUI	NHS DS	Custom HTML	Proto-type Kit	Task Time	Chunks	Work-load
1	Patient Name Input	Yes	No	Yes	No	18.5	0.4	low
2	Patient Name Input	No	Yes	No	Yes	22.0	0.4	low
3	Patient Banner and Name Display	Yes	No	Yes	No	6.3	0.7	low
4	Patient Banner and Name Display	Yes	Yes	Yes	No	5.2	0.7	low
5	Patient Banner and Name Display	Yes	Yes	No	Yes	13.2	0.7	low

or not the NHS Design System guidelines were applied for the relatively simple UIs evaluated. HCI modelling revealed that the conflicting advice between the Design System and the CUI resulted in quantitative differences in task time. In the case of the patient name input, this was due to the CUI guideline requiring a drop down selection for 'title' which is a free text box in the NHS Design system version. An even more significant increase in task time was caused when using the prototype kit to produce a version of the patient banner that required three clicks to expand zone 2 fully.

Quantitatively measuring these differences without HCI modelling would require expensive and time-consuming user testing. As previous empirical work is represented in the model (the coefficients in the model are derived from previous studies of human performance), empirical user testing would have been redundant in quantifying these differences. The time and money involved may be better used to conduct qualitative evaluations and improve the overall human-centred design process. For the CUI and the NHS Design system, qualitative studies in the form of user interviews, expert evaluations and focus group discussions had already been performed, allowing this evaluation to focus on quantitative measurements of efficiency and working memory load, which had not been done during the development of the guidelines.

Due to the relative simplicity of the UI components developed and tested for this experiment, there was not any difference between the working memory load when using the CUI alone or in combination with the NHS design system. However, the modelling accurately represents the difference between the components, showing that clicking tasks require slightly higher working memory use than typing tasks. For more complex models, such as the entire workflow for clerking in a new patient, the working memory modelling would be more helpful in determining the differences between CUI and DS guidelines.

The demonstration of HCI modelling in this study suggests that including HCI modelling as a step in the overall design process as described in Fig 1 could be beneficial and add to the scientific rigour of the guidelines. If HCI modelling is not used, the alternative is to conduct accurate quantitative user testing, which, as it is difficult and expensive to conduct these tests, is often not done. Therefore, guidelines are often based on expert opinion and qualitative feedback, as described in the introduction.

5.7.3 Conclusion

In this study, I was able to demonstrate design artefacts based on the two major NHS user interface guidelines, effectively updating the NHS CUI to adhere to the

NHS Design System for EHR components (the Patient Banner and Patient Name Input). This is significant as the NHS Design System does not currently include guidance for EHR components. With this work, I have shown that this is feasible and could enable the development of a complete set of EHR guidelines based on the NHS Design System.

I have also demonstrated that utilising HCI-modelling rather than empirical user testing is a feasible approach for increasing the efficiency and scientific rigour of the design of UIs for digital health technologies. Further study is needed to apply HCI modelling to the full CUI and NHS DS guidelines to enable further updating and development of the guidelines. Once completed, these guidelines could be modified to improve quantitative usability using further modelling, which, if followed by software developers, could lead to overall improved usability and safety of digital health technologies in the future.

Chapter 6

Discussion

In this final discussion chapter, I discuss the results of this DPhil project. The chapter first discusses the answers to each of the five research questions. I discuss some limitations of using HCI modelling to evaluate digital health technologies while remaining optimistic that this technique could play an important role in quantitative digital health technology evaluations. Then, I discuss how new artificial intelligence-based digital health technologies make the need for high-quality evaluation techniques even more critical for ensuring digital health systems are safe and effective. Finally, I conclude the thesis by summarising the main results of my research and the implications for digital health policies.

6.1 Research Questions

This DPhil aimed to answer the following research questions:

1. Does the CHPL database show significant variation in the time it takes to complete clinical tasks in the different Electronic Health Record (EHR) systems used in the National Health Service (NHS)?

2. How do the NHS Common User Interface (CUI) guidelines specify the design of EHR systems, focusing on the Patient Name Input and the Patient Banner?

3. How should the NHS CUI guidelines be implemented within a modern web technology stack to adhere to the NHS Design System guidance?
4. How long does it take, and does working memory become overloaded when users complete tasks using newly developed Patient Name Input and Patient Banner designs that adhere to the NHS CUI and NHS Design System guidelines?
5. Is Human-Computer Interaction (HCI) modelling feasible for evaluating UI designs in terms of efficiency and working memory load, and could it be used to develop evidence-based UI guidelines for Digital Health Technologies such as EHRs?

6.1.1 Research Question 1

Does the CHPL database show significant variation in the time it takes to complete clinical tasks in the different Electronic Health Record (EHR) systems used in the National Health Service (NHS)?

The analysis results of the CHPL dataset [11] demonstrate significant usability differences between different DHT developers and even between different products from the same developers. My analysis of the broad SED categories (such as CDS or Medications List) showed no statistically significant difference in TTR. However, these categories do not represent specific tasks, and a wide variety of tasks are included in each category. As discussed in Chapter 3, as there is no standardised set of tasks, it is impossible to systematically demonstrate specific areas of DHT use that are problematic from a usability point of view. As part of the SED process, developers are required to submit PDF reports of their usability tests. As these reports contain a significant level of qualitative detail on the results of the tests, including specific areas of problems, it may be possible to conduct an in-depth analysis of these reports, which could be a promising area for future research. A range of usability tests of DHTs are also reported in the academic literature, as described in Chapter 1. These studies are usually performed as part of the software development process for publicly funded academic projects [44, 83, 20]. Although they offer insights into problems with specific technologies, it is difficult to draw broad conclusions about the particularly problematic areas, such as differentiating between the challenges of selecting the correct patient from the patient list view and correctly prescribing a drug. Several usability surveys have been reported in the literature [43, 53, 48]. These do help identify problem areas perceived by clinicians. However, these may result from the inherent difficulty of performing the tasks and do not compare tasks in a fair and quantifiable way.

Poor usability in digital health technologies, particularly Electronic Health Record (EHR) systems, has been linked to increased rates of clinical errors. Howe et al. [34] identified numerous usability-related issues in EHR systems that contribute directly to errors in medical documentation and decision-making. For example, confusing interfaces and inefficient workflows can lead to incorrect data entry or missed information, posing serious patient safety risks. Such usability challenges can cause delays in clinical tasks, increasing the potential for mistakes during high-pressure scenarios. Therefore, improving the usability of these systems is critical for ensuring that they support, rather than hinder, clinical accuracy and patient safety.

Lowry et al. [50] emphasise how poor usability increases the cognitive load on healthcare providers, which can result in user fatigue and task-related errors. When clinicians are forced to navigate complex or poorly designed systems, they must dedicate additional mental effort to interacting with the technology, leaving less cognitive capacity for clinical decision-making. This can be especially dangerous in environments where quick and accurate decision-making is essential, such as emergency departments. Pacheco et al. [62] highlighted the broader implications of poor usability, linking it to errors and clinician burnout. They showed how EHR systems that are difficult to use or require excessive time to complete tasks can contribute to frustration and exhaustion among clinicians. This burnout can lead to a decline in the overall quality of care, as fatigued clinicians are more prone to mistakes. By addressing usability issues and streamlining workflows, health systems can reduce these risks and improve healthcare providers' and patients' safety and well-being. These findings reinforce the need for a comprehensive approach to usability improvement in digital health technologies, integrating human factors research and system design best practices.

6.1.2 Research Question 2

How do the NHS Common User Interface (CUI) guidelines specify the design of EHR systems, focusing on the Patient Name Input and the Patient Banner?

I described in Chapter 1 how several UK and international initiatives aim to provide guidance, regulate and certify the UI designs and usability of digital health technologies (DHTs). In the USA, the HITECH Act provided a mechanism for a process of certification and self-evaluation that continues to this day through the Safety-Enhanced Design (SED) programme [71]. As DHTs have become more ubiquitous and important in the processes of making clinical decisions and treating patients, governments, including the UK and USA, have begun to introduce more strict regulations. Although complicated by the issue of classifying some types of DHTs as "medical devices", initiatives such as the Digital Technology Assessment Criteria (DTAC) [18] and NICE's Evidence Standards Framework (ESF) [60] demonstrate that safety and human-centred design are considered important priorities for healthcare systems like the NHS.

Compared to these initiatives, the NHS Common User Interface (CUI) project was the most comprehensive attempt to provide robust and strict guidelines for systems. Although they had begun to be implemented in the NHS through the National Programme for IT, the failure of the overall Programme and the recent deprecation of the CUI means that newer systems will stop adopting these guidelines [19, 37]. However, the NHS has developed a new Design System and set of Service Standards that follow current best practices for user-centred design, such as including users in the development process and using an adaptive and agile approach to development [16, 59]. The Design System and Service Standard are somewhat enforced by the Digital Technology Assessment Criteria and reflected in the NICE Evidence and Standards Framework for DHTs [60, 18].

As described in Chapter 4, the NHS CUI provides detailed guidelines for specific aspects of EHR user interfaces. By reviewing the documentation held in the UK's national archives, I extracted and reviewed the specific guidelines for the Patient Name Input and Patient Banner guidelines. These took the form of a series of rules with illustrations to demonstrate how the rules should be implemented. By describing these in detail, I was able to plan the development of the artefacts for this thesis that used these guidelines, combined with the NHS design system to create up-to-date versions of the Patient Name Input and the Patient Banner.

The NHS CUI did not focus on human-centred design or the importance of user testing. However, current guidelines such as the NHS design system rightly emphasise the need for human-centred design and provide good quality guidance on accessibility and standardisation of the user experience. Regulations, such as the US SED process, ask providers to conduct quantitative and qualitative usability testing but do not set a standard that needs to be complied with. Future guidelines and regulations should include the requirement to provide evidence of high-quality usability and high levels of safety in the form of quantitative usability results that set a benchmark for what is acceptable. HCI modelling could offer an efficient and effective methodology (see RQ4 and RQ5 below).

6.1.3 Research Question 3

How should the NHS CUI guidelines be implemented within a modern web technology stack to adhere to the NHS Design System guidance?

As described in Chapter 5, I implemented the CUI guidelines using the NHS guidelines for the Patient Banner and the Patient Name Input CUI guidelines with some minor limitations. The CUI guidelines are not designed to be implemented using web standards such as HTML and CSS but were developed to be adopted by native Windows applications and were originally demonstrated with the Microsoft Silverlight system. However, I was able to implement the Patient Banner and Patient Name Input CUI guidelines in HTML using the NHS Design System CSS, as demonstrated in the artefacts developed for this thesis. Using the NHS prototyping kit, it was also possible to implement most of the CUI guidelines for the Patient Banner using the Design System CSS and full prototyping kit components.

By effectively demonstrating these artefacts, I provide evidence that it is still possible to use the NHS CUI guidelines, even for web-based systems that follow the current NHS Design System guidelines. This is a significant finding because modern EHR systems could still use the CUI guidelines and adhere to the NHS Design

System guidelines. The qualitative research and human-centred design process that went into developing both the CUI and the NHS Design System could, therefore, be used in current commercial systems, saving developers costs and standardising the design of user interfaces. As described in the literature discussed above, using UI designs developed this way could likely improve patient safety, improve clinical user satisfaction, and reduce burnout. However, as discussed in Chapter 1, the ubiquitous and safety-critical nature of EHR systems in the modern NHS means we need additional evidence that these designs are safe and effective. HCI modelling can provide this quantitative data on efficiency and working memory load to evaluate the current best implementation of the CUI and NHS Design system guidelines using my artefacts (described below).

6.1.4 Research Question 4

How long does it take to view and input data, and does working memory become overloaded when using newly developed Patient Name Input and Patient Banner designs that adhere to the NHS CUI and NHS Design System guidelines?

To provide robust, quantitative evidence of efficiency and working memory load, I used HCI modelling to quantify the time it takes users to complete tasks using the new artefacts I created implementing the Patient Banner and Patient Name Input in HTML, CSS and Javascript. As I described in Chapter 5, the specifics of the differences in efficiency between CUI-only designs and designs that adhere to both guidelines show that there may be more work to do to improve the designs iteratively, followed by repeat HCI modelling to quantify improvements. The working load memory modelling showed that the relatively simple components designed for this DPhil project did not overload working memory. However, the techniques will be useful for evaluating more complex workflows when further components are designed and put together in longer task sequences.

6.1.5 Research Question 5

Is Human-Computer Interaction (HCI) modelling feasible for evaluating UI designs in terms of efficiency and working memory load, and could it be used to develop evidence-based UI guidelines for Digital Health Technologies such as EHRs?

As shown in Chapter 5, quantitative HCI modelling provides a convenient, practical and robust way of testing the usability of different design patterns. Rather than relying on user feedback and questions or conducting expensive usability studies where participants may not represent general populations, HCI modelling provides a more robust and scientific way of designing systems. HCI modelling can allow for rapid design iteration and does not exclude future formal usability studies that could validate HCI models or provide additional qualitative feedback. This is unsurprising as computer modelling is now commonly used in many scientific endeavours, from epidemiology to climate change research. In the DPhil, I have shown that modelling is a practical, relatively inexpensive and valuable addition to the process of designing and evaluating digital health technologies such as Electronic Health Records.

Digital health applications may have common usability and resultant patient safety issues that can be modelled using predictive HCI approaches. However, specific types of digital health interventions may also have type-specific UI patterns that, if modelled as a common function of a particular system, may make it easier to develop more general models. Using the World Health Organization Digital Health Intervention (DHI) classification system [81], it could be envisaged that each type of system, such as a telemedicine system (DHI 2.4) or health care provider training system (DHI 2.8), would have a common HCI predictive model that takes into account the cognitive processes involved in using that type of system. For example, a training system would include cognitive models of how the system enables the user to learn how to manage a clinical problem, retain the knowledge over time (perhaps by repeatedly "topping up" their knowledge), and recall the information when needed.

Despite these ongoing issues with clinical usability described above, many researchers have advised taking a heuristic approach [54], building on and adapting the Nielsen heuristics for healthcare contexts [82]. As discussed in Chapter 1, many large-scale projects have been undertaken to develop UI guidelines for digital health systems; however, without establishing an evidence-based approach to guideline development, it has been difficult to maintain or build on these guidelines as technology develops. Although these approaches can aid the design of systems that adhere to industrial usability standards, they represent a broad-brush approach that lacks the kind of scientific rigour required by other healthcare interventions, such as new pharmaceuticals. Greater consideration and use of predictive models integrated into a human-centred design approach may be needed to ensure that evidence-based UI design guidelines can be developed over time. The results of modelling-based studies could ensure that systematic reviews and meta-analyses of usability studies generate evidence that is generalisable beyond the specific contexts of the studies.

6.1.5.1 Integrating Predictive Modeling With Human-Centred Design

Using predictive models to inform the HCD process could accelerate the design of digital health systems. By having a validated evidence base of UI designs to draw on, designers could eliminate a large number of potential designs that might meet basic usability heuristics or that could be appealing to early testers but that could be shown through predictive modeling to have poor usability. Figure 6.1 shows how HCI modelling could fit into the process of designing the UI for a digital health application. The design process moves from implementing the computer algorithms needed for the software to function (developed using deductive logic with a high level of epistemic certainty) to modeling how users would interact with the UI of the system using HCI cognitive models. Once designs that show poor results with modelling are weeded out, the project will then enter a human-centred design phase in which the system is trialled with real users (for example, nurses and physicians who will use a digital health system on the wards) and repeatedly iterated until the software is sufficiently acceptable to pilot. At this stage, human-in-the-loop simulations can be conducted as the system is piloted. Finally, more formal quantitative and qualitative evaluations in clinical contexts can provide higher-level empirical evidence (albeit with lower epistemic certainty than with in-silico HCI modeling). At each stage, in keeping with the design thinking approach, the development team can move back to modeling and HCD to improve the design if needed. In addition to showing whether a particular application works, real-world evaluations based on HCI models will show which models work in the real world, building the evidence base for future design guidelines.

UIs for digital health applications are currently designed using techniques developed for commercial software applications based on human-centred design pro-

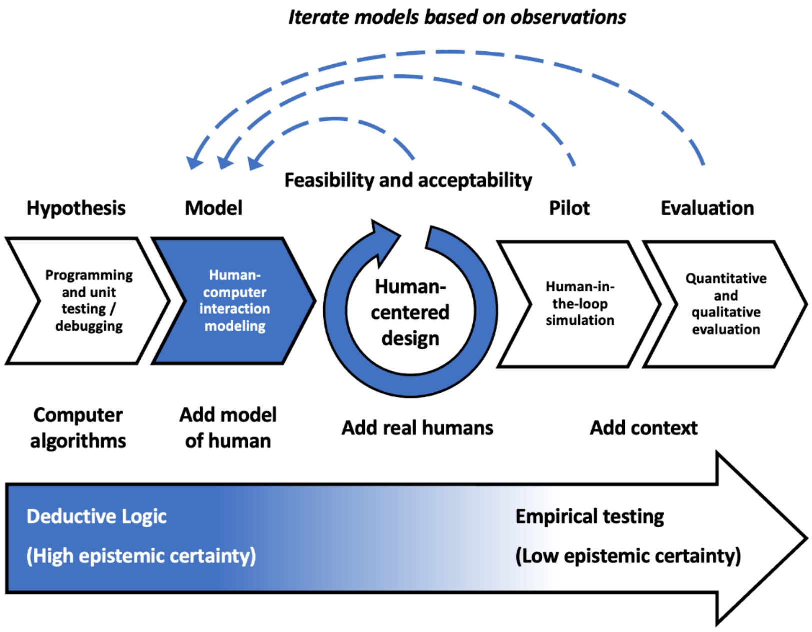

Figure 6.1: Predictive human-computer interaction modeling could augment the human-centered design process and help us understand how an application achieves real-world effectiveness

cesses and heuristics. Predictive HCI modelling of applications may help improve the design process and allow for more scientific progress toward safer and more effective digital health systems. In Chapter 2, I described how predictive HCI modelling has developed from individual cognitive modelling to distributed cognitive models and provided examples of how these models can be integrated into sociotechnical modelling approaches. Although predictive HCI modelling has fallen out of favour in recent years, as the demand for more evidence of the safety and effectiveness of digital health systems increases, it is worth re-evaluating whether HCI modelling can contribute to the science of evidence-based digital health system design. Future research on the integration of predictive modelling with usability and software engineering approaches (such as usability testing and human-in-the-loop simulations) is both needed and warranted.

6.1.5.2 Limitations of HCI Modelling

The main limitation of HCI modelling is the wide range of potential values that different users have (so-called fast-man vs slow-man [9]) for the calculated timings and the lack of alignment of HCI models with new research in cognitive modelling. Most HCI laws and modelling methodologies date back to the 1980s or even the 1950s, when computer systems were first designed. In recent decades, significant advances in quantitative visual perception, cognition and learning have been made that could be integrated into HCI modelling to provide more accurate and generalisable models. This would make the models more complex, and work is needed to ensure that more complex models still represent 'average' users. However, even as approximate models of perception and cognition, the quantitative outputs of HCI modelling help compare different UI designs to each other, even if the estimates of timings and working memory load would benefit from updating to modern, more complex models of perception and cognition.

Another limitation of using quantitative modelling is the potential for researchers and designers to prioritise quantitative data over qualitative data, such as the results of user interviews and ethnographic observations, which are necessary to understand user requirements. For this DPhil thesis, I built on the qualitative research used to create the CUI and the NHS design systems as my starting point (using the document review to extract the outputs of the qualitative research), and I used HCI-modelling to quantitatively evaluate the artefacts which were based on this earlier research. As I described above, I recommend that HCI modelling be integrated into the HCD process and not to replace it. For EHR components (and other new digital health technologies) that have not been researched before, high-quality qualitative research must be carried out to gather the user requirements in line with the HCD process prior to applying HCI modelling to produce quantitative data.

6.1.6 Linking TTR and HCI Modelling Results

In this thesis, it was not possible to directly compare the results of the modelling with the results from the CPHL dataset as the modelling was performed on artefacts that I created by combining two existing sets of design guidelines. However, if access to the systems included in the CHPL were given to a modeller, it would be relatively straightforward to create HCI models of the tasks described in the CHPL for each system and compare the results with the human-subject tests. It would be important to ensure that the systems being tested were the same. In order to do this, the modelled tasks could be specified by the "optimum" user who created the denominator time that is used for the TTR on the same system that was tested. If the results of the modelled TTR were similar to the human-subject TTR, then it could be argued that modelling could be used in place of human-subject tests, which may be much more cost effective. In practice, some combination of human-subject testing and modelling would be preferable to ensure ongoing validity of the evaluation regime.

6.1.7 Implications for DHT Evidence Standards

The current evidence standards for digital health technologies are challenged by integrating healthcare-based research methods into digital technologies. The standards would be improved by first acknowledging that digital systems are qualitatively different from drugs or medical devices and then moving to develop research methods established in information sciences, such as Design Science Research. Focusing evaluation and standards on well-defined user interface design standards would give systems developers greater clarity and accelerate both innovation and adoption of digital health technologies without getting bogged down with unnecessary clinical trials and inappropriate evaluations. By shifting to a new paradigm of robust HCI modelling and information science-based research methodologies and developing clear design guidelines, regulators could have a more straightforward and practically useful way of regulating the digital health industry.

6.1.8 Future Research: Implications for HCI Modelling and Regulating Next-Generation AI and AGI Systems

As digital health technologies evolve, there is a growing interest in transitioning from traditional Electronic Health Record (EHR) systems to AI-enabled approaches. AI can significantly improve the efficiency and effectiveness of digital health tools by enabling faster, more accurate clinical decision support and reducing the cognitive load on clinicians [77]. However, this transition must be grounded in robust usability principles to avoid exacerbating existing challenges.

Incorporating AI into digital health systems requires careful consideration of technical and human factors. While AI can assist with complex data analysis and predictive modelling, the success of AI-enabled tools depends on their integration into clinical workflows. Krittanawong et al. [47], emphasise that AI systems must not only be accurate in their predictions but also intuitive and easy for clinicians to use. If AI systems are challenging to navigate or interpret, their benefits may be overshadowed by usability issues similar to those faced by traditional EHRs. Therefore, designing AI tools that support clinician decision-making without adding unnecessary complexity is crucial. This requires a focus on user-centred design and thorough testing to ensure that AI enhances, rather than hinders, clinical care.

The implications of AI for digital health systems extend beyond task automation and decision support. As AI technologies become more sophisticated, they have the potential to transform how care is delivered by predicting patient outcomes, identifying risk factors, and personalising treatment plans. However, the transition to AI must be managed carefully to ensure these tools are safe and effective. A study by McKinney et al. [52] highlighted the importance of validating AI models in real-world clinical settings to ensure their reliability and minimize the risk of errors. As AI becomes more integrated into digital health, maintaining a strong focus on usability will be vital to ensuring that these tools meet the needs of healthcare providers and patients alike. The shift to AI offers immense potential, but only if usability challenges are addressed through thoughtful design and rigorous evaluation.

6.1.8.1 How should we regulate Generative AI-based clinical decision support systems?

We are now entering a 3rd wave of artificial intelligence (AI). The first wave saw the introduction of so-called expert systems. These systems use hand-coded algorithms that comprise decision trees (if-then statements) based on representations of expert knowledge. For example, IF blood pressure > 120 THEN prescribe anti-hypertensives. These systems are more nuanced and complex than a single statement and can be built up of hundreds of if-then statements to form clinical decision support systems. Modern systems such as UpToDate and the NHS Pathways algorithms that power NHS 111 use this approach to support decision-making and triage.

The second wave of AI had its beginnings many decades ago when scientists first attempted to mimic how neurons process information in the human neocortex [51, 70, 79, 29, 69]. Neurons work by adding up the action potentials of incoming signals from other connected neurons. When the incoming signals reach a certain threshold, the neuron fires, adding to the incoming signal of other neurons in the network. Across the network, this process of adding up signals and then firing if a threshold is reached can enable decisions and outputs based on the sum of different inputs. Scientists copied this structure to create the Artificial Neural Network (ANN). Because each node (or neuron) in the network needs the power of a computer processor to add up the incoming signals and decide whether the threshold has been reached to produce an output signal, creating large ANNs was beyond the power of single-CPU computers. With many inputs coming in at once, an ANN needs each neuron to calculate its output in parallel. With the advent of parallel processing and GPUs, which enable millions of parallel calculations, ANNs started to become useful in the mid-2000s. This enabled the second AI wave, with real-world applications in healthcare from radiology image recognition to risk scores from oxygen sensors [29, 69].

More recently, breakthroughs in training shortcuts such as 'back propagation' and transformer-based models combined with lowered costs and increased GPU capability has resulted in a remarkable leap to the third wave: generative AI [76, 5]. With the advent of generative AI systems, companies such as Tesla and OpenAI believe they can build AI systems capable of replicating "general" intelligence similar to humans. Instead of using an ANN to recognise a certain type of image or process a certain set of signals, the ANN acts as a general-purpose reasoning engine. To do this, it uses human language as the basis of its understanding of the world [78]. The model is first taught what words mean by building relationships in the network with other words or phrases. For example, the word blue is linked to sky, water, colour, paint, low mood, etc. This is encoded mathematically, resulting in a unique number code for each word or phrase. It can use this encoding to understand sentences and descriptions of the world, which it represents as knowledge in the network. This network then becomes a model of the world, represented as the connections between billions of nodes (or neurons) in much the same way every human being holds a model of the world in our own neocortices. This model can then be used by human users to answer questions about the world (at least the model of the world represented in the network) or to reason using laws represented in the model. For example, the model may have learnt about intuitive physics from descriptions of how a ball moves when kicked in a book it has read during the training process.

Over the next decade, it will be important to find ways to ensure that AI systems are used effectively and safely in healthcare, particularly for clinical decision support. We can build on the work done on the NHS Common User Interface, as many components will remain useful. Using HCI modelling and user testing, existing components can be adjusted, and new components can be created. For example, it will be important for clinicians to understand the decision-making process the AIs have gone through. This will likely take the form of the same kind of 'if-then' algorithms described in the first wave of expert systems. It may be difficult for AIs to describe how they recognise patterns in radiology images or complex biological signals, but they should be able to describe how they pull together the evidence base to make diagnostic or treatment decisions. For example, what studies were relevant to the patient, were the data unbiased and accurate, or were some studies better than others? How can you combine the results of different studies for a patient with multiple co-morbidities? Conversational user interfaces may be the best way to show this to the clinician and patient as they decide on treatment options. However, presenting data visualisations is also going to be necessary, and these can be subject to misinterpretation if human perception is not carefully considered.

6.2 Conclusion

The overall contributions of this DPhil lie in advancing the understanding and application of usability principles within digital health technologies (DHTs), focusing on Electronic Health Records (EHR) systems. By combining the NHS Common User Interface (CUI) guidelines with the NHS Design System (DS) framework, this work provides a novel approach to enhancing EHR usability in the NHS. The thesis introduces and evaluates new artefacts, the Patient Name Input and Patient Banner, and through Human-Computer Interaction (HCI) modelling, demonstrating a cost-effective, quantitative method for assessing usability without requiring extensive human-subject testing. This research contributes to the field of Clinical Informatics (intersecting computer science and clinical medicine) by providing results that can inform the design of EHR user interfaces. The research lays a foundation for future work in improving usability across more CUI components for EHR systems and for investigating the clinical usability and safety of new AI-based clinical decision support systems. It provides a methodological framework for developing evidence-based guidelines in digital health technologies that could be applied beyond updating the CUI.

The thesis also has implications for informing digital health policies. As governments introduce new legislation to regulate DHTs, there is an opportunity to standardise safety-critical DHT user interface design elements (such as the patient banner) and support scientific work to develop evidence-based guidelines. New regulations should be based on scientifically robust data if they are to be adopted safely and without causing increased workload and burnout for clinical staff or confusion and stress for patients trying to access healthcare services. However, treating digital health technologies like drugs or physical medical devices is impractical and may be expensive and unproductive. There are well-defined and developed existing information science methodologies, such as HCI modelling and Design Science Research, that can be relatively easily applied to digital health technology design, as shown in this thesis. These tools provide the basis of a scientific approach to developing DHTs that is practical, enables rapid prototyping and iteration, and can provide quantitative data for comparisons and benchmarking. This approach complements the industry standard human-centred design (HCD) design process that is used to ensure the software meets user requirements identified through qualitative research methods by adding quantitative data derived from scientific models of human perception, cognition, and motor functions.

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Appendix 1: R code for CHPL analysis in Chapter 3

```r
# Analysis of CHPL Database
# Chris Paton
# 2023

# Create a vector of package names
packages <- c("readr", "broom", "data.table", "ggplot2", "tidyverse", "dplyr", "gt")

# Install packages
install.packages(packages)

library(readr)
library(data.table)
library(ggplot2)
library(tidyverse)
library(dplyr)
library(gt)
library(broom)

#Read CSV file and put into chpl data frame

chpl <- read_csv("chpl-sed-all-details-20220801_074008.csv")

#Change colnames

colnames(chpl) <- c("id", "dev", "product", "version", "criteria",
                    "task", "scale", "rating", "rating_sd",
                    "time_mean", "time_sd", "time_deviation",
                    "time_optimal", "success_mean", "success_sd",
                    "errors_mean", "errors_sd", "steps_deviation",
                    "steps_optimal", "occupation", "education",
                    "product_exp", "prof_exp", "computer_exp", "age",
                    "gender", "assist")

#Remove old criteria codes

chpl <- filter(chpl,
               chpl$criteria == "170.315 (a)(1)" |
               chpl$criteria == "170.315 (a)(2)" |
               chpl$criteria == "170.315 (a)(3)" |
               chpl$criteria == "170.315 (a)(4)" |
```

```
                 chpl$criteria == "170.315 (a)(5)" |
                 chpl$criteria == "170.315 (a)(9)" |
                 chpl$criteria == "170.315 (a)(14)" |
                 chpl$criteria == "170.315 (b)(2)" |
                 chpl$criteria == "170.315 (b)(2)")

# Clean Data

  #Remove all duplicated results from chpl (not including demographics)
  chpl <- unique( chpl[ , 0:18 ] )

  # Remove the rows with time values < 1
  chpl <- chpl %>%
    filter(time_mean > 0 & time_optimal > 0)

  # Remove the rows with missing values
  chpl <- na.omit(chpl)

  # Remove rows with negative time standard deviation
  chpl <- chpl %>%
    filter(time_sd >= 0)

  # Remove duplicate rows based on time_mean, time_sd, and time_optimal
  chpl <- chpl %>%
    distinct(time_mean, time_sd, time_optimal, .keep_all = TRUE)

  # Remove the rows with time values < 1
  chpl <- chpl %>%
    filter(time_mean > 0 & time_optimal > 0)

# Change category names

  chpl <- chpl %>%
    mutate(category = case_when(
      criteria == "170.315 (a)(1)" ~ "Meds",
      criteria == "170.315 (a)(2)" ~ "Labs",
      criteria == "170.315 (a)(3)" ~ "Image",
      criteria == "170.315 (a)(4)" ~ "Contra",
      criteria == "170.315 (a)(5)" ~ "Demo",
      criteria == "170.315 (a)(9)" ~ "CDS",
      criteria == "170.315 (a)(14)" ~ "UDI",
      criteria == "170.315 (b)(2)" ~ "Recon",
      criteria == "170.315 (b)(3)" ~ "E-Pres",
      TRUE ~ as.character(criteria)
```

```
    ))

# Table 1: Summary Statistics

  # Number of Vendors for CHPL as a total
  dev_n <- chpl %>%
    count(dev)
  number_of_developers <- nrow(dev_n)
  view(chpl)
  print(number_of_developers)
  product_n <- chpl %>%
    count(product)
  number_of_products <- nrow(product_n)
  print(number_of_products)

  # Calculate total number of tasks for each vendor
  vendor_total_tasks <- chpl %>%
    group_by(dev) %>%
    summarise(total_tasks = n(), .groups = 'drop')

  # Rank vendors by total number of tasks and get the top 20
  top_20_vendors <- vendor_total_tasks %>%
    arrange(desc(total_tasks)) %>%
    slice_head(n = 20) %>%
    pull(dev)

  # Update CHPL so just has top 20 vendors
  chpl_20 <- chpl %>%
    filter(dev %in% top_20_vendors)

# Figure 2: All tasks for 20 vendors

  # Count the number of tasks for each criteria
  category_counts <- chpl_20 %>%
    count(category) %>%
    arrange(desc(n))

  # Figure 2: Bar Chart of Number of Tasks for Each Category for Top 20 Vendors
  pdf("Chapter4Figure2.pdf")
  ggplot(category_counts, aes(x = reorder(category, -n), y = n, fill = category)) +
    geom_bar(stat = "identity", show.legend = FALSE) +  # show.legend = FALSE to remove the legend if not needed
    labs(title = "Number of Tasks for Each Task Category",
         x = "Task Category",
         y = "Number of Tasks") +
```

```r
    geom_bar(stat = "identity", colour = "black") +
    theme_minimal() +
    theme(legend.position = "none") +
    geom_text(aes(label = n), vjust = -0.5)
  dev.off()

#Figure 3: Tasks for Vendor Product for Top 20 Vendors

  # Create a df for products and tasks for each of the top 20 vendors
  vendor_product_task_count <- chpl_20 %>%
    group_by(dev, product) %>%
    summarise(tasks = n(), .groups = 'drop') %>%
    # Arrange by vendor's total tasks and then by tasks per product
    left_join(vendor_total_tasks, by = c("dev" = "dev")) %>%
    arrange(desc(total_tasks), desc(tasks)) %>%
    rename(Vendor = dev, Product = product)

  pdf("Chapter4Figure3.pdf")
  ggplot(vendor_product_task_count, aes(x = reorder(Vendor, -total_tasks), y = tasks, fill = Vendor)) +
    geom_bar(stat = "identity", show.legend = FALSE, colour = "black") +
    labs(title = "Number of Tasks for Each Product by Developer",
         x = "Developers",
         y = "Number of Tasks for Each Product (Stacked by Developer)") +
    theme_minimal() +
    theme(legend.position = "none", axis.text.x = element_blank()) +
    geom_text(aes(y = total_tasks, label = total_tasks), vjust = -0.5)
  dev.off()

# Table 2: TTR mean and SD for all 20 vendors

  # Calculate Task Time Ratio TTR = ratio of Task Time divided by Optimal Task Time
  ttr <- mutate(chpl_20, TTR = (chpl_20$time_mean / chpl_20$time_optimal) * 100)

  view(ttr)

  #Trim Outliers
```

```
  quartiles <- quantile(ttr$TTR, probs=c(.25, .75), na.rm = FALSE)
  IQR <- IQR(ttr$TTR)
  Lower <- quartiles[1] - 1.5*IQR
  Upper <- quartiles[2] + 1.5*IQR
  ttr_no_outlier <- subset(ttr, ttr$TTR > Lower & ttr$TTR < Upper)

  view(ttr_no_outlier)

  # Creating the TTR summary
  ttr_summary <- summary(ttr_no_outlier$TTR)

  # Convert the TTR summary to a data frame
  ttr_summary_df <- data.frame(
    Statistic = names(ttr_summary),
    Value = as.numeric(ttr_summary))

  # Write the TTR summary data frame to a CSV file
  write.csv(ttr_summary_df, "Chapter4Table2.csv", row.names = FALSE)

# Figure 4: Distribution of TTR

  pdf("Chapter4Figure4.pdf")
  ggplot(ttr, aes(x = TTR)) +
    geom_histogram(bins = 30, fill = "blue", color = "black") +
    labs(title = "Distribution of TTR", x = "TTR", y = "Frequency") +
    theme_minimal()
  dev.off()

# Figure 5: TTR by Category among top 20 vendors

  # Group by ’category’ and summarize
  ttr_summary <- ttr_no_outlier %>%
    group_by(category) %>%
    summarize(
      n = n(),  # Count of rows per group, which is ’n’ in your case
      Mean_TTR = mean(TTR, na.rm = TRUE),  # Mean of TTR
      Median = median(TTR, na.rm = TRUE),  # Median of TTR
      Q1 = round(quantile(TTR, 0.25, na.rm = TRUE), 2),  # 1st quartile (25th percentile)
      Q3 = round(quantile(TTR, 0.75, na.rm = TRUE), 2)   # 3rd quartile (75th percentile)
    ) %>%
```

```r
    mutate(IQR = paste(Q1, Q3, sep = " - ")) %>%  # Concatenating Q1 and Q3 as a range
    select(-Q1, -Q3)  # Optionally, remove Q1 and Q3 columns, retaining only the 'IQR' column

  # Calculate medians for each category
  medians <- ttr_no_outlier %>%
    group_by(category) %>%
    summarize(median_TTR = round(median(TTR), 1))

  # Create boxplot for Figure 5
  p <- ggplot(ttr_no_outlier, aes(x = category, y = TTR, fill = category)) +
    geom_boxplot() +
    labs(title = "Box Plots of TTR for SED Categories",
         x = "Category",
         y = "TTR") +
    theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, hjust = 1),
          legend.position = "none")

  # Adding median values as text
  pdf("Chapter4Figure5.pdf")
  p + geom_text(data = medians, aes(label = median_TTR,
          y = median_TTR), vjust = -0.5, size = 3)
  dev.off()

# Table 3: ANOVA of TTR by category

  # ANOVA
  anova_results <- aov(TTR ~ category, data = ttr_no_outlier)
  summary_result <- summary(anova_results)
  anova_df <- as.data.frame(summary_result[[1]])
  write.csv(anova_df, "Chapter4Table3.csv")

# Text: Mean TTR

  average_ttr <- ttr_no_outlier %>%
    summarize(average_TTR = mean(TTR, na.rm = TRUE))

  print(average_ttr)

# Figure 6: TTR by Vendor

  #Create boxplot
  pdf("Chapter4Figure6.pdf")
  ggplot(ttr_no_outlier, aes(x = TTR, y = dev, fill = dev)) +
```

```
    geom_boxplot() +
    labs(title = "Box Plots of TTR by Developer",
         x = "TTR",
         y = "Developer") +
    theme_minimal() +
    theme(legend.position = "none", axis.text.y = element_blank())
  dev.off()

  # ANOVA
  anova_results <- aov(TTR ~ dev, data = ttr_no_outlier)
  summary_result <- summary(anova_results)
  anova_df <- as.data.frame(summary_result[[1]])
  write.csv(anova_df, "Chapter4Table4.csv")

# Figure 6: TTR by Vendor Product

  # Filter for the "XXXX" developer and select the columns for product and TTR
  xxxx_ttr <- ttr_no_outlier %>%
    filter(dev == "XXXX") %>%
    select(product, TTR)

  view(xxxx_ttr)

  # Group by 'Product' and summarize
  ttr_xxxx_product_summary <- xxxx_ttr %>%
    group_by(product) %>%
    summarize(
      n = n(),  # Count of rows per group, which is 'n' in your case
      Mean_TTR = mean(TTR, na.rm = TRUE),  # Mean of TTR
      Median = median(TTR, na.rm = TRUE),  # Median of TTR
      Q1 = round(quantile(TTR, 0.25, na.rm = TRUE), 2),  # 1st quartile (25th percentile)
      Q3 = round(quantile(TTR, 0.75, na.rm = TRUE), 2)   # 3rd quartile (75th percentile)
    ) %>%
    mutate(IQR = paste(Q1, Q3, sep = " - ")) %>%  # Concatenating Q1 and Q3 as a range
    select(-Q1, -Q3)  # Optionally, remove Q1 and Q3 columns, retaining only the 'IQR' column

  View(ttr_xxxx_product_summary)

  #Create boxplot
  pdf("Chapter4Figure7.pdf")
```

```
ggplot(xxxx_ttr, aes(x = TTR, y = product, fill = product)) +
  geom_boxplot() +
  labs(title = "Box Plots of TTR by Product for a Single
     Developer",
       x = "TTR",
       y = "Product") +
  theme_minimal() +
  theme(legend.position = "none", axis.text.y = element_blank
     ())
dev.off()

# ANOVA
anova_results <- aov(TTR ~ product, data = allscripts_ttr)
summary_result <- summary(anova_results)
anova_df <- as.data.frame(summary_result[[1]])
write.csv(anova_df, "Chapter4Table5.csv")
```

Appendix 2: HTML code for CUI-only Patient Banner

```
<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="UTF-8" />
<meta name="viewport" content="width=device-width, initial-scale=1.0" />
<title>Patient Banner</title>
<link
rel="stylesheet"
href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/5.15.1/css/all.min.css"
/>
<style>
body {
margin: 0;
padding: 0;
font-family: "Arial", sans-serif;
}


.header {
display: flex;
justify-content: space-between;
background-color: rgb(0, 94, 184);
border: 1px solid #000;
color: #fff;
}


.logo {
padding: 10px
}


h1 {
font-size: 16px;
}


h2 {
font-size: 12px;
}


.search {
```

```
padding: 7px 20px;
border: 1px solid #000;
margin: 27px;
background-color: #fff;
font-size: 12px;
text-align: left;
color: #333;
font-style: italic;
}


.nav {
padding: 10px 0;
border: 1px solid #000;
border-top: none;


background-color: #eee;
}


.nav-items {
display: flex;
justify-content: space-between;
list-style: none;
margin: 0;
padding: 0 10px;
font-size: 12px;
}


.nav-item {
margin: 0;
}


.breadcrumbs {
padding: 10px;
font-size: 12px;
border: 1px solid #000;
border-top: none;
border-bottom: none;
background-color: #eee;
}


.patient-banner {
```

```
min-width: 650px;
}
.zone1 {
padding: 20px 10px;
border: 1px solid #000;
display: flex;
align-items: center;
justify-content: space-between;
min-width: 500px;
overflow: hidden;
height: 30px;
font-size: 18px;
}


.patient-name {
flex: 0 1 auto;
font-weight: bold;
margin-right: 5px;
}


.patient-details {
flex: 0 1 auto;
display: flex;
}


.item {
padding: 0 5px;
}


.banner-label {
font-style: italic;
white-space: nowrap;
}


.data {
font-weight: bold;
white-space: nowrap;
}


.link {
font-style: italic;
```

```
text-align: right;
}


.toggle-content {
border-left: 1px solid #000;
border-bottom: 1px solid #000;
padding: 7px 10px;
display: none;
}


.zone2 {
display: flex;
justify-content: space-between;
align-items: center;
font-size: 12px;
cursor: pointer;
}


.zone2 > div {
}


.address-box, .contact-box, .alert {
border-right: none;
border-top: none;
flex-grow: 1;
display: flex;
flex-direction: column
}


.contracted {
border-left: 1px solid #000;
border-bottom: 1px solid #000;
padding: 7px 10px;
}


.grey {
background-color: #999;
color: #fff;
}


```

```
.white {
}


.empty-box {
flex-grow: 1;
}


.alert-box {
display: flex;
align-items: center;
flex-grow: 1;
}


.alert-icon {
display: inline-block;
width: 12px;
height: 12px;
transform: rotate(45deg);
display: inline-flex;
align-items: center;
justify-content: center;
border: 1px solid #000;
margin-right: 10px;
}


.alert-icon span {
transform: rotate(-45deg);
display: inline-block;
transform-origin: center;
font-size: 0.8em;
}


.expand {
border-right: 1px solid #000;
}


.expand-icon {
font-size: 1em;
}


```

```
@media (max-width: 850px) {
.zone1 {
font-size: 14px;
}
}


</style>
</head>
<body>
<div class="header">
<div class="logo">
<h1>Oxford University Hospitals</h1>
<h2>NHS Foundation Trust</h2>
</div>
<div class="search">Search the OUH website</div>
</div>
<div class="nav">
<ul class="nav-items">
<li class="nav-item">Patient Details</li>
<li class="nav-item">Edit Current Patient</li>
<li class="nav-item">Add New Patient</li>
<li class="nav-item">List Patients</li>
</ul>
</div>
<div class="breadcrumbs">
Home > Section > Subsection
</div>
<div class="patient-banner">
<div class="zone1">
<div class="patient-name">
CHANDRASEKHAR Subramanyan (Mr)
</div>
<div class="patient-details">
<div class="item">
<span class="banner-label">Born</span>
<span class="data">14-Jul-1945</span>
</div>
<div class="item">
<span class="banner-label">Gender</span>
<span class="data">Male</span>
</div>
<div class="item">
<span class="banner-label">NHS No.</span>
<span class="data">129 728 7652</span>
</div>
</div>
```

```
</div>
<div class="zone2" onclick="toggleContent()">
<div class="address-box">
<div class="contracted">
<span class="banner-label">Address</span>
<span class="data">340 Gloucester R...</span>
</div>
<div class="toggle-content">
<div class="banner-label">Usual address</div>
<div>340 Gloucester Road Walton</div>
<div>Tewkesbury</div>
<div>GL20 4RT</div>
<div class="link">View all addresses</div>
</div>
</div>
<div class="contact-box">
<div class="contracted">
<span class="banner-label">Phone and email </span>
<span class="data">020 8123 4567</span>
</div>
<div class="toggle-content">
<div>Home 020 8123 4567</div>
<div>Work 0118 496 0823</div>
<div>Mobile 07700 900555</div>
<div>Email rama@abc.xyz.com</div>
<div class="link">View all contact details</div>
</div>
</div>
<div class="empty-box">
<div class="contracted">
<span class="banner-label"> </span>
<span class="data"> </span>
</div>
<div class="toggle-content">
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
<div class="empty-box">
<div class="contracted">
<span class="banner-label"> </span>
<span class="data"> </span>
</div>
<div class="toggle-content">
```

```
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
<div class="alert">
<div class="contracted">
<div class="alert-box">
<div class="alert-icon"><span>A</span></div>
<div>
<span class="data">Known allergies</span>
</div>
</div>
</div>
<div class="toggle-content">
<div>Latex 14-Nov-1961</div>
<div>Peanuts 15-Aug-1997</div>
<div>Penicillin 02-Oct-2003</div>
<div> </div>
<div class="link">View all allergies</div>
</div>
</div>
<div class="expand">
<div class="contracted">
<svg xmlns="http://www.w3.org/2000/svg" width="10" height="10"
   fill="currentColor" class="bi bi-chevron-double-down"
   viewBox="3 3 10 10">
<path fill-rule="evenodd" d="M1.646 6.646a.5.5 0 0 1 .708 0L8
   12.293l5.646-5.647a.5.5 0 0 1 .708.708l-6 6a.5.5 0 0 1-.708
   0l-6-6a.5.5 0 0 1 0-.708z"/>
<path fill-rule="evenodd" d="M1.646 2.646a.5.5 0 0 1 .708 0L8
   8.293l5.646-5.647a.5.5 0 0 1 .708.708l-6 6a.5.5 0 0 1-.708 0
   l-6-6a.5.5 0 0 1 0-.708z"/>
</svg>
</div>
<div class="toggle-content">
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
</div>
```

```
<script>
function toggleContent() {
const contentDivs = document.querySelectorAll('.toggle-content');
const zone2contracted = document.querySelectorAll('.contracted');
let zone2hidden = true;
contentDivs.forEach(div => {
if (div.style.display === 'none' || div.style.display === '') {
div.style.display = 'block';
zone2hidden = false;
} else {
div.style.display = 'none';
}
});


if(zone2hidden) {
zone2contracted.forEach(zone2contracted => {
zone2contracted.classList.remove('grey');
zone2contracted.classList.add('white');
});
} else {
zone2contracted.forEach(zone2contracted => {
zone2contracted.classList.remove('white');
zone2contracted.classList.add('grey');
});
}
}
</script>
</body>
</html>
```

Appendix 3: HTML code for CUI and NHS Design System Patient Banner

```
<!DOCTYPE html>
<html lang="en" dir="ltr">


<head>
<meta charset="utf-8">
<link rel="stylesheet" href="css/style.css">
<title>Patient Banner</title>
<style>
body {
margin: 0;
padding: 0;
}


.patient-banner {
min-width: 650px;
background-color: #fff;
}
.zone1 {
padding: 20px 10px;
border: 1px solid #aeb7bd;
display: flex;
align-items: center;
justify-content: space-between;
min-width: 500px;
overflow: hidden;
height: 80px;
font-size: 18px;
}


.patient-name {
flex: 0 1 auto;
font-weight: bold;
margin-right: 5px;
}


.patient-details {
flex: 0 1 auto;
display: flex;
}
```

```
.item {
padding: 0 5px;
}


.banner-label {
font-style: italic;
white-space: nowrap;
}


.data {
font-weight: bold;
white-space: nowrap;
}


.link {
font-style: italic;
text-align: right;
}


.toggle-content {
border-left: 1px solid #aeb7bd;
border-bottom: 1px solid #aeb7bd;
padding: 7px 10px;
display: none;
}


.zone2 {
display: flex;
justify-content: space-between;
align-items: center;
font-size: 12px;
cursor: pointer;
}


.zone2 > div {
}


.address-box, .contact-box, .alert {
```

```
border-right: none;
border-top: none;
flex-grow: 1;
display: flex;
flex-direction: column
}


.contracted {
border-left: 1px solid #aeb7bd;
border-bottom: 1px solid #aeb7bd;
padding: 7px 10px;
}


.grey {
background-color: #999;
color: #fff;
}


.white {
}


.empty-box {
flex-grow: 1;
}


.alert-box {
display: flex;
align-items: center;
flex-grow: 1;
}


.alert-icon {
display: inline-block;
width: 12px;
height: 12px;
transform: rotate(45deg);
display: inline-flex;
align-items: center;
justify-content: center;
border: 1px solid #000;
margin-right: 10px;
```

```
}


.alert-icon span {
transform: rotate(-45deg);
display: inline-block;
transform-origin: center;
font-size: 0.8em;
}


.expand {
border-right: 1px solid #aeb7bd;
}


.expand-icon {
font-size: 1em;
}


@media (max-width: 850px) {
.zone1 {
font-size: 14px;
}
}


</style>
<script src="node_modules/nhsuk-frontend/dist/nhsuk.min.js"
    defer></script>
</head>


<body>
<script>
document.body.className = ((document.body.className) ? document
    .body.className + ' js-enabled' : 'js-enabled');
</script>
<header class="nhsuk-header nhsuk-header--organisation" role="
    banner">
<div class="nhsuk-width-container nhsuk-header__container">
<div class="nhsuk-header__logo">
<a class="nhsuk-header__link" href="/" aria-banner-="Anytown
    Anyplace Anywhere NHS Foundation Trust homepage">
<svg class="nhsuk-logo" xmlns="http://www.w3.org/2000/svg"
    viewBox="0 0 40 16" height="40" width="100">
```

```
<path class="nhsuk-logo__background" fill="#005eb8" d="M0 0 h40v16H0z"></path>
<path class="nhsuk-logo__text" fill="#fff"
d="M3.9 1.5h4.4l2.6 9h.1l1.8-9h3.3l-2.8 13H9l-2.7-9h-.1l-1.8 9H1.1M17.3 1.5h3.6l-1 4.9h4L25 1.5h3.5l-2.7 13h-3.5l1.1-5.6h-4.1l-1.2 5.6h-3.4M37.7 4.4c-.7-.3-1.6-.6-2.9-.6-1.4 0-2.5.2-2.5 1.3 0 1.8 5.1 1.2 5.1 5.1 0 3.6-3.3 4.5-6.4 4.5-1.3 0-2.9-.3-4-.7l.8-2.7c.7.4 2.1.7 3.2.7s2.8-.2 2.8-1.5c0-2.1-5.1-1.3-5.1-5 0-3.4 2.9-4.4 5.8-4.4 1.6 0 3.1.2 4 .6"
>
</path>
</svg>

<span class="nhsuk-organisation-name">Oxford University Hospitals</span>
<span class="nhsuk-organisation-descriptor">NHS Foundation Trust</span>
</a>
</div>

<div class="nhsuk-header__content" id="content-header">

<div class="nhsuk-header__menu">
<button class="nhsuk-header__menu-toggle" id="toggle-menu" aria-controls="header-navigation" aria-expanded="false">Menu</button>
</div>

<div class="nhsuk-header__search">
<button class="nhsuk-header__search-toggle" id="toggle-search" aria-controls="search" aria-label="Open search">
<svg class="nhsuk-icon nhsuk-icon__search" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" focusable="false" width="27" height="27">
<path d="M19.71 18.29l-4.11-4.1a7 7 0 1 0-1.41 1.41l4.1 4.11a1 1 0 0 0 1.42 0 1 1 0 0 0 0-1.42zM5 10a5 5 0 1 1 5 5 5 5 0 0 1-5-5z"></path>
</svg>
<span class="nhsuk-u-visually-hidden">Search</span>
</button>
<div class="nhsuk-header__search-wrap" id="wrap-search">
<form class="nhsuk-header__search-form" id="search" action="https://www.nhs.uk/search/" method="get" role="search">
```

```
<label class="nhsuk-u-visually-hidden" for="search-field">Search the NHS website</label>
<input class="nhsuk-search__input" id="search-field" name="q" type="search" placeholder="Search" autocomplete="off">
<button class="nhsuk-search__submit" type="submit">
<svg class="nhsuk-icon nhsuk-icon__search" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" focusable="false" width="27" height="27">
<path d="M19.71 18.29l-4.11-4.1a7 7 0 1 0-1.41 1.41l4.1 4.11a1 1 0 0 0 1.42 0 1 1 0 0 0 0-1.42zM5 10a5 5 0 1 1 5 5 5 5 0 0 1-5-5z"></path>
</svg>
<span class="nhsuk-u-visually-hidden">Search</span>
</button>
<button class="nhsuk-search__close" id="close-search">
<svg class="nhsuk-icon nhsuk-icon__close" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" focusable="false" width="27" height="27">
<path d="M13.41 12l5.3-5.29a1 1 0 1 0-1.42-1.42L12 10.59l-5.29-5.3a1 1 0 0 0-1.42 1.42l5.3 5.29-5.3 5.29a1 1 0 0 0 1.42 1.42l5.29-5.3 5.29 5.3a1 1 0 0 0 1.42 0 1 1 0 0 0 0-1.42z"></path>
</svg>
<span class="nhsuk-u-visually-hidden">Close search</span>
</button>
</form>
</div>
</div>


</div>


</div>
<nav class="nhsuk-header__navigation" id="header-navigation" role="navigation" aria-label="Primary navigation" aria-labelledby="label-navigation">
<div class="nhsuk-width-container">
<p class="nhsuk-header__navigation-title"><span id="label-navigation">Menu</span>
<button class="nhsuk-header__navigation-close" id="close-menu">
<svg class="nhsuk-icon nhsuk-icon__close" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" focusable="false" width="27" height="27">
<path d="M13.41 12l5.3-5.29a1 1 0 1 0-1.42-1.42L12 10.59l-5.29-5.3a1 1 0 0 0-1.42 1.42l5.3 5.29-5.3 5.29a1 1 0 0 0 1.42 1.42l5.29-5.3 5.29 5.3a1 1 0 0 0 1.42 0 1 1
```

```
0 0 0 0-1.42z"></path>
</svg>
<span class="nhsuk-u-visually-hidden">Close menu</span>
</button>
</p>
<ul class="nhsuk-header__navigation-list">
<li class="nhsuk-header__navigation-item nhsuk-header__navigation-item--for-mobile">
<a class="nhsuk-header__navigation-link" href="/">
Home
<svg class="nhsuk-icon nhsuk-icon__chevron-right" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" width="34" height="34">
<path d="M15.5 12a1 1 0 0 1-.29.71l-5 5a1 1 0 0 1-1.42-1.42l4.3-4.29-4.3-4.29a1 1 0 0 1 1.42-1.42l5 5a1 1 0 0 1 .29.71z"></path>
</svg>
</a>
</li>
<li class="nhsuk-header__navigation-item">
<a class="nhsuk-header__navigation-link" href="#">
Patient Details
<svg class="nhsuk-icon nhsuk-icon__chevron-right" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" width="34" height="34">
<path d="M15.5 12a1 1 0 0 1-.29.71l-5 5a1 1 0 0 1-1.42-1.42l4.3-4.29-4.3-4.29a1 1 0 0 1 1.42-1.42l5 5a1 1 0 0 1 .29.71z"></path>
</svg>
</a>
</li>
<li class="nhsuk-header__navigation-item">
<a class="nhsuk-header__navigation-link" href="#">
Edit Current Patient
<svg class="nhsuk-icon nhsuk-icon__chevron-right" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" width="34" height="34">
<path d="M15.5 12a1 1 0 0 1-.29.71l-5 5a1 1 0 0 1-1.42-1.42l4.3-4.29-4.3-4.29a1 1 0 0 1 1.42-1.42l5 5a1 1 0 0 1 .29.71z"></path>
</svg>
</a>
</li>
<li class="nhsuk-header__navigation-item">
<a class="nhsuk-header__navigation-link" href="#">
Add New Patient
```

```
<svg class="nhsuk-icon nhsuk-icon__chevron-right" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" width="34" height="34">
<path d="M15.5 12a1 1 0 0 1-.29.71l-5 5a1 1 0 0 1-1.42-1.42l4.3-4.29-4.3-4.29a1 1 0 0 1 1.42-1.42l5 5a1 1 0 0 1 .29.71z"></path>
</svg>
</a>
</li>
<li class="nhsuk-header__navigation-item">
<a class="nhsuk-header__navigation-link" href="#">
List Patients
<svg class="nhsuk-icon nhsuk-icon__chevron-right" xmlns="http://www.w3.org/2000/svg" viewBox="0 0 24 24" aria-hidden="true" width="34" height="34">
<path d="M15.5 12a1 1 0 0 1-.29.71l-5 5a1 1 0 0 1-1.42-1.42l4.3-4.29-4.3-4.29a1 1 0 0 1 1.42-1.42l5 5a1 1 0 0 1 .29.71z"></path>
</svg>
</a>
</li>
</ul>
</div>
</nav>
</header>
<nav class="nhsuk-breadcrumb" aria-label="Breadcrumb">
<div class="nhsuk-width-container">
<ol class="nhsuk-breadcrumb__list">
<li class="nhsuk-breadcrumb__item"><a class="nhsuk-breadcrumb__link" href="#">Home</a></li>
<li class="nhsuk-breadcrumb__item"><a class="nhsuk-breadcrumb__link" href="#">Section</a></li>
<li class="nhsuk-breadcrumb__item"><a class="nhsuk-breadcrumb__link" href="#">Subsection</a></li>
</ol>
<p class="nhsuk-breadcrumb__back"><a class="nhsuk-breadcrumb__backlink" href="#">Back to Subsection</a></p>
</div>
</nav>
<div class="nhsuk-width-container">
<main class="nhsuk-main-wrapper" id="maincontent" role="main">
<div class="patient-banner">
<div class="zone1">
<div class="patient-name">
CHANDRASEKHAR Subramanyan (Mr)
</div>
<div class="patient-details">
```

```
<div class="item">
<span class="banner-label">Born</span>
<span class="data">14-Jul-1945</span>
</div>
<div class="item">
<span class="banner-label">Gender</span>
<span class="data">Male</span>
</div>
<div class="item">
<span class="banner-label">NHS No.</span>
<span class="data">129 728 7652</span>
</div>
</div>
</div>
<div class="zone2" onclick="toggleContent()">
<div class="address-box">
<div class="contracted">
<span class="banner-label">Address</span>
<span class="data">340 Gloucester R...</span>
</div>
<div class="toggle-content">
<div class="banner-label">Usual address</div>
<div>340 Gloucester Road Walton</div>
<div>Tewkesbury</div>
<div>GL20 4RT</div>
<div class="link">View all addresses</div>
</div>
</div>
<div class="contact-box">
<div class="contracted">
<span class="banner-label">Phone and email </span>
<span class="data">020 8123 4567</span>
</div>
<div class="toggle-content">
<div>Home 020 8123 4567</div>
<div>Work 0118 496 0823</div>
<div>Mobile 07700 900555</div>
<div>Email rama@abc.xyz.com</div>
<div class="link">View all contact details</div>
</div>
</div>
<div class="empty-box">
<div class="contracted">
<span class="banner-label"> </span>
<span class="data"> </span>
</div>
<div class="toggle-content">
```

```
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
<div class="empty-box">
<div class="contracted">
<span class="banner-label"> </span>
<span class="data"> </span>
</div>
<div class="toggle-content">
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
<div class="alert">
<div class="contracted">
<div class="alert-box">
<div class="alert-icon"><span>A</span></div>
<div>
<span class="data">Known allergies</span>
</div>
</div>
</div>
<div class="toggle-content">
<div>Latex 14-Nov-1961</div>
<div>Peanuts 15-Aug-1997</div>
<div>Penicillin 02-Oct-2003</div>
<div> </div>
<div class="link">View all allergies</div>
</div>
</div>
<div class="expand">
<div class="contracted">
<svg xmlns="http://www.w3.org/2000/svg" width="10" height="10"
   fill="currentColor" class="bi bi-chevron-double-down"
   viewBox="3 3 10 10">
<path fill-rule="evenodd" d="M1.646 6.646a.5.5 0 0 1 .708 0L8
   12.293l5.646-5.647a.5.5 0 0 1 .708.708l-6 6a.5.5 0 0 1-.708
   0l-6-6a.5.5 0 0 1 0-.708z"/>
<path fill-rule="evenodd" d="M1.646 2.646a.5.5 0 0 1 .708 0L8
   8.293l5.646-5.647a.5.5 0 0 1 .708.708l-6 6a.5.5 0 0 1-.708 0
```

```
l-6-6a.5.5 0 0 1 0-.708z"/>
</svg>
</div>
<div class="toggle-content">
<div> </div>
<div> </div>
<div> </div>
<div> </div>
<div class="link"> </div>
</div>
</div>
</div>
</div>
</div>
</nav>
<script>
function toggleContent() {
const contentDivs = document.querySelectorAll('.toggle-content');
const zone2contracted = document.querySelectorAll('.contracted');
let zone2hidden = true;
contentDivs.forEach(div => {
if (div.style.display === 'none' || div.style.display === '') {
div.style.display = 'block';
zone2hidden = false;
} else {
div.style.display = 'none';
}
});


if(zone2hidden) {
zone2contracted.forEach(zone2contracted => {
zone2contracted.classList.remove('grey');
zone2contracted.classList.add('white');
});
} else {
zone2contracted.forEach(zone2contracted => {
zone2contracted.classList.remove('white');
zone2contracted.classList.add('grey');
});
}
}
</script>
```

```
</main>
</div>
<footer role="contentinfo">
<div class="nhsuk-footer" id="nhsuk-footer">
<div class="nhsuk-width-container">
<p class="nhsuk-footer__copyright">&copy; Crown copyright</p>
</div>
</div>
</footer>
</body>
</html>
```