Evaluating how nurse communication during shift handovers can be improved using interactive data visualisation.

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Declaration Statement

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I hereby certify that the material, which I now submit for assessment on the programme of study leading to the award of Master of Science, is entirely my own work and has not been taken from the work of others except to the extent of such work which has been cited and acknowledged within the text of my own work.

No portion of the work contained in this research project has been submitted in support of an application for another degree or qualification to this or any other institute.

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(Candidate Name)

01.05.2021

Date

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ABSTRACT

Data Visualisation is prolific across business and science but is less utilised in healthcare settings with poor usability cited as the major barrier within digital healthcare systems. This is particularly evident inpatient documentation and nurse handover processes (Khan, Mukhtar, Ahmad, Gondal, Ilyas, 2017). This paper argues that the use of a digital data visualisation dashboard to view, record and store patient information will improve nurse shift handovers in the following areas: the communication of essential information, the efficiency of handovers and overall satisfaction with the shift handover process. The paper describes the discovery research undertaken and how key findings revealed that current shift handover methods are primarily paper based, lack standardisation and are time consuming with excessive documentation and interruptions on the ward. These research findings were leveraged to inform a UX design process and experiment which demonstrate the benefits of a digital dashboard prototype over a paper method for nurses performing shift handovers.

CCS CONCEPTS • Data Visualisation • Healthcare Informatics • Interactivity • Dashboards • Usability

Additional Keywords and Phrases: Nursing, Healthcare, Shift Handover, Electronic Health Records

1 INTRODUCTION

Data visualisation and dashboards in business gather summary data to provide the necessary information for business management to make key decisions. In a healthcare environment, clinical dashboards provide the same method of discovery to healthcare management as well as informing day-to-day clinical activities (Maktoobi & Melchiori, 2016). Khan et al. (2017) describe how several data visualisation best practices and methods have been put forward in a number of disciplines. They state that in comparison, healthcare data visualisation is not as advanced in its application with poor usability cited as the reason why common paper-based approaches are preferred over the use of electronic healthcare systems.

Information visualisation can help health care professionals, support services and patients to interpret diagnoses and medical decisions, while sharing background information that could include guidelines, clinical evidence, and patient data. Attempts to use data visualisation in healthcare include patient cohort analysis, dashboard design of an electronic health record (EHR) and the use of digital cognitive maps to enable clinical handovers (Sharma, Stranieri, Firmin, Mays, Burstein, 2018). Clinical handovers between nurses are key to ensuring good communication, a high standard of care and patient safety. The use of data visualisation to present EHRs to nursing staff can support the process and knowledge needs of nursing units in facilitating their important work and contributing to a patient's overall care and outcome (Matney, Maddox, Staggers, 2014).

The research project described in this paper aims to understand the state of the art of data visualisation usability in healthcare and clinical settings. A competitor analysis and a literature review helped to identify gaps in the research identified and inform the research problem. Research questions and hypothesis around the usability of a nurse shift handover were outlined and a research methodology detailed the data collection methods, design, prototype, and participants involved. The results of this research were analysed which informed the iterative development and testing of a design solution to the research problem.

2 LITERATURE AND PRACTICE REVIEW

2.1 State of the Art

2.1.1 Data Visualisation

Data visualisation plays an important role in data analytics, in particular with big data where it is often difficult for the user to identify the information without proper analysis (Mani & Fei, 2017). With so many sources of data available, there is a need to extract a form of pattern or meaning from the information presented (Glover, 2016). There are a number of desktop and online visualisation tools available to users (which include Excel, Tableau and Cognos) that can interpret data and present it as visualisation(s). Patterson, Blaha, Grinstein, Kaveney, Sheldon, Havig, Moore (2014) state that the modern approach to visualisation should incorporate human cognition that allows users to gain insight, reasoning and understanding from a visualisation. Their research supports the theory that the visual presentation of information will allow users to perform problem solving in complex areas while stimulating the retrieval of past similar cases from the user's short-term memory for analysis. Similarly, Few (2006a) states that data visualisation is only effective when it is aligned to the way people see and think, and for it to work effectively, we must understand people and their requirements. This is particularly relevant to the research of this paper by understanding how the nurse handover happens while considering nurses' opinions and views to inform the design of handover information.

2.1.2 Data Visualisation in Healthcare

Data visualisation in Healthcare supports the exploration and discovery of insights in healthcare data for patients, clinicians and policy makers allowing them to make better decisions (Shortliffe & Cimino, 2014). This data comes from three primary domains, personal, clinical, and public health information. Personal health information originates from the patient with their own health practices and the use of sensors and health monitors. Clinical health information is increasingly available in the form of an electronic health record (EHR) which, when used in conjunction with visualisation, can provide insight on treatments. Public health information allows policy makers to make more informed decisions and is collected by governments for analysis (Shneiderman, Plaisant, Hesse, 2013).

Rind, Wang, Aigner, Miksch, Wongsuphasaat, Plaisant, Shneiderman (2011) define an EHR as the complete set of information that is related to the past, present and future health status or health care provided for a patient. Rind et al. state that reliable data entry and retrieval is the basic function of an EHR system but that there is a need for powerful exploration and query functionality to realise the full benefit of EHR systems. Data visualisation and interactive design are ways to improve the understanding of this complex data and will be used in this research study to benefit nurses during the handover of a shift.

Research by the HSE (2016) in their Strategic Business Case for a National Electronic Health Record indicates that in the USA, Kaiser Permanente, one of the largest not-for-profit healthcare delivery systems has 100% adoption of multifunctional EHRs. This research also states that in the UK and Northern Ireland, as of 2015, over 55 million patients can book GP appointments, order prescriptions, and access their medical record summary information online. Maktoobi and Melchiori (2016) undertook a review of recent papers describing a series of clinical dashboards that offer to better support clinical activities. A number of the tools that they reviewed visualised the data of EHRs. While their research indicates a step towards a better use and understanding of these records, the adoption of EHR systems to replace the traditional paper systems has led

to only a slight improvement in quality of care and in some cases a drop in quality (Himmelstein et al., 2010). To improve healthcare with interactive data visualisation, several challenges have been identified by Shneiderman et al. (2013). They involve providing the right information to clinicians in the correct format and fulfilling the need for a range of tools using data visualisation. Such tools will enable clinicians to improve the quality of care for patients, team decision making, cohort comparison and an overall improvement in medical communication.

2.1.3 User Experience

Building on these challenges, Khan et al. (2017) developed an electronic health record for obstetrics that focused on improving usability and patient healthcare. Using visualisations to oversee progress, inconsistencies in data and risks to patient health, the dashboard enabled a physician to monitor a patient's healthcare record over a period of time. The proposed system was assessed alongside the already developed system. As part of the within group study, the effectiveness of the visualisations was measured by a Single Ease Question (SEQ), a questionnaire on user background, computer skills and system usage, and a System Usability Scale (SUS) filled out by participants at the end of each session for both systems.

The results showed that the visualisation techniques used in the EHR record provided a benefit and enhancement to the user experience. While the evaluation of the tool utilised some quantitative methods to gauge the tool's effectiveness, the outcome was not presented as one dashboard, but rather as individual visualisations (Figure 1), which did not present a holistic experience or user flow. Further research by Khan et al. into user journeys, as-is and to-be scenarios and user interviews would have provided a richer study of the interfaces. This study intends to utilise these research methods to develop a richer, more empathetic understanding of nurses and the handover process.

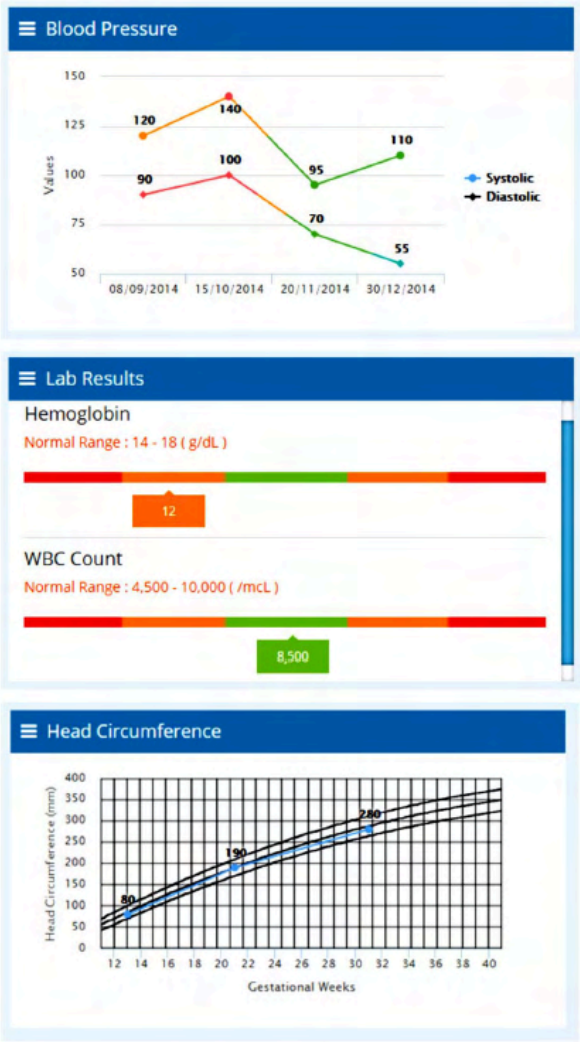

Figure 1: Identifying anomalies in patient data. (Khan et al., 2017)

An investigation into the use of EHRs by nurses was undertaken by Chetta, Carrington, Forbes (2015). They state that the use of EHRs in clinical settings presents new opportunities for data analytics to be introduced into nursing practice. Access to the records was beneficial to nurses but recording, retrieving and analysing the data proved difficult with issues highlighted relating to communication and validation of the data (Carrington & Tiase, 2013). Often nursing staff are unable to sort through the vast data available in an EHR to find the information they need (Rind et al., 2013). The article by Chetta et al (2015) presented three connected visualisations that enabled nurses to better communicate and make decisions (Figure 2). The visualisations were based on the concepts put forward by Forbes, Surdeanu, Jansen, Carrington (2013). This calls for the use of EHRs to better

enable a nurse's day-to-day workflow, where they can determine a patient's outcome based on vital signs, handoff reports and historical data. The first interface Chetta et al (2015) put forward provided an overview of potentially high-risk outcomes for a patient. The second interface enabled nurses to investigate clinical events that are likely to be associated with high-risk outcomes. The third interface provided a timeline that shows vital signs for a patient and spoken or written recorded data.

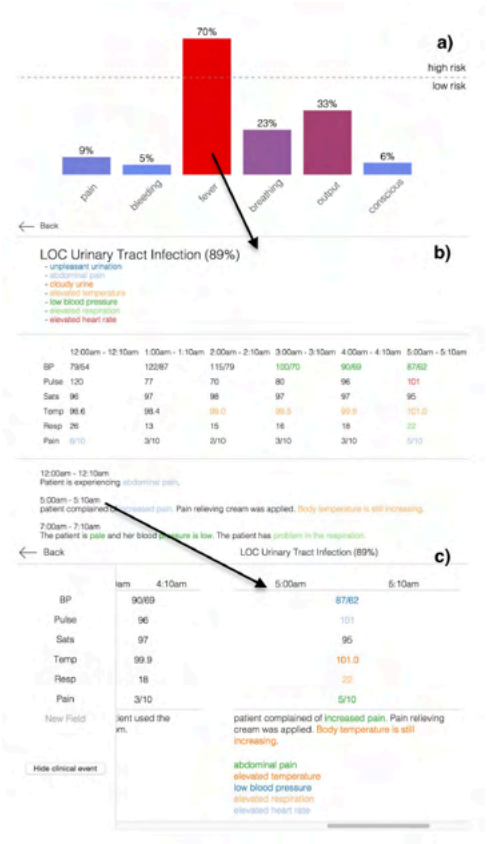

Figure 2: Typical workflow of a nurse using their tool. A) Outcomes chart. B) Clinical events list. C) Augmented flow sheet timeline. (Chetta et al., 2015)

While Chetta et al (2015) provide a set of dashboards and usage scenarios to describe the features there was little work done in the way of user experience research, design, and testing. As-is, and To-be, scenarios, complete user journeys coupled with quantitative and qualitative testing could have provided results in a richer more in-depth study that would create a better overall experience for clinical users of such dashboards. This identified gap is the focus and aim of this study's research: to develop a richer, empathetic understanding of nurses and the handover process.

From the literature consulted, three main areas of improvement have been identified: Communication, Efficiency and Satisfaction.

Communication – Studies of nurse behaviour have found that nurses make an effort to talk to one another face-to-face as shifts change (Carrington, 2012b). Information is often exchanged verbally and these verbal summaries of patient health during handovers between nurses can be misinterpreted or sometimes ignored (Carrington, 2012a). While the HSE (Health Service Executive) in Ireland has introduced EHR systems in a number of areas of clinical practice like maternity care (HSE Ireland, 2017a) and Endoscopy (Manitex, 2017), a lot of work is still done through paper based records and verbal communication, in particular with nursing care and handovers (HSE Ireland, 2015). The HSE utilises the ISBAR (Identity, Situation, Background, Assessment and Recommendation) technique amongst staff to aid in the handover process (Arora, Johnson, Meltzer, Humphrey, 2008). The use of an interactive visualisation system to translate the available EHR data and to document paper and verbal records from nursing staff will help to improve communication between nurses during a handover (Forbes et al., 2013).

Efficiency – The quality of handovers can be negatively affected by a number of issues. A lack of standardised handover tools, inaccurate information, miscommunication due to language, social or skill issues, and a lack of training all contribute to an ineffective handover (Abraham, Kannampallil, Patel, 2014). Baker, Barach, Battles, Gustasfon, Beaubien, Salas (2006) describe how healthcare workers that adopt techniques used by high performing teams, such as information exchange, supporting behaviour and team feedback, will share a common vision or goal and learn to work more efficiently. The techniques help to facilitate a proper handover leading to increased individual, team, and patient satisfaction. An interactive data visualisation tool can help to align a team around a common goal, make them more efficient and is effective in enabling nurses to reason more clearly about a patient's health (Chetta et al., 2015).

Satisfaction – When confronted with existing EHR systems, users found they lacked intuitive navigation, had slow responses, and didn't present an overview of patient care (Stevenson et al., 2015). In a research survey to gain insight into nurses' perception, attitudes and preferences to EHRs, Moody et al. (2004) state that EHR systems were not user friendly based on participant responses. 100 nurses from 23 units partook in the survey where they stated they had to chart on paper first and then transfer to the EHR system through a desktop computer. Stevenson et al. (2015) assert the need for a paradigmatic shift in how EHRs are designed. This should incorporate working collaboratively with nurses to understand the complexity of the of the role to provide them flexible and intuitive systems.

2.2 Competitor Analysis

A competitor analysis was undertaken (Figure 3) to gain an insight into the platform and software features of EHRs and electronic patient records (EPRs) nationally and internationally and to identify any gaps in the market (White, 2019). An article by Dydra (2020) identifies 5 companies as the major EHR providers internationally: Epic, Cerner, Meditech, Allscripts and Athenahealth. These companies specialise in the development of health information technology and EHR software, serving organisations of different sizes and offering different workflows (Brown, 2019). All products operate on a cloud platform with Allscripts Professional and Athenahealth having an app platform. Cerner and Epic were two products to allow customised specialties while all products except Cerner had a patient portal feature. Cerner and Epic control 85% of the large hospital EHR space in the United States. KLAS research reports that of the only 3 large private-sector organisations that purchased EHRs

in 2018, all purchased Epic moving away from Cerner or Allscripts (Bryant, 2019). Cerner and Epic hold a market share for EHR systems in the Republic of Ireland and Northern Ireland respectively. Cerner provides its Cerner Millennium System to St. James Hospital in Dublin (Edwards, 2018) while Epic has recently signed a deal with the Health and Social Care Northern Ireland (HSCNI) to provide integrated electronic health and social care record systems (Hoeksma, 2020). Annotation of the product interfaces found that they lacked a user-friendly experience and UI with complicated layouts and crowding of information.

	Cerner Millenium	Epic	Allscripts Professional	Athenahealth	Kainos Evolve
Platform					
Cloud	✓	✓	✓	✓	✓
On-premise	✗	✗	✓	✗	✗
App version	✗	✗	✓	✓	✗
Software features					
Clinical workflow	✓	✓	✓	✓	✓
Document management	✓	✓	✗	✓	✓
Lab integration	✓	✓	✓	✓	✓
Patient demographics	✓	✓	✓	✗	✓
Patient history	✓	✓	✓	✓	✓
Patient portal	✗	✓	✓	✓	✓
Reporting and analytics	✓	✓	✓	✓	✓
Voice recognition	✓	✓	✓	✓	✓
Medical templates	✓	✓	✓	✓	✓
Scheduling	✓	✓	✓	✓	✓
Customised specialities	✓	✓	✗	✗	✗

Figure 3: Competitor Analysis of the main national and international EHR providers showing a similar suite of features across the products.

2.2.1 Cerner

Cerner Millennium (Figure 4 and 5) offers an institution wide view into patient care for larger hospitals and care providers with multiple specialties. Cerner offers a cleanly designed user interface, but this does not translate to an easy-to-use product. Users report the system is not intuitive in its use with repetitive workflows for simple tasks and the need for extensive training to use the product efficiently (Brown, 2019).

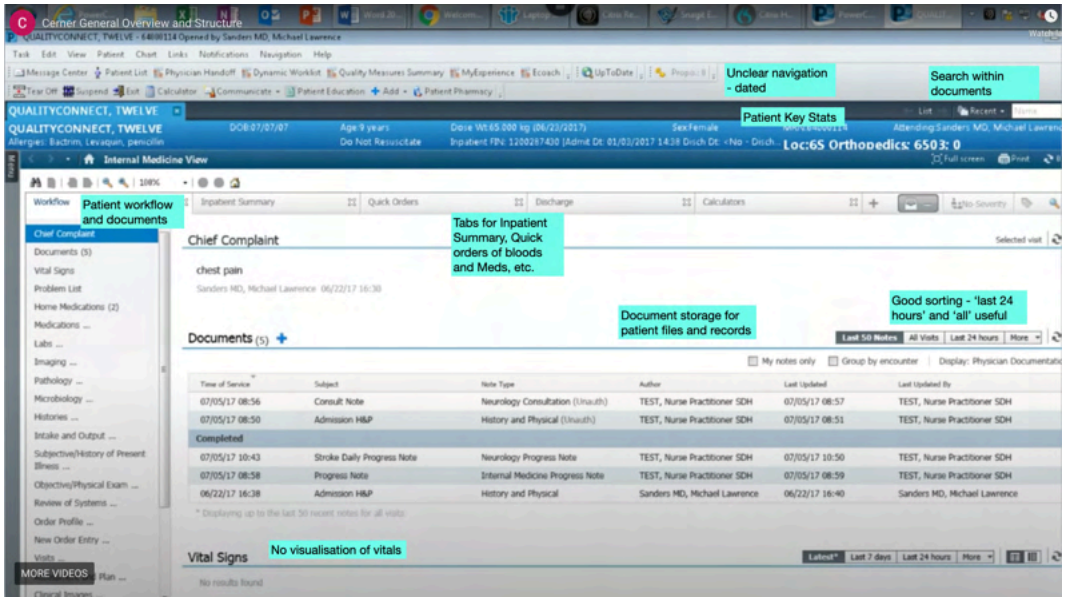

Figure 4: Cerner Millennium System – Workflow (Cerner Training, 2017)

Cerner offers a suite of solutions that help institutions improve patient care. Alongside the Cerner Millennium System, Cerner PowerChart (Figure 5) makes it easy to review a patient's clinical data to streamline patient visits (Software Connect, 2020).

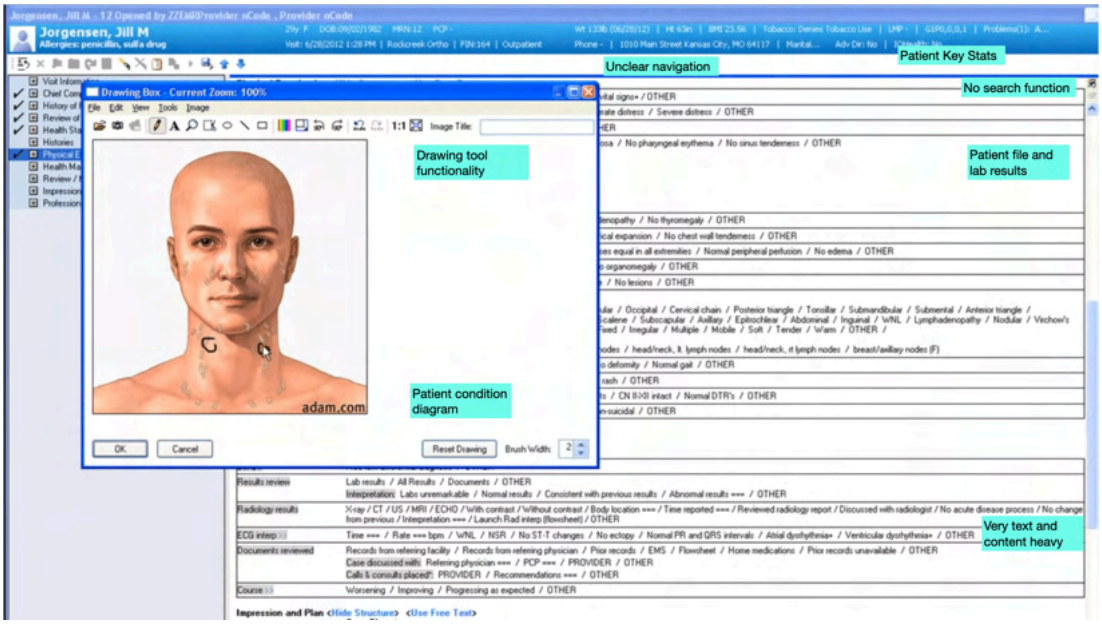

Figure 5: Cerner PowerChart – Patient View (Software Connect, 2020)

2.2.2 Kainos Evolve

The Kainos Evolve system (Figure 6) is implemented in University Hospital Galway and makes clinical information available at the point of care while supporting 24/7 multi-disciplinary access to patient records across the hospital (eHealth Ireland, n.d.). The system had been adopted by 48 hospitals in the U.K. and is accessible by tablet and desktop devices. The user interface design displays a patient profile with associated records, correspondence, and notes.

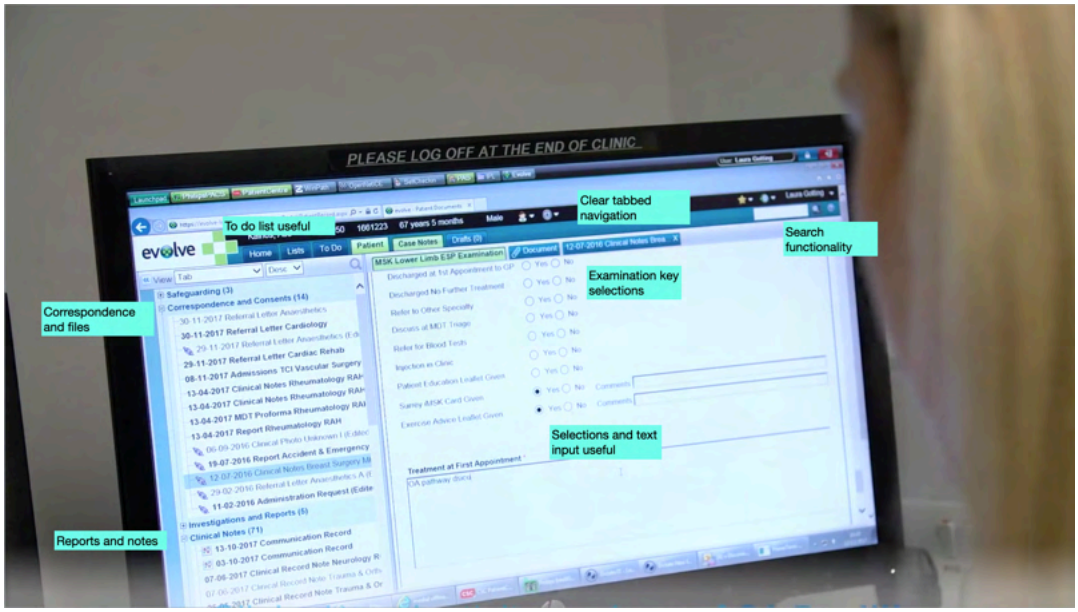

Figure 6: Kainos Evolve – UI (Kainos, n.d.)

From the source material available on the products and systems discussed, none of the systems appear to utilise data visualisation in their interfaces for their EHRs, although some of the companies offer analytics services on their respective websites. The systems for Cerner are text heavy with somewhat dated visual design systems implemented. Kainos Evolve offers a clearer interface in particular with their tablet offering. All systems offer a similar EHR functionality with Epic and Kainos offering a more integrated approach across multiple devices. As Smith et al. (2016) have stated, there is a need for continuous testing and releasing of these products to ensure they fulfil the demands of the user, enhance patient safety, and provide the required information in the most efficient way possible.

2.3 Proposed Research Problem

Based on the research discussed in the previous section, there is an opportunity to design and validate an interactive data visualisation tool that will improve the usability of EHRs and clinical handovers between nurses. Poor communication between health care professionals has been linked to numerous misinterpretations that have led to disastrous events in patient health (Stevenson, Nilsson, Petersson, Johansson, 2010). This

ineffective communication has caused complications in therapy which has led to approximately 98,000 patient deaths per year in the United States (Kohn et al., 2000) with estimated costs of $12 billion annually (Effken & Carrington, 2011). Further risks associated with the clinical handover involve wrong or delayed treatment, lack of trust and confidence with staff and patients, poor use of time and a lack of training (Department of Health, 2015).

Chetta et al. (2015) and Forbes et al. (2013) have documented solutions that address some of these issues in an interactive visualisation tool for nurses. Both studies conclude that further evaluation and investigation into a nurse's workflow and the visualisations used is required. This presents an opportunity for this research to design and test an interactive data visualisation tool that focuses on the handover between nursing staff at the end of shifts. The tool can be evaluated in terms of how it can improve upon 3 main areas using quantitative and qualitative methods: Communication, Efficiency and Satisfaction.

2.3.1 Purpose statement – Mixed methods

The purpose of this mixed methods sequential exploratory study is to identify the impact of interactive data visualisation dashboards on the usability of clinical handovers between nurses. Qualitative discovery interviews with 5 participants were undertaken to inform a survey that was shared with 29 participants. The information gained from these research activities then informed an interactive design prototype that was A/B tested alongside an analogue paper template with 16 purposefully selected individuals using quantitative and qualitative measures.

2.3.2 Research Question

Based on the above research, this study aims to answer the following research questions.

Q1: Will communication between nurses during shift handover be improved using an interactive dashboard over a paper method?

Q2: Do nurses better perform a shift handover with an interactive dashboard over a paper method?

Q3: Are nurses more satisfied performing a shift handover with an interactive dashboard over a paper method?

2.3.3 Hypotheses

The following hypotheses were formed to answer the research questions above:

H1: Nurses that use an interactive dashboard to perform a shift handover communicate essential patient information more effectively than those that use a paper method.

H2: Nurses that use an interactive dashboard perform a shift handover more effectively than those that use a paper method.

H3: Nurses that use an interactive dashboard to perform a shift handover are more satisfied than those that use a paper method.

3 METHODOLOGY

To carry out the study there was a requirement to research and design an interactive data visualisation prototype tool for nurses for use during clinical handovers which would address the problems highlighted in the research questions. The tool functions as a series of interactive dashboards accessed by tablet or desktop device. A user-centred design thinking process (empathise, define, ideate, prototype, test) as advocated by the Stanford d.school and David Kelley (Gibbons, 2016) was utilised throughout the study. To validate the hypotheses an analogue paper prototype, based on current methods and templates used by nurses, was also be designed test as part of the study.

3.1 Overview and Rationale

The research project was broken into 3 distinct phases. Phase 1: User Research and Requirements, Phase 2: Design, Prototype and Test and Phase 3: Final Experiment (Figure 7). At each stage of the study appropriate research methodologies were employed to strategise, execute and assess the product development and objectives (Rohrer, 2014).

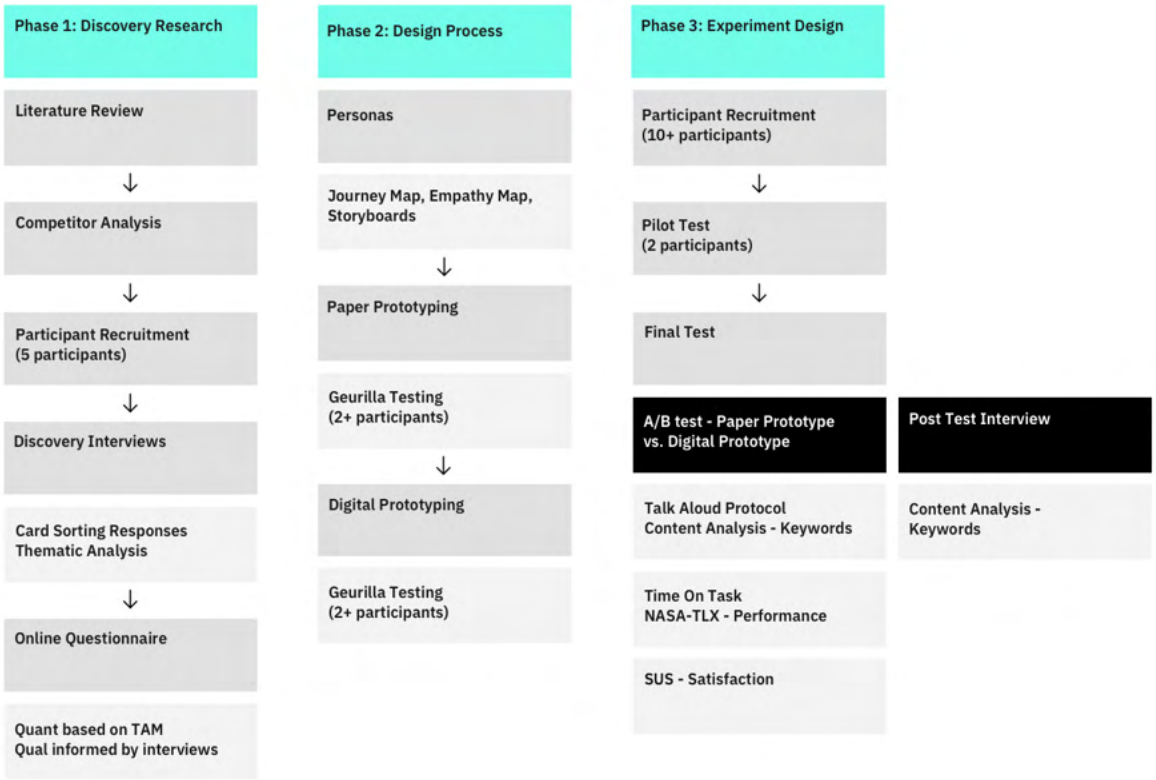

Figure 7: Research Overview

In Phase 1, alongside the literature review, a competitor analysis of EHR tools in healthcare and digital shift handover was undertaken to inform the design process, understand usability issues, know the strengths and weaknesses of current offerings and focus efforts in a target market (Douglas, n.d.).

Discovery interviews were conducted by phone call with 5 nurses from different hospitals and fields of nursing with the qualitative responses being analysed using thematic analysis (Braun & Clarke, 2006). The interviews provided insight into what nurses thought about the current handover process and the challenges that they face (Pernice, 2018). Participant roles varied from junior to senior roles across several wards. Studies by Abraham et al. (2013) and Stevenson et al. (2015) were referenced to inform the questions asked regarding a handover's support of everyday clinical practice and its user-friendliness. The interviews lasted approximately 30 minutes with questions on their daily routine, with particular focus on their current handover process. Informed consent was signed digitally before each interview with details being strictly confidential ensuring anonymity for participants.

The interviews informed the design of an online survey that was distributed to nurses through social channels and hosted on the INMO (Irish Nurses and Midwives Organisation) website for three weeks. The survey allowed for a better understanding of the end user reaching a wider group and mitigating the risk of designing an improper solution (Gray, n.d.). A mixed-method methodology was chosen to optimise the breadth and depth of the study and take into account the complexity of primary care research (Vedel, Kaur, Hong, El Sherif, Khanassov, Godard-Sebillotte, Sourial, Yang, Pluye, 2018) ensuring adequate information on current processes and to tailor the methods to the target sample (Ponto, 2015). By integrating both quantitative and qualitative methods, the data collected was more comprehensive, taking into account the socio-cultural context and real-world environment while providing a more complete view of the problem and potential solutions (Shaw, Larkin, Flowers, 2014). Quantitative questions were based on the Technology Acceptance Model (TAM) which uses two scales, perceived usefulness and perceived ease of use, as fundamental determinants of user acceptance (Davis, 1989). A third scale for satisfaction was also included in the survey to gauge satisfaction with current processes. A Likert Scale was used to measure responses on a scale of 1 to 5 from 'Strongly Disagree' to 'Strongly Agree'. The Likert Scale measures attitude in a scientifically accepted and validated manner (Joshi, Kale, Chandel, Pal, 2015). Several qualitative questions were asked at the end of the survey which were similar in nature to the questions asked in the discovery interviews.

In Phase 2 an iterative user-centred design process (Gibbons, 2016) was used to create user journey maps, personas, empathy maps, problem statements and storyboards. Current shift handover practices were identified through HSE material which has documented the handover process in a YouTube video (HSE, 2015). Paper and lo-fi prototypes were designed progressing to digital prototypes with guerrilla usability testing conducted to inform the iterations. Remote Usability Lab Studies were utilised to test prototypes and iterate further on the behavioural insight uncovered.

In Phase 3, a pilot test of the digital prototype was conducted. In the final test 16 test participants engaged in a controlled remote A/B test using a think aloud protocol while being observed. An A/B test was chosen as the final experiment as it can measure the actual behaviour of users in real world conditions while measuring small differences in performance (Nielsen, 2005). The think aloud protocol provides rich verbal feedback as the user interacts with a prototype (Nielsen, 2012) and was used to inform a content analysis on each prototype.

The content analysis collected and tallied the occurrence of phrases while developing an understanding of the meaning of communication. This method can lead to the suggestion of answers to research questions and hypotheses testing (Cavanagh, 1997). The keywords 'accuracy', 'patient safety', 'critical information', 'scope of information' and 'understanding of information' were identified from the literature review as key terms to identify an improvement in nurse communication at shift handover (Chetta et al., 2015; Vinu & Kane, 2016). The A part of the test presented users with an analogue paper handover prototype based on current ISBAR methods. The B part of the test presented users with a digital dashboard prototype.

A SUS (System Usability Scale) measured satisfaction and a NASA-TLX (Task Load index) measured the usability of each prototype during testing. The SUS is a Likert Scale measured across 10 statements that cover a variety of aspects of system usability (Brooke, 1996). A NASA-TLX (Task Load index) is useful for studying complex tasks in healthcare and was used after each task to measure the effectiveness of each prototype and show any improvement in performance (Laubheimer, 2018). Time on task was utilised to measure handover effectiveness alongside the NASA-TLX. The geometric mean of time on task scores were used to measure task performance. Taking the geometric mean of the time on task scores ensures a large score does not skew results and will account fairly when metrics are a negative (Nielsen, 2001).

Alongside the A/B test, qualitative interview questions based on the Technology Acceptance Model were asked to enable an analysis of the content responses (Braun & Clarke, 2006). Due to limitations in the recruitment of nurses to participate in the final test, a content analysis of qualitative responses was conducted on a smaller sample size of 16 available participants. A quantitative analysis would have required a larger sample size of 50 plus participants which the study was not able to recruit at the time. Informed consent was signed before each test with details being strictly confidential ensuring anonymity for participants.

4 PHASE 1 – DISCOVERY RESEARCH

4.1 Discovery Interviews

Nurses interviewed said they used written methods of recording patient information for the handover. Some digital records were accessed for bloods, imaging, and bed allocation but no EHRs were used. Notes are documented in their nursing notes and patient care plans and in the majority of cases an ISBAR template is used for handover along with a ward occupancy white board documenting patient information.

"If a handover goes past 8.30am, I am catching up all day often missing my breaks."

Nurse B

"I tend to give too much information which can make handovers lengthy – it's hard to summarise all the key details."

Nurse C

" There are constant interruptions from patients needing meds, doctors doing rounds, theatres ringing for patients."

Nurse D

Thematic analysis was used to sort group responses (Figure 8) into themes related to the research questions (Braun & Clarke, 2006) in the online tool Miro. Braun and Clarke state that a theme captures something important about the collected data in relation to the research question and can present a level of patterned meaning within the data set. The responses for each question and participant were read through in detail and produced interesting statements. A card sorting technique was used to identify the key themes (Rohrer, 2014). Please refer to Appendix 2 and 3 for the full discovery interviews and analysis.

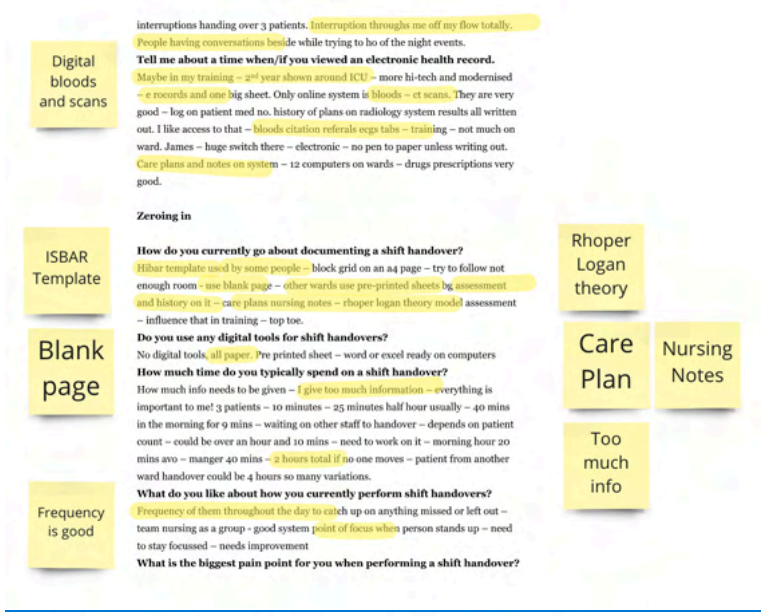

Figure 8: Thematic Analysis of responses from nurse interviews posted on Miro

4.2 Online Survey

A Quantitative/Qualitative survey was created and distributed online to gain attitudinal insight. 29 participants took part in the survey with a 100% response rate. The survey was hosted through Microsoft forms and was live for 3 weeks while responses were submitted. Aggregated numbers for each response were provided by Microsoft Forms in the form of numerical data and charts. A tabulated excel sheet was created with quantitative results analysed by calculating their percentage value first. Results were cross tabulated to look for insights rather than just statistics (Typeform, n.d.). This cross tabulating discovered differences in approach to shift handover between participant experience level, hospital type and method of recording.

Background questions (Figure 9) revealed that 62% of respondents had more than 10 years' experience in nursing and the remaining 38% were in the 1 to 10 years of experience range. The role 'Staff Nurse' accounted for 72% of respondent's roles while 3 individuals were a 'Community Mental Health Nurse', 'Midwife' and 'Senior Enhanced Psychiatric Nurse' respectively. 52% of respondents worked in public hospitals with 42% in private. All nurses performed a handover with 55% of nurses performed a day and night shift with 31% solely on day shifts and 14% on nights alone.

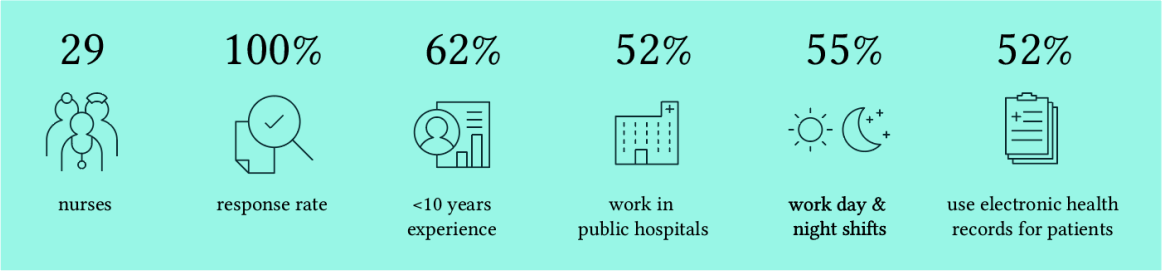

Figure 9: Key statistics from the Online Survey background questions

52% of respondents indicated they use EHRs in their daily work with similar results coming from public and private hospitals when cross tabulated. Respondents indicated they use their nursing notes (34%), ISBAR method (28%) and care plan (17%) when documenting their handover notes.

The survey results show that verbal and written methods are used mostly for shift handover in public hospitals while 53% of respondents in private hospitals use audio recordings. Nursing notes and the ISBAR method are the most common processes for documenting a handover. Perceived usefulness and ease of use scores were high for current handover processes. Interestingly 83% of overall respondents find current methods easy to use while 27% of overall respondents don't find the methods useful.

55% of respondents were satisfied with their current process. Of concern is that 55% of respondents have confidence in the information they provide while 45% have confidence in the information they receive. Interestingly, respondents that used audio/digital recordings had less confidence in the information they provide over those that used verbal/written methods (Figure 10).

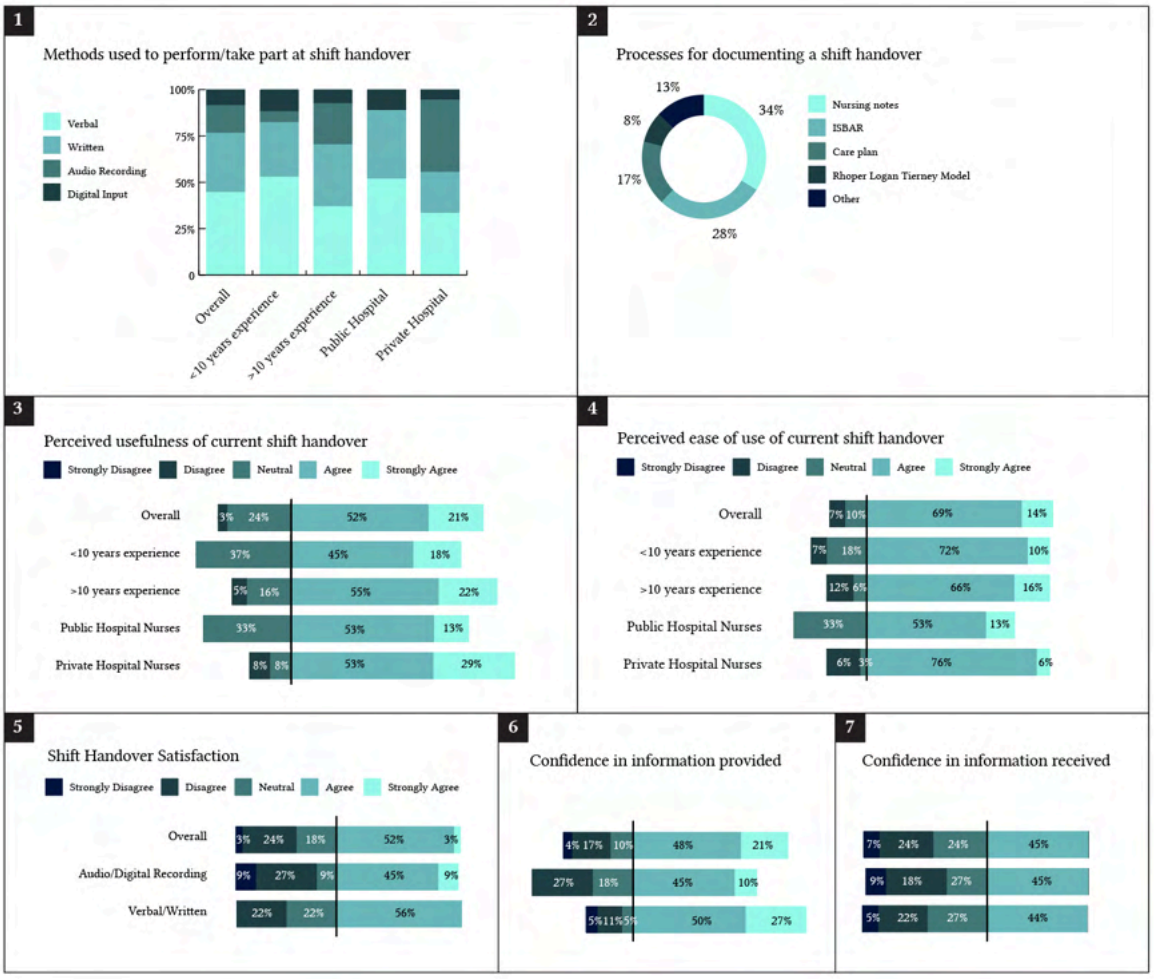

Figure 10: Key statistics from the Online Survey on methods, processes, usefulness, ease of use, satisfaction, and confidence

Several qualitative questions were asked at the end of the survey. All answers were pasted into post it notes in Miro and a thematic analysis of the responses was undertaken to identify themes. When asked what they liked about the current handover process respondents commented on the speed and efficiency of current methods, a structured approach, the importance of key information and the benefits of audio recording notes. This correlates with some of the quantitative answers with respondents stating that 76% strongly agree and 24% agree that a structured shift handover is important. Only 52% of respondents agree that their current shift handover is well structured. 66% strongly agree and 34% agree that the summarisation of information is important during a shift handover with 59% agreeing and 17% strongly agreeing that information is repeated during handover. This data indicates the need for a tool that is efficient to use with a structured layout of content and that summarises key patient information for nurses to easily understand.

When answering what are the barriers to an effective handover (Figure 11) key themes with respondents were the need for clear communication and information, the time taken, accents and language, interruptions, and distractions.

"Depending on the person handing over, all the information may not be communicated, often important information is left out or questions can't be answered."

Nurse A

"Some people can speak too fast, and it is difficult to take notes. Some accents are hard to understand as well, being a non-native English speaker, it can be difficult at times."

Nurse B

Figure 11: Thematic analysis of qualitative questions asked in the Online Survey highlighting barriers to an effective handover

Key themes from respondents' answers for ways to improve the current shift handover process were identified as better time and efficiency, a structured process, key information communicated, better functionality and an improved method of delivery. Please refer to Appendix 4, 5 and 6 for the full survey results and analysis.

4.3 Summary of Findings

The findings from the discovery interviews and online survey illustrate the need for improvements across several areas around the nurse shift handover. Taking the insights discovered in the discovery interviews and online survey the key themes were tabulated for relevancy across the 3 areas that the hypotheses focus on, communication, efficiency, and satisfaction (Figure 12). The final design artefact produced in this research attempts to improve upon these areas, although some, such as staff shortages, are outside the scope of the study.

	Communication	Efficiency	Satisfaction
Handover length		✓	✓
Staff shortages		✓	
Summarised information	✓	✓	✓
Pre-populated templates	✓	✓	✓
Interruption management	✓	✓	
Standardisation of handovers	✓	✓	
Less documentation and writing		✓	✓
Missing information	✓		✓

Figure 12: Tabulated key insights from the interviews and online survey mapped across the 3 areas of the hypotheses

5 PHASE 2 - DESIGN PROCESS

The insights gained from the research activities outlined in Phase 1 informed the creation of user journey maps, personas, empathy maps and storyboards. These research outputs foreground the characteristics and needs of the nurses' user group when making key design decisions (Harley, 2015). Personas were created to represent two of the key user demographics identified in the research, senior nurses with over 10 years of experience, and junior nurses with less experience.

5.1 Personas & Empathy Maps

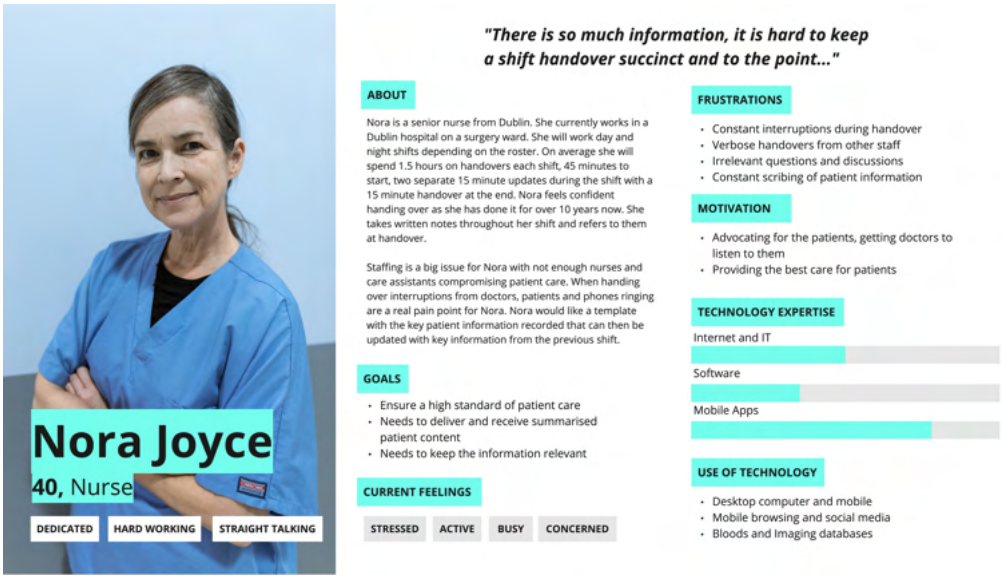

Figure 13: Nora (Senior Nurse) – Persona

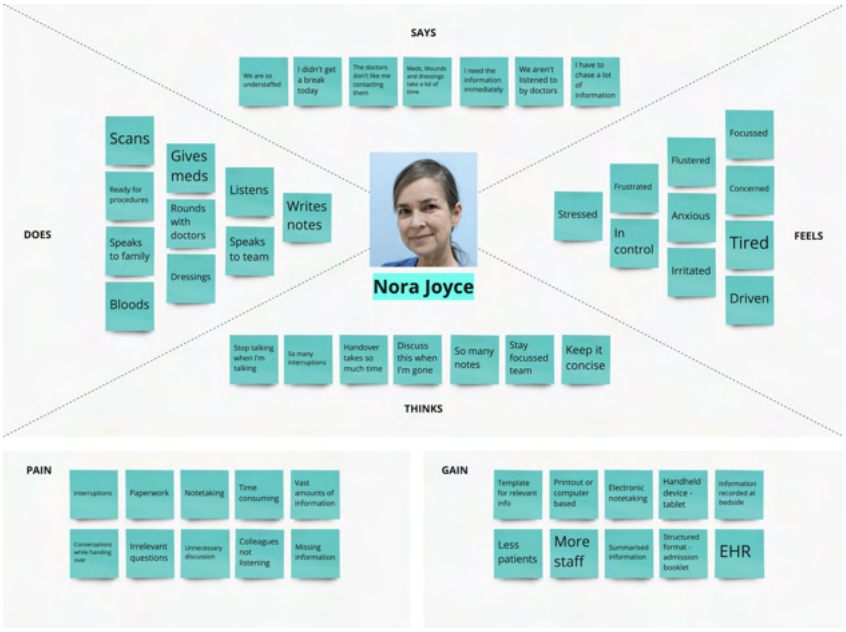

Figure 14: Nora (Senior Nurse) – Empathy

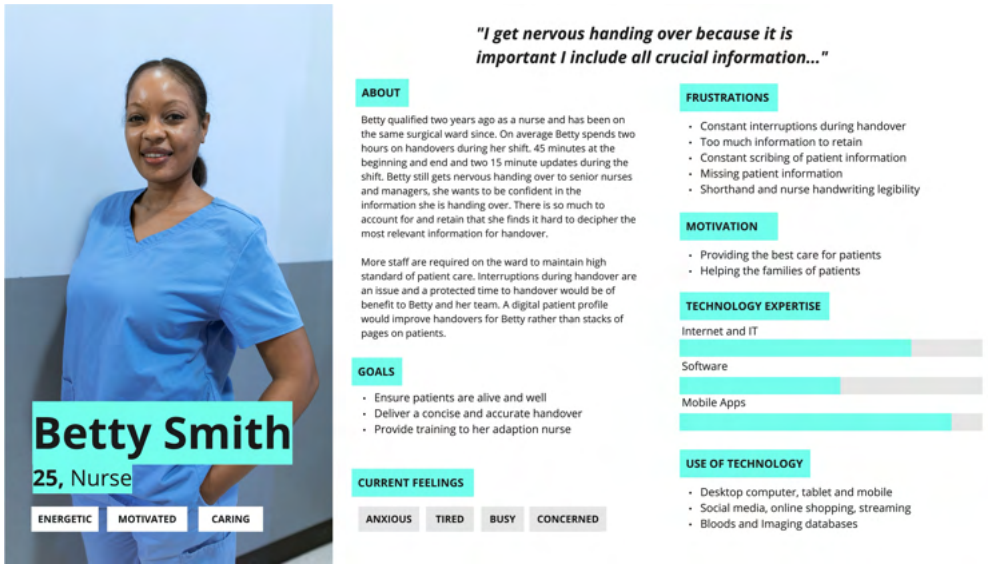

Figure 15: Betty (Junior Nurse) – Persona

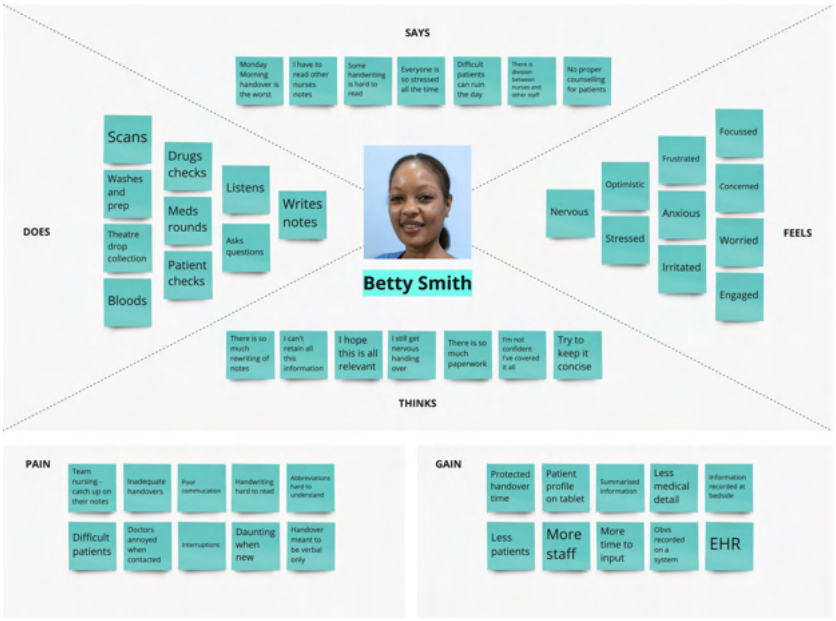

Figure 16: Betty (Junior Nurse) – Empathy

5.2 Journey Maps

The Journey maps show the ‘As-Is’ scenario that the Nora and Betty personas currently experience on a typical day. Based on the accounts provided by the nurses interviewed, a scenario was created for the senior and junior nurse personas.

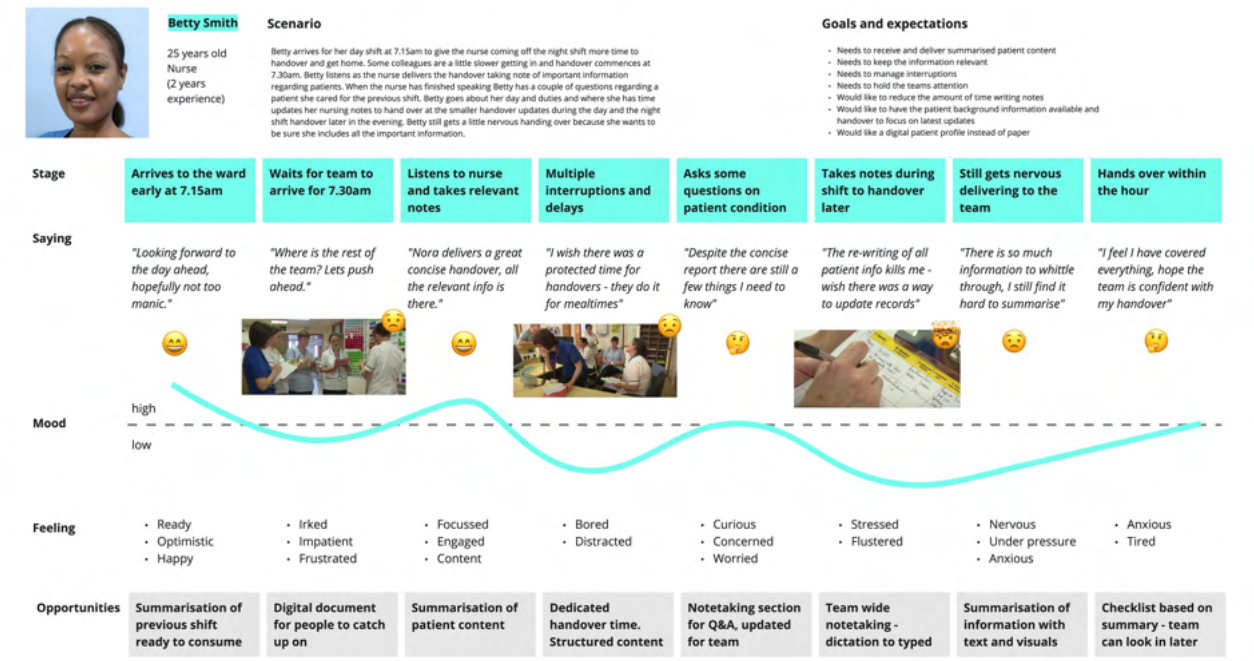

Figure 17: Nora (Senior Nurse) – Journey Map

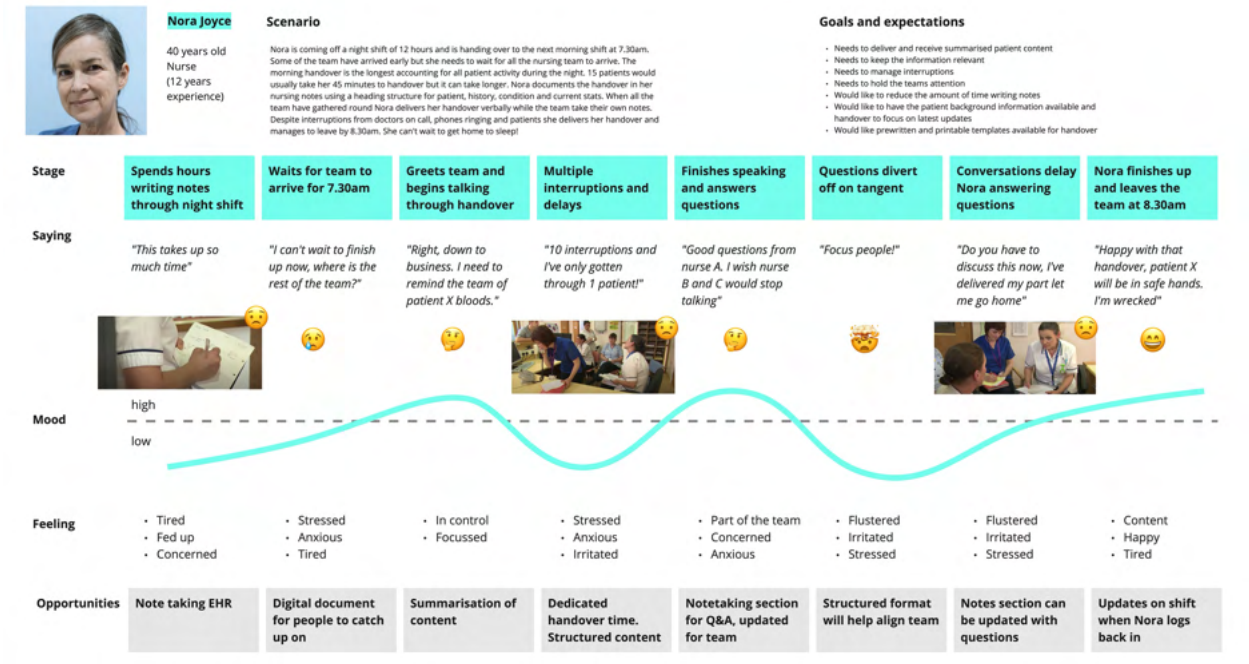

Figure 18: Betty (Junior Nurse) – Journey Map

5.3 Problem Statements

Nora (Senior Nurse)

(Who) Nora, a Senior Nurse working the night shift, **(What)** can use a digital device to record patient information which she can refer to at handover, **(Wow**) providing a concise and efficient handover with all key patient information and tasks communicated.

Betty (Junior Nurse)

(Who) Betty, a Junior Nurse working the day shift, **(What)** can use a digital device to view patient information before and during handover, **(Wow)** receiving a concise and efficient handover with all key patient information and tasks communicated.

5.4 Storyboards

Storyboards were created to show the 'To-Be' scenario that both personas would ideally encounter at the end of a shift and the beginning of a new shift. A storyboard was created for each persona based on the wants and needs of the nurses documented in the interviews and survey responses from phase 1.

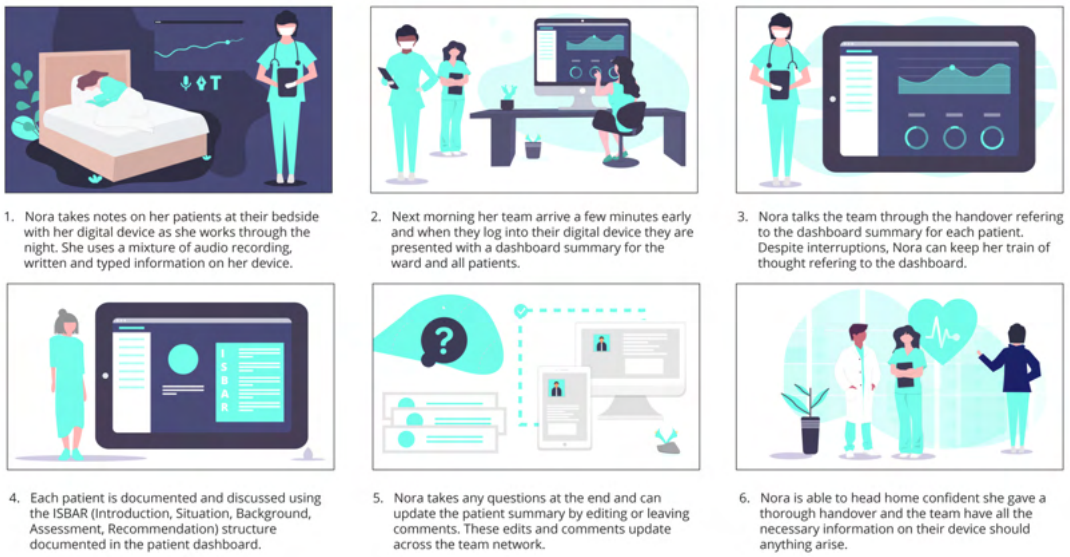

Figure 19: Nora (Senior Nurse) – Storyboard Night Shift to Day Shift

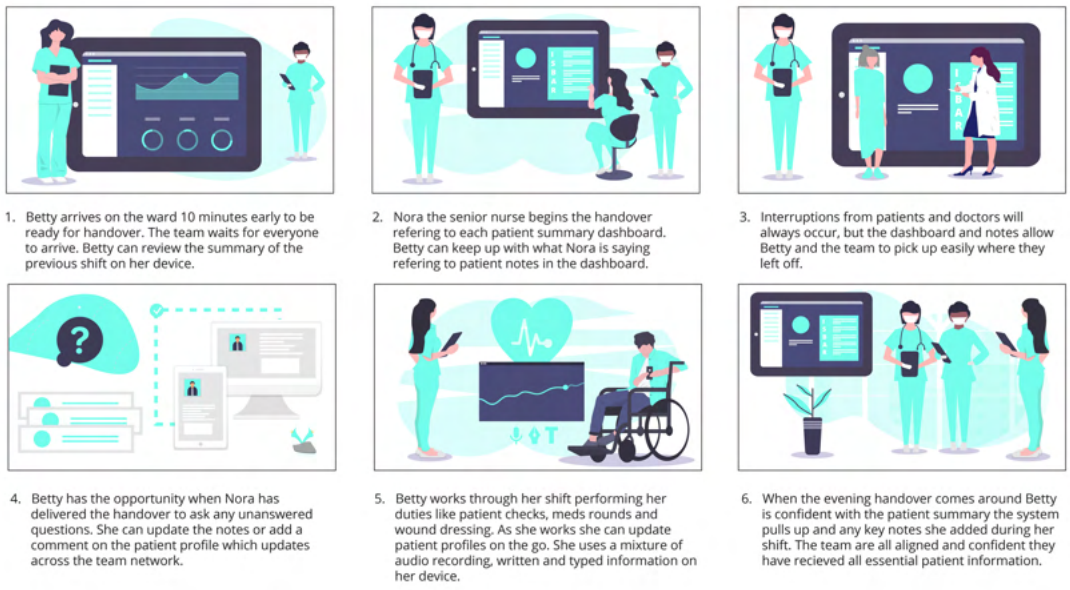

Figure 20: Betty (Junior Nurse) – Storyboard Day Shift to Night Shift

5.5 Paper prototypes

The 'Digital Prototype' was created in a paper prototype first, and guerrilla tested with 2 participants for early feedback. Paper prototyping and testing early has been shown to have the biggest improvements in the user experience of a design (Nielsen, 2003). The paper prototype consisted of a Ward Overview, Handover Patient list and Handover Patient Profile (Figure 22 & 23).

5.5.1 Ward Overview

The overview screens of the prototype dashboard tool work in a similar way as the Patient Communication Board (Figure 21) showing ward occupancy, staff, and patient status.

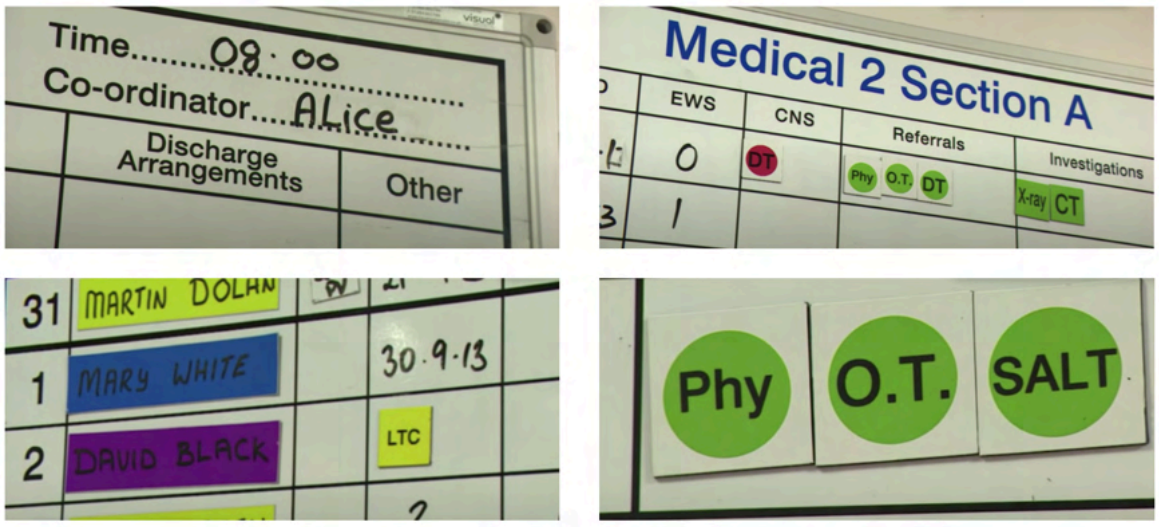

Figure 21: HSE Patient Communication Board

Quick links to add a patient or begin a handover were primary actions. (Figure 22) Ward statistics were available alongside a nurse roster and patients on the ward. The data visualisations chosen were based on the nurses' requirements from the discovery research and interviews, with patient data summarised in the most effective charts based on the Abela Chart Chooser (Abela, 2006) and principles outlined by Stephen Few (Few, 2006).

Figure 22: Ward Overview – Data visualisation with ward stats, key actions, nurses on ward, patient profiles and collapsible main navigation

5.5.2 Handover

The handover screen (Figure 23) provides a list of patients on the ward. Nurses can view each patient profile in an editable digital ISBAR template. Key details were grouped under each ISBAR heading. Searchable tags were included on the patient Identity. Timelines were introduced for admission and medical history. The Patient Assessment shows an overview of nurse observations from previous shifts through data visualisation alongside key scores for patients' observations and vitals.

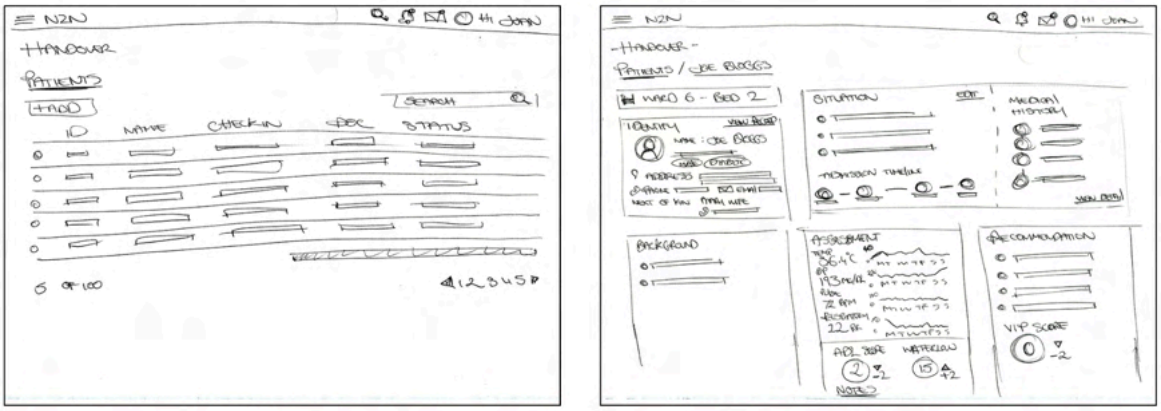

Figure 23: Handover – All Patient Overview, search patients. Editable fields, history and admission timeline, breadcrumb nav, patient details and records, scores, and statistics

The 'Paper Prototype' for the AB test based on current methods was also paper prototyped for early feedback from the participants. The prototype was based upon methods currently used by nurses as detailed by the HSE Ireland (2015/2017) and follows the ISBAR method, recommended as best practice by the HSE (HSE Ireland, 2017b).

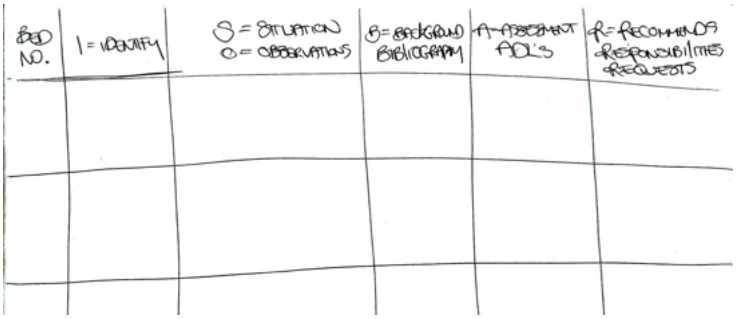

Figure 24: ISBAR Paper Prototype for the AB Test

At this stage of the design a card sorting exercise with participants was undertaken to help refine the architecture by exposing each participants' mental model (Rohrer, 2014). 30 cards based on keywords identified from competitor analysis research and nurse feedback were created in Optimal Workshop, with participants sorting them into logical groupings. The key groupings created by the 2 participants were Notes, Observations, Patient Details, Patient Scores and Ward Info which aligned with the structure the paper prototypes were beginning to take on (Figure 25).

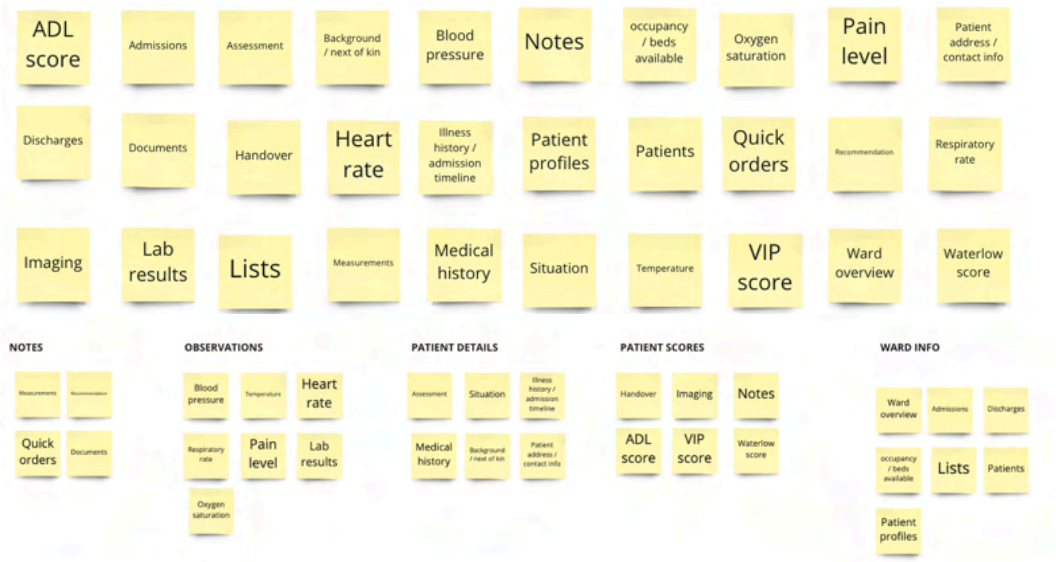

Figure 25: Card sort technique of keywords related to content

The guerrilla testing with 2 participants took place remotely using Zoom video calls with the paper prototypes being shared on Miro (Figure 26) to facilitate collaboration and live annotation during the discussion. Key findings from the paper prototypes were:

Overview

- Overview is like current methods which are spread over multiple tools
- Staff absence or illness should be noted
- The addition of ADL scores would allow for an estimation of workload for the shift
- Lab results and scans were identified to be included in the main nav

Handover Profile

- Doctors needed to be included on the patient profile
- Early Warning Score needed to be included as it was key for Doctors to know as a summary score
- Vitals are important and required as they influence the EWS
- Scores could change over a matter of hours so a visualisation could help track the change
- There was a need to be able to check and uncheck items

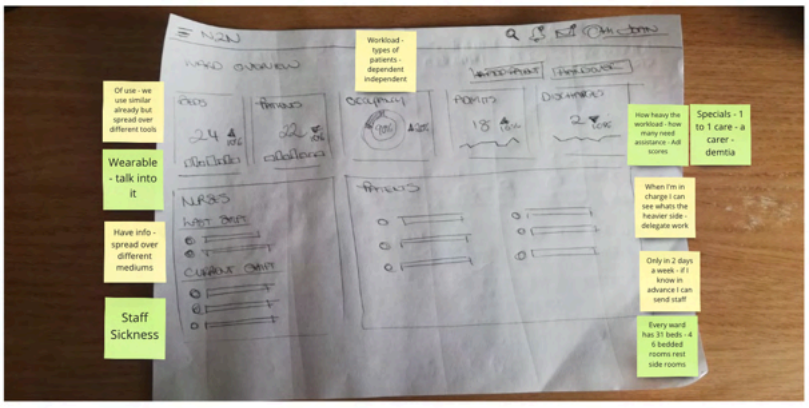

Figure 26: Ward Overview feedback in Miro

Please refer to Appendix 12, 13 and 14 for the full paper prototype design and analysis.

5.6 Mid-fi Wireframes

Following this test and review of findings, an iterated mid-fi digital prototype was designed with further guerrilla testing on 2 more participants (Moran, 2019). The 'Paper Prototype' for the A/B test was rendered digitally to allow for participants to engage with the prototype remotely and remove any complications with printing on the participants' side for the final experiment. The guerrilla testing took place over Zoom calls with Prototypes demonstrated through Invision and feedback recorded in the comments.

5.6.1 Digital Prototype for AB test

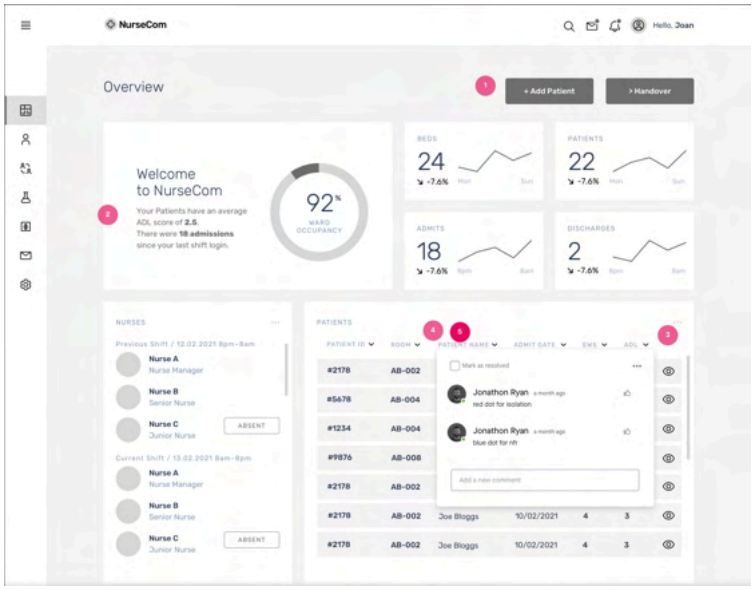

Figure 27: Ward Overview – Data visualisation with ward stats, key actions, nurses on ward and patient profiles

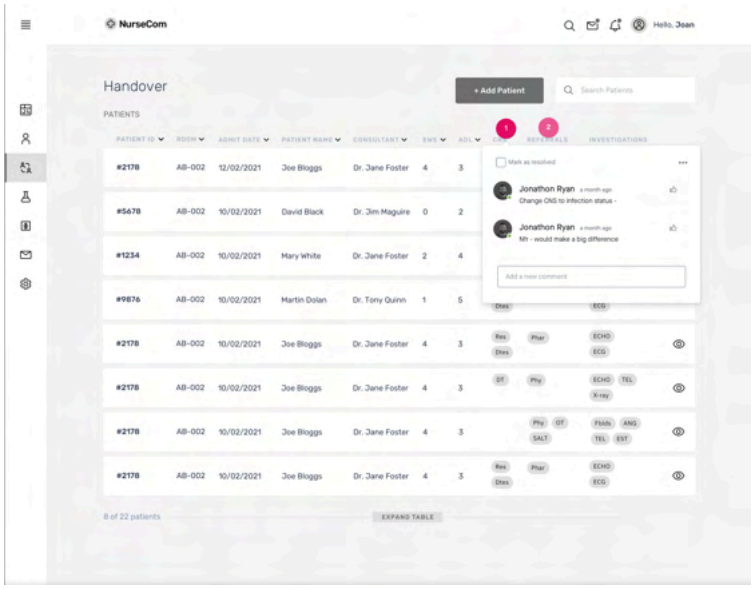

Figure 28: Handover – All Patient Overview, search for patient function

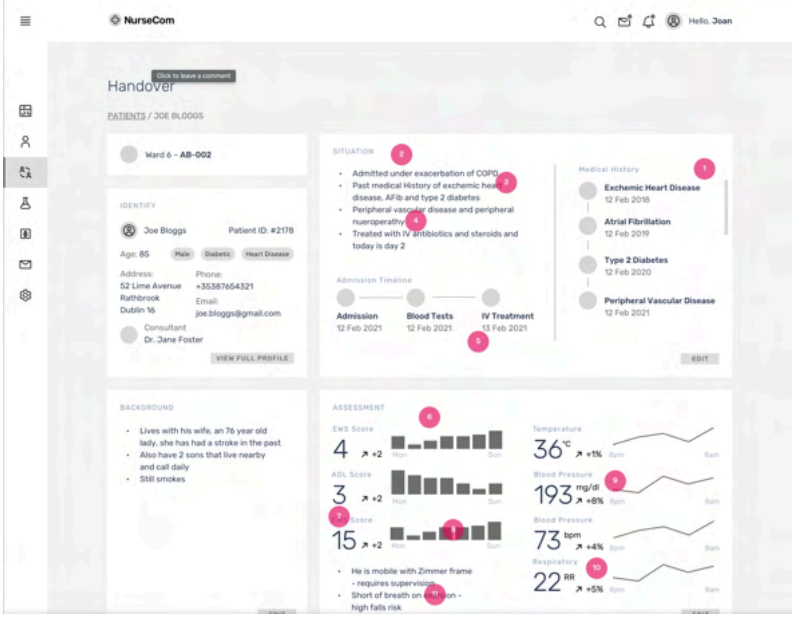

Figure 29: Handover – Editable fields, history and admission timeline, patient details and records, scores, and statistics. Bar charts were used for weekly scores while trend lines were used for daily vital observations, both ways of viewing data over time.

Key findings from the digital prototypes for the B part of the test were:

Ward Overview

- Need the ability to remove a patient from the list
- Need to know infection status for a patient
- Need to know if the patient is NFR (not for resuscitation)
- Need to know the consultant
- Colour warning system on scores

Handover Profile

- Need to know what drugs they are given in timeline
- EWS and ADL should be over the shift length – other scores can be weekly

Please refer to Appendix 18 for the full mid-fidelity digital prototype and feedback.

5.6.2 Paper Prototype for A/B test

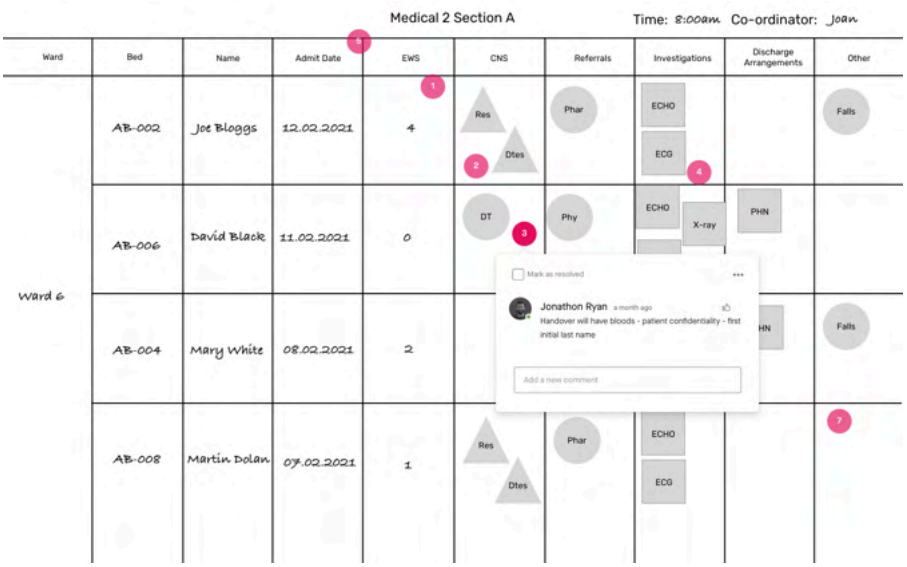

Figure 30: Patient Communication Board for the AB Test

ISBAR - Clinical Handover Sheet

Identify (I) Situation (S) Background (B) Assessment (A) Recommendation (R)

Identify	Situation	Background	Assessment/ADLs	Recommendations Goal/Risk/Read Back

Figure 31: ISBAR Paper Prototype for the AB Test

Key findings from the paper prototypes for the A part of the test were:

Patient Communication Board

- The addition of Consultants to the Patient Communication board

- Removing the ADL score as not currently used
- Removing the CNS column
- Ensuring patient confidentiality by only using first initial
- Introduction of colour – yellow for complete and red for not complete

Please refer to Appendix 17 for the full mid-fidelity paper prototype and feedback.

5.7 Hi Fidelity Prototype

The feedback from the mid-fidelity prototypes was implemented for the final iteration of the prototype into a hi-fidelity design. Both the paper and digital prototypes were updated in Sketch and Invision with functionality including tooltips and clickable buttons for the latter.

The IBM Design Language and Carbon design library were utilised to design and layout the digital prototype. Carbon hosts a suite of components, typography, data visualisation guidelines and accessible colour palettes that are available freely online to design with (Figure 32).

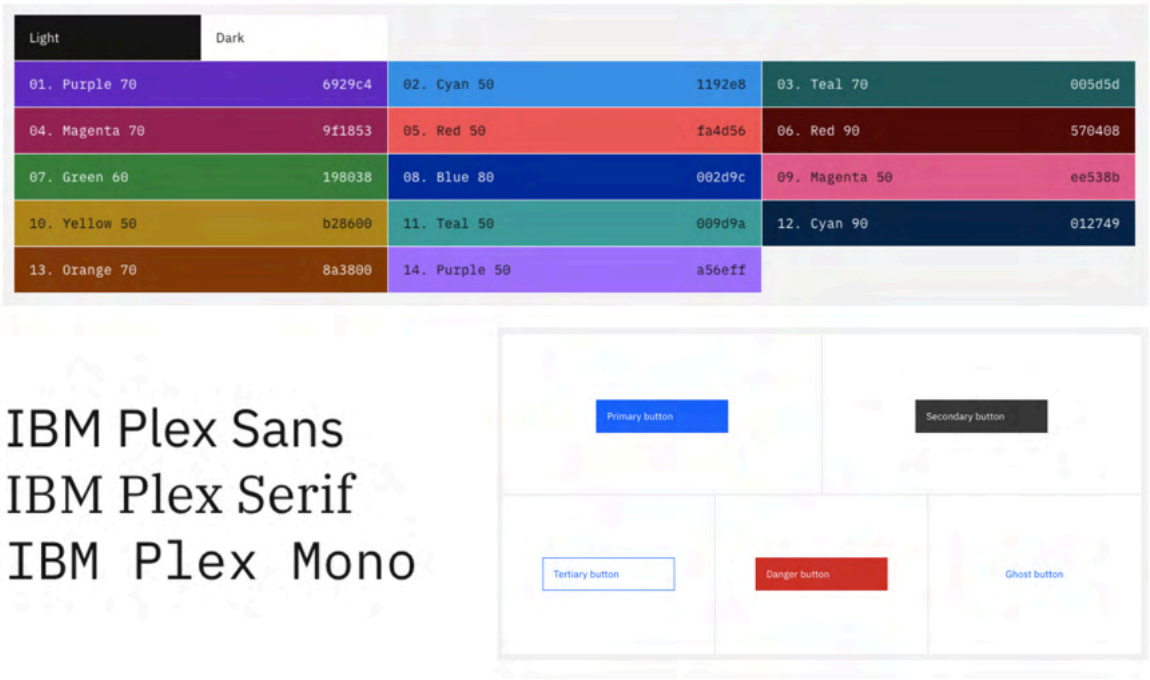

Figure 32: IBM Carbon Design System with data visualisation colour palette, IBM Plex Sans for typography and button components

5.7.1 Digital Prototype for A/B test

Nursecom was the name chosen for the digital prototype product as a play on the words ‘Nurse’ and ‘Communication’. A log in screen was included in the user flow for realism.

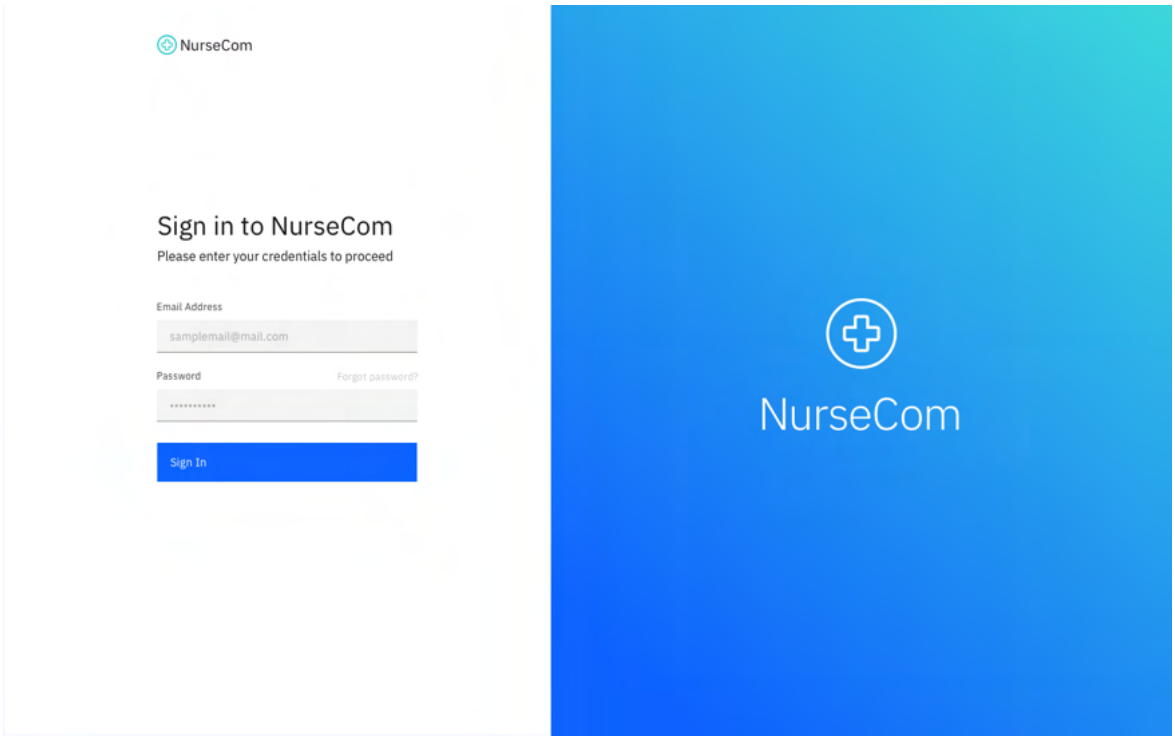

Figure 33: NurseCom Login

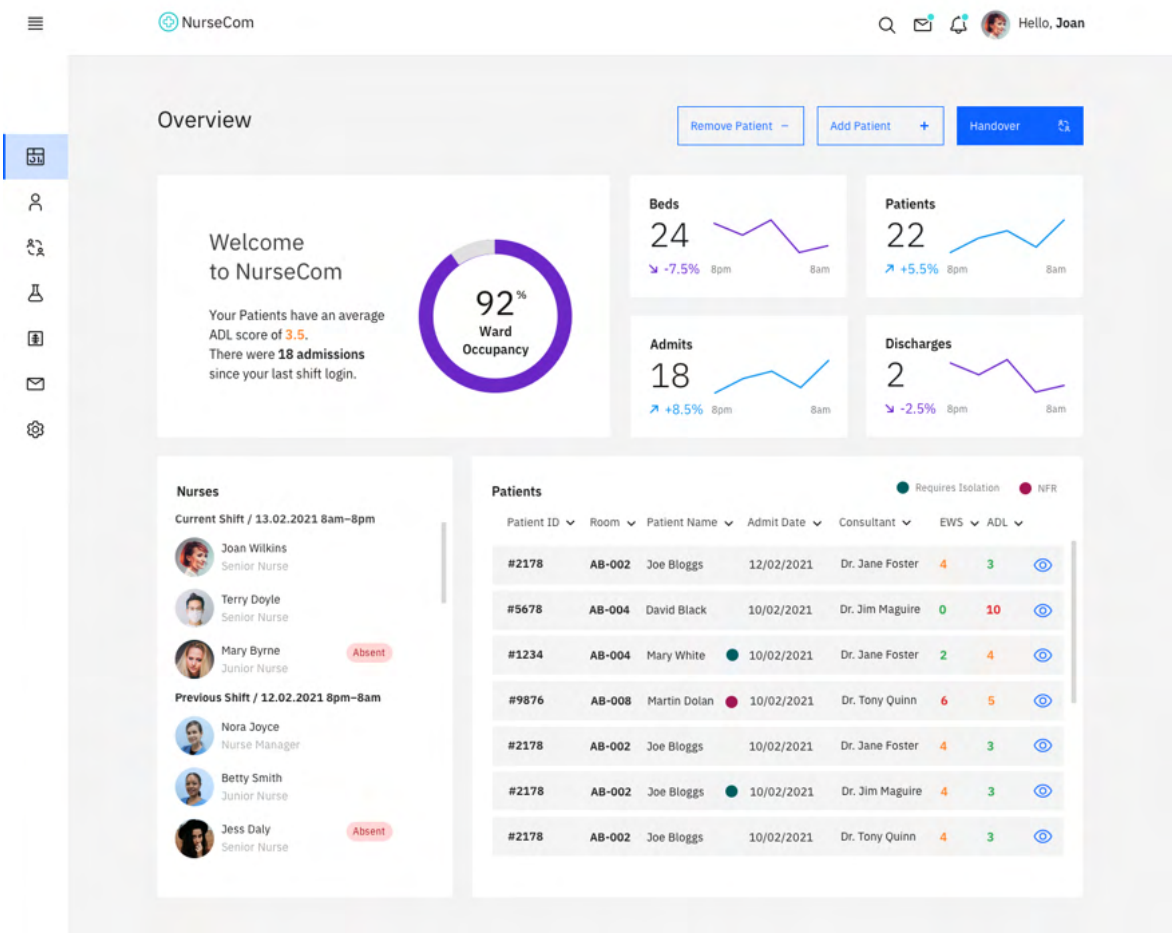

Figure 34: Ward Overview – Data visualisation with ward stats, key actions, nurses on ward and patient profiles. Remove Patient button was introduced based on feedback along with colour coding for scores, status, and the addition of consultants on the Patients section.

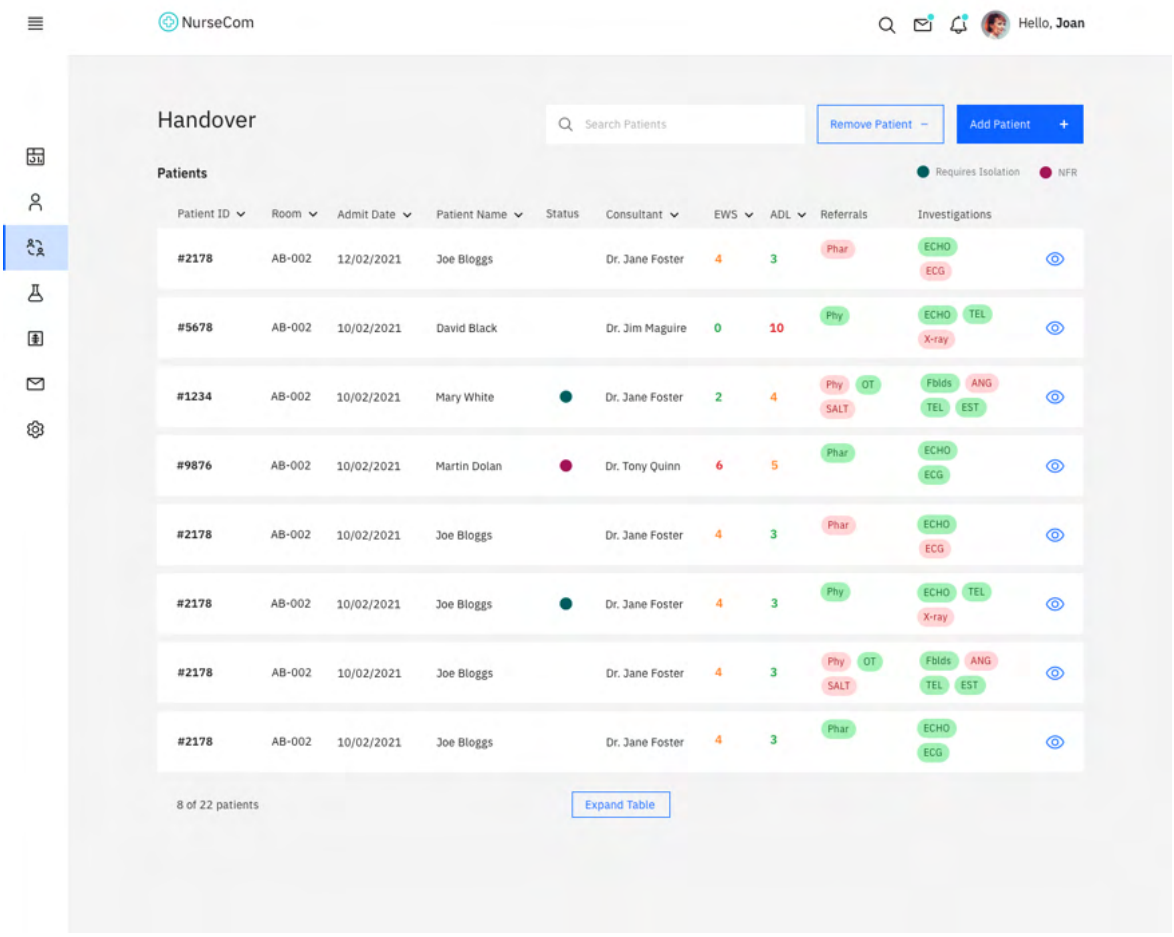

Figure 35: Handover – All Patient Overview with colour coded scores and tags, status, and a search for patient function

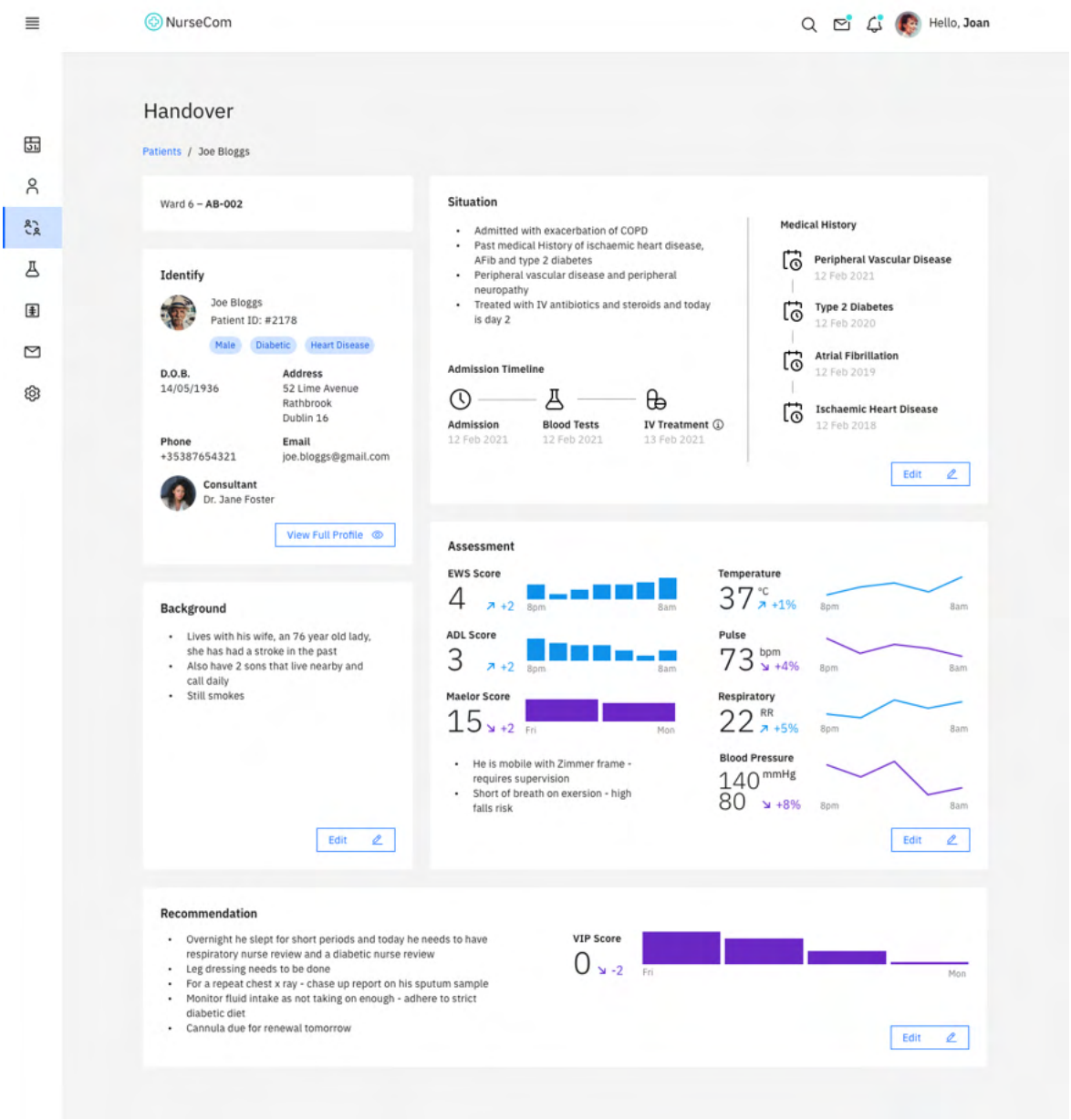

Figure 36: Handover Patient Profile - Editable fields, history and admission timeline, patient details and records, scores, and statistics. Timelines were changed on some scores to 12-hour shift to track the frequency or recording.

Please refer to Appendix 21 for the full hi-fidelity digital prototype.

5.7.2 Paper Prototype for A/B test

ISBAR - Clinical Handover Sheet

Identify (I) Situation (S) Background (B) Assessment (A) Recommendation (R)				
Identify	Situation	Background	Assessment/ADLs	Recommendations Goal/Risk/Read Back

Figure 37: ISBAR Paper Prototype for the A/B Test

Medical 2 Section A Time: 8:00am Co-ordinator: Joan

Ward	Bed	Name	Admit Date	Consultant	EWS	Referrals	Investigations	Discharge Arrangements	Other
Ward 6	AB-002	J. Bloggs	12.02.2021	Dr. Foster	4	Phar	ECHO, ECG		Falls
	AB-006	D. Black	11.02.2021	Dr. Maguire	0	Phy	ECHO, X-ray, TEL	PHN	
	AB-004	M. White	08.02.2021	Dr. Foster	2	Phy, OT, SALT	Fbids, ANG, TEL, EST	PHN	Falls
	AB-008	M. Dolan	07.02.2021	Dr. Maguire	1	Phar	ECHO, ECG		

Figure 38: Patient Communication Board for the A/B Test

Please refer to Appendix 20 for the full hi-fidelity paper prototype.

6 PHASE 3 – EXPERIMENT DESIGN

The final test consisted of an A/B test of the hi-fidelity digital prototype and the paper-based prototype to measure against one another. This test was a within-subjects test design where each participant was tested under each condition to maximise the available participant feedback. The A and B of each test was alternated with participants to prevent any learning effects (Creswell, 2018). A pilot test with 2 participants was conducted in advance of the actual test to validate the wording of tasks and to estimate accurate session timings. It was an important rehearsal to ensure a smooth execution later as all testing in the experiment would be conducted remotely (Schade, 2015).

Two fictional patient handovers were created based on the HSE Ireland's available training material that were read aloud during the test to simulate a handover. The test consisted of 3 tasks for each prototype (Figure 39).

Task 1 – Can you tell me how many patients are on the ward, when Patient A was admitted and what is their EWS score?

Task 2 – A simulated patient handover on the Identify and Situation sections of ISBAR

Task 3 – A simulated patient handover on the Assessment and Recommendation sections of ISBAR

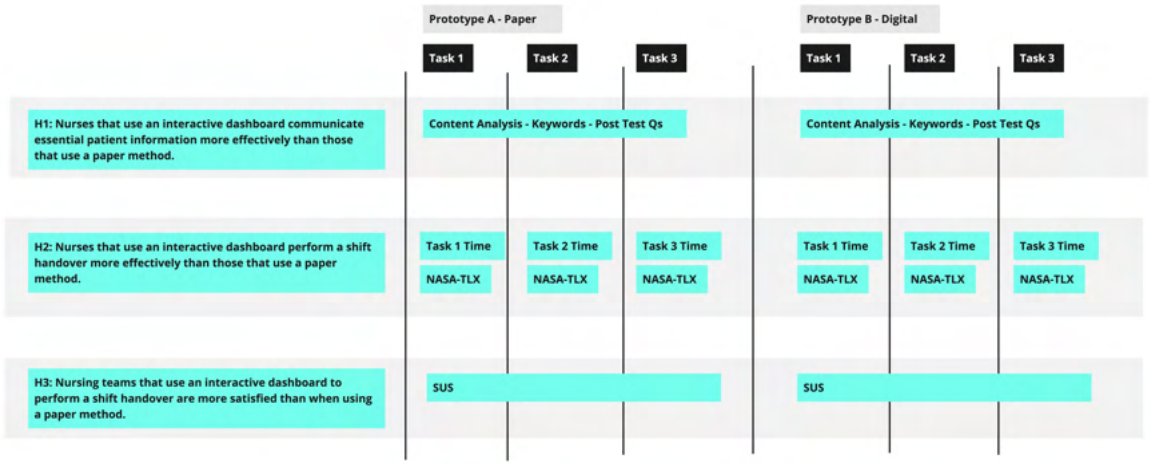

Figure 39: Experiment tasks related to each hypothesis

For the paper prototype participants had to observe, listen, and write details down during the handover. The Patient Communication Board was displayed on-screen, and they were given task 1 to complete. The ISBAR template was then displayed on screen. Participants were asked to have a blank piece of paper and pen ready. Participants drew a five-column grid with the 5 ISBAR headings like what they were seeing in the template on screen. This avoided any necessity for printing. Participants had to listen and write down the information they heard during the simulated patient handover for task 2 and 3.

The digital prototype involved participants navigating, reading, confirming, and updating content on the handover dashboard, again across the 3 same tasks.

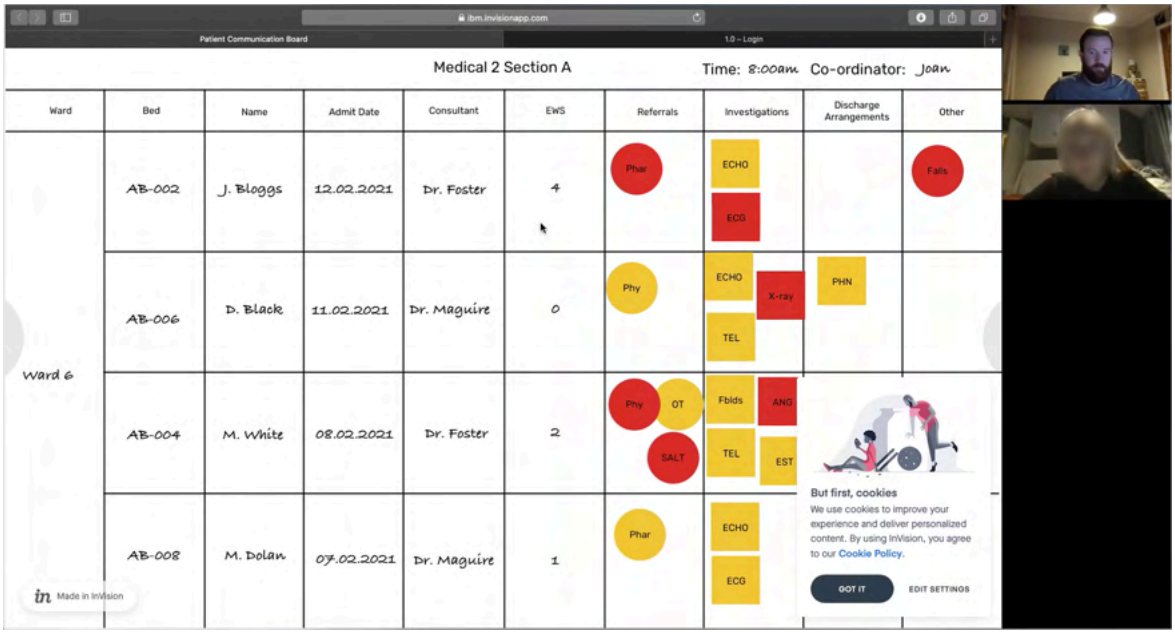

Figure 40: Testing the paper prototype with participant

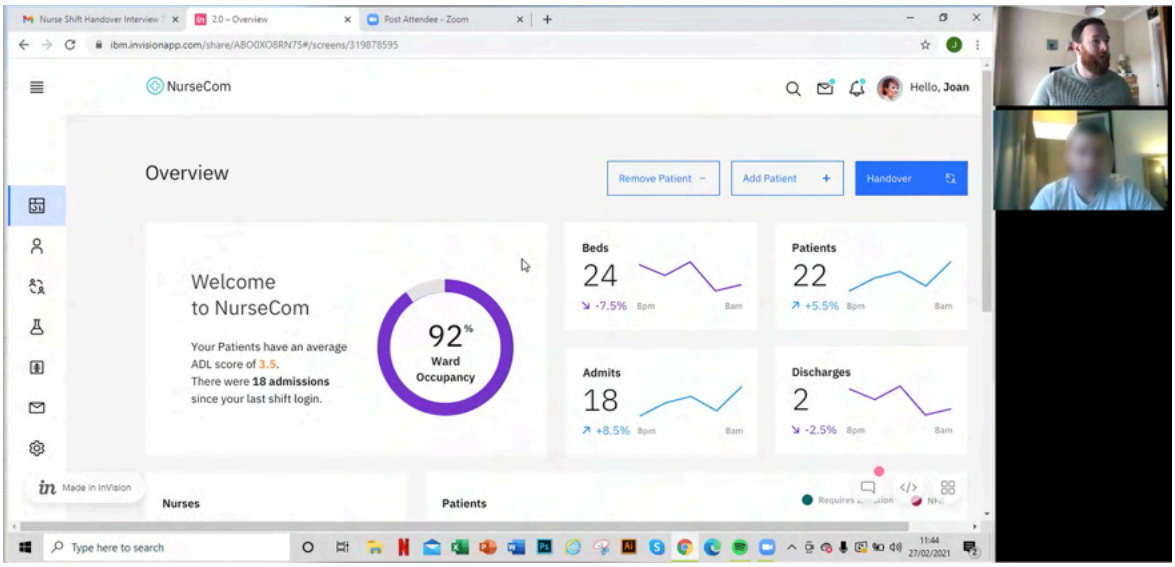

Figure 41: Testing the digital prototype with a participant

6.1 Recruitment

Participants were recruited for the test from nurses interviewed and those that completed the online survey in Phase 1 of the study. Nielsen recommends 5 test participants (Nielsen, 2000) but for there to be statistical significance to the research Hinderer Sova and Nielsen (2003) stipulate at least 10 to 12 participants. For t-tests of the data to be significant, 16 participants were recruited to take part in the final A/B test with a script and the evaluation material prepared (Hinderer & Nielsen, 2003). A schedule was set over a period of 2 weeks with time slots available in the evenings and on weekends. All participants were dealt with under strict anonymity with informed consent forms signed.

Please refer to Appendix 22 for the full testing scripts, recordings, and consent forms.

7 RESULTS

7.1 Quantitative

Analysis of the results in SPSS indicated the data was not normally distributed and did not meet the assumptions of parametric techniques. Non-parametric tests were used which were suitable for the nominal and ordinal data retrieved from testing and the small sample size of 16 participants (Pallant, 2010). The Wilcoxon Signed Rank Test was used because it is designed for use with participants that are measured on two different conditions as was the case for this experiment (testing both paper and digital prototypes). The Wilcoxon could compare SUS scores between prototypes and the Time on Task and NASA TLX scores between tasks. The Friedman Test was used to measure the same sample of participants under three different conditions. It compared NASA TLX scores for digital and paper prototypes for the three tasks on paper and digital prototypes, Time on Task for the three tasks on paper and digital prototypes and the average Time on Task between the digital and paper prototypes. The Asymp. Sig. (2 tailed) achieved by each test was less than or equal to .05 therefore the two sets of scores for each test were statistically significant (Pallant, 2010).

7.1.1 Time on Task

Friedman Test comparing Time on Task for Task across all tasks for Paper (A) and Digital (B) Prototypes

Ranks

	Mean Rank
A-TIME-1	1.28
A-TIME-2	2.81
A-TIME-3	4.34
B-TIME-1	1.91
B-TIME-2	6.00
B-TIME-3	4.66

Test Statistics[a]

N	16
Chi-Square	74.480
df	5
Asymp. Sig.	.000

a. Friedman Test

The results of the Friedman Test indicated that there was a statistically significant difference in Time on Task scores across all tasks for paper and digital prototypes "$_2$ (2, n = 16) = 74.48, p < .000).

Please refer to Appendix 25 for the full Wilcoxon Signed Ranks Test and Friedman Test for Time on Task.

Time on Task Average Times

Table 1: Time on Task Average Times

Task	Paper Prototype	Digital Prototype
1	00:13	00:22
2	00:31	02:44
3	00:59	00:59

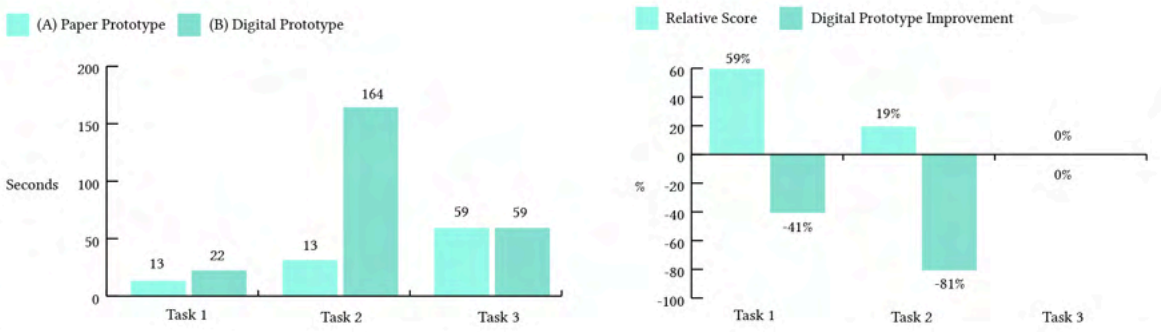

Figure 42: Time on Task Score and % of Improvement

Task 1: relative score 59% (dis-improvement of 41%)
Task 2: relative score 19% (dis-improvement of 81%)
Task 3: relative score 100% (improvement of 0%)

Calculating the Geometric Mean (Nielsen, 2001) of the 3 scores, an **overall improvement in Time on Task of 0%** was achieved. The findings are significant here and show efficiency was not achieved with the digital prototype hence a null hypothesis.

7.1.2 NASA Task Load Index

Friedman Test comparing NASA TLX means across Task 1, 2 and 3 for Paper (A) and Digital (B) Prototypes

Ranks

	Mean Rank
B-T1-TLX-MEAN	3.13
B-T2-TLX-MEAN	3.63
B-T3-TLX-MEAN	1.59
A-T1-TLX-MEAN	2.22
A-T2-TLX-MEAN	5.38
A-T3-TLX-MEAN	5.06

Test Statistics[a]

N	16
Chi-Square	56.175
df	5
Asymp. Sig.	.000

a. Friedman Test

The results of the Friedman Test indicated that there was a statistically significant difference in NASA TLX scores across the three tasks for paper and digital prototypes "$_2$ (2, n = 16) = 56.18, p < .000).

Please refer to Appendix 25 for the Wilcoxon Signed Ranks Test and Friedman Test for NASA TLX.

NASA TLX Average Means

Table 2: NASA TLX Average Means

Task	Paper Prototype	Digital Prototype
1	14.17	10.83
2	45	19.17
3	45.83	10

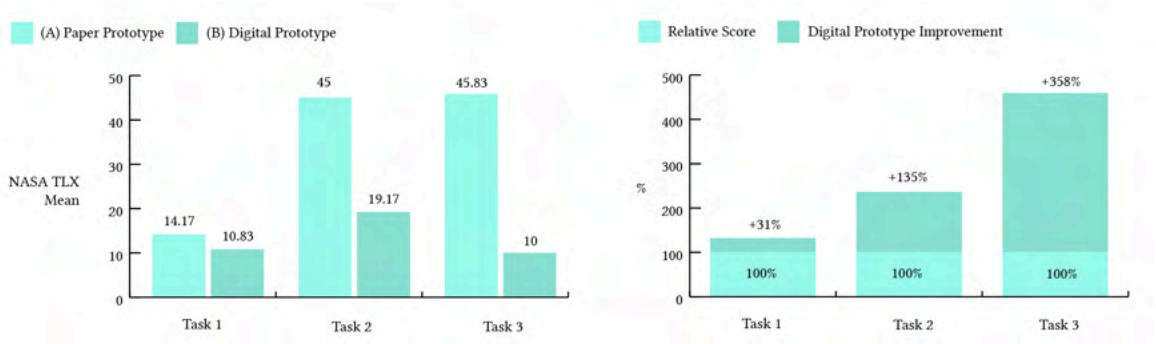

Figure 43: Time on Task Mean and % of Improvement

Task 1: relative score 131% (improvement of 31%)

Task 2: relative score 235% (improvement of 135%)

Task 3: relative score 58% (improvement of 358%)

Calculating the geometric mean of the 3 scores, an **overall improvement in Mental Workload of 114%** was achieved.

7.1.3 System Usability Score (Satisfaction)

Wilcoxon Signed Ranks Test to compare SUS Scores from Paper(A) and Digital (B) Prototypes

Ranks

		N	Mean Rank	Sum of Ranks
B-SUS-SCORE - A-SUS-SCORE	Negative Ranks	2[a]	2.50	5.00
	Positive Ranks	14[b]	9.36	131.00
	Ties	0[c]		
	Total	16		

a. B-SUS-SCORE < A-SUS-SCORE

b. B-SUS-SCORE > A-SUS-SCORE

c. B-SUS-SCORE = A-SUS-SCORE

Test Statistics[a]

	B-SUS-SCORE - A-SUS-SCORE
Z	-3.272[b]
Asymp. Sig. (2-tailed)	.001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

A Wilcoxon Signed Rank Test revealed a statistically significant increase in satisfaction when using the Digital Prototype, z=-3.272 p< .001, with a large effect size (r=.58). The mean rank for Satisfaction increased from the Paper Prototype (MS=2.50) to the Digital prototype (MS=9.36).

Please refer to Appendix 25 for the Wilcoxon Signed Ranks Test for SUS.

SUS Average Scores

Table 3: SUS Average Scores

	Paper Prototype	Digital Prototype
SUS	71.6	87.8

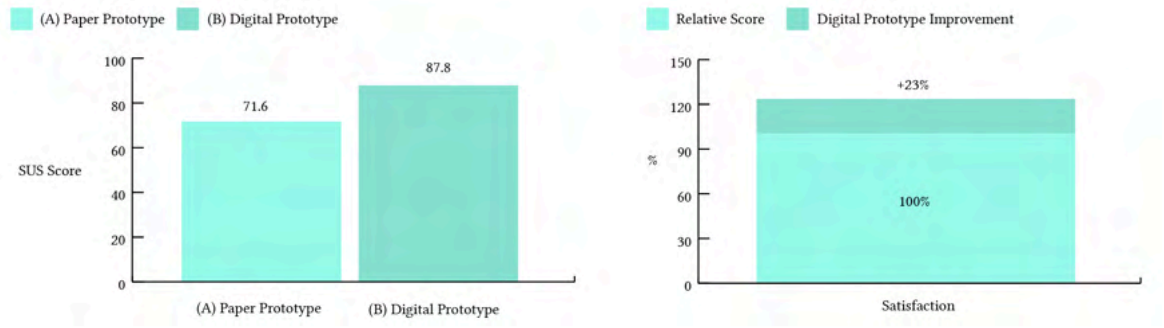

Figure 44: Satisfaction Score and % of Improvement

SUS: relative score 123% (improvement of 23%)

An overall improvement in Satisfaction of 23% was achieved.

7.1.4 Post Test Interview

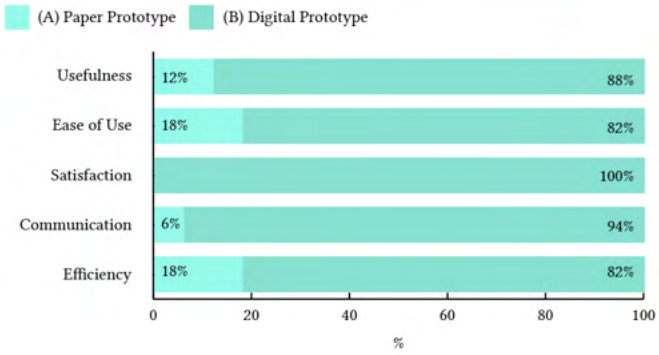

Figure 45: Post-test interview % of participants

The digital prototype scored significantly higher in the 5 areas of the post-test interview in terms of usefulness, ease of use, satisfaction, communication of essential patient information and efficiency.

7.2 Qualitative

The content analysis aimed to identify the 5 keywords and phrases 'accuracy', 'patient safety', 'critical information', 'scope of information' and 'understanding of information'. These keywords were indicative that the digital prototype was more effective in the communication of essential patient information. Tests and interviews were transcribed and read through several times. The text was highlighted into meaning units and the meaning units labelled with codes (Figure 46). The codes were then sorted into categories based on their similarities to the 5 keywords and each other. Categories were labelled with themes under the 5 keywords, tracked by a colour for each participant (Figure 47) and measured for their significance (Graneheim & Lundman, 2004). The top 3

highest rated themes were counted, and a mean was calculated for each keyword (Table 4). Please refer to Appendix 26 for the full content analysis.

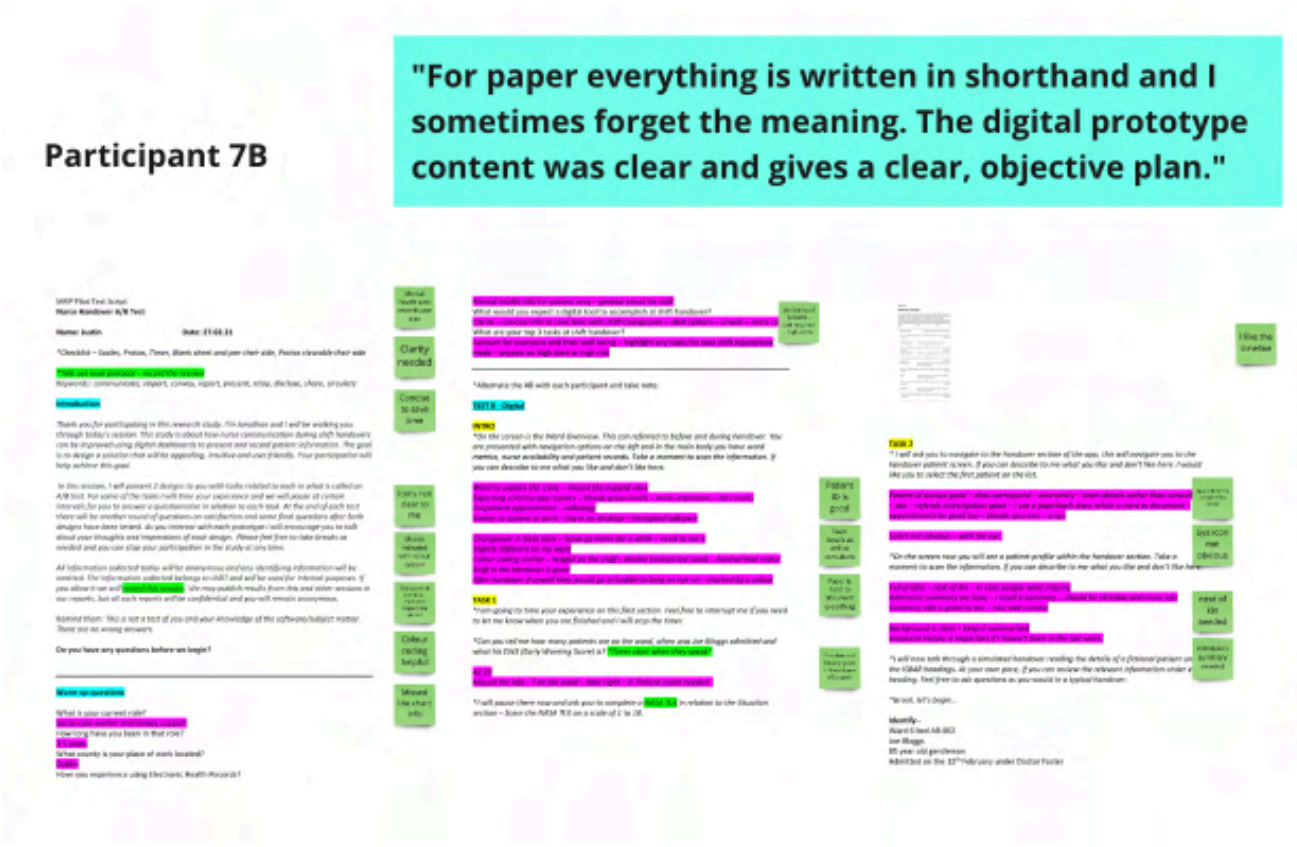

Figure 46: Content analysis highlighting and coding the interview scripts

Figure 47: Content analysis grouping categories from the code under the 5 keywords and phrases

Table 4: Content Analysis keywords, categories and mean

Accuracy	Speed and Efficiency	Accuracy	Quick reference	Mean
	69% (n=11/16) *"The digital prototype is faster"* *"Handwriting can be time consuming and difficult"*	63% (n=10/16) *"I would be less likely to make errors with the digital prototype"* *"There is less margin for miscommunication with the digital prototype"*	31% (n=5/16) *"With the digital prototype all the information is there at a glance"*	A mean of 54% of participants commented on 'Accuracy' being improved with the digital prototype.
Patient safety	Diligence	Safety	Confidence	Mean
	38% (n=6/16) *"Nothing is lost in translation with the digital prototype"* *"All the information is recorded so the handover is better, individuals are accountable"*	31% (n=5/16) *"With the digital prototype there is a clear patient situation"* *"The Recommendation section is good it sets up my day with the patients"*	25% (n=4/16) *"I would have more confidence in the information I receive on the digital prototype as the whole team sees it and can spot anything amiss"* *"The digital prototype seems like it would build trust and good habits"*	A mean of 31% of participants commented on 'Patient Safety' being improved with the digital prototype.
Critical Information	Scores	Key information	Timeframe	Mean
	81% (n=13/16) *"Isolation and Not for resuscitation are very useful"* *"A verbal handover will not include scores"*	63% (n=10/16) "*The digital prototype is better as it includes more detailed and concise information"* *"All the information is displayed in one place with the digital prototype"*	56% (n=9/16) *"The timeline is a good summary of important information"* *"More detail is needed on the timeline"*	A mean of 67% of participants commented on 'Critical Information' being improved with the digital prototype
Scope of information	Team	Summarised Information	Scope	Mean
	50% (n=8/16)	31% (n=5/16)	13% (n=2/16)	A mean of 31% of participants commented on the 'Scope of

	"The team information is good to know who is in charge and who is on the shift" *"All doctors and team members need to be shown for all illnesses"*	*"Summarised information is important"* *"We use audio and have to listen to it all – it is summarised well in this digital prototype"*	*"The digital prototype provides a more complete handover with more detail than a verbal with scores and observations"* *"With paper and verbal methods, it is harder to capture everything"*	Information' being improved with the digital prototype
Understanding of information	Ease of use	Clear Layout	Helpful Charts	Mean
	75% (n=12/16) *"The digital prototype is more user friendly"* *"I received more information and detail with the digital prototype"*	63% (n=10/16) *"The digital prototype content is well laid out and documented"* *"The information is clear and concise in the digital prototype"*	50% (n=8/16) *"I like that the charts show me what has happened over time"* *"The charts help to spot any variation in observation readings"*	A mean of 63% of participants commented on the 'Understanding of Information' being improved with the digital prototype.

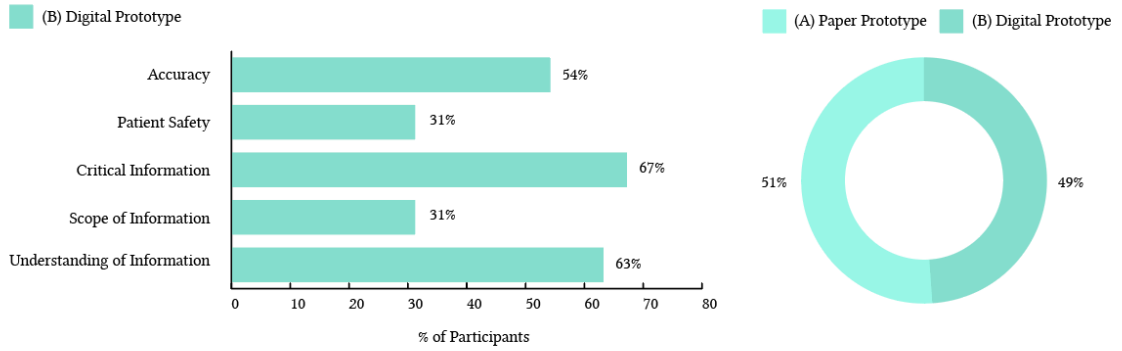

Figure 48: Content analysis % of participants and overall mean

From these scores an **overall mean of 49%** of participants indicated that the digital prototype communicated essential patient information more effectively than the paper prototype.

8 DISCUSSION

8.1 H1: Nurses that use an interactive dashboard to perform a shift handover communicate essential patient information more effectively than those that use a paper method.

The results from the quantitative analysis of the post-test interview show that 94% of participants said that the digital prototype communicated essential patient information more effectively than the paper prototype. The Qualitative Content Analysis highlighted several areas that nurses found the digital prototype enhanced the communication of essential patient information.

Nurses indicated through their responses that the accuracy of the handover improved with the digital prototype with there being less chance of errors being made with the recorded information. Some nurses advised caution in regard to the recording of all patient information and observations, and concern that nurses must continue with physical patient exams and not rely solely on the digital information.

Patient scores were important to Nurses as a summary of patient health and mobility and such scores are often not included in a verbal handover as per nurse feedback. Nurses found that the digital prototype provided them with more detailed and concise information on patient identity, admission and medical history, their background, current assessment, and the recommendation for treatment that day.

Nurses spoke of how the digital prototype was more user friendly, providing a clear layout of the patient information. The data visualisation charts were useful to the nurses in most cases, with patient status displayed over time being of benefit. Ward overview charts on the other hand were seen as unnecessary and more for a managerial level of the hospital ward.

The results of the qualitative content analysis echo the quantitative though not to the same extent, with 49% of participants indicating that the digital prototype communicated essential patient information more effectively than the paper prototype. Though the content analysis results were almost 50/50, the claim can be made based on the data of the post-test interview and the content analysis that the hypothesis is proven and that nurses who use an interactive dashboard to perform a shift handover communicate essential patient information more effectively than those who use a paper method.

8.2 H2: Nurses that use an interactive dashboard perform a shift handover more effectively than those that use a paper method.

Quantitative analysis for the Time on Task indicated that there was no improvement in time taken for the digital prototype over the paper prototype, in some instances a marked dis-improvement with Task 1 and 2 taking significantly longer on digital than paper. Remarkably, 82% of participants stated in the post-test interview that the digital prototype was more efficient to use than the paper prototype with many participants stating in the test and post-test interview that the digital prototype was faster to use. This indicates that participants found the digital prototype faster while not actually being the case. The longer times taken on the digital prototype may be due to the lack of familiarity with the tool, whereas participants were much quicker at writing for the paper prototype due to their day to day use of the method. The positive reaction to the digital prototype by participants may be due to the novelty factor as experienced by participants in a recent longitudinal study on the impact of iPad use on teaching and learning (Tay, 2016).

Quantitative analysis for the NASA TLX indicated that there was an overall improvement in mental workload of 114% based on the geometric mean of the 3 tasks. Responses from the post-test interview to the TAM based questions of “Perceived Usefulness’ and ‘Perceived Ease of Use’ indicated that 88% of participants said the

digital prototype was more useful than the paper prototype and 82% of participants said the digital prototype was easier to use than the paper prototype.

Though Time on Task results would indicate a null hypothesis, the digital prototype achieved better scores for mental workload on all three tasks resulting in an overall improvement of 114%. This score combined with the results of the post-test interview allows the claim to be made that the hypothesis is proven and that nurses that use an interactive dashboard perform a shift handover more effectively than those that use a paper method.

8.3 H3: Nurses that use an interactive dashboard to perform a shift handover are more satisfied than those that use a paper method.

Quantitative analysis for the SUS indicated that there was an overall improvement in satisfaction of 23% when using the digital prototype. 100% of participants stated in the post-test interview that they were more satisfied with the digital prototype over the paper prototype. This data allows the claim to be made that the hypothesis is proven and that nurses who use an interactive dashboard to perform a shift handover are more satisfied than those who use a paper method.

9 CONCLUSIONS & FUTURE WORK

9.1 Summary

This study argued that the use of a digital data visualisation dashboard to view, record and store patient information can improve nurse shift handovers in the communication of essential information, the efficiency of a handover and the overall satisfaction with the shift handover process. Through the discovery research undertaken, the study illustrated how current shift handover methods are primarily paper based, lack standardisation and are time consuming with excessive documentation and interruptions on the ward. The research conducted was leveraged to inform a UX design process and experiment that demonstrated the strengths of a digital dashboard prototype over a paper method for nurses to perform shift handovers.

9.2 Key contributions

Studies conducted to date lacked the use of a complete end-to-end UX design process (Khan et al., 2017). This study demonstrates the benefits of a UX design process in uncovering empathetic insights that inform the design of a solution to meet user needs. Discovery interviews and surveys highlighted the key needs of nurses in wards around staffing, interruptions and the vast amounts of handwriting and paperwork required for patients at shift handover. The A/B experiment and post-test interviews that followed illustrated the challenges faced by nurses and the issues with a paper handover. The test highlighted the improvement a digital prototype can make in the communication of essential information, the understanding of the information and accuracy of information provided. Through a content analysis of the experiment feedback and post-test interview responses it was shown that a digital prototype can improve the communication of essential patient information between nurses at handover. The efficiency of the handover using a digital prototype did not result in a reduction in Time on Task for the handover, but it did improve the mental workload and performance of nurses as seen in the results of the NASA Task Load Index. Handover satisfaction also improved with the digital prototype based on nurse responses to the System Usability Scale.

9.3 Limitations

Limitations of the study were mostly due to the current pandemic situation. A qualitative ethnographic field study with nurses in their working environment would have delivered more in-depth insight on nurses' workflow and feedback on prototypes. However, due to current restrictions with COVID-19 it was not possible to use these methods or gain the access required to achieve this kind of study. Due to the pandemic and the pressures healthcare staff are currently under it was difficult to recruit large numbers of participants for the A/B experiment. The minimum viable number of 16 participants were recruited to satisfy the t-tests conducted on the experiment data. In addition to these constraints pandemic restrictions meant that in person user testing was not possible. Ideally in person tests of the digital prototype on tablet devices would have been conducted and recorded alongside the use of a written paper template.

The inclusion of participants from a variety of nursing roles would benefit the research by providing a broader view of the shift handover. More participants from a single field of practice would also be of benefit to focus on more exact measures and patient information required for their specific field. Participants in this study came from a variety of nursing roles, each with their own requirements and standards which at times made it difficult to find consensus on what needed to be iterated. The prototype would ultimately need to be customised for specific roles and wards to establish a deeper understanding and value from results.

The scope of the prototype and what was achievable to design and test was limited to the constraints of a part time MSc research project. With more time, further iteration of the design based on the feedback received would enable a more complete design that could potentially improve the results of the quantitative and qualitative measures. Alongside this, participants were keen to see how the patient notes and care plans outside of a handover would link up to the handover, so this is a significant consideration and addition in the future development of a minimal viable product (MVP).

9.4 Future Research

Future research and work would involve the iteration of the digital prototype based on the feedback provided by nurses during testing. The key feedback involved removing some of the manager level ward overview charts and providing more emphasis on the patient overview section including additional measures like diet, falls risk and blood results on the timeline in an expanded view. Additional iteration and testing would need to take place to include care plans and full patient notes in their respective sections of the product interface. Feedback from nurses included the request to record audio notes and for a feature to convert their audio to typed patient notes. Future testing of such a feature would require a dictation task using the prototype.

More work is required to iterate and test the data visualisations used to represent key information to nurses. The data visualisations chosen were based on the nurses requirements from the discovery research and interviews, with patient data summarised in the most effective charts (Abela, 2006) and design principles (Few, 2006). Feedback from nurses indicated particular use of colours they are familiar with, for example red for circulatory and blue for respiratory measures and conditions. Baseline measurements were requested by several nurses as it was important to see what level a patient's scores were when they entered care, for example if they were low coming from a home environment or if they were high coming from an Emergency Room.

Additionally, further research in the form of a longitudinal study over a period of months would potentially find more reliable data for the metrics used in this study. This longer form of study coupled with a larger pool of participants to further test and record performance on a digital and paper prototype, would strengthen the results

provided thus far. The positive feedback received from the nurses involved in this study indicates a real need for further exploration and design of the handover process in a digital format grounded in UX design principles. Their willingness to participate and eagerness for a digital process, alongside the proven improvements in communication, efficiency and satisfaction are testament to the potential for further research and design in this area.

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