# Digitising a Medical Clerking System with Multimodal Interaction Support

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## ABSTRACT

The Royal Bournemouth and Christchurch Hospitals (RBCH) use a series of paper forms to record their interactions with patients; while these have been highly successful, the world is moving digitally and the National Health Service (NHS) has planned to be completely paperless by 2020. Using a project management methodology called Scrum that is supported by a usability evaluation technique called System Usability Scale (SUS) and a workload measurement technique called NASA TLX, a prototype web application system was built and evaluated for the client. The prototype used a varied set of input mediums including voice, text and stylus to ensure that users were more likely to adopt the system. This web based system was successfully developed and evaluated at RBCH. This evaluation showed that the application was usable and accessible but raised many different questions about the nature of software in hospitals. While the project looked at how different input mediums can be used in a hospital, it found that just because it is possible to input data is some familiar format (e.g. voice), it is not always in the best interest of the end-users and the patients.

## CCS CONCEPTS

• **Human-centered computing →User studies**

## KEYWORDS

Multimodal interactions, medical clerking, digital health

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## 1 INTRODUCTION

Errors in patient records are a serious problem in hospitals, yet they are not the only problem that paper-based patient records face. An observational study was completed in a University Clinic in which they found that 81% of physicians did not have access to all the information they wanted during a patient's visit [1]. Alongside this, they found that the paper forms physicians used were not flexible enough for their needs, with context missing on the rationale behind certain processes. Such issues have also been noted in other studies [2–4].

The Royal Bournemouth and Christchurch Hospitals (RBCH) currently use a paper-based method to track an inpatient visit throughout the course of their stay. There are currently two different forms used for this purpose; a twenty-page detailed booklet form called the Hospital Inpatient Record (HIR) and a smaller, concise four-page booklet form called the Ambulatory Emergency Care (AEC) proforma shown in Fig. 1. The former is used for longer overnight visits while the latter is used in Ambulatory and Emergency for simpler, shorter visits.

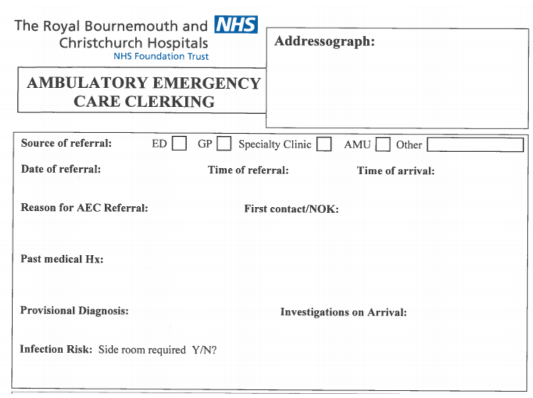
The Royal Bournemouth and Christchurch Hospitals NHS Foundation Trust
AMBULATORY EMERGENCY CARE CLERKING
Addressograph:
Source of referral: ED ☐ GP ☐ Specialty Clinic ☐ AMU ☐ Other ☐
Date of referral: Time of referral: Time of arrival:
Reason for AEC Referral: First contact/NOK:
Past medical Hx:
Provisional Diagnosis: Investigations on Arrival:
Infection Risk: Side room required Y/N?

**Figure 1: First page of the AEC booklet, a form for simple ambulatory visits.**

Both forms allow for various mediums of input such as the typical written values, measurement matrixes and even drawings for certain areas as seen in Fig. 2. Such information allows for detailed analysis of patient symptoms and the expected diagnosis. Alongside this, RBCH has a number of different software applications to store numerical data such as test results.


**Figure 2: Example of a complex input medium on HIR.**

This paper reports the process of building a web based record system that mimicked the clinical process of the AEC. Mobile devices were a key a factor of the research and thus the paper discusses how different inputs allowed in the AEC were mapped using multimodal interactions techniques such as voice input, handwriting as well as typing and the implications.

## 2 ELECTRONIC PATIENT RECORDS

### 2.1 Summary Care Record

With the advent of Electronic Patient Records (EPR) in healthcare around the world, digitalisation is playing a larger part in how patients interact with hospitals in their everyday lives. One example of this happening is with the Summary Care Record (SCR) in which important patient information created from GP medical records is made available to authorised staff across the country [5]. The SCR would be the next big step in complete digitalisation, allowing remote access to patient information consequently allowing for emergency care of unconscious patients. However, the use of SCR has been debated heavily with some stating that the lack of individual responsibility of the patient's records will effectively make the data inaccurate and useless [6]. Others believe that the use of SCR violates privacy and human rights, citing an example in Finland where a hospital found details of one of their staff members being HIV positive and thus 'hounded her out of her job' [7].

A qualitative study was taken in the UK to find patients' attitudes to SCR [8]. They found that although the patients were cautious of the privacy issues surrounding the SCR, most of those asked responded positively to the concept. There were misconceptions around the SCR, such as what it can and cannot achieve. We can therefore see how implementing a software project as large and optimistic as the SCR is no easy task and requires work on not just the quality and accuracy of the applications and their data, but the perception of the project and the avoidance of misconceptions that may be held.

### 2.2 Electronic Patient Records (EPRs) vs. Paper Patient Records (PPRs)

A study was taken in American family-run practices in which nurses were asked to survey their patients. Half of the surveys were taken through paper forms and the other half through hand-held computer devices [9]. The paper forms resulted in a higher return rate with 94% of the forms returned against an 82% return rate by hand-held computers, where one of the hand-held computers was stolen. However, the error rate of these paper forms far outweighed those of the hand-held computers; 35% resulted in errors from the use of paper forms, against 3% with the use of hand-held computers. Another study in the Netherlands tested the effects of the introduction of EPRs into General Practitioners (GP). It found that the waiting time of laboratory results to reach each GP were reduced from 2 days to 1 hour after collection [10]. The majority of GPs (15 out of 24) reported more accurate and complete information, moreover, ten GPs reported that EPRs lessened the work taken to process the data. These studies demonstrate the conflicts involved with using EPRs over the traditional Paper Patient Records (PPR). There are various benefits with using EPRs as demonstrated, such as the increased availability and fewer errors. However, the studies show concerns; the introduction of EPRs can lead to single points of failure, as in the first example where the portable device was stolen [9]. It is difficult to objectively measure the effectiveness of EPRs against PPRs because of the vast amount of different use cases for EPRs. The studies shown in this chapter look at the impact of EPRs for specific use-cases due to a "gold standard of comparisons" being missing [11].

The validation of input provided by EPRs ensures more accurate and complete data entry, yet this can be a disadvantage due to the usability of these EPRs compared to the PPRs. With unavoidable rules and severely reduced flexibility, the staff using the EPRs found them time-consuming and harder to use.

## 3 METHODOLOGY

### 3.1 Scrum and Card Sorting

Scrum was used as the project management methodology because of the "tolerance for change" [12] and increased customer satisfaction [13] which are both crucial to the success of this project. Scrum allowed the project to stay flexible down to the last few weeks in which new requirements were still being discovered due to the complex nature of this software. Card sorting was used for usability purposes to gather the client's opinion on the structure of the system i.e. which menu structure to derive from the paper copies. Card sorting has been shown to lead to enthusiastic users that provide significant feedback on both the usability and accessibility of a web site [14].

### 3.2 Usability Evaluation

Cognitive Walkthrough and Heuristic Evaluation techniques were considered but not utilised as both techniques depend on the experience of the evaluator, which can differ from what the end-user may find. Cognitive walkthroughs simulate users' problem solving processes by walking through a set of typical user tasks [15]. This is especially relevant with this research because of the environment the end-users are in and the skill set that is required to complete their tasks. Below are the usability evaluation and workload measurement techniques utilised.

*System Usability Scale* . The System Usability Scale (SUS) [16, 17] is a ten-item questionnaire with quantitative response options (strongly agree, disagree etc.) which can be given to the relevant users. The results of this questionnaire are then put through a formula to create a score out of 100 of which demonstrates how usable the system is perceived to be (With 68, through research, being the average level for a system). The use of SUS allows for a quick and wide-ranging evaluation of the usability of the system. This was important for this research project as it gave access to end-user feedback. This type of evaluation was completed at the end of the project with the doctors and nurses at RBCH and surrounding regions.

*NASA Task Load Index* . NASA Task Load Index (NASA TLX) is a subjective workload assessment tool which measures the workload of using applications [18]. This looks at six subscales of which make up the overall score given to the user's experience; (1) mental demand; (2) physical demand; (3) temporal demand; (4) performance; (5) effort; (6) frustration. This was used alongside the SUS to measure the mental (and in some cases, physical) workloads of using the system. NASA TLX is task-oriented while SUS is system-oriented. This was useful for this project as the environment they work in can be stressful.

## 4 RESULTS AND DISCUSSION

### 4.1 Analysis and Design

A visit to the hospital (i.e. RBCH) occurred early into the research. The meeting consisted of talking to the different teams around the hospital about the AEC and how they would like a portable device in which to enter data about a patient. After which a number of different pieces of software that RBCH use were shown such as their picture archiving and communication systems (PACS). The important points raised during this visit were the usability concerns of an EPR on a portable device, with the nurses specifying that a stylus option would make using the software significantly easier.

The first iteration of the design was provided by the client in the initial meeting. This version included the pages that the application should contain and was suited around a more traditional page-per-action architecture. Once some of the initial requirements were gathered and the technologies available to the project investigated, the design was adapted to be more granular with a focus on individual fields and the type of data that is entered. The card sorting exercise enabled the client to easily mark the data types and formats of the various input fields. This was especially useful with the drawing elements of the form. For example, with the respiratory examinations shown in Fig. 4, in which music notes can be used to indicate that a patient show signs of asthma in their breathing. The card sorting exercise enabled the client to easily mark the data types and formats of the various input fields. This was especially useful with the drawing elements of the form. For example, with the respiratory examinations shown in Fig. 3, in which music notes can be used to indicate that a patient show signs of asthma.

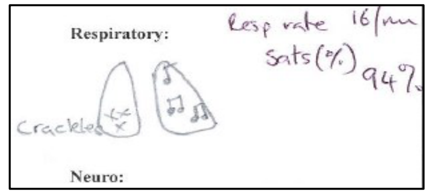


**Figure 3: Respiratory field annotated after card sorting.**

The design illustrated in Fig. 4 is this second iteration which again was created by the client. The client and the authors both agreed that a tabular menu structure within a single-page application for the input section would suit the project's needs.

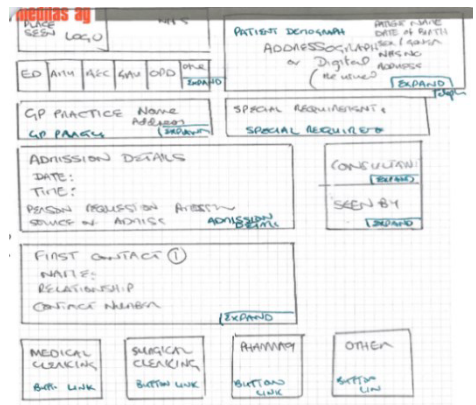


**Figure 4: A page from client's second design.**

The design uses a single page application approach for the different views of the patient data, this means that when entering data of a patient, the details are all on one web page and all the information is asynchronously loaded and submitted. This all leads to a more dynamic feel to the application and reduces the mental load of having to navigate the application to find what information the users want to enter. The input page uses a tabular view of the different sections of the AEC as indicated by the card-sorting exercise. These separate the input fields and attempt to ensure the page is not cluttered and shows only the most necessary information.

### 4.2 Implementation and Evaluation

Dictation and keyboard input mediums were natively implemented as part of the mobile device and therefore, only the handwriting functionalities needed to be developed alongside this drawing aspect mentioned above. The handwriting was implemented via a full-screen modal that displayed a grid that the end-users could adopt touch input to enter their desired value and return a textual result. The drawing implementation was similar to the handwriting aspect in that it utilised touch input. Instead of returning a textual value, it instead saves the resulting image compressed and attached to the relevant patient. This functionality can be seen in Fig. 5.

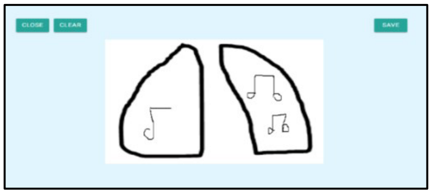


**Figure 5: Example of indicating Asthma on a patient.**

Once development was completed, two evaluations were held; one at the hospital with five participants being Doctors and Nurses and another two Nurses at a separate date. Each participant was asked to perform eight tasks and then fill out the SUS and NASA TLX. They are also asked to give open comments about the prototype. For a specialised domain such as AEC, it is difficult to organise a large number of experts and hence this research has not sought statistical significance; instead, the aim was to conduct preliminary evaluations on the proposed Paperless Medical Clerking System. The final SUS score has a range from 62 to 77 and a mean score of 72.86. When looking at the SUS averages, we can see that this score indicates a "C" grade [20], otherwise known as "Good" which shows that the application is usable but still requires some work. The average score for SUS is 68 which can be seen as the 50th percentile [16, 21], which means that the vast majority of participants scored the application above the average. Interestingly, participant 5's score was below this average which brings about the issue of SUS, what was wrong with the usability of the application to make that participant score lower than the average. SUS does not answer this, it is purely a classification tool to indicate if the application in question is usable, and it is not used for diagnostic purposes. The final scores for the NASA TLX (Fig. 6) show a varied range with a low score of 18 to a high score of 38, the mean average for this is 27.1. It is stated that any score below 50 is perceived as acceptable [19] which would mean that the score from this NASA TLX indicates that the paperless systems in question is accessible with low levels of workload. However, this looks at each classification as a combination for each participant. With this system being a software product, certain workload classifications are not as important as others.

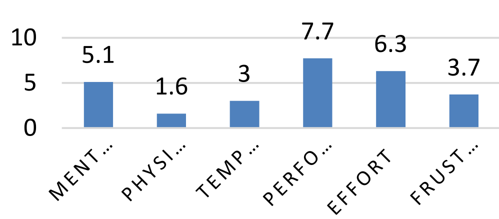


**Figure 6: Mean NASA TLX results by classification.**

There were a wide variety of comments throughout the evaluations, all participants questioned had a positive outlook, stating that it was a "very simple system to use", "logically laid out" and "could have real benefits to the hospital", yet many points of interest were raised. One important point that was raised a participant was the lack of certain data fields. One of the fields indicated was the next of kin contact details which was originally present on the AEC but not considered amongst the different design iterations. It would appear that there are different priorities for important data fields amongst the staff at the hospital and therefore, several group discussions amongst the staff would be required to build out a list of data fields that they need. Another important point raised was the use of voice input within the hospital. They gave the example of a patient with dementia where talking clearly into the portable device (to get the best possible response) would breach certain confidentiality agreements and would make the patient feel uncomfortable. One way around this would be the careful selection of the input medium per the field being entered; however, this does not counter the confidentiality issues with the voice input.

Finally, the most common and seemingly the most concerning point raised was the duplication of data input with one participant stating "I would be concerned over repetitive input of data from other sources". The effect of this on the end users should have been another focus and future iterations of this application will consider this.

## 5 CONCLUSIONS

Many of the comments raised by the Doctors and Nurses gave insight into how they view software in healthcare. All participants were positive about the necessity to move paper based forms into a digital format. The participants were in favour of the traditional keyboard medium, with many of them stating they already owned a tablet at home and were used to using that functionality. Sufficient focus was placed on how the end-users feel using the application but not enough was placed on how the patients would feel. With the examples of the voice input, oversights were made and in the future, this would have to be rectified. There are a number of improvements that could have been made to this study. Firstly, performing usability evaluations on the AEC proforma before starting the project would allow us to compare and contrast on the study above. There are again limitations to this, such as the familiarity the end users have with the AEC proforma which would only be countered by having the end users become familiar with the application in question. More participants would be required to get a varied and more accurate response but the scheduling of these evaluations made that difficult because of the busy nature of hospitals. Finally, the use of the application in a real-life clinical environment would have given us the best possible outlook at how it would be used. However, there are many ethical concerns when it comes to interacting with patients and that would not have worked with the scope of this research.

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