Behind closed doors – a distributed cognition study of infusion pump use in round-the-clock haematology treatment

Frances Gant
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Abstract
The primary aim of this study was to improve understanding of the use of infusion pumps in the context of round-the-clock nursing care. The context of study is two inpatient haematology wards in one hospital, where medicine is administered on a 24-hour basis. Data gathering and analysis was guided by distributed cognition principles and the Distributed Cognition for Teamworking (DiCoT) framework. Observational and interview methods were used to gather qualitative data of nurses' work with the pumps, and communications across the wards and through shift changes. Analysis of actual practice allows comparison with prescribed instructions. The study finds that these wards have a physical layout and a clinical culture that impact on the use of infusion pumps. The wards include patient side rooms, which isolate the pumps along with the patient, interrupting communication flow. With a main aim of maintaining a continuous flow of multiple infusions, nurses use pumps as reminders for task progression. A secondary aim of the project was to explore application of DiCoT models that have been developed through other case studies. This setting is dynamic, involving a complex system of activity, with particular constraints due to physical layout. Use of existing DiCoT models, including the System Activity model, was conducive to structuring analysis, and representing activities and resources involved in this context. Issues with ease of use of the DiCoT models are discussed. The domain description and issues identified here have the potential to inform device design. Where the pumps are isolated, nurses need ways to communicate with them; nurses adopt alternative use strategies to maintain a timely flow of infusions within the cycle of care.
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Introduction

This paper takes an exploratory approach to investigating the use of digital infusion pumps within a round-the-clock nursing care context. My perspective is that understanding collaborative healthcare work requires descriptions of the work domain as a whole. The environment under investigation in this project has impact on the use of pumps due to its physical layout and a clinical approach of maintaining a continuous flow of medicines. An initial interest in possible contrast between night and day work has been modified to consider the context as a cycle of care, which requires constant action and communication to meet system goals of stability and provision of treatment.

I have conducted an observational study, inspired by contextual design and grounded theory approaches; using analytical techniques from a distributed cognition perspective. The DiCoT framework is adopted and shown to be effective in supporting analysis, domain descriptions and identification of issues that can inform design.

In the wider context, this project will add to the body of knowledge for understanding medical device usage which is the concern of Computer-Human Interaction for Medical Devices (CHI+MED); a research project between UCL (University College London), Swansea University, Queen Mary University of London and City University.

I present the ward context and devices of interest in the background chapter below. This is followed by a literature review, which discusses previous studies in the medical domain and papers using distributed cognition approaches. The method chapter details how the study was initially planned and how it was adapted once data gathering began. Analysis includes models and descriptions derived from data and presents issues that emerge. In the discussion chapter I consider the issues presented; the contribution of the DiCoT framework to this study; the limitations of the project as carried out; and my reflections on method and difficulties.
Background

Haematology wards
The two haematology wards that are the focus of this study are located on two different floors of the same hospital building. Both provide individual patient rooms so that they can be occupied by patients of any gender. Patients are treated for a range of blood disorders and following bone marrow transplants.

Twenty-four hour nursing care is needed, in order to administer the treatment regimens for haematology patients. The specialist nurses have a culture of ‘whole patient’ treatment; they work without care assistants, attending to patients top-to-toe and developing a global knowledge of their needs.

All patients on these wards receive medicines via infusion pumps as a main basis of their treatment. In some cases the chemicals pose a safety risk on external contact and are consequently handled with utmost care. In all cases there is an aim to administer the treatment as quickly and safely as possible.

Infusion pumps
The infusion pumps examined in this study are BBraun devices. The majority of observations are of procedures with volumetric pumps. A smaller number of procedures were observed using the syringe driver model. Both types introduce cancer medicines, antibiotics, hormones, nutrients, vitamins and mineral infusions to patients in controlled way. Potent chemicals in cancer treatment require administration over prolonged time in correct dosage. Doses are delivered over periods of up to 36 hours. Infusion pumps allow for accurate, automated delivery.

There are records of adverse incidents with infusion pumps, causing injury or death to patients (Husch, et al., 2005). The volumetric infusion pumps are categorised as ‘high risk’ devices since they can be operated in ways that cause harm to patients. There is a need to understand how devices are used in context to inform future designs.
Literature review

Multiple authors have identified a need to describe the contexts of use for medical technologies, in order to ensure that normal work practices promoting resilience are supported, rather than disrupted, when new technologies are introduced (Ash et al., 2004; Bardram & Bossen, 2005; Furniss et al., 2011; Nemeth et al., 2004).

Normal work is described as “expert, habitual and unspoken routine” activities. The value of investigating this work is to recognise vulnerabilities, prevent adverse incidents and indentify work-arounds that mitigate error (Furniss, Blandford, & Mayer, 2011). In looking at a haematology and oncology day care unit, Furniss et al. find that recoveries from error happen frequently, demonstrating a resilient system; resilience being where the system copes without incident despite frequent “performance deviations”. Paying attention to low-level interaction disturbances allows these recoveries to be noted and learned from.

Ash et al. (2004) note that “subtle silent errors” come about through mismatches between the functioning of information systems and the real-life demands of healthcare work. They argue that awareness of issues around technological change will improve education, design and research; helping to avoid these mismatches. They note that computer applications deal best with automated routines, and not so well with the complex nature of medical work, where “contingencies are the rule” (Ash, Berg, & Coiera, 2004).

By examining the networks of artefacts that support coordination of work, Bardram and Bossen identify properties that can inform technological design. Non-digital artefacts, such as whiteboards and patient care records, are seen to have multiple purposes and different degrees of combinations. Aspects such as physical materiality, template provision and linkage to real world changes and notifications need to be appreciated and preserved in technological changes (Bardram & Bossen, 2005).

Greater awareness from research into the healthcare domain “provides a basis for creating better computer-supported cognitive artefacts that will make teamwork processes more resilient and increase patient safety” (Nemeth, Cook, O’Connor, & Klock, 2004). To develop this awareness, studies must take place within actual work environments, since this is where the decisions and actions are laid bare and can be observed.

Observational methods

Qualitative methods were used in this study, following adoption of similar techniques by several previous investigations of medical work (Ash et al., 2004; Carayon et al., 2005; Furniss et al., 2011; Nemeth et al. 2004; Patel et al., 2000; Rajkomar, 2010; Tang & Carpendale, 2007). Qualitative research techniques are seen to “provide deep insight and can both identify problems and answer the ‘why’ and ‘how’ questions that quantitative studies cannot answer” (Ash, Berg, & Coiera, 2004).

Observation is well suited for studying the work of medical teams, since the work carried out by these teams includes complex activity, with multiple actors in socio-technical space. Through observation, Furniss et al. found issues with infusion pump technologies that would not have been identified through interview or questionnaire alone (Furniss D., Blandford, Rajkomar, Vincent, & Mayer, 2011). One of the advantages of using observation for study is that “actual” work practices
can be captured, as opposed to “prescribed task actions”, which participants are more likely to report, affording it “strong face validity” (Carayon, et al., 2005).

Complex information sharing between nurses, through a variety of media, was observed in a hospital by Tang and Carpendale (2007). They are able to reveal how a multitude of common and personal information spaces are used actively and interact. Demonstrating how these support information flow during nurses’ shift change and how a variety of visual cues help nurses carry out their tasks (Tang & Carpendale, 2007).

There are some limitations to be noted of observational methods: the potential for intrusiveness; the time and effort to collect and analyse data (and objectivity in these); lack of cognitive process information and comprehensiveness of studies (Carayon, et al., 2005). According to Nemeth et al. (2004), research in the healthcare domain must necessarily be bounded, to deal with the hypercomplexity and “messy details” involved. This study is designed to take these points into account.

**Distributed cognition and DiCoT**

As a means of making sense of the data collected from collaborative teamwork situations, distributed cognition (DC) is well supported in the literature (Furniss & Blandford, 2006; Hutchins, 1995; Nemeth et al., 2004; Perry, 2003; Rogers & Ellis, 1994). Perry describes DC as an “ideal method for discovery of artefactual, social and cultural dimensions of work”; making it possible to relate these back to systems development in Human-Computer Interaction (HCI). The DC analytical goal is to describe how distributed units are coordinated, by analysing the interactions between individuals, media representations and the environment (Perry, 2003).

With the ‘web of artefacts’ in medical work documented by Bardram and Bossen (2005), we can see how distributed cognition fits well for these analyses. They describe the use of information spaces where team members communicate and ‘read’ the status of the work system. Artefacts lessen the amount of ‘articulation work’ required from actors. The network of non-digital artefacts, including forms, whiteboards, schedules and personal notes, is ‘ongoingly coordinating’ and provides meaning for collaboration. The network supports work by operating as a resource for situated action (Bardram & Bossen, 2005).

Distributed Cognition for Teamworking (DiCoT) is adopted here as a way to structure observations and analysis (Furniss & Blandford, 2006; Rajkomar & Blandford, 2011). Through this framework, models are built to understand the situation under investigation. Previous studies have applied DiCoT in flexible ways to fit with the context. Furniss & Blandford (2006) organise DC principles according to anticipated models in their study of an ambulance control centre. The methodology includes techniques with roots in Contextual Inquiry (Beyer & Holtzblatt, 1999) and Grounded Theory (Charmaz, 2006). This flexibility has also been utilised in UCLIC masters theses of Webb (Webb, 2009) and Rajkomar (Rajkomar A., 2010). Webb and Rajkomar both extended DiCoT models to allow for analysis in ways that existing models did not support.

Rajkomar’s study investigates use of infusion pumps within an intensive care unit. He finds that in using DiCoT, he is able to identify potential areas of improvement for devices and user training. Where existing models are inadequate for the context in question, Rajkomar extends and develops models as required. This study will follow his approach, and adapt it where needed.
Night/day work

Communication between nursing shifts is a well studied area; because the shift handover is established as an important part of continuity of patient care (Kerr, 2002). Kerr finds that handover practices are distributed over time, socially among staff and technologically through a range of artefacts and that the communication performs informational, social, educational and organisational functions. The handover phenomenon is of some interest in this study, as part of the information flow between team members, but is not a main focus.

Searches for literature referring to differences between night and day work produced on the whole non-relevant results for this study. It was difficult to find comparisons of medical night and day work in particular. This is echoed by Nilsson et al. (2008), who find that nurses’ work at night has not been previously examined. Their study, of the duties and working conditions of Swedish hospital night nurses, describes conditions of working silently, in dimmed lighting, and of decision making while fatigued. Overnight, the organisation is seen as recovering from daily activities (Nilsson, Campbell, & Andersson, 2008).

Topics of concern in the literature for night shift work are mainly around fatigue, performance, safety and health effects for different working people. In the medical domain, clinical resident performance is the subject of much literature, where their working hours span multiple shifts. A study of anesthesia residents’ night work found variations in task activity from day shift, and that clinicians used strategies to compensate for fatigue while maintaining patient care (Cao, et al., 2008).

Concern for the quality of nursing practice for shifts of 12.5 hours, as well as future research issues, are discussed by Fitzpatrick et al., 1999. They note that the usefulness of findings is limited by disparate (and conflicting) research from healthcare systems in different countries, along with changes in technology since some of the earlier research (Fitzpatrick, While, & Roberts, 1999). Assessment of the effects of shift work is beyond the scope of this paper; of more relevance are the interactions between clinical staff and the technologies used for their work, through different times of day.

Studies of night-time situated use of infusion devices seem not to be readily available; previous studies of such devices focus on emergency and intensive care settings, during daytimes (Carayon, et al., 2005; Furniss et al., 2011; Rajkomar, 2010).

Recent papers from Furniss, Blandford and Rajkomar have discussed the use of infusion pumps in an Oncology Day Care Unit. They focus on the context of use for the pumps as well as their design and actual use in ‘normal work’. Issues of battery power and VTBI (volume to be infused) are identified through observations and analysis with DiCoT. They emphasise that this is a work in progress and it is therefore essential to conduct similar studies in different wards.

This paper will contribute to the understanding of ecological contexts of infusion pump use, by exploring different temporal variations of normal work in oncology and haematology wards. It is therefore innovative in context.
**Method**

This study was carried out with an exploratory method over a period of approximately four weeks; data gathering was planned to cover a spread of time phases throughout day and night. The basis of the planning was the nurses’ shift patterns and infusion schedules on the wards. I aimed to be present at periods when use of infusion pumps was both more and less intense, and at times when different shift personnel were handing over duties. Observations were carried out on week days only. The following tables set out the planned focus for observations.

**Focus of observations**

I planned to look at similar data points to Rajkomar (2010) in order to collect comparable data and to be able to build DiCoT models from these. I adopted some of his questions as a starting point, with the assumption that new questions would arise through observations.

**Situated use of infusion pumps data points**

<table>
<thead>
<tr>
<th>Area of interest</th>
<th>Planned data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>• How do nurses use infusion pumps?</td>
<td>• Observations of nurses administering infusions</td>
</tr>
<tr>
<td>• Interruptions and distractions that occur.</td>
<td>• Interviews of nurses</td>
</tr>
<tr>
<td>• Difficulties of using the devices.</td>
<td></td>
</tr>
<tr>
<td>• Strategies to cope with these difficulties.</td>
<td></td>
</tr>
</tbody>
</table>

**DiCoT data points**

<table>
<thead>
<tr>
<th>Area of interest</th>
<th>Planned data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical layout</td>
<td>• Observations of ward/bed layout</td>
</tr>
<tr>
<td></td>
<td>• Still pictures of ward/bed layout</td>
</tr>
<tr>
<td>Artefacts</td>
<td>• Observations of nurses administering infusions</td>
</tr>
<tr>
<td></td>
<td>• Observations of artefact use</td>
</tr>
<tr>
<td>Information flows</td>
<td>• Observations of nurses administering infusions</td>
</tr>
<tr>
<td></td>
<td>• Observations of interactions among nurses, patients and other staff</td>
</tr>
<tr>
<td></td>
<td>• Interviews of nurses, doctors and other staff</td>
</tr>
<tr>
<td>Social structures</td>
<td>• Observations of interactions among nurses</td>
</tr>
<tr>
<td></td>
<td>• Interview of charge nurses</td>
</tr>
<tr>
<td>System evolution</td>
<td>• Interviews of nurses and other staff</td>
</tr>
</tbody>
</table>

Observations, for domain orientation and data collection, were followed by preliminary analysis, which informed further observations and led to emergent questions for interviews with staff.

Once the project was cleared as an audit study by the hospital Research and Development department, I obtained ethical clearance through my university department. Permission to observe
on the wards was given by the clinical division audit lead; and an honorary observer contract given by NHS human resources. The time period for gaining full permission for my study was around six weeks.

**Data gathering**

Two inpatient haematology wards (A and B) were the focus of the investigation. Initial observations were carried out over a total of 28 hours, across 6 visits, 3 in each ward. Two of these sessions were overnight for longer periods of time (12 and 8 hours each).

I observed a total of 47 pump interactions carried out by 21 different nurses; 27 pump interactions were observed on day shifts, 19 at night. All observed participants were given information sheets explaining the study, and signed their consent for me to follow and make notes of their work. Where anyone chose not to participate, or I hadn’t approached them for consent, I took no note of their actions.

Ad hoc interviews, with the nurses on duty at the time, allowed me to ask questions about what actions they had taken and why. Some of them also volunteered information about their techniques and experiences with the infusion pumps.

I attended a device training and assessment session for nurses, conducted in a learning hospital. This helped to expand my understanding of how the pumps work, as well as observe how nurses are instructed to operate them.

Following the main observation period, I conducted semi-structured interviews with 2 charge nurses and 2 ward nurses to clarify and verify analysis. Audio recording of these interviews was transcribed to add to the analysis.

**Physical layouts**

I took early surveys of the wards to draw up sketches of the layouts of corridors and rooms (see physical model). I was able to gather room names and identify positions of key information sharing areas. Charge nurses and other staff provided information on the functions of different rooms and areas, such as the treatment rooms where medicines are prepared, or the nurses’ station, where nurses carry out administration duties.

**Observations**

To observe the infusion administrations, I approached nurses entering the treatment rooms, where infusions are prepared before being taken to patients’ bedrooms. If consenting, I observed the nurse according to data gathering points above, noting their actions and any artefacts used in the procedure.

I followed the nurse to the patient’s room, if appropriate. In each room the nurse (or myself) made an explanation of my presence to the patient and any visitors there, to put them at ease and gain their consent for me to stay.

The room set up for Ward A involves a double entry, with clean ante-room between the corridor and each bedroom. In some cases wearing an apron was necessary to enter the room. Aprons were put on and taken off within the clean area; and disposed of on exit. This arrangement of rooms added to
the complexity of the observation. Infection control procedures are the same on Ward B, without the ante-room areas.

In order not to distract nurses during infusions, I kept any questions to a minimum. However, some nurses were forthcoming and happy to describe what they were doing, which allowed me to ask specific questions. Alternatively, I noted questions I had about their actions and asked them later.

I also attended some handover meetings, where I noted information exchanged by the nurses. Due to patient confidentiality these were recorded with hand written notes, not audio.

**Interviews**
Short interviews were carried out at times when nurses were available. This was difficult during periods of busyness on wards. Some interviews were briefly conducted between their tasks. I often took advantage of the time before and after visiting a patient’s room, when the nurse and I were performing infection control procedures, and walking to and from the treatment rooms. This was also useful in that the experience of the infusion procedure was recent and I could ask about specific pump interactions that I had observed. These were recorded with note taking only; audio recording was not appropriate or practical.

Quiet times on the ward were good for asking clarifying questions of nurses, when their activities could be more conveniently interrupted. I also conducted semi-structured interviews with participants, by arrangement, to clarify and verify the data I was gathering; and to fill in gaps in my understanding. I audio recorded these interviews. The questions I used came from my observation periods. I asked questions even if I had noted an answer from another respondent, as a way of verifying what other actors had informed me.

**Photographs**
I took images of key artefacts as well as physical location and notices. Photography wasn’t possible in patient occupied rooms. I obtained images of empty rooms when available. These would act as prompts for my reasoning and for description of physical aspects of the workplace.

**Materials**
The materials and equipment used for data gathering included: note books for jotting observations, layout sketches and interview notes; digital camera for still photos of layouts and artefacts; digital audio recorder for individual interviews; interview sheets, with planned questions listed; information sheets and consent forms created for provision to participants of data collection. Examples of planned questions are listed in Appendix A; the information sheet and consent form can be seen in Appendix B.

**Note taking technique**
I used a structured note taking approach, based on Rajkomar’s (2010) technique. This helped to code the different aspects of what I observed. The codes I employed here are as follows:


I utilised mainly the O, I, Q and A codes, with occasional use of codes S or T, of which I realised some were essentially thoughts that formed questions, and this is what they became. Precise use of these
codes was difficult during observations. I found it was better to get the information noted rather than be over concerned with how it was coded. I transcribed and sorted through data soon after collection, so that the meaning of my jottings was fresh.

See Appendix C and D for samples of handwritten and transcribed notes.

Data Analysis

I analysed my transcribed notes with a Grounded Theory approach, using the principles of distributed cognition as a reference (Furniss & Blandford, 2006). I highlighted sections in the text that were pertinent to these principles. I interpreted the notes using the understanding I had formed of the study context to that point. I colour-coded data from the two wards, to make the sources obvious, and to identify differences and commonalities. I then extracted key data that was relevant to DiCoT model headings of Physical, Artefact, Information Flow, Social, Evolution and System Activity and constructed those models in a separate file.

I diverged from the method of extracting all O, I and A coded text (Rajkomar 2010), due to the volume of notes. I realised rearrangement of such large amounts of text would be time consuming. In the sample where I attempted this method, I found that such a large amount of data lost its structure in terms of time and place by collecting it under headings.

Text labelled ‘Question’ (Q) (and some with S and T codes) was added to my list of questions for further investigation. S and T text, where it did not add to questions, formed the basis of my discussion of difficulties and self reflection.

In order to analyse pump interactions more closely I extracted text that described interaction sequences and collated them in spreadsheet tables. I included details of ward, room number, nurse ID and time, so that a picture of interactions over time and in different rooms could be developed. This allowed examination and comparison of different nurses’ approaches to pump interaction. Appendix E shows an extract from this tabulation.

I examined the extracted text, layout diagrams and photographs to develop narratives which represent the system. Following the approach used by Rajkomar (2010), I simplified the narratives from comprising several levels (Furniss & Blandford, 2006) to a single level description, accompanied by emerging issues. This allowed me to quickly create a descriptive account of the work system observed.

Data validation

As an ongoing approach, I validated my interpretations with ward staff, to make sure my understandings of their work were correct. Interviews with charge nurses and ward nurses were valuable for verifying interpretations and filling gaps in analysis. The charge nurse interviews also added to my understanding of the overall approach for their work goals, since they take a high level view of the wards.
Analysis

This chapter presents an account of the clinical setting for the infusion pumps and their operation. Issues are identified that impact on the use of pumps. An overview of the shift cycles is followed by descriptions generated using DiCoT models. I use data from both wards to describe the nurses’ work and to identify issues of note. Where data differs significantly, I indicate which ward it refers to (A or B).

Round-the-clock flow of infusions and nursing care

When a nurse comes on duty, they are joining a cycle of round-the-clock care. They need to gather information about new and developing situations on the ward. Work is not planned, in the sense of any scheduled daily activities for each nurse. The ward manager informed me that they “never know what the shift will hold.”

The nurse may have previous knowledge of the patients they are assigned to for the shift; they could also be taking on a new patient. Patients may remain on Ward A for two weeks or more and Ward B for three to five weeks, depending on their condition. During that time, nurses will work several shifts and become familiar with a patient and their needs. This familiarity comes through their own contact with patients, and from hearing other nurses’ and clinicians’ formal and informal reports. The medical team is multidisciplinary. Clinicians of different disciplines are referred to work with patients. Doctors oversee and prescribe treatment for patients. Treatment includes medicines, nutrition, physiotherapy and complementary therapies.

There are overlaps of shifts that allow for handovers; the longest of these is between the early and late shifts (between around midday to mid-afternoon). Shift times (early, late and night) are as follows: Ward A: 7:30am-3:30pm; 12:00pm-8:00pm; 7:30pm-8:00am. Ward B: 7:45am-3:45pm; 12:45pm-8:45pm; 8:00pm-8:30am. Figure 1 illustrates the timing of shifts and infusions.

Figure 1 Shift cycles for both wards, showing overlaps, handover, infusion commencement and busy times.
The work is structured according to a regular pattern of infusion schedules and patient monitoring. It varies according to the particular treatment prescribed for each patient, or the patient’s personal needs during the nurse’s shift. Infusions are scheduled for 6:00am, 2:00pm and 10:00pm on Ward A and 1:00am, 9:00am and 5:00pm on Ward B. Since each nurse has several patients to treat, they will start some infusions before, and some after these times. The set-up times may also change if a patient needs infusions at a slower rate, and therefore take an hour or two longer than normal. A nurse took this approach for a patient who reacted badly to a faster infusion of medicine. The schedule of infusions may also vary if there have been delays or interruptions in administration of any previous infusions. I describe the infusion process, and what disturbances or interruptions may occur in the System Activity and Information Flow models.

I use several models to describe how knowledge of patients and their treatment is shared between nurses and other clinicians.

**DiCoT models**

**Physical model**
The side room arrangement in this context is a key factor impacting on the use of pumps. This section describes and illustrates the isolation of the pumps. Appendix F contains physical layout diagrams of ward areas not shown below.

**Ward level**
Both wards are arranged in U-shaped corridors, with all patient side rooms arranged on the outside of the corridor (see Figure 2 and Appendix F). Treatment rooms and other types of utility room are on the inside edges. There is no one place where all side rooms and their call lights can be seen.

On average, nurses are responsible for 3-4 patients on day shifts and 4-5 at night. These patients’ rooms are not always adjacent, making the nurses’ pattern of room visits more complex. Ward B is the larger of the two wards visited, with 22 rooms (to Ward A’s 12). A nurse treating a patient in the furthest room on Ward B, has a long journey to make from the treatment room and back. Rooms 20-25 are on the other side of double doors from the rest of the ward (rooms 26-41). Observational, photographic and interview data, of the nurse allocation board on Ward B, show that nurses have their patient rooms spread over the whole ward, rather than concentrated in the same region. For example, on one night shift a participant nurse was assigned rooms 20,22,30,31 and 41; spreading their duties the full length of Ward B. The charge nurse explained that this is to share out the ‘mileage’. They also aim to have the neediest patients in rooms close to the nurses’ station, because those rooms are visited most frequently. Figure 2 shows the layout of Ward A. Appendix F contains the layout of Ward B.

Patient call lights are located in the ceiling outside their corresponding room; they are illuminated when a patient presses the call button next to their bed. There are secondary, repeater lights, at corridor corners, which indicate a path from the nurses’ station to the correct section of corridor for the patient call. An audible tone is activated to notify that a patient call has been made. Display screens at the nurses’ station, and a secondary screen, show which number room has called (and at what time).
Trolleys for specialist use (e.g. bone marrow and septic treatments) are lined up along a blank wall close to the treatment room. Ward B also keeps the medical notes trolley here, which on Ward A is placed at the nurses’ station. The fridges containing blood and chemotherapy bags are on Ward B and accessed by staff from Ward A, who make trips in the lift to collect them.

**Figure 2** Ward A physical layout, showing relationships of rooms and key elements (not to scale). Further layout models in Appendix F.

**Side room level**

Side rooms make it possible to physically isolate patients from others. They are a clean space, marked by a closed door. Positive pressure rooms, with closed doors, protect vulnerable patients from infection risks on the outside (Figure 3). Negative pressure rooms allow for infectious patients to be isolated, protecting others. Nurses negotiate the furniture and contents of the rooms to access the patients and pumps. They appear to take it in their stride and work around any obstacles, such as televisions, tables and bedside cabinets. Comments were made by nurses about difficulties in reaching to turn off call buttons, and annoyance at the televisions being ‘in the way’.
Horizon of observation and situation awareness

Nurses on Ward A usually can’t see patients unless they are inside the room. Visual contact happens when a nurse goes in for scheduled treatment or the patient calls them. Ward A doors and ante-room doors are mostly closed and obscure the view. Glass panels in the doors are semi-frosted and can be adjusted, by use of a lever, to fully frosted, further preventing any visual access into rooms.

Ward B doors have the same type of glass panels; making the situation similar. On this ward, doors to rooms are sometimes left fully open; indicating a lower risk of infection with the patient. It is more possible on Ward B to be aware of a patient or pump status by seeing into the room.

Pumps in side rooms

Pump alarms are audible from the corridor outside of rooms. However, unless a nurse is passing close by, they may not be noticed. One nurse, when standing in the corridor, asked the rest of the team nearby if she was the only one able to hear a pump that was alarming. On Ward B, it can be difficult to hear a pump alarm in the corridor, due to the distances between rooms. Nurses remarked that the current pumps are not as loud as previous pumps used and that one needs to be right outside a door to confirm that a pump inside is the one alarming. Pumps are not audible from one side room to another. This latter point indicates a different situation to a more open ward with curtain separators.

Where electrical leads are attached to a pump, there may be competition with other devices for electrical sockets. A main electrical supply strip is fixed on the wall behind each bed, with multiple
outlet sockets that are normally sufficient for purpose. Even so, I observed one instance when a student nurse needed to use an available lower wall socket to accommodate a pump, instead of the main strip.

**Infection control procedures have to be repeated if a nurse needs to exit and re-enter a room**

Clinicians entering side rooms must clean their hands, and put on protective aprons and gloves. The protective clothing supplies are mounted on walls outside rooms. For Ward A rooms, these supplies are on the walls inside the ante-room areas. Aprons and gloves are discarded on exit and hands cleaned again. These measures prevent the spread of infection into and out of the room.

There is a high cost in time for entering and exiting a room. If nurses discover unexpected issues once inside the room, they may need to exit to deal with these issues. This appears to be dealt with as a matter of course in most cases. Observed incidents included: nurses finding a patient not connected up with any lines, therefore needing to collect new lines from the treatment room; discovering a leak in a saline bag, which had to be replaced; finding not enough, or no pumps available; finding a pump with a battery warning, so that a charger lead was needed. On one occasion the nurse discovered there were more pumps available than expected, and was pleased to be able to fetch a second set of medicine to run at the same time.

All re-entries to rooms add significantly to the time nurses spend on a particular activity. This means the nurses need to maintain an internal plan and an awareness of anything they might need if they enter a room. There is potential for improved situation awareness, and a reduction in the required number of visits, to be supported by pump technology. If status of an infusion is known before entry this would be a valuable resource for nurses. Further pump issues are described in the Artefact and System Activity models. Physical model descriptions of Nurses’ Stations and Treatment Rooms can be found in Appendix G.

**Artefact model**

The artefacts observed in use on the haematology wards can be seen to form a ‘web’ which supports the work of the nurses and the infusion activity, as well as other patient care tasks (Bardram & Bossen, 2005).

Artefacts observed include:

- Infusion pumps
- Drug charts
- Drug labels and stickers
- Fluid bags and lines
- Set trays
- Whiteboards
- Handover sheets
- Personal notes
- Nursing and medical notes
- Ward diaries
Here, I will focus on key artefacts and their relation to the infusion process, rather than the whole of patient care. The artefact descriptions of personal notes, nursing and medical notes, and ward diary are contained in Appendix H.

**Infusion pumps**

As a mediating artefact a pump in operation represents the current status of an infusion. Pumps with illuminated green lights, absence of alarm, and a display of moving arrows, show that all is well with the flow of medicine. Figures on the pump interface provide information about time and volume remaining before the end of an infusion. Where a pump shows a yellow or red light, and emits a tone, it signals that attention is required.

The nurses are seen to use the pumps in alternative ways to the manufacturer instructions: as reminders before the end of an infusion, to give themselves time to prepare the next one; as calculators to reach a target time value, instead of entering the time as digits; and in their approach to priming the line.

**Alarms**

The main reasons for pumps to alarm are: when the programmed volume or time of infusion has been reached; if there is an occlusion, high pressure or air detected in the line; or an empty battery. In these cases the pump stops (except for empty battery, which is a three minute warning). A stopped pump requires attention, by fixing occlusions or power supply, and restarting, or by taking out, changing lines and resetting for new infusions. Nurses don’t necessarily distinguish between red light, stopped pump alarms, and yellow light, pre-alarms. One nurse told me he didn’t really know what each signified, and just responded to whatever message was on the pump screen at the time.

Pre-alarms for end of programmed parameters and battery supply give early warnings, but don’t stop the pump. Reminder alarms happen when a pump is left for two minutes during set up. These reminder alarms are very common, due to nurses performing multiple tasks at once; reminder alarms are reset with ‘ok’ and generally treated as unremarkable.

**Using pumps for reminders**

Alarms aren’t always seen as reasons for ‘alarm’. They are frequently used by nurses as scaffolding for progression to a next task phase. Observations and reports show that nurses will enter a lower volume to be infused (VTBI) than the full amount of infusion at set up. They do this to give themselves time to prepare the next infusion of fluid and allow for its set up without delay. Saving time in this way is an instance of coordination of resources.

> “If you’re giving 100ml over an hour, you might put in that there’s 90 or 95ml in the bag. Then it starts beeping (you’ve been busy with other things) it reminds you to sort things out and gives you a few minutes to go and get the new drug.” (Ward nurse)

See Information Flow model for issues of potential breakdown that emerge from this activity.

**Using pumps for calculations**

The parameters needed to run an infusion include rate, volume and time. These are entered by nurses into the pump in a variety of ways. I observed *Rate* entered as the first parameter on most occasions; *VTBI* was sometimes entered first, but often as second parameter, or not at all. I only recorded 3 interactions where I noticed *Time* entered as a parameter. My notes are incomplete on
many of the interactions observed, due to domain unfamiliarity on my part and rapid speed of interaction by nurses. Prescribed device instructions allow for entry of two parameters, with the third being calculated by the pump (BBraun Infusomat Space, Instructions for Use, 686E).

Nurses sometimes just “know” or can quickly work out the correct figures for particular infusions (such as commonly administered drugs and simple round-numbered rates and volumes); and in these cases the pump display matches their expectations – a representation of goal parity. An assumption can be made that if a set of figures doesn’t match an internalised expectation, this will prompt a nurse to check the settings.

“I know these numbers, after so many years... the pump backs up my maths.” (Ward nurse)

Example calculation by nurse: Rate 340ml/h; VTBI 170ml; Worked it out in head for 30 minutes. (Fieldnote)

For less regular parameters, and where a partial infusion has been run, nurses will enter and adjust ‘guestimate’ parameters until the display shows a correct target. Where a nurse knows the time an infusion should take they will nudge the number value up or down for another parameter (rate or VTBI) until the pump displays the required time. One nurse changed the VTBI in order to speed up the time of an infusion, instead of changing the target rate.

O: Hanging a new 100ml bag of antacid; Rate set 420ml/h; VTBI 100ml; No drip sensor.  
I: How did he know what rate to put in?  
A: He just ‘knew’... “Actually I didn’t even think... when I put in the VTBI I could see the time it would take & I knew it could be faster (doesn’t need to be precise for that drug). I just changed the VTBI until it said around 15 mins. Or I could have set the time and it works out the VTBI...” (Fieldnote of nurse actions)

This statement shows how the nurse is unconsciously using the pump as a resource to alleviate cognitive load of a calculation. Nurses described display of the infusion time as a useful ‘feature’ of the pump. This emergent theme from the data indicates a method of number entry that diverges from instructed procedures. It presents an interesting area for further investigation, but is beyond the scope of this study.

Further discussion of the role of pumps is included in the Information Flow model.

**Priming with or without the pumps**

Operation instructions tell the user to fill the infusion line, then insert, then prime, then connect to patient. I saw no nurse both filling the line and priming with the pump. This is because it reduces the volume of bags, both making calculations more difficult and wasting medicine.

Nurses approached priming in two different ways that I saw. Where they used the pump to prime they would say it keeps air out of the line. More often the line is primed by hand, sometimes before leaving the treatment room; these nurses explain it is the way they were trained, so they continue with this method. One nurse explained that he prefers using the pump stand to prime, so that the line is not coiled and it is easier to see any bubbles.
I did not collect data on the rates of success or disturbances following use of either method. A nurse that always uses the pump to prime informed me that in his experience, he never had air-in-line problems.

**Drug charts**
The official name for these forms is “In-patient medication prescription and administration record”. They are pre-printed booklet forms into which clinicians enter information on all of a patient’s treatments. This includes type of medication (including nutritional), dose and period of prescription. Doctors write the prescriptions, which are double-checked by pharmacists and nurses for suitability. The prescriptions represent a plan for future action. Nurses starting a shift collect up charts for their assigned patients and refer to them for what infusions to prepare.

Each occasion of a drug administration is signed by the administering nurse and checked by a second nurse. This confirms goal parity for the planned treatment, and provides a historical record of treatment given. When filled over time, the drug charts form part of a patient’s medical notes. The drug charts are continually referred to, and updated. I saw them being used by all clinicians at different times.

When a second nurse checks the medicines of another, they compare drug containers on the counter with the described medicines in the chart. One nurse that noticed an incorrect calculation raised it with the other nurse and they checked all patient details on each side of the chart.

> **O: N17 checks drugs for N16. She explains verbally and he checks against chart. They find a calculation is wrong. Check patient details on both sides of sheet, holding it up between them.**  
> **(Fieldnote)**

I observed drug charts being used as locations for notes to doctors and post-it checklists for nurse actions. They were also used as coordination spaces during treatment preparations; nurses position drugs on the chart for the patient it represents.

**Drug labels**
Yellow printed sticky labels indicate when a drug has been added to a bag of fluid. They are filled out with key details and placed onto the bag containing the drug solution. Details written by the administering nurse should include: their own name and signature, date, time of drug administration, type of drug and dose, the patient’s name and hospital number. One nurse described the purpose in this way: “So that when I walk in, having never met the patient, I immediately know what drug he’s having, when they put it up, how long it’s got to run.”

A nurse adding drugs to more than one bag of saline at the same time used the drug labels as scaffolding to indicate which drug should go in which bag and prevent mixing of fluids. These labels then help other nurses identify which pump is introducing which drug; “...you follow the line up to the yellow sticker, checking what was written on it”

The absence of a label acts as an indicator that the fluid is plain saline or glucose, and therefore can be treated differently to a drug infusion. I interviewed a nurse after she had reduced an infusion rate to 20ml/hr, who stated that, “the pump alarm tells me [VTBI] has gone through. I looked at the bag, no sticker, so not a drug: to be honest, I didn’t look at screen. But I could tell, looking at the bag, that I just needed to reduce the rate, assumed it is glucose...”
**Stickers**
Other stickers are used to mark lines, pumps and syringes, to indicate they are ‘different’ from other artefacts. I noted use of yellow cytotoxic tape on a chemotherapy line, fixed below the drip chamber to act as a warning for correct handling. Other makeshift stickers were torn from drug labels to mark syringes out from others. One nurse stated that he would put a sticker on a pump to alert him to a dangerous fluid that needed greater care, e.g. potassium chloride or insulin.

**Fluid bags and lines**
Fluid bags are in several different commonly used sizes, visually representing their volume e.g. 100ml, 250ml, 500ml and 1000ml. Nurses are aware that the marked volume of a bag is not accurate to its actual contents. They will therefore factor this in to their calculations, and underestimate volume, for pump set up. They also have developed abilities to visually assess the remaining volume of a partially infused bag.

Plain bags contain mainly saline (sodium chloride solution) or glucose. They are given to patients for hydration and blood pressure adjustments and to flush through before and after drug doses. Cytotoxic chemotherapy bags are marked with blue plastic covers.

Nurses will leave a bag in the patient room, at hand for flushing an infusion line when the main drug has gone through. These bags, hanging on pump stands (on hook corresponding to correct line) or laid in blue set trays, indicate the intended next task in the infusion process.

There can be some confusion between innocuous fluids and dangerous ones, if bags can’t be observed closely. One nurse informed me about an instance where she had been expecting to see a flush bag, because of handover information from another nurse. When she briefly looked into the room and saw no label on the bag, this fitted her expectation. Returning to the room, to take down the line, she found the bag was potassium, not saline. This meant she couldn’t stop the infusion at that time. The potassium solution had been put up by another nurse in the time since the handover where she was told the patient was on a flush.

Infusion line sets come with coloured clips attached, indicating their type of line. I was informed that on Ward A, only one type of line is used, so that the line selection stage of pump set up is not utilised. Ward B charge nurse reported that they use three different types of line. In a training session nurses from both wards discussed the line selection function, the majority were not aware of the different line types, or whether they were used on their wards.

Volume of lines is probably variable; some nurses say they are different lengths. Therefore priming reduces volume of a bag by different amounts. This has to be taken into consideration when calculations are made.

**Set trays**
When preparing a set for infusion, nurses use blue plastic trays which represent a “clean field”, once wiped with alcohol. Retrieval, cleaning, use, re-cleaning and stacking of a tray marks out a cycle of action by the nurse. When clean, only other clean items are put into the tray. This is part of the Aseptic Non Touch Technique (ANTT) approach, which prevents infection.
Contents of a tray are resources gathered for the task of infusion (Image 1); the type and amount of items, filled or non-filled syringes, labelled or unlabelled bags, indicate progress in the preparation task. Items collected outside the tray also represent the steps taken or to be taken in the task.

![Image 1 Set trays prepared and ready for use. Tray on left contains a fluid bag marked by a drug label, indicating addition of a drug. The patient’s drug chart is placed behind the tray to represent the goal of administration to that patient.](image)

**Whiteboards – “Allocation”, “To do” and “Nurse admin”**

Wards A and B have differently arranged whiteboards, due to physical space on the wards as well as the different number of patient beds (variations marked A or B). See Physical Model, Appendix G, for details of whiteboard locations. Whiteboard space is used to show: patient name and bed number; allocation of nurses to patients – across each shift; patient level of need, via ‘acuity scores’ (B); meds to give or blood samples to take and what times; scheduled events like x-rays, nurse break times (B); notes for doctors or pharmacists; doctor or pharmacist names and contacts (B).

‘To do’ tasks are seen by all staff and can be taken up by other team members if not done. Nurses add new items or erase them, as they are finished or action plans changed. During discussions about a patient, nurses will stand and look at the board as a prompt.

Allocation boards are used as a resource for the whole multidisciplinary team, so if someone needs information about a particular patient from the assigned nurse... “any member of the multidisciplinary team can walk in and see that ‘Katie’s looking after x’ and then go and find Katie.” Names of nurses on each shift remain on the board for 24 hours, until the corresponding shift restarts. This represents a temporary record of nurse responsibility (Image 2).
Handover sheets

Passing information forward about the events and developments of each shift is coordinated through handover sheets. These sheets contain details about every patient on the ward. Each nurse has a printed copy of the main record given to them at start of shift handover. An interview with a charge nurse provided this description of the handover sheet: “It’s about the patient’s clinical observations, whether they are well at that point, to drugs and procedures that need to be given that day, to what has happened and how that’s impacting on the rest of their care. Anything and everything about that patient, that will progress towards their health and safety, and discharge. But most of the time it’s just prompts... like ‘needs fragmin at certain time’ or ‘has had this much diarrhoea’ is having xray’... “ (Charge nurse interview)

At the handover meeting all nurses are told about all patients by a previous shift nurse, and add notes to the printed sheet. These include notes about what IV infusions need to be administered. Throughout their shift they will tick off completed tasks and add notes that they can pass on to other staff and the next shift (Image 3). Their marks and notations are personal, but do share characteristics with other nurses, such as drawing a checkbox next to a ‘to do’ item, to indicate it needs completion. They will also mark on the sheet which patients they are assigned to, as a secondary reminder to the allocation board.

Information on the handover sheets is a duplicate of the more detailed nursing notes. Handover sheets are destroyed after each shift, making them a temporary redundant resource.

The printed version is created using a Handover Sheet File on the shared server. Nurses update this periodically (on the Ward A night shift and on each Ward B shift). Ward A master file is overwritten on update. Ward B retains each handover sheet file as a record of treatments given and nurse allocation; the charge nurse will be able to review the files in the case of any incidents.

As a representation of the occupants of the ward, it contributes to coordination of resources and setting of goals. A nurse returning from annual leave, looking at her sheet, remarked that “things have changed so much,” indicating that the handover sheet gives an overall picture of ward status, that can be ‘read’ by those familiar with it.
Information Flow model

Flow of information is web-like in character. There is communication between all actors in the ward in relation to patient care. From the start of a nurse’s shift they will interact with team members from the previous shift; receiving (and giving) information. Information relating to infusion procedures is interwoven within this flow. I have developed a model diagram for the information flow in the infusion process context (Figure 4). The labelled communications are described in Table 1; numbered processes show primary communications for infusion administration, lettered show secondary, supporting communications. Descriptions in Table 2 highlight the main information flow properties for the process. Key roles are played by the drug chart, the nurse, the pump and the handover sheet.

Potential breakdowns in flow of information

This analysis shows potential points for breakdown of the information flow, which have consequences for the global goal of patient treatment. Processes 5 and 7 in the flow model can be seen as having this property, where nurses are using pumps as reminders for moving to their next task phase. The illustration here shows that the patient is part of the communication process with the pump. If this loop is interrupted by a patient not calling the nurse (7), and the nurse does not detect the pump alarm (5), then the schedule of infusions is disrupted.
Figure 4 Flow of information by communication channels for the process of infusion administration. See Table 1 for descriptions of each communication path; and Table 2 for description of flow properties that emerge from this model.
### Table 1 - Flow model description for context of infusion process

#### PRIMARY COMMUNICATIONS

<table>
<thead>
<tr>
<th>Process</th>
<th>First direction</th>
<th>Second direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Doctor to drug chart</td>
<td>Doctor enters the prescribed treatment into drug chart.</td>
<td>--</td>
</tr>
<tr>
<td>2. Drug chart to nurse</td>
<td>Drug chart shows the nurse what treatment to administer.</td>
<td>Nurse records administration of treatment.</td>
</tr>
<tr>
<td>3. Handover sheet to nurse</td>
<td>Handover sheet print out contains information about patient condition and treatment required (passed on from previous shift).</td>
<td>The nurse adds their own notes at handover meeting. Sheet is updated with notes about patient care through the shift.</td>
</tr>
<tr>
<td>4. Nurse to drug label</td>
<td>Nurse places details of prescription administration onto the drug label.</td>
<td>Drug label lets the nurse know which bag to inject with the drug during preparation. When attached to fluid bag, this represents that the bag contents are ‘drug’ to anyone who sees it.</td>
</tr>
<tr>
<td>5. Nurse to pump</td>
<td>Nurse enters parameters of infusion into pump program.</td>
<td>Pump indicates status of infusion. Pump alarm indicates need for attention.</td>
</tr>
<tr>
<td>6. Pump to patient</td>
<td>Pump alarm is a behavioural trigger that alerts patient to call nurse.</td>
<td>--</td>
</tr>
<tr>
<td>7. Patient to nurse</td>
<td>Patient calls nurse via patient call system – which is a behavioural trigger for nurse to attend. Patient will verbally inform nurse of their needs.</td>
<td>Nurse attends patient and pump. Call alarm is switched off to indicate answered call.</td>
</tr>
</tbody>
</table>

#### SECONDARY COMMUNICATIONS

<table>
<thead>
<tr>
<th>Process</th>
<th>First direction</th>
<th>Second direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Whiteboard to nurse</td>
<td>Whiteboards display planned actions; and nurse to patient allocations.</td>
<td>Nurse will make notes of planned actions. And erase completed ones.</td>
</tr>
<tr>
<td>B. Nurse to patient</td>
<td>Nurse makes frequent visits to monitor patient.</td>
<td>Nurse checks on patient condition on any visit: verbal, touch, visual, gestural communication.</td>
</tr>
<tr>
<td>C. Nurse to nurse</td>
<td>If another nurse changes settings on a pump (adjusting flow rate, for instance) they will inform the nurse assigned to that patient. Nurse will have frequent face to face communications with buddy, student nurses, shift coordinator, and nurses from other shifts about Patient treatment and status. Shared knowledge of patients, nurse and doctor information are passed through ad hoc conversations. The handover meetings and one-to-one</td>
<td></td>
</tr>
</tbody>
</table>
Handovers are key times for this sharing of group knowledge. They also have informal social communications, which normalise and relax the atmosphere on the ward, where patients and their families are going through upsetting circumstances.

<table>
<thead>
<tr>
<th><strong>D. Drug chart to nurse 2</strong></th>
<th>Drug chart shows correct medicines for infusion. Nurse checks these against prepared drugs.</th>
<th>Nurse 2 signs to show infusion is correct.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E. Drug chart to nurse on next shift</strong></td>
<td>Drug chart shows history of medicines administered on previous shift.</td>
<td>--</td>
</tr>
<tr>
<td><strong>F. Whiteboard to other nurses</strong></td>
<td>Whiteboard shows planned actions by Nurse in relation to Patient – if not carried out, these can be taken on by the other nurses, on this shift or next.</td>
<td>--</td>
</tr>
<tr>
<td><strong>G. Pump (Drug label and Fluid bag) to other nurses</strong></td>
<td>Pump display indicates ongoing infusion status. Pump alarm indicates need for attention. Fluid bag indicates state of progress of infusion. Drug label indicates drug is added to bag.</td>
<td>--</td>
</tr>
<tr>
<td><strong>H. Nurse and Nurse 2 to handover sheet file</strong></td>
<td>Key information input to file for handover.</td>
<td>--</td>
</tr>
<tr>
<td><strong>I. Handover sheet file to next shift nurse</strong></td>
<td>Handover sheet is printed out to pass information to next shift nurses.</td>
<td>--</td>
</tr>
<tr>
<td><strong>J. Doctor to Nurse</strong></td>
<td>Face to face communication of intentions for treatment.</td>
<td>Face to face communication of patient status and clinical opinion.</td>
</tr>
<tr>
<td><strong>K. Doctor to Patient</strong></td>
<td>Face to face communication. Verbally inform patient of their condition and treatment.</td>
<td>Verbally and physically shows their condition to doctor.</td>
</tr>
</tbody>
</table>

For simplification, elements excluded from this flow analysis are: communication between Nurse 2 and the patient; direct communications between all other nurses and between the doctor (and other clinicians) with all other nurses; student nurses; distinctions between different types of whiteboard as made by wards A and B; information used by doctor (and other clinicians) from the whiteboards.
**Table 2 - Description of main flow properties for context of infusion**

<table>
<thead>
<tr>
<th>Process</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse is decision hub in relation to the patient they are caring for.</td>
<td>Nurses interpret the prescription information in terms of their knowledge of the patient, and their clinical experience of IV medicine, as well as policies and procedures laid down. They may be making a decision on an appropriate drug for their patient, based on previous reactions or known allergies. They will communicate with the doctor and pharmacists to request prescriptions are made or altered if necessary.</td>
</tr>
<tr>
<td>Drug chart is an information hub.</td>
<td>Drug chart contains planned and recorded patient treatment. Each prescribed drug has its own section; every administration is noted and signed by two nurses to confirm, representing a history of action. The chart provides nurses with a reference for goals to be met. Schedules are loosely set by the chart, to be interpreted by nurses.</td>
</tr>
<tr>
<td>Pump is an information hub.</td>
<td>The pump contains the data for the infusion; this is represented in its display and by alarms or absence of them. Artefacts connected to pumps (fluid bags and drug labels) give key representations of the situation to actors.</td>
</tr>
<tr>
<td>Handover sheet is an information filter.</td>
<td>Handover sheet contains key information passed from one shift to the next. It is a summary of details available from other sources, e.g. drug charts and face to face handovers between nurses. (group and one-to-one). (See Artefact model for more information on handover sheets.)</td>
</tr>
<tr>
<td>Pump-to-nurse (5) is a potential breakdown point for the flow.</td>
<td>Nurses do not always hear or see pump alarms in side rooms.</td>
</tr>
<tr>
<td>Patient-to-nurse (7) is a potential breakdown point for the flow.</td>
<td>A sleeping patient does not operate their call button.</td>
</tr>
</tbody>
</table>
System Activity model

System Activity model is relevant to this study because the primary activity of infusions with pumps is integral to a system of round-the-clock care, which consists of multiple secondary activities. It is useful in this context, where activity is complex and dynamic. I have adapted the model to describe activities applicable to the systems I have observed. Points 1 and 2 are presented here; points 3-7 can be found in Appendix I. Figure 5 shows the primary activity of infusion administration and secondary activities that influence it.

![Figure 5 System Activity Diagram for the haematology wards](image)

Infusion administration

“It's about safety and speed, when you've got to do a lot of work in a short space of time... haematology has a far higher quantity of IV administration than other areas. We're giving so much fluid. We normally give a drug, flush it through, give another, flush it through...”

(Interview with charge nurse)

Infusions, being a key basis of haematology treatment, are a primary activity for nurses. They are administered on a schedule of three times a day and can last up to 36 hours. In some cases, they don’t end during a nurse’s shift.

Different infusions of antibiotics, chemotherapy and other chemical treatments need to be given in particular order and within the time available. For example, a potassium infusion will be given before chemotherapy, since the latter will deplete the patient of potassium. This organisation is seen as planning for “line space” as a limited resource. Nurses will make a mental plan for their work, to fit with this resource.

Infusion preparation and pump interaction sequences

In the whole context of patient care, infusion preparation and pump interaction are two sub-task sequences, separated by locations of treatment room and patient room. Different interruptions or disruptions can occur for each.
In the treatment room, nurses work smoothly around each other, as well as staff such as pharmacists and housekeepers who may be there. A preparation sequence may be interrupted if another nurse needs help with a patient, or by a question from a colleague. The preparation technique and collection of resources on the bench, allows for ease of resumption of the task, or for another nurse to take over if necessary. In the patient room, ANTT procedures mean that clean gloves must be applied after any contact with the patient, and before working with the giving set in the tray. This adds to the task steps for setting up a new line. As described in the Physical model, there may be issues discovered on entry to the room, such as a missing pump or a patient requirement, which will interrupt the interaction.

Pump interactions observed suggest that sequences vary greatly from one instance to the next. There are several reasons for an interaction to take place. These include: setting up a new line to an unconnected patient; flushing a current infusion; connecting the next drug to a flushed line; finishing the remainder of an infusion; adjusting flow to slower or faster rate; stopping a pump to allow a pause to take blood samples; finishing and taking down lines. For all these, each nurse may have a different preference for a sequence of actions and entering of parameters.

A common task is to set the same fluid bag up for a slow flush and then increase the rate over a time, which means nurses will return to a pump periodically to change settings. A nurse commented that “I wouldn’t need to go back if I could set it for more than one programme.” They either have to remember to go back, or rely on the pump alarm (and the patient) to prompt them. Over time, if their return is delayed, each incremental increase in rate can add up to a significant overall delay.

Strategy for setting parameters depends on the reason for the interaction, as well as factors such as the type of substance being infused (e.g. saline, drug or blood), and the presence or absence of a drop sensor. When a drop sensor is absent, VTBI will be set. Disturbances in administering infusions can include: blocked entry ports to patient; lack of, or faulty equipment; patient sickness or reaction to drugs; changes in doctor decisions; breakdown of communication flow between pump and nurse.

Interleaving of pump interactions
Where more than one pump was being used, I observed some interleaving of interaction steps. For example one nurse alternated in opening two pumps, inserting lines and entering parameters to each and starting the pumps together at the end:

**Interleaved action sequence:**
- Connects pre-primed line to patient.
- Pump 1 open and insert line.
- Pump 2 open and insert line.
- Pump 1 left at ‘Rate set’ message screen.
- Pump 2 ‘Open clamp’ message on screen.
- Pump 2 Skips ‘Last Therapy’.
- Pump 1 Reminder alarm; Attaches drip sensor to line 1; Rate, same at 100ml/h
- Pump 2 Drip sensor attached
- Pump 2 Sets rate and VTBI for pump 2 (Rate 100ml/h)

When two pumps are being set up in this interleaved way the incidences of interruption by reminder alarms increases, since a pump will be left with its door open or without parameters set for more than the prescribed time.
**Nurse-nurse interactions**
Infusions are prepared in the treatment room, in advance of going to the patient room. During this preparation time, nurses interact with others for different reasons. They may leave a preparation part way through in order to help with another task, such as checking drugs.

If they change an infusion rate on a pump for a patient not assigned to them, they need to inform the responsible nurse. After making such a change one nurse went from room to room, to find and tell the other nurse, telling me “...I would need to remember if I was busy with other things.” This indicates a need to keep the information in mind, until they see the other nurse. If a nurse forgets, this is a breakdown in the information flow; currently they have no way to record their action and the pump does not represent the last changes made.

Other nurse to nurse interactions are described in the Information Flow and Social Structure models (see Appendix J for Social Structure model).

**Evolution model**
The BBraun pumps have been in use on these wards for around three years. As such they are an established element of the work domain. Only a few references are made to previous pumps, in relation to how the current pumps work.

Nurses reported the BBraun pumps to be “pretty simple” to use. Operation of pumps is learned through initial training and then as part of their work on the wards described to me as “learning on the job.” Qualified nurses only are allowed to operate pumps connected to patients. Student nurses are able to observe how pumps are used during their training on the ward (and training sessions).

During a device training session, nurses shared their procedures for using pumps and their different approaches to priming. Two of them showed the group their technique of expelling all air from fluid bags, by injecting extra liquid into them. In this arena, nurses from both ward teams were meeting and passing on expertise.

The following chapter will consider issues raised and the utility of these models.
Discussion
Within the cycle of 24-hour care, pumps are operated to deliver infusions, meeting a continuous schedule. An overall goal of keeping lines flowing to maintain this schedule has been identified.

The original interest of this study was to investigate the use of infusion pumps and what differences, if any, might exist between day and night work contexts. An overall assessment of the data would suggest that any differences are fairly trivial. The team is smaller at night, and there is less ward ‘traffic’. Night work requires nurses to perform their duties in lowered light conditions (sometimes using torches to help them see), when they are more likely to become fatigued. They work with the joint aims of letting patients sleep, while delivering prescribed medicines.

The pumps behind closed doors
Detection of pump alarms may be marginally more difficult at night, where the patient is relied on to alert the nurse. This issue can also apply to day contexts. While the patient is part of the communication loop between nurse and pump, the issue will remain. For this context, where patients and pumps are located in side rooms, the pump itself would need to operate the room call system, bypassing the patient action. ‘Staff call’ is a listed feature of the devices studied here; the ward infrastructure doesn’t support it, however (and it was not in the scope of this study to investigate how this could be made to work). Any adaptation would need to take into account that nurses are constantly mobile in this environment and not able to monitor a central (static) status display.

Alternative uses for pumps
Actual use of the devices diverges from manufacturer instructions. Nurses’ strategies for setting pumps to finish in advance of a complete infusion show a need for them to be reminded of infusion status, to save time in their overall cycle of activities. The cost in time, of returning to the pump to reset it for the remainder of the infusion or to change a flow rate, is high for this context, where nurses have to perform complex infection control procedures to enter a side room.

Distributed Cognition and DiCoT
The use of a distributed cognition perspective and the DiCoT framework has provided a structure and focus for data gathering and analysis. Building of models, based on DC principles, allowed me to generate descriptions and highlight salient points. I have been able to use DiCoT models flexibly, to suit my context of study. The Physical, Artefact, Information Flow and System Activity models have been helpful for analysing the infusion process. The Social Structure model contribution was limited due to my focus on the work of nurses only, and the shallow hierarchy and complexity of their goals. System Activity and Info Flow models allowed for discussion of social interactions. As advice for other investigators, I would suggest these models be approached as flexible guides to structure data and help with thinking in a pragmatic way.

Limitations of study
The descriptions in this paper may be applicable to other haematology settings; my data does not comment on this. The interaction sequences will differ somewhat for contexts where pump software and settings are different; this may vary between hospitals, wards and services. I have not recorded the software versions used here. This could be included in future investigations. This context has
evolved from previous service configurations and with its own culture, based on the demands of the service it gives to patients. However, adoption of widespread, modern clinical approaches may make the observations here relevant to wider contexts.

This study does not record the outcomes of different approaches to infusion set up. Therefore, I can’t comment on whether, for instance, hand priming or pump priming techniques have any consequences for the process later on. Attention would need to be given to a single pump and a cycle of infusions over time to record this data.

It is probable that my presence as an observer affected the behaviour of the participants (Kerr, 2002). Possibly, I caused more distraction than usual, although I tried to minimise this effect. How far nurses changed their behaviour is difficult to assess. It did not seem obvious that they were taking any more care than usual, or modifying their conversation, but I cannot verify this. I became aware that some nurses were concerned I was noting information they considered sensitive. To begin with I took notes of many things that have not informed the analysis directly, but my approach was to gather details, even if they seemed irrelevant, in order to assess if other data indicated they were important. It is to be expected that in such a safety conscious environment, participants feel uncomfortable at being watched. The charge nurses were supportive advocates of my research.

**Difficulties and self reflection**

Transcribing notes soon after sessions was difficult when I had several observations scheduled in succession, especially after night shifts, which were fairly draining. More time between sessions would perhaps have given space for transcribing and questioning data, so that new questions could guide subsequent observations. As it was, I did attempt to iterate my observations, paying attention more to pump interaction steps and to key artefacts, as I became more aware.

It was sometimes difficult to follow through with a whole sequence of preparation and infusion. I might find a nurse with a set tray ready prepared and follow them to a room straight away, missing the preparation. The nurses might divert from their intended activity and carry out a new task when the first was not possible (patient in the toilet, for example). This meant some of my notes are of incomplete sequences, having been interrupted between preparation and infusion. It might be a good approach to shadow a single nurse for a large part of their shift, in order to observe a complete pattern of activity.

Most nurses were happy for me to shadow their work, answering questions and offering information, and patients were consenting to my presence in their rooms. I had some negotiation to make on the night shift, where nurses were concerned about patients not being able to consent while sleeping. We worked out that I should be introduced to patients before they went to sleep, otherwise I wouldn’t enter their rooms.

The night shift was a tiring time to observe. I tried to conserve my energies by resting during quiet periods. Nevertheless, it was physically demanding to be awake and on my feet, when my body wanted to sleep.

The condition of patients did not overly disturb me, in that I had no knowledge of their prognoses. There were some people more obviously sick, and that was sobering to see. The nurses’ attitude is light-hearted and respectful towards patients, which lightens the atmosphere where patients are in
sad situations. At one handover meeting nurses found out that a patient had been “given days” to live; this saddened the whole room of people, including me. Nurses showed obvious compassion at hearing this news. The awareness of someone’s imminent death weighed on my thoughts for a while after that.

Future investigators might find it useful to have two phases of data gathering; one without knowledge of the correct device operation, followed by one with. Having no preconceptions of what I should be seeing allowed me to note pure observations and not jump to conclusions. On the other hand, prior knowledge of how the pumps work (and the manufacturer instructions) would help with noting the interaction steps in more accurate detail. Pump interactions were difficult to follow: it is hard to watch both the screen output as well as button pressing. Nurses program the pumps very rapidly and their hands often cover the interface as they operate it, so I was sometimes unclear of the exact action taken. I relied on what I could see on the screen, which became more familiar after a few observations. Video would be a useful way to record and review interactions, if ethical clearance permits.

The notes I took are largely interpretive of what I observed. I aimed to jot down accurate statements and events, but I necessarily had to be selective; I think I have captured the main point of what participants said and did. Being a novice in the healthcare domain was advantageous in that I viewed the actors and the environment with new eyes. This lack of domain knowledge is seen as an advantage by Blandford and Rugg (2002) (ref. Furniss & Blandford, 2006), where initial unfamiliarity helps with noticing of details. As my familiarity grew, my understanding allowed development of insights.

**Conclusion**

Using observation and interview methods, I have created an account of the normal work of specialist haematology nurses “in the wild” (Hutchins, 1995). These methods, along with a distributed cognition approach and DiCoT analysis, have allowed me to describe activities of the system and identify issues for attention. As an examination of a novel environment of use for digital infusion pumps, this study contributes to the understanding of contexts in which these devices are operated. Investigation of the work done around the clock has highlighted continuous use, over extended periods of time, as important considerations.

Where pumps are isolated in side rooms, nurses rely on patients to alert them to pump alarms. There is a need here for solutions to enable the pump to communicate directly with ward staff while they go about other duties. The aim should be to increase situation awareness of the infusion status, reducing the need to directly see or hear the device. Adoption of alternative uses highlights areas for the attention of device designers. Use of the pumps as reminders, among other alternatives, helps these nurses to maintain both the flow of infusions, and the cycle of care required by the patients.
References


Appendices

Appendix A – Example questions
Appendix B – Informed consent form and information sheet
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Appendix D – Transcribed notes extracts
Appendix E – Pump interaction analysis table extracts
Appendix F – Physical Model layouts
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  Ward A Negative pressure room level model
  Ward B Nurses’ Station physical model
  Hand sketched physical layouts
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Appendix H – Artefact Model extracts
Appendix I – System Activity model extracts
Appendix J - Social Structure and Goal Structure
Appendix A – Example questions

HANDOVERS

- What is the goal of shift handovers?
- When are handover sheets updated on computer? By who?
- Do they have their own notes/marks for HS, or a shared system?
- What happens to all the handover sheets – paper and electronic?

DOCUMENTS/INFO FLOW

- Whiteboards – what are main uses? Who are they for? (B has 3 boards, A only 2).
- What different kinds of information go into patient record and drug chart.
- Using chart as a reminder or catching up on record keeping?
- Where are drug charts kept after filled/end?
- Data on drug label – what is it? (prescription?) – who reads this?
- When they take obs levels, etc, how do they record/remember them and what do they do with that info?
- Patient record on PC (CDR). What data is taken from screen into patient folder?
- Do they put information into an electronic patient record? Who sees this?
- Does B have a ward diary? What is ward diary used for? Who maintains it?
- Does all patient information get collated in final place?
- What are PCs used for? By who?

EXPERTISE

- How does a nurse know what drugs to administer; dosage etc.?
- Do nurses make decisions about rate of dose? How do they make these decisions?
- What are you checking when you double check another’s drug set?
- Do you have a system for preparing a set for infusion? Why do you do it that way?
- Can you tell what treatment they are preparing, by looking at what another nurse has on the counter?
- If you see a fluid bag in a patient’s room (hanging or in a tray), what does that tell you? Do you do anything about it? Do you leave bags like this?
- Setting VTBI – nurses minus some priming vol. and sometimes a bit for leeway – what is that for? How do they work this out? Why do they do this?
- How do they know the priming volume of a line?
- Do you need to deal with infusions other nurses have put up?
- How do you distinguish between different lines connected to the pumps? Positioning or colour coding?
- Do you use stickers to mark different things?
- Do you have an idea of what a call is about before you go into the patient room? Do you do anything to prepare when going in?

PUMP BUSINESS

- Does air in line get detected by the pump? What sort of air is that (big or small bubbles...)?
- 45 -

- When pump detects air what do they do?
- When pump detects high pressure, what does that mean? And what do they do?
- How do they use ‘line selection’ (Space Line/Neutrap)? What differences are there to the lines? How do you tell them apart? How are they used (chemo or not)?
- When do nurses use a drip sensor, or not? Reasons?
- Why would they use VTBI if not needed?
- What problems and fixes do they have with drop sensors?
- What do you do when the pump has flashing yellow light?
- If a pump goes wrong, what do they do?
- What will they do about ‘nearly empty’ battery?
- Do they know about the version of software and the settings on their pumps?
- Are patients shown how to unplug and allowed to walk about?
- Why do nurses accompany patients who leave the ward with pumps? Do they need to interact with pumps during these excursions?

WORK, SHIFTS

- How is night work different for them?
- What different schedules are there (shift rotation, etc.)
- Is worked planned in advance? How?
- How long are daily work schedules kept after the day
- How many nurses per patient/patients per nurse?
- Do nurses know at handover who they are assigned to?
- How do you decide on which nurse is assigned to which patient?
- Do nurses change patients regularly... “3 day rule”?
- What is the team structure – for each shift; and across the ward as a whole?

OBSERVATIONAL QUESTIONS

- Where are patient call relay screens?
- What bodily supports are used in infusion process?
- Can you see/hear pump status from outside rooms?
Appendix B – Informed consent form and information sheet

Informed Consent Form for Participants

Title of Project: Understanding the usage of interactive medical devices, through night and day work, from a distributed cognition perspective

This study has been approved by the UCL Research Ethics Committee; Project ID Number: MSc/1011/019

(This form is to be completed independently by the participant after reading the Information Sheet and/or having listened to an explanation about the research.)

Participant’s Statement

I ........................................................................ agree that I have

• read the information sheet and/or the project has been explained to me orally;
• had the opportunity to ask questions and discuss the study;
• received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.

I understand that my participation may be audio recorded and I am aware of and consent to, any use you intend to make of the recordings after the end of the project.

I understand that I am free to withdraw from the study without penalty if I so wish and I consent to the processing of my personal information for the purposes of this study only and that it will not be used for any other purpose.

I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed: Date: July 2011

Investigator’s Statement

I, Frances Gant, confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signed: Date: July 2011
Information Sheet for Participants

Title of Project:
Understanding the usage of interactive medical devices, through night and day work, from a distributed cognition perspective

This study has been approved by the UCL Research Ethics Committee Project ID Number: MSc/1011/019

Name, Address and Contact Details of Investigators:
Frances Gant
100 Kimberley Avenue, London, SE15 3XH
f.gant@ucl.ac.uk

You will be given this information sheet to keep.

You are invited to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way.

Before you decide whether you want to take part, it is important for you to read the following information carefully and discuss it with others if you wish.

Ask if there is anything that is not clear or you would like more information.

This study is aimed at understanding the difficulties that health practitioners face when using interactive medical devices.

Particularly looking at infusion pumps, and the practical workarounds developed to overcome difficulties.

The results of the study will help inform the design of future devices so that they are better suited for the context in which they are used.

You can choose whether to take part or not.
It is up to you to decide whether or not to take part. If you choose not to participate it will involve no penalty or loss of benefits to which you are otherwise entitled.

You can stop it at anytime, without giving a reason.
If you decide to take part you are still free to withdraw at any time and without giving a reason.

Data will be kept safe.
All data will be collected and stored in accordance with the Data Protection Act 1998.

You will be observed using the devices and interviewed afterwards (if time).
The interview will depend on the free time you have available and can be cancelled at any time.
If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form.

Thanks
Appendix C – Hand notes samples

Samples of fieldnote jottings from two separate observation sessions (top and bottom).
Appendix D – Transcribed notes extracts

Highlighted segments indicate grounded theory coding. Pump interactions are picked out in bold red.

Extract 1

08:25
New shift team at station WB. They erase yesterday’s early shift names and write in their own next to patients... Three for each qualified nurse. N36 goes first - “I’ll take...”

Share out patients between them [T: Q: possibly on a ‘willing to’ and ‘preference’ basis?].

O: they collect up drug charts for their patients and get drugs (oral and syringe) together.

08:50
Doc arrives for ward rounds with N16 (from my first obs – a lead nurse – who is doing a management day).

Breakfast being served.

PT & OT on ward.

Bed 24 N31

3x pumps

1 and 2 alarming

Nurse stops them.

Takes down bag on pump 2 – traces line to it.

Pump 1 – sets VTBI, Rate stays same.

Pump 2 – sets VTBI 100ml, Rate same.

N31 tells SN5 they need to go back in 30 mins & she must check what he needs to do before then.

Bed 24 – no optical sensors. 2x chargers.

Bed 39

3x pumps. 2x chargers, in pumps 2 & 3. Low battery on pump 1.

Pump 3 is syringe driver on 1ml/h

Pump 2 VTBI finished

Rate changed to 20ml/h

I: N31 – could see “there’s only 20ml or so left, set it to run until I can find what drugs to put up...”

09:30

O: Pump on reception desk, waiting for pick up by medical physics for repair. Label: “Pump keeps on bleeping and zeroed itself on several occasions.”

09:35

In drug room. (Radio on.)

N32, N31 (+2)

Trays cleaned & prepped to start.

4x nurses prepping at one time.

5x trays on counter.

N32 chats to chemonurse as she prepares her syringes. N32 cleans second tray and takes one out.

O: Ns have diff. colour necklines (find out these are sizes).

Bed 39 N31

Stops setting up pump to explain how paracetemol affects infected patients to SN5.

Pump 2

Hangs drug (antacid)

100ml bag

Rate set 420ml/h

VTBI 100ml

No drip sensor.

I: Q: How did he know what rate to put in?

A: He just ‘knew’... “actually I didn’t even think... when I put in the VTBI I could see the time it would take & I knew it could be faster (doesn’t need to be precise for that drug). I just changed the VTBI
(fg: note – may be wrong notation – may = rate) until it said around 15 mins. Or I could have set the time and it works out the VTBI. That’s quite a good feature of that pump.

**Extract 2**

04:40
O: N9 adds notes to WB in drug room – a note to [name] about handover sheet file [photo]
O: N7 is in bed 8 – pump line must be blocked again – she’s explaining to patient that line gets blocked because cannula is in a funny place”.
04:46 (daylight increasing)
04:50
Bed 8 pump alarming. N7 taking meds into her; restarts pump – it stopped because blocked by bent arm.
05:10
Bed 8 pump alarming.
O: N9 in drug room, prepping infusions “got to get a few in”.
N9 writes on drug label – sticks on bag 1; needle onto syringe; bag 1 adds drug; bag 2 drug label.
For bed 5; Finds N7 (in break room) to check her drugs.
05:20 N9
**Bed 5 Antibiotics.** Preprimed bag attached to patient. Pump 2 sets the rate, resets data. 2nd bag hung for later.
**Pump 1 resets data – remains on previous rate 83ml/h.**
**Pump 2 is on 100ml/h.**
I: Data is reset for fluids over next 24 hours.
Q: how do they know what time the 24 hours started?
Pump 2 message still ‘battery nearly empty’.
**Patient’s temperature tab checked using torch.** Blinds are down. But lighter than before.
05:25
O: drug room – N9 preps new set; primes line; checks drugs and initials drug chart.
N7 collects all bits in tray. Assembles set...
O: Bed 2 – Has no pumps; N9 gets one out of Bed 3 – stand with 2 pumps, one lead. Wipes down with cleaning cloth – whole thing top to bottom.
N9 shows me the new “high risk category” sticker on top of pump.
<table>
<thead>
<tr>
<th>GOOD SEQUENCE</th>
<th>pump sequence</th>
<th>difficulty or notes</th>
<th>bed</th>
<th>nurse</th>
<th>time</th>
<th>ward</th>
<th>date</th>
<th>RATE 1st or 2nd</th>
<th>VTBI 1st or 2nd</th>
<th>TIME 1st or 2nd</th>
<th>PRIME with</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD SEQUENCE</td>
<td>Connects pre-primed line to patient. Pum 1 open and insert line. Pum 2 open and insert line. Pum 1 at rate set message screen. Pum 2 open clamp message on screen. Pum 2 Skip 'Last Therapy'. Pum 1 Reminder alarm Attracts drip sensor to line 1 Rate, same at 100ml/h Pum 2 drip sensor attached Pum 2 Sets rate and VTBI for pump 2 (Rate 100ml/h)</td>
<td>Alarm on pump 2 – &quot;doesn't like flow&quot; – &quot;give a squeeze to drip chamber&quot;. Both pumps running, green lights.</td>
<td>5</td>
<td>N9</td>
<td>21:10</td>
<td>WARD A</td>
<td>13-Jul</td>
<td>1</td>
<td>2</td>
<td>2 optcs</td>
<td>HAND</td>
</tr>
<tr>
<td>GOOD SEQUENCE</td>
<td>Pump is flashing red with ‘open door’ message. Drip sensor is on. Pre-primed line inserted to pump. Rate set at 83 ml/h; VTBI for 900-something ml – less priming volume and “a bit of leeway as well”</td>
<td></td>
<td>8</td>
<td>N7</td>
<td>01:30</td>
<td>WARD A</td>
<td>13-Jul</td>
<td>1</td>
<td>2</td>
<td>HAND</td>
<td></td>
</tr>
<tr>
<td>GOOD SEQUENCE</td>
<td>Both pumps have stopped. Pump 2 message &quot;battery nearly empty&quot;. Both pumps set at rate of 10ml/h. Reminder alarms go off and she stops them. Pum 1 sets VTBI and time (not noted) (Pum 2 VTBI 11:29, time 1:08 - perhaps this note of what pump is showing.) Reminder alarms go off and she stops them again. Pum 1 - Changes bag Sets VTBI at same. Pum 2 – no sensor, so no VTBI set. Pum 2 Rate set to 10ml/h</td>
<td></td>
<td>5</td>
<td>N9</td>
<td>02:20</td>
<td>WARD A</td>
<td>13-Jul</td>
<td>1</td>
<td>2</td>
<td>3 optic</td>
<td></td>
</tr>
<tr>
<td>CHEMO NURSE WITH PUMP 2</td>
<td>Pump 1 running at 140ml/h (Potassium). Pump 2 turned on, insert line R-L. Gets a phone call and silences it in back pocket. Primers line 16ml, with 100ml saline bag. Leave on clip. Fixes cytotoxic tape below drip chamber. Pump 2 Reminder alarm, left to beep. Chemo nurse takes blood samples. VTBI 19.95ml Rate 20ml/h. Pump 'interm' isn't at zero.</td>
<td>Chemo is delayed by doc, because patient might need antibiotics.</td>
<td>2</td>
<td>Chemo Nurse</td>
<td>09:30</td>
<td>WARD A</td>
<td>18-Jul</td>
<td>2</td>
<td>1</td>
<td>pump</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix E - Pump interaction analysis table extracts

| WARD  | NURSE | PUMP 1 line change inserts line R-L, closes door. Fits optic sensor onto chamber. Prime line: Y “should make it bubble free” Helps position patient’s pillow. PT has been talking to her. N13 explains drug to patient. Replaces it on line. (fg? Did she prime with saline first?) - not priming again... Rate 140ml/h VTBI 50ml Over 30 mins – I know these numbers, after so many years & “the pump backs up my maths.” |
|-------|-------|-------------------------------------------------|-----------------|---|---|---|---|---|---|---|
|       |       | "I always prime with the pump. Some lines are longer and so need to add a bit extra VTBI."
|       |       | **PROBLEM** Pump 1. Sets VTBI 50ml, Rate 250ml/h (Time says 10 mins). Optical sensor is attached. Returns to pump and resets the VTBI at 980ml |
|       |       | I ask her if that is only for 10 minutes. Nurse returns to pump and resets the VTBI at 980ml. O: Looks like she put in the wrong VTBI to begin with. |
|       |       | **PROBLEM** Pump 2 is syringe driver on 1ml/h Pump 2 VTBI finished Rate changed to 20ml/h |
|       |       | Nurse could see “there’s only 20ml or so left, set it to run until I can find what drugs to put up...” |
|       |       | **PROBLEM** Pump 2 Hangs drug (antacid), 100ml bag Rate set 420ml/h VTBI 100ml |
|       |       | Q: How did he know what rate to put in? A: He just 'knew'... “actually I didn’t even think... when I put in the VTBI I could see the time it would take & I knew it could be faster (doesn’t need to be precise for that drug). I just changed the [VTBI] until it said around 15 mins. Or I could have set the time and it works out the VTBI. That’s quite a good feature of that pump.” |

Frances Gant 2011
### Original task was to flush and disconnect patient from pumps.

3x pumps. Stops all pumps – because he realises he’s “taking bloods in 5 mins” (needs patient off infusions before doing that). No volume data – ‘not on fluid balance’. Takes lines out of pumps.

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:40</td>
<td>Original task</td>
<td>Closes the line clamps... “I’m not trusting the internal pump clamps.”</td>
</tr>
</tbody>
</table>

### Pump 2 changes flush. (Another nurse has put this up.)

Same rate – 420ml, VTBI 100ml ‘for this bag’ (new drug).

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:20</td>
<td>Pump 2</td>
<td>39 N31 10:20 WARD B 19-Jul same 1</td>
</tr>
</tbody>
</table>

### 1x syringe driver

2x pumps, both green light.

Pump 1 medium battery strength.

Pump 2 low battery – on mains charge. Syringe driver.

Hangs bag, saying “this is your…”

Pump 3

Inserts line R-L

Pump message: close clamp (already primed and closed).

Set VTBI 60ml

Set Rate 60ml/h

“It runs over an hour”

Open clamp on line & start.

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:30</td>
<td>Pump 3</td>
<td>27 N24 10:30 WARD B 19-Jul 2 1 hand</td>
</tr>
</tbody>
</table>
Appendix F – Physical Model layouts

Ward B rendered ward level model
Ward A Negative pressure room level model
This is one of the larger rooms on ward A. It represents a typical single-door room on both wards.

Ward B Nurses’ Station physical model

WARD B NURSES’ STATION
Hand sketched physical layouts

Nurses stations
Ward B top; Ward A bottom. Ward B nursing notes folders are kept on cabinets across the corridor from main desk area. The Allocation whiteboard for Ward B is located on the pillar here.
Treatment rooms (originally noted as ‘drugs room’): Ward A top; Ward B bottom. All supplies are at hand for working at bench. Allocation/‘To do’ and nurse admin whiteboards in A; ‘To do’ whiteboard in B. Cupboards are mounted on the walls and supplies containers and fridges are located under work benches.
Appendix G – Physical Model extracts

Nurses’ stations
The nurses’ stations are open areas, cut out at corners on the wards. They consist of an L-shaped desk containing up to 3 networked computer terminals and phones and a printer/scanner; chairs to sit at the desk; cupboards with administrative supplies, files, manuals, books. There are also medical devices located here, such as glucose meters and tablet scanners (not in scope of study). This is where the resuscitation carts are kept and the ‘pod’ transport (PTS) terminals are located.

The Ward B allocation whiteboard is located on the side of the pillar at the nurses’ station, making it accessible to anyone in the corridor at that point. Their nurse admin board is on the corridor wall nearby.

Cabinets arranged around the corner pillar in Ward A are used as a surface to stand nursing notes folders, and for storage of filing and form supplies. Ward B has these cabinets arranged on the other side of the corridor, extending the admin area. Nurses update their notes at the desks; when desks are fully occupied on Ward B, nurses work on filing cabinets and trolleys on the other side of the corridor.

The nurses’ station is a shared space, used by all clinicians at all times. The label “Nurses’ Station” is really a historical misnomer, since doctors and pharmacists access patient records and test results alongside nurses. (But it hints at a notion that the ward is really the territory of nurses, who spend the most time here.) There is discussion of patient condition and treatment at the stations; clinicians verbally pass information between themselves, taken from the screens and paper records.

Treatment rooms
These are central to the wards. However, in Ward B the treatment room is located between the last two thirds of the rooms. (The catering room takes up one section of this ward.) Nurses need frequent access to the treatment rooms, to prepare infusions. The rooms on both wards are fitted with combination locks. These are generally not set to lock, since activity is so frequent in these rooms.

All supplies needed for infusion preparation are arranged at hand in the treatment room. (With the exception of more dangerous chemicals, such as potassium chloride and insulin, which are kept in a separate locked store on Ward A and a separate drawer on Ward B). Nurses are familiar with the locations of supplies, so that their assembly of equipment and medicine becomes fast and fluid.

On Ward A, the allocation and nurse administration whiteboards are both on the treatment room wall. Clinicians and official ward visitors will need to enter, or look into the room, for information from these boards. Ward A allocation board is also used for ‘to do notes’. On Ward B, a ‘to do’ board is the only whiteboard in the treatment room. This whiteboard is used mainly when there is a large workload to keep track of. In the Ward B’s previous location, the treatment room was larger and the board more prominent. It is now more hidden by its position and so less used (see Artefact model for more details of whiteboard use).

Normally there might be 3 or 4 nurses working in the treatment rooms, at times this number increases significantly. During one day shift there were 8 people in the Ward B treatment room at
one time. This amount of activity and crowding makes for a challenging environment to concentrate on infusion preparations.

To protect the nurses from distraction, signs on the treatment room doors instruct delivery personnel not to interrupt nurses while they are preparing drugs. Nurses are able to hold conversations while carrying out preparations. But for safety and drug security reasons, they should not leave medicines unattended.

Appendix H – Artefact Model extracts

Personal notes
Nursing notes folders and drug charts are not taken into rooms as infection control. Nurses therefore have to find ways to retain or record observation data (heart rate, blood pressure, temperature, etc) until they can enter these into the nursing notes, back at the nurses’ station. They were seen using different papers from pockets, potsit notes, and paper towels at hand to note the stats. The transfer of information is sometimes delayed by other activities. I observed one nurse writing up details of three separate patients at once. Her personal system, using three paper towels, served the purpose well; she knew which patient was which, due to differences in her notes.

Nursing and medical notes
Information about all that happens daily to a patient, their treatment, condition, tests and results, goes into the nursing notes. These are kept centrally at the nursing stations. They are there for quick and easy reference on the patient by all clinicians. On discharge, these notes are combined into the patient medical notes, which the doctors have been maintaining on their ward rounds.

Ward diary
I noticed the ward diary on Ward A; the charge nurse described it as a daily record of ward round decisions, nurse-patient allocations, and a notification of planned events. It is a record of activity, but it was mainly completed during day shifts and not at night; so it is incomplete. The Ward A charge nurse will review the diary in the case of any incidents. An interview indicates that the ward diary for Ward B is used for staffing. To show who is scheduled to work, who is on duty or off sick. It contains no information of ward events. They use their archived files of the handover sheet for this.

Appendix I – System Activity Model extracts
Points 1 and 2 (Infusion administration and Nurse-nurse interactions) are contained in the Analysis chapter.

Patient monitoring and total care
In the patient room, nurses carry out patient monitoring tasks, as well as administer infusions. I noted a qualified nurse telling a student about the importance of not getting distracted by the patient when setting up infusions. Taking clinical observations, such as heart rate and temperature, is done at least four times daily; more, if the patient is sick. Other monitoring includes fluid balance
and nutrition. A nurse will communicate with the catering operative to arrange the right food for their patient.

Haematology nurses work in a culture of ‘caring for the whole patient’. This top to bottom care involves all tasks, from clinical administrations to personal care. Prolonged care enables nurses to develop a “global assessment” of the patient.

**Equipment movement and provision**

I was told by multiple participants that there are “never enough” pumps. Power leads and drop sensors are also in short supply, being often damaged by disconnection and reconnection. Low battery warnings were observed frequently, but shortage of equipment means they usually aren’t taken to the charging stations, or put into maintenance mode. Pumps and connectors are moved from room to room as needed.

**Cleaning & maintenance**

Malfunctioning pumps are sent away for repair. I saw a pump on the ward reception desk, waiting for pick up by medical physics. An attached label recorded the ward of origin and the problem: “*Pump keeps on beeping and zeroed itself on several occasions.*” The charge nurse informed me that they have no way of fixing pumps themselves, so send them away quickly when they go wrong.

Ward cleaners are on duty daily, to empty bins and clean floors. The housekeepers clean all surfaces daily. Deep cleaning happens when a room is empty, in preparation of the next patient. Nurses work around these cleaners.

**Patient movement**

Patients may move around their rooms while attached to pumps, to visit the toilets or sit out of bed. Sometimes pumps are not plugged back into the electricity supply, depleting batteries further. If a patient is attached to a pump and needs to leave the ward for tests, a nurse needs to accompany them, and other nurses need to cover for their absence. A patient may be moved from one room to another if they start or stop being infectious to others. The negative or positive pressure of the rooms is not adjustable. When patients are moved, the pumps used for them will also move rooms. I was told that infectious patients may have to move to other wards if a negative pressure room is not available. Pumps therefore will leave the ward at this point.

A charge nurse informed me: “*The extreme lack of pumps across the ward means that we would avoid as much as possible allowing any pump to leave the ward. Occasionally if the patient is very unwell we may have to transfer the patient with the pump, but would try to return with the pump once patient safe.*”

**Specialist consultation**

Doctors prescribe drugs on patient admittance, and will adjust prescriptions, such as pain killers, on prompting or request by nurses. Ward rounds by senior doctors look at the progress of patients with their treatment and can result in orders for new tests and changes to the treatment regimen. This means a prescription may change between the start of a shift and the end. Nurses make decisions on the rate of infusion, depending on needs of patients, within certain guidelines. Chemotherapy nurses, pharmacists and physical therapists are also part of the multidisciplinary team.
Appendix J - Social Structure and Goal Structure

The social structure is shallow and involves many shared goals for patient care. For the duration of their shift, nurses will have goals of caring for their own assigned patients, but share these with all other nurses on the shift. Buddy relationships facilitate and structure the sharing of goals for the teams. The social and goal structure can be represented as in Figure (i) and is described below.

Social Structure and Goal Structure Model

The Charge Nurse, as ward manager, has a goal (G) of coordinating patient care across the ward at all times. This involves drawing up shift schedules to include the right amount of staff, with the right level of expertise. The goal of coordinating the care across the shift (SG1) is shared between the ward manager and nurse in charge. SG1 is the shared goal of patient care between nurses on the shift and the nurse in charge. Responsibility for individual patient care is represented by goal SG11 (the nurse in charge also has their own subgoal at this level). SG2 is a goal, shared between the shift nurse and doctor, of providing the patient with the appropriate prescriptions. SG3 is shared between the nurse and student in relation to developing clinical skills. SG3 is related to patient care, in the sense that student nurses carry out care duties alongside qualified nurses. In practice, the goals are shared across a wide team and the relationships are web-like and less hierarchical.

Patients on the haematology wards are receiving treatment from doctors and pharmacists in four different clinical teams: Acute Haematology, Bone Marrow Transplant, Haemoglobinopathies and Anticoagulation teams. These make up the haematology service. Nurses are caring for patients across all teams.
The nursing team structure is based on a buddy system, where nurses support each other by looking after the other’s assigned patients if needed; Image (i) shows the whiteboard on Ward B, displaying buddy arrangements for current shift. If a nurse goes off the ward or takes a break, their buddies will know what to do for their patients, and will update the nurse about any events on their return. Ward A buddies are in pairs; in Ward B’s larger team they form buddy groups of 3-4. At handover on Ward B, one buddy will collect information about the others’ patients and take it to the main shift handover meeting. Ward A handover can involve all nurses on duty, due to smaller size of the team.

Student nurses will “come and go” at different times; they are allocated to a ward nurse and mentored by them. The process of passing on expertise to a student allows the qualified nurse to rehearse their technique through demonstration. In explaining issues with different drugs, for instance, a nurse will be able to reinforce their own practice. The student nurses are an extra cognitive resource for their mentor. Students support the work of ward nurses, by remembering what subsequent actions need to be taken with a patient. Ward nurses will ask for reminders, such as returning to a patient to change an infusion, or taking blood samples.

The nurse in charge allocates patients and leads the shift. They stay aware of what’s going on across the whole ward; and deal with problems, such as reallocating nurses if a patient becomes acutely sick. All nurses on the team will inform the coordinator of patient status. I observed interactions where nurses passed information verbally, from memory, about condition and treatment of
patients. The nurse in charge is chosen in advance by the ward manager (or charge nurse) when they draw up shift rotas. I was informed by a ward manager that the choice depends on many different factors. A junior nurse might be put in charge to practice their leadership skills; or, if there is an anticipated need for more expertise on a particular day, a more experienced nurse will be assigned.

Ward managers have an overall responsibility for patient care on the ward. They may also work on a shift, but not necessarily as the shift coordinator. There are also different bands of nurse seniority and a certain amount of expertise needs to be present for each shift. This allows for passing on of clinical expertise from senior to junior nurses. One nurse stated that he loves the teamwork of the ward, that everyone is helpful and this means they “learn from each other.”

Although individual nurses are assigned to take care of particular patients, the workload is shared between team members. Nurses continually support each other in tasks and activities, such as attending patient calls, taking over with flushes and removing completed infusion lines. They will communicate what actions they have taken, to keep the other nurses aware of a patient’s status. In one instance, a patient needed to be moved in their bed, which involved lifting them. The issue was discussed between the nurses and decided on the basis of whom amongst them was able to lift heavy weight at that time.