Ergonomics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/terg20

Work Domain Analysis for understanding medication safety in care homes in England: an exploratory study
Rosemary H.M. Lim\textsuperscript{a}, Janet E. Anderson\textsuperscript{b} & Peter W. Buckle\textsuperscript{c}
\textsuperscript{a} Reading School of Pharmacy, School of Chemistry, Food and Pharmacy, University of Reading, Reading, UK
\textsuperscript{b} Florence Nightingale School of Nursing and Midwifery, King's College London, London, UK
\textsuperscript{c} Royal College of Art, London, UK
Accepted author version posted online: 03 Jun 2015.

To cite this article: Rosemary H.M. Lim, Janet E. Anderson & Peter W. Buckle (2015): Work Domain Analysis for understanding medication safety in care homes in England: an exploratory study, Ergonomics, DOI: 10.1080/00140139.2015.1057542
To link to this article: http://dx.doi.org/10.1080/00140139.2015.1057542

Disclaimer: This is a version of an unedited manuscript that has been accepted for publication. As a service to authors and researchers we are providing this version of the accepted manuscript (AM). Copyediting, typesetting, and review of the resulting proof will be undertaken on this manuscript before final publication of the Version of Record (VoR). During production and pre-press, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal relate to this version also.

Please scroll down for article

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions
Work Domain Analysis for understanding medication safety in care homes in England: an exploratory study.

Rosemary H.M. Lim*, Janet E. Anderson b and Peter W. Buckle c

a Reading School of Pharmacy, School of Chemistry, Food and Pharmacy, University of Reading, Reading, UK.

b Florence Nightingale School of Nursing and Midwifery, King’s College London, London, UK.

c Royal College of Art, London, UK.

* Corresponding author. Email: r.h.m.lim@reading.ac.uk
Address: Room 1.05c, Food Biosciences Building, PO Box 226, Whiteknights, Reading, Berkshire RG6 6AP
Telephone: +44 118 378 8010
Work Domain Analysis for understanding medication safety in care homes in England: an exploratory study.

Abstract

Medication safety and errors are a major concern in care homes. In addition to the identification of incidents, there is a need for a comprehensive system description to avoid the danger of introducing interventions that have unintended consequences and are therefore unsustainable. The aim of the study was to explore the impact and uniqueness of Work Domain Analysis (WDA) to facilitate an in-depth understanding of medication safety problems within the care home system and identify the potential benefits of WDA to design safety interventions to improve medication safety. A comprehensive, systematic and contextual overview of the care home medication system was developed for the first time. The novel use of the Abstraction Hierarchy (AH) to analyse medication errors revealed the value of the AH to guide a comprehensive analysis of errors and generate system improvement recommendations that took into account the contextual information of the wider system.

Keywords: care homes, nursing homes, human factors, medication safety, patient safety, work domain analysis

Practitioner summary

It is widely acknowledged that a systems approach is necessary to improve medication safety. This study used a cognitive engineering method, Work Domain Analysis, to map the care home medication system and analyse medication errors. A macro-level view of the system was developed and this has provided a knowledge base for future interventions.
1 Introduction

There are few studies investigating medication safety in care homes for older people in England (Furniss et al. 2000; Fahey et al. 2003; Zermansky et al. 2006; Alldred et al. 2007; Lunn et al. 2007; Barber et al. 2009) and even fewer that used a systems approach to understand the problem (Barber et al. 2009). This is surprising considering residents over 65 in care homes are a vulnerable population at risk of adverse events. There were 462,910 care home beds in England at the end of March 2013 (CQC 2013) and this figure is set to rise as life expectancy increases. Safe treatment of this population is complex and challenging: they are usually prescribed multiple medications, experience age-related pharmacokinetic and pharmacodynamic changes, and may have some form of cognitive and/or physical impairment. The paucity of systematic studies of care home medication safety that adopt a holistic systems approach to identifying problems and solutions could be a factor that has impeded progress in this area. A systems approach considers the interactions between the human (e.g. psychological, physical, social, etc) and their environment, the type of tasks performed (e.g. physical, informational, social), and is about contextualising a problem or solution within this knowledge base (Carayon 2006; Dul et al. 2012).

Medication safety and errors are a major concern in care homes. A study of 256 residents conducted across 55 English care homes (Barber et al. 2009) [Care Home Use of Medication Study (CHUMS)] found a high rate of medication errors; 69.5% of care home residents reviewed experienced at least one type of medication error (prescribing, dispensing, administration and/or monitoring). Factors contributing to these errors included lack of co-ordination between healthcare settings, lack of information, inaccurate information in records, high workload, lack of medicines training and dependency on verbal communication (Barber et al. 2009). These findings carry substantial implications for safety in care homes and highlight many systems failures.

Although the CHUMS study (Barber et al. 2009) identified systems factors that contributed to care home errors using well established tools for analysing errors (Taylor-Adams and Vincent 2004) (The London Protocol), we propose that this may not be sufficient for designing interventions. A crucial part in the analysis of errors using The London Protocol involves the use of a Framework of Contributory Factors. This framework contains a context-free list of error contributory conditions from which the analysis of errors (together with a description of the clinical context and the errors
identified) are based. The output of the analysis is the identification of error contributory factors and recommendations for mitigating errors are developed based on these factors. However, this approach to developing recommendations does not take into account the inter-relationship among error contributory factors and the effect that any new interventions may have on the current system. Hence, it would be difficult to relate resultant system recommendations to the wider context of the system being studied (Lim, Anderson and Buckle 2008).

We contend that a comprehensive understanding of the whole system, not only the parts of the system within which medication errors had occurred could provide a framework from which error contributory factors and the proposed interventions can be analysed, reviewed and tested before being implemented in practice. Contextualising error contributory factors within a wider understanding of both ‘what the system is’ and ‘how it operates’ can avoid the danger of introducing interventions that have unintended consequences and are therefore unsustainable. A whole system approach is needed, which involves methodically mapping the various structural and functional elements of the system. These include organisations involved in providing medication, organisational functional divisions, the allocation of tasks and responsibilities within those divisions, the processes and tools used to achieve outcomes, and how outcomes are defined and measured (Ramo 1973; Chapanis 1996; Vicente 1999). Central to this is an understanding of how system components interact. The need is for a comprehensive system description in addition to the analysis of incidents and the identification of problematic system factors.

In this study, we conducted a Work Domain Analysis in order to develop a map of the care home medication system to facilitate deeper understanding of the system. The aim of the study was to explore the impact and uniqueness of the map to facilitate an in-depth understanding of medication safety problems within the care home system and identify the potential benefits of work domain analysis to design safety interventions to improve medication safety.

**Work Domain Analysis (WDA)**

WDA is the first of five phases of analysis in Cognitive Work Analysis (CWA). CWA (Vicente 1999) is a suite of tools for analysing and modelling complex systems. The CWA method enables an understanding of the constraints of a work system (which defines its boundaries or limitations). Constraints are the boundary conditions within which work must be achieved. By analysing these constraints, we gain insight into the factors that
enable or hinder safe work practices (Vicente 1999). WDA, the phase of analysis used in this study, analyses the purpose and structure of the work system. Subsequent phases of CWA analyses the tasks that need to be performed (Control task analysis), the ways in which tasks can be performed (Strategies analysis), how tasks are organised among workers and automations (Social organisation and cooperation analysis) and the competencies of workers required to perform tasks (Worker competencies analysis).

Initially developed in the cognitive engineering discipline and widely used in high-risk industries (e.g. aviation (Naikar and Sanderson 2001, Kilgore et al. 2008), naval (Bisantz et al. 2003), military command and control (Jenks et al. 2008), road transport (Salmon et al. 2007; Cornelissen et al. 2013), the application of CWA in healthcare is only developing. Jiancaro, Jamieson and Mihailidis (2014) noted that although CWA has been applied in healthcare for about 20 years, there is little known about its effectiveness or future research needs and concluded that the greatest contribution to date may be the capacity of the methodology to enable fuller understanding into the “deep structures” of a system being analysed.

Most healthcare applications of the method have focused on the development of interfaces and computer systems, especially in intensive care (e.g. Effken et al. 2001, Miller 2004, Sharp and Helmicki 1998). Other applications include the development of decision support tools (Hajdukiewicz et al. 2001; Effken et al. 2011), understanding of contributors to inpatient falls (Lopez et al. 2010), inpatient medication management system (Pingenot et al. 2009) and team working (Ashoori et al. 2014).

2 Method
The methods used in this study are presented in two parts; the first section describes the development of a map of the care home medication system and the second details the method used to analyse medication errors.

2.1 Developing a map of the care home medication system
2.1.1 Setting
Seven care homes in East Anglia, England with between 27 to 55 residents in each were recruited. These care homes provided nursing care for residents who were either over 65 years of age, had a terminal illness or had a mental disorder, excluding learning disability or dementia. Residents were recipients of services from the general practice, hospital,
community pharmacy and community nursing team. Ethical approval was gained from the appropriate ethical review committee and participants gave informed consent.

2.1.2 Data sources

General contextual information

Data were collected from all seven care homes.

1. Profiles of care homes

Background information about the structure and processes in the care homes were collected and included the type of care provided, the size of the care home, staffing levels, staff credentials and relevant training received, healthcare practitioners involved in residents’ care, processes relating to medication provision and descriptive information about the care home’s relationships with relevant healthcare practitioners.

2. General observations

The period of observation typically lasted two full working days (up to 16 hours) for each care home during which the analyst observed the general layout of the care home including the general atmosphere, lighting, temperature and noise levels, residents’ mood in general and how they interacted with staff members, staff’s attitude towards residents, relatives and visitors, team working, time pressures, management and staff communication, and how documents such as patient care records were kept in terms of clarity and completeness. Data were collected using a previously piloted field notes template and informal interviews with willing staff members to assess their attitudes of working in the care home medication system.

3. Structured, focused observations

Two medication administration rounds per home were observed. Each medication administration round lasted between 2-3 hours. The analyst assessed how the medication administration round was organised, the atmosphere (e.g. calm, busy, noisy) during the round, the nature, frequency and length of interruption(s), the drug trolley (how medication was organised and dispensed prior to administering to residents) and the medication administration record (MAR) (details on the MAR for example the accuracy of medication details and accuracy of documentation following medication administration).
Detailed contextual information

Detailed information relating to the functioning of care homes was collected from one 27-bed care home. This care home provided personal and nursing care to older patients (> 65 years old) with a range of health issues including mental health issues. The size, type of care provided and resident profile is typical of care homes in England.

1. Documents relating to the overall functioning of the care home were identified by an analyst (RL) and the care home manager. These included the care home information leaflet, care home introduction document, staff policies and procedures manual, and the Commission for Social Care Inspection (CSCI) report (Note: The CSCI is now the Care Quality Commission).

2. A semi-structured interview with the care home manager lasting approximately 1.5 hours was conducted to explore the general functioning of this care home including the challenges faced.

2.1.3 Analysis

The care home medication system was defined as the interdependent network of functions and processes involved in managing residents’ medication needs. It included functions that occurred outside the physical boundary of the care home, such as those carried out by GPs and pharmacists, because they affect how the care home medication system functions. Social care, although closely linked to how care homes function, was excluded from the analysis because the focus of the study was on the medication system.

We used the AH as our modelling tool. The AH represents five distinct conceptual levels: the functional purpose of the system, the values that determine whether the system is fulfilling its purpose, the main functions that the system should fulfil, the functions afforded by physical objects, and the physical and technological devices that are used. The hierarchy is populated with nodes at each of these five levels and the levels are linked to show the means-ends relationships. Nodes at one level provide the means for achieving the ends of the level below it.

The development of the AH was an iterative process. Documents, observation notes and interview transcripts were entered into NVivo7, a widely used and readily available software package for the management and analysis of qualitative data. Textual
data were coded according to the framework of the AH. A thematic analysis was conducted by a single analyst (RL). A first draft of the AH was developed and graphically represented using the CWA tool (Jenkins et al. 2007), a software tool specifically designed to support the analytic process of CWA and represent the outputs. Data sources were then revisited to check for information that might disconfirm the draft AH. A second draft of the AH was then developed by two analysts working together (RL and JA). To produce the second draft, the content of the AH was reviewed for its relevance, meaning and clarity over three separate sessions totalling about eight hours. A glossary of the contents in the AH was developed to explain its meanings.

Validation
The AH was validated (content validity) with five subject matter experts (SMEs). They were healthcare staff who worked in or with care homes and had expert knowledge of the medication system (see Table 1). Semi structured interviews were conducted with the SMEs. Three were interviewed individually and two took part in a joint interview. A copy of the AH and the glossary were provided to them. The researcher introduced the study, gave an overview of the analysis, and, using the AH and glossary, gave a full explanation of the model, the terms used in it and the relationships it portrayed. The SMEs were then asked their opinion of the relevance of each function at each abstraction level, whether there were functions that were missing, and the accuracy of the means-ends links. Based on the recommendations of the SMEs the AH was revised. A final version was then produced.

Insert Table 1

2.2 Analysis of medication errors

2.2.1 Tools
The AH of the care home medication system developed in this study (Figure 1) and case summaries of medication errors (n=9) were used. These errors were identified in the seven care homes reported in section 2.1. Methods to identify medication errors are reported in Barber et al. (2009, 342), (the medication errors identified formed part of the results presented in the paper). To identify medication administration errors (the type of errors reported in this study), the analyst (RL) observed two medication administration rounds per
resident. RL used a data collection tool that consisted of a list of medications that the resident was prescribed, and matched it to the actions of the staff administering medicines, to identify whether a medication administration error had occurred. Error case summaries were produced by the analyst (RL) and involved developing a narrative of each error case using interview transcripts, field notes from observations, medical records, care home profiles and medication reviews specific to each case.

2.2.2 Procedures

Each medication error was analysed following four steps.

Step 1: Referring to the AH, work categories at the purpose-related functions (PRF) abstraction level were listed. We decided to start the analysis at this abstraction level because medication errors were identified and classified according to stages of care (such as prescribing, monitoring of medication, dispensing and medication administration) and this corresponded to the conceptual representation of work categories at the PRF level.

Step 2: Error case summaries were analysed to identify which (if any) of the work categories listed were implicated in the errors. These were documented.

Step 3: We then referred back to the AH to identify work categories at the abstraction level below, object-related processes (ORP), that were means-ends linked to those identified in Step 2. We targeted this level because the means-ends links revealed “how” errors could have occurred. For example, “medication administration” identified in Step 2 was linked to “communicate” and “record-keeping” at the ORP level below suggesting a potential contribution to the medication administration error. A list of work categories linked to those identified in Step 2 was made.

Step 4: We revisited error case summaries to identify which (if any) of the work categories listed in Step 3 were implicated in the errors and documented these.

Finally, a set of recommendations to improve safety in the care home medication system was developed using a systematic approach. For each error analysed, a set of recommendations was made corresponding to the work categories relevant to that error, as identified in Step 4. Then, recommendations developed for individual errors were collated.
and further analysed by identifying common themes before producing high-level recommendations.

3 Results

3.1 AH of the care home medication system

Figure 1 shows the AH of the care home medication system.

As shown in Figure 1, the overall purpose of the system is to provide health care to residents. The provision of healthcare is externally constrained by the requirements of laws and regulations, guidelines, policies and procedures and this was represented as a purpose of the work system because it guides all activities within the system.

At the “values and priority measures” level, the criteria for measuring how well the work system fulfils its functional purposes, are described. Potential conflicts within the organisation may occur. For example the care home may want to optimise currently available finances by employing minimum levels of care home staff, purchasing the cheaper but not necessarily quality piece of equipment or cut down on investments in staff training. By doing so, the trade-off could be a compromise in staff and resident safety, thereby reducing the quality of healthcare provision. Similarly, focusing the care home’s resources solely on maximising the quality and safety of residents and staff may not meet the financial priorities of the care home. The care home management has to balance different pressing priorities when making organisational and operational decisions.

Four work components were identified at the purpose-related functions level: “medical diagnosis”, “treatment prescribing”, “medication supply” and “medication administration” and they represented the main functions that need to be co-ordinated and fulfilled in the work system. It is unlikely that these work components can be performed solely within the care home. For example, making a medical diagnosis and prescribing treatment would sometimes require residents to be admitted to the hospital or to make a visit to their general practitioner because the facilities (such as the medical or surgical team, equipment) may not be available within the care home. With regards to the supply and administration of medication, the care home usually co-ordinates care with other healthcare professionals. For example a district nurse may attend the care home to administer specific medication such as injections, to residents. Supplies of medication are ordered directly from the GP or via the community pharmacy and collected or delivered
by the community pharmacy or the dispensing GP. These examples highlight the importance and challenge of organising and co-ordinating different healthcare staff and the resident, to ensure that information is communicated accurately and promptly between staff with different roles and disciplinary backgrounds to accomplish any of these functions safely and in time.

The next level is “object-related processes” and work components here represent the capabilities and limitations of the physical objects available in the work system. Eleven work components were identified at this level of the AH and examples include “communicate”, “record-keeping”, “medication review”, “medication order”, “medicines dispensing” and “medication giving”. Fulfilling these work components would require input from other healthcare settings and practitioners. For example, medication ordering (requesting a medication) could be performed by the care home, the community pharmacy, GP surgery or relatives and friends of the resident.

Finally, the “physical objects” level describes the physical objects in the work system. A total of 49 physical objects were identified and included tools or equipment, personnel and infrastructure. We considered the care home medication system as a predominantly intentional system meaning that human goals, decisions and actions determine how work is achieved. Thus we have included personnel (such as the care home resident, relatives, friends, healthcare staff) at this level. The list of physical objects in the AH was not intended to be exhaustive and represented the physical objects that were identified from the three iterations of the AH. In the validation process, SMEs noted that the physical objects were the aspect of the analysis that was most likely to differ across care homes, so our approach was to include representative types of objects at this level of the analysis. Several physical objects contained similar information about the care home medication system. For example, care records, nurses’ diary, handover book, GP medical records, community pharmacy records, hospital medical records all contain information about residents’ care plans, medical issues and medication. Thus, they provide similar functionality but the quality of information provided varied considerably. These records were also located in different healthcare settings. The availability of multiple information sources with different levels of detail could lead to challenges in maintaining accurate records, and timely retrieval of information that in turn could have a negative impact on medication safety.

An important feature of the AH is the means-ends links between work categories at different levels of the AH. The means-ends links provide a way to explore how changes in
one area of the system might affect other areas, and suggest novel trajectories of action that could be explored in subsequent system improvement efforts. “Communicate” and “record-keeping” were two work components with the most links in the AH suggesting that they played key roles in the safe provision of medication.

3.2 Analysis of medication errors

3.2.1 Work categories at the purpose-related functions level

Two work categories were identified to have contributed to the nine medication administration errors analysed. These were “medication administration” and “medication supply medication”. Problems with “medication administration” were considered to have contributed to all the medication administration errors whilst “medication supply” contributed to two medication errors. A lack of medication supply contributed to the omission of a medication in two medication administration rounds. This highlighted the dependencies between “medication administration” and “medication supply” in the care home medication system. Medication could be administered by professionals in and outside the care home, and likewise the supply of medication was dependent on co-ordination with pharmacies. This suggests that need for effective co-ordination within and outside the care home to ensure the safety and effective running of the care home medication system.

3.2.2 Work categories at the object-related processes level

Table 2 shows a summary of the error analysis of the work categories linked to “medication administration” and “medication supply” that were considered to have been implicated in the errors. Following this, the most frequent contributors to errors are discussed.

Insert Table 2.

Communicate

Communication problems were identified within and outside the care home. For example, problems between the care home and community pharmacy resulted in uncollected medications in the community pharmacy. Non-availability of that specific medication led to the resident not being given the prescribed medication. Staff members in the care home and community pharmacy were unable anticipate the consequences of their action or non-
action beyond the immediate effect that the resident’s medication was not collected. The lack of foresight due to poor understanding of the whole care home medication system can have a detrimental effect on patients.

Within the care home, there was incomplete communication of information and lack of communication between care home staff members. In one care home, it was the responsibility of the care home manager or duty managers who do not routinely administer medication, to communicate all types of information about medication to care home staff members who administer medication. Insufficient information about the change of a resident’s medication therapy was given and this led to wrong assumptions about the new regime resulting in resident being given the wrong dose of medication. In other cases, reasons for medications not being available for long periods of time was not investigated, resulting in residents not receiving their prescribed medication.

Communication problems between care home staff and residents were also identified. Issues such as cognitive impairment and high levels of trust in care home staff members’ knowledge of medication prevented residents from communicating with staff regarding their medication.

**Record-keeping**

There were problems with records that were unclear and not up-to-date. Care homes use multiple sources of information and multiple record keeping devices, often leading to duplication of information. A change in medication information was not reflected in every information source that routinely contains information about medication. In some cases the recorded information about the medication change was not clear causing the care staff to make wrong assumptions about the resident’s medication dosage.

In some errors, the wrong information was recorded. A care home staff had documented giving a medication when it had not been given. Certain information such as to give medication before food, had not been recorded in the main information source regularly used by care home staff members that administer medication. Medication information recorded on dispensing labels and patient information leaflets (PILs) was not utilised by care home staff when giving medication. This led to medication being given by the wrong administration technique.
“Record-keeping” was identified to be tightly linked to “communicate”. Record-keeping is a form of written communication. It is crucial to note that these two work categories are not means-ends related or hierarchical. They are both required to fulfil the purposes of the work categories at the purpose-related function level.

Medication giving

Problems with “medication giving” related to the omission of medication in the medication administration round and errors relating to the wrong dose, physicochemical properties of the medication, administration techniques and not following instructions given. Medication omissions were a consequence of the unavailability of medication and the medication being forgotten because it was placed in a separate compartment in the drug trolley. Non-updated MDS and MARs resulted in a wrong (old) dose of medication given to the resident. A few care home staff members used the wrong administration technique for example the use of inhalers. Another care home staff member had the wrong knowledge about the physical property of a medication and had not given the medication according to the administration instructions printed on the dispensing label.

The problems with “medication giving” were not due solely to the act of giving medication. There were clear links with problems in communication, record-keeping, medication storage and dispensing showing the relationships between work categories at the object-related processes level.

The interface between the community pharmacy and care home creates vulnerabilities and increases the risk of medication errors. Co-ordinating the delivery of care and medication across this interface was challenging for communication and record keeping and led to a number of errors.

4 Discussion

We believe this is the first time an English care home medication system was mapped using WDA and the first time an AH was used to analyse medication errors in care homes. The study revealed several key benefits of using WDA to map the care home medication
system and analyse medication errors, and the potential for WDA to improve medication safety in care homes.

4.1 Formative contextual constraint-based framework to understand the care home medication system

This study has extended current knowledge of the care home medication system by providing a formative, constraint-based framework for visualising the medication system and its functions in a systematic and comprehensive manner. Current approaches to understanding medication safety in care homes have focused on deriving insights through analyses of medication errors (Gurwitz et al. 2000, 2005; Lunn et al. 2007; Barber et al. 2009) and the effects of specific interventions on residents’ medication treatment (Furniss et al. 2000; Zermansky et al. 2006). These studies provide system improvement recommendations primarily through investigating what has gone wrong within the system. However, the context within which errors occurred or where interventions were made, were absent. This study on the other hand focused on building a knowledge base about the system to provide the context and framework for further analysis of the care home medication system (Buckle et al. 2003). Relationships between work categories shown in the AH through the means-ends links were an advantage; it provided the means for understanding the work system and the implications of work categories in light of the wider system. When designing system interventions in a tightly-coupled system such as the care home medication system, it is potentially less likely to miss key components of the system if a comprehensive AH framework was used as a starting point.

4.2 Contextual framework for medication error analysis

This paper reports the first application of AH to analyse medication errors in care homes. We found one other published study that investigated the causes of medication errors in care homes (Barber et al. 2009). The London Protocol (Taylor-Adams and Vincent 2004) was used in Barber et al.’s (2009) study and is a generic framework of system and individual factors that may contribute to errors. Using The London Protocol, analysts review each factor listed to identify relevance to the error. It can be difficult to determine the relative importance or consequences of these contributory factors in the wider care home medication system because the framework does not indicate how factors were related to each other.
This study used the AH of the care home medication system developed to analyse medication errors. The AH provided a contextual framework to analyse errors and avoided the problems of contextualising generic error analytical framework and decontextualising error cases which is often complex processes and may not increase our understanding on errors. Mapping error case summaries to the AH did not reveal missing work categories within the AH or means-ends links between work categories, thereby validated the AH further. Using the AH to analyse errors increased the comprehensiveness of the analysis process because the analyst was guided to consider all work categories that were means-ends linked which may not, in the first instance appeared to have contributed to errors. It would be less likely to miss work categories that may have been implicated in errors. The links also show each work categories’ relevance and relationship with each other in the wider context of the care home medication system.

4.2.1 Recommendations for system improvement

A key issue identified in the analysis of errors was the deficiency in the care home information system. Hence, it is logical to target this aspect of the system when generating recommendations for system improvements.

Access and use of information

The availability of information should be made apparent to staff who require it whether within or outside the care home. Staff members need to have relevant information so that they can make appropriate decisions and judgements.

The AH of the care home medication system can be used as a tool to help staff visualise the system within which they work. Staff can see the importance of different types of information by referring to the means-ends links linking work categories at different abstraction levels. Then, staff can better judge the usefulness of the information in light of the context of the whole care home medication system and use it effectively and accurately. In the errors analysed, information on the dispensing labels and patient information leaflets (PILs) was not utilised and reasons for these could be that staff were not aware of the availability of information and did not know the value of the information.

Record-keeping
In complex socio-technical systems like the care home, variations in work systems, practices and organisations are inevitable. No two care homes function in the exact same way. Instead of standardising every aspect of the running of the care home, a crucial point to consider could be to ensure that information is recorded and updated promptly and clearly. However, without a clear view of the whole care home medication system, it is difficult to determine what information to record. The AH can be used to help determine the type of information to record. By reviewing the means-ends links that link work categories at different abstraction level, the type of information to record can be determined. For example, “medication supply” at the purpose-related functions abstraction level is means-ends linked to “medication order” (among other work categories) at the object-related processes abstraction level below. Hence, information about “medication order” should be considered when records are made about “medication supply”. The information recorded could also act as alerts or reminders to care staff such as alerting the care staff that two types of dispensing systems are being used or reminders to perform particular tasks.

Centralised records

Centralising records could help reduce the likelihood of not updating a particular source of information and also ensure that all staff members have access to the same information. The AH of the care home medication system shows that work categories cannot be fulfilled solely within the care home itself. Examining the work categories at the purpose-related functions abstraction level in more detail, three of the four work categories, “medical diagnosis”, “treatment prescribing” and “medication supply” cannot be performed solely within the care home. Hence, there is a need for co-ordination with other healthcare settings to fulfil these work categories. This further supports the need for a common source of information so that every healthcare setting has access to relevant information.

Resident involvement

Care home residents are a valuable source of information and they should be encouraged to be more involved in their own healthcare, if they are able and want to. The analysis of errors identified that residents were often passive receivers of care during the medication administration rounds. Residents can provide invaluable information about the care home medication system. By referring to the AH, “resident” at the physical objects level is
means-ends linked to many work categories at the object-related processes abstraction level above, showing their crucial role in fulfilling the work categories such as “communicate”, “medication review”, “health status monitoring” and “medication giving”. The impact of resident involvement extends to the work categories at the purpose-related functions abstraction level. For example, “communicate” at the object-related processes level is means-ends linked to every work category at the level above.

4.3 AH to guide design of interventions

The AH can be used to guide improvement activities. The work components identified at the purpose-related function level represent categories of work that have a defined aim, such as diagnosis and prescribing. These work components are linked to object-related processes that further show how they could be achieved, and values and priorities of the system that determines its performance. See Table 3 for an example. The analysis can therefore be used to systematically assess how changes in one area of the work system might affect other areas.

Insert Table 3

The previous section discussed methods used to analyse medication errors. Using The London Protocol (Taylor-Adams and Vincent 2004), recommendations to improve the system are generated based on error contributory factors identified. These recommendations addressed factors related to individual errors and not necessarily those of the wider deficient system. The AH provided an understanding of how and why errors occurred within the wider system and can lead to the generation of recommendations that address system problems rather than problems surrounding individual errors.

Studies conducted in other sectors with applications such as identifying problems and generating safety improvement recommendations in aircraft-automation systems (Xu 2007) and evaluating design proposals for new systems such as that of Airborne Early Warning and Control (Naikar and Sanderson 2001) have also highlighted the importance and the value of a macro-level view of the system and the interactions that occur to contextualise and inform decisions made to improve safety. The same AH can be used throughout the system’s life-cycle from analysis, to the design of solutions for system improvement, to evaluation of improvements for their effect on safety (Sanderson 2003).
4.4 Further use of AH to improve safety

The results of this analysis could be used to identify training needs, develop training programmes and guide training delivery and evaluation (Sanderson 2003). As suggested by the SMEs in this study, staff need to develop an accurate mental model of the system in which they work and they need to understand how their actions affect other parts of the system. Further study could identify how the AH could be used in this. One way forward would be to develop a training package based on the work categories at each abstraction level in the AH, starting at the purpose-related functions level; both the training needs and the functional specifications of the training system itself (Naikar and Sanderson 1999; Lintern and Naikar 2000). This would provide staff with an overall contextual view of the care home medication system.

The design of specific interventions requires further research. Interventions can be identified based on the requirements of the system as represented by the AH, but the specific features of an intervention require in depth understanding of the tasks that workers undertake, the information they require and the interactions between different staff. Application of later stages of CWA, such as control task analysis, and other human factors techniques such as hierarchical task analysis and process mapping could assist in this (Colligan et al. 2010).

4.5 Limitations

There are several limitations to this study. Data for the analysis were collected in a small sample of care homes. Although the extent to which the findings can be generalised is not known, we increased validity by involving a group of SMEs to review the analysis. In addition, error analysis did not reveal gaps within the AH. It is possible that some of the information contained in the lower levels of the AH were specific to the care homes we studied, but the SMEs expressed the view that the work categories at the three highest levels the AH were representative of care homes in general. Future research could test this with a larger sample of care homes. Validation of the AH using scenario analysis could increase validity (Burns et al. 2001; Burns and Hajdukiewicz 2004).

The AH could guide the data collection for error analysis. The sample of errors was limited to medication administration errors. In future, other types of errors identified in the care home for example, prescribing, monitoring and dispensing errors, could potentially
be analysed using the AH. Separate AHs of the GP surgery and community pharmacy systems, or AH from different object world views (Torenvliet et al. 2008 and Naikar 2013) may be helpful in understanding the contribution of problems within the GP and pharmacy to errors in the care home. To analyse errors, it was necessary to first construct the AH of the care home medication system. The process of construction was time-consuming and required specific skill and expertise compared to using an off the shelf error analytical tool. However, the value of the analysis based on the AH could outweigh the problem of having to spend more time and resources at the start of the analysis. The AH could also be retained in the system for other uses such as the design of interventions.

5 Conclusion

A map of the care home medication system was developed using WDA. It provided an overview of the care home medication system and a framework for contextualising our understanding of safety problems and for designing interventions. The AH of the care home medication system was used in a novel way to analyse medication errors and the findings revealed additional insight to the context and causes of errors. WDA showed promise for understanding the complexity and developing interventions to improve medication safety in care homes.

6 Acknowledgements

The first author was funded by Hinchingbrooke Health Care NHS Trust to undertake a PhD programme at the time of the study. We thank Janet Watkinson and, care home staff and pharmacist who participated in this study. The authors were part of the wider Care Home Use of Medicines Study (CHUMS) research team and would like to thank the whole team for their contribution in terms of care home knowledge.

7 References


Xu, W. 1007. “Identifying problems and generating recommendations for enhancing complex systems: applying the abstraction hierarchy framework as an analytical tool.” 
*Human Factors* 49:975-994.

List of tables

Table 1. Description of subject matter experts.
Table 2. Summary of error analysis corresponding to work categories that contributed to medication errors.
Table 3. Using AH to guide safety improvement activities: an example.
Table 1. Description of subject matter experts.

<table>
<thead>
<tr>
<th>Subject matter expert</th>
<th>Brief background description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmacist</td>
<td>Previous experience as a community pharmacist providing medication services to care home, care home inspector, primary care trust pharmacist and research pharmacist</td>
</tr>
<tr>
<td>Care home manager 1</td>
<td>Manager of a care home providing personal care and nursing services. A trained nurse.</td>
</tr>
<tr>
<td>Care home nurse</td>
<td>Lead clinical nurse in a care home providing personal care and nursing services</td>
</tr>
<tr>
<td>Care home manager 2</td>
<td>Manager of a care home providing personal care only. Not a trained nurse.</td>
</tr>
<tr>
<td>Care assistant</td>
<td>Care assistant in a care home providing personal care only. New member of staff with no background in nursing.</td>
</tr>
</tbody>
</table>
Table 2. Summary of error analysis corresponding to work categories that contributed to medication errors.

<table>
<thead>
<tr>
<th>Work categories (no. of times implicated in error)</th>
<th>Summary of error analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communicate (9)</td>
<td>Communication problems were identified between care home staff and community pharmacy staff, care home staff and care home residents, and care home staff in the care home.</td>
</tr>
<tr>
<td>Record-keeping (9)</td>
<td>Problems with record-keeping included not updating records, recording the wrong information, not recording information, making unclear records and not using recorded information.</td>
</tr>
<tr>
<td>Monitor health status (2)</td>
<td>Difficulties visually observing and making judgements of the health status of care home residents for example, the level of pain experienced by residents resulting in poor care.</td>
</tr>
<tr>
<td>Medication review (2)</td>
<td>A comprehensive review of medication was not routine: the medication management component had not been conducted.</td>
</tr>
<tr>
<td>Transport medication (2)</td>
<td>The medication transportation system was not robust as it sometimes depended on one person to collect or deliver medication, and no records were made of the urgency or completion of task.</td>
</tr>
<tr>
<td>Order medication (2)</td>
<td>The medication ordering system was complex resulting in delays and inaccuracies of the medication order.</td>
</tr>
<tr>
<td>Dispense medication (3)</td>
<td>Information on the dispensing label and MAR chart was not updated and led to wrong dose of medication being given. Medication dispensed in wrong dispensing systems resulting in medication not being given to residents.</td>
</tr>
<tr>
<td>Check stock supply of medication (2)</td>
<td>There was no system to check stock supplies of medication. Medication changes were not taken into account resulting in insufficient amount of medication available for administering to residents.</td>
</tr>
<tr>
<td>Give medication (9)</td>
<td>Problems included giving the wrong medication, not giving medication and not following instructions when giving medication.</td>
</tr>
<tr>
<td>Store medication (1)</td>
<td>The medication storage system was complex: medications are stored in different places due to legal and physicochemical properties resulting in unintended omission of medication.</td>
</tr>
</tbody>
</table>
Table 3. Using AH to guide safety improvement activities: an example.

**Optimising prescribing safety**

- Means ends links can guide improvement activities
- The Prescribing work component is linked to the next level down in the AH. This shows that prescribing requires communication, record keeping, monitoring health status, medication review, disposal of medication and ordering medication. Work components at the object-related processes level, represent all categories of work that should be examined for opportunities for optimisation when designing interventions to improve safety.
- The work components at the object-related processes level are linked in turn to the lowest level of the AH, which shows the physical objects that can be used to fulfil the "Prescribing" functions. To improve safety objects at this level could be examined for omissions, duplication and opportunities for optimisation
- The Prescribing function is linked to the level above in the AH which shows the values and priority measures. These show why prescribing needs to be carried out – e.g. to maximise the quality of healthcare provision. The values and priority measures can be used to develop measures of performance and ensure that the work system meets appropriate legislation (e.g. Care Standards Act 2000; Medicines Act 1968, Misuse of Drug Regulations 2001) and quality standards such as national minimum standards for care homes for older people.
List of Figures

Figure 1. An abstraction hierarchy of the care home medication system.