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A work system analysis of the medication administration process in a Norwegian nursing home ward

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ABSTRACT

Nursing home patients often have multiple diagnoses and a high prevalence of polypharmacy and are at risk of experiencing adverse drug events. The study aims to explore the dynamic interactions of stakeholders and work system elements in the medication administration process in a nursing home ward. Data were collected using observations and interviews. A deductive content analysis led to a SEIPS-based process map and an accompanying work system analysis. The study increases knowledge of the complexity of the medication administration process by portraying the dynamic interactions between the major stakeholders in the work system, and the temporal flow of the activities involved. Secondly, it identifies facilitators and barriers in the work system linked to the medication administration process. Most barriers and facilitators are associated with the work system elements – tools & technology, organisation and tasks – and occur early in the medication administration process.

1. Introduction

Medication administration causes a significant number of healthcare-related adverse events in primary care (Andersson et al., 2018; Ferrah et al., 2017; Marchon and Mendes Jr, 2014). In recognition of this, the World Health Organization (WHO) has promoted a worldwide effort to reduce medically related harm by 50% over the period 2017–2021 (WHO, 2017).

About one-third of all adverse drug events (ADE) are associated with medication administration errors (MAE) that are preventable (WHO, 2016). 13–31% of the residents in nursing homes have experienced medication administration errors (MAE) (Ferrah et al., 2017). Estimates of ADE's in nursing homes range from 1.2 to 10.8 incidents per 100 resident-months (Al-Jumaili and Doucette, 2017). Nursing home patients often have multiple diagnoses and a high prevalence of polypharmacy and are therefore at high risk of being subjected to adverse drug events (ADE) (Herr et al., 2017). This may result in additional monitoring, interventions, hospitalisation or death (Handler et al., 2006).

Nursing homes vary greatly in terms of demographics, patients, staff, regulations and norms. This variability is seen in the elements of the sociotechnical work system; physical environment, persons, tools & technology, organisation and processes. Several of these work system factors may influence medication safety in nursing homes, for example, the use of technology, medication knowledge and training, interprofessional collaboration, access to physician and pharmacist, staff/resident ratio, workload and time pressure, and interruptions (Al-Jumaili and Doucette, 2017; Carayon et al., 2006; Huang and Gramopadhye, 2014). A human factors systems approach seeks to grasp the complexity of the interconnected socio-technological system of the medication administration process. The System Engineering Initiative for Patient Safety (SEIPS) (Carayon et al., 2006) has been applied to a variety of healthcare research, education and practices (Carayon et al., 2006; Carayon et al., 2014; Gurses et al., 2010; Karsh et al., 2005; Pronovost et al., 2009; Shekelle et al., 2013; Sittig and Singh, 2009). The current study uses an adapted version of the original SEIPS model to explore the complexity of the MAP (Fig. 1) (Carayon et al., 2006).

The sociotechnical work system represents the structure and produces work processes that shape outcomes. The person/team is at the centre of the work system, i.e. the nurse, medical doctor, patients or a group of individuals (e.g. team, organisational unit). The individual or team can exhibit cognitive, physical and psychosocial characteristics influenced by the internal/physical and external environment, tools and technology, tasks and organisation (Carayon et al., 2006; Holden et al.,

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2013). This reflects an underlying principle of systems orientation where the person/team is an embedded component of a sociotechnical system (Dul et al., 2012).

1.1. The medication administration process

Medication administration is ingrained in the nursing home work system, and specific tasks related to medication administration are often difficult to separate from other work processes in the daily care of the patients (Carayon et al., 2014; Jennings et al., 2011). The medication administration process (MAP) can be represented in six stages, from ordering, transcribing, dispensing, preparing, administering and observing (Carayon et al., 2014; Odberg et al., 2017). It involves different stakeholders performing different tasks using technologies such as electronic medication administration records (eMAR) while relating to organisational conditions, rules and guidelines within a physical environment. The major stakeholders in the current study are registered nurses (RN), medical doctors (MD), nurse assistants (NA), the patients and the pharmacists. The pharmacists were not a focus in the study, as they perform their role externally to the nursing homes in the current context, the only communication being via electronic or other correspondence. MAE's may occur anywhere along the MAP, and errors committed in the first stages may affect the consecutive stages to cause potential ADE's such as the patient falling critically ill due to receiving the wrong dosage or drug. Examples of other MAE's may be failures of omission, mistaken patient identity or wrong route of administration.

There are many reasons why MAE's occur; some contributing factors are interruptions, poorly designed eMAR, lack of guidelines, high workload, poor interprofessional cooperation, lack of leadership and inadequate competence among staff (Al-Jumaili and Doucette, 2017; Andersson et al., 2018; Carayon et al., 2014; Dilles et al., 2011). There are also several measures designed to reduce the risk of MAE's, such as double-checking of medications, updated checklists, the introduction of bar-coding technology, training in medication knowledge, teamwork training and various efforts to reduce interruptions. However, few interventions in themselves seem to have any significant effect in reducing MAE's in nursing homes. In order for efforts to improve medication safety in nursing homes to be effective, they should be multifaceted as well as requiring a healthy management and strong leadership with adequate resources (Al-Jumaili and Doucette, 2017; A. Andersson et al., 2018; Carayon et al., 2014; Dilles et al., 2011).

1.2. Process modelling

There is general acknowledgement in the human factors literature that to increase overall understanding of the health care system, we need to focus on processes within the work system rather than tasks (Wooldridge et al., 2017). Care processes can be wound treatment, patient transport or medication administration. Other processes taking place simultaneously in the work system can be the introduction of new software, changing guidelines or renovations of the patient bathrooms. There are also the cognitive processes of the persons involved, that may explain or describe why and how some act in a certain way. These processes take place within the work system simultaneously. They interact and are part of what makes healthcare systems complex (Holden et al., 2013).

There are numerous ways of modelling processes in healthcare, but some have proven more influential than others. Jun et al. (2009) found that flowchart and swimlane diagrams[1] were most commonly used, while flowchart diagrams were more accessible. Likewise, system diagrams of a similar type have proven useful when engaging in identifying risks in healthcare processes (Simsekler et al., 2018). Process modelling is one way to comprehend better how persons, technology, physical environment, organisational factors and care processes interact and work (Jun et al., 2009). It differs from more traditional flowcharts by including the stakeholders as separate headings in the top row, thereby portraying the persons performing different tasks in the MAP. According to Wooldridge et al. (2017), a SEIPS-based process modelling technique may provide a powerful tool in identifying barriers and facilitators in healthcare work processes.

By integrating the work system into the process map, the resulting diagram presents a holistic representation of the activities involved in the process while also retaining a general overview of the dynamic interactions of the involved system elements. The process modelling in this study is based on Wooldridge et al. (2017) and incorporates the work system elements in the SEIPS model, systematically visualising the MAP.

Since there are few studies that investigate medication administration within nursing homes as a whole, the current study aimed to explore the dynamic interactions of stakeholders and work system elements in the MAP in a nursing home ward. The following research question

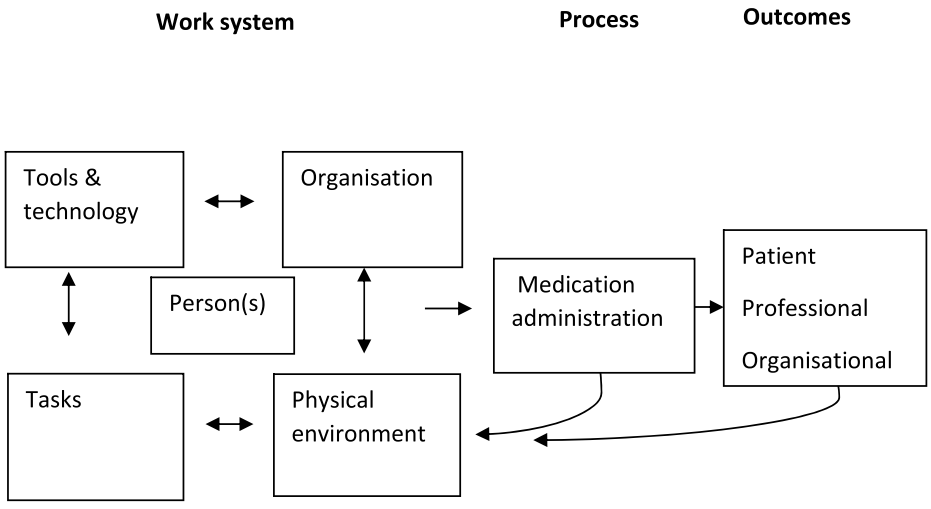

Fig. 1. An adapted SEIPS model based on Carayon et al. (2006).

[1] Cross-functional process map to illustrate workflow and interrelated activities, which visually distinguishes job sharing and responsibilities (Damelio, 2016).

guided the study: How can SEIPS based process modelling visualise barriers and facilitators in the medication administration work system of a nursing home ward?

2. Methodology

2.1. Design

The study used a qualitative design (Morse, 2016). Data were collected using (1) observations of the medication administration process in a nursing home, supplemented with (2) interviews with healthcare professionals in the nursing home. A deductive content analysis used combined data from the observations and interviews to inform the SEIPS-based process modelling.

2.2. Setting

The study took place in a Norwegian nursing home ward with palliative patients in need of medical treatment. The palliative ward had six patient rooms, mostly occupied for the duration of the study. A small nurse station was centrally located with an inner office for the nurse manager. Computers, charts, documents, a printer, telephone, and a mobile medication trolley were housed in the nurse station. Two parallel corridors provided access to the patient rooms as well as a common living room with a small kitchenette. The medicine room was 60 m away in the opposite part of the building past another ward. Patients had a varying length of stay as some needed only short-term assistance (2–5 days); if their condition improved, they were discharged; if it worsened, they were transferred to other facilities. Other patients stayed for weeks or months. Most patients had extensive medical regimes including administration of oral medications, infusions, and patches at four regular intervals each day. The staff consisted of 25 members – six full-time registered nurses (RN), two nurse assistants (NA) and an associated medical doctor (MD) in a 50% with two regular visits per week. The remaining staff members had either short-term engagements or held less than 50% positions at the ward.

2.3. Recruitment

The nursing home ward is part of a network of development centres in Eastern Norway and was chosen due to the leaders expressing an intention to participate in relevant research. The main author contacted the manager of the nursing home in January 2016, and the manager of a palliative ward agreed to participate. All the staff members were briefed in a joint meeting and asked to take part in the study, to which they agreed. The staff members were informed that they might be asked to participate in interviews at a later stage.

The inclusion criteria set for the interviews were that the participants had a regular position working 50% or more and that they had a role during the medication administration process. After three months of observations, the staff members fulfilling the inclusion criteria were asked to participate in the interviews. In all, 9 staff members, ranging from nurses[2] with post-graduate education in palliative care, RN's, a nurse manager, an MD, and NA's were asked. All agreed to be interviewed, and they were again informed of confidentiality and of the possibility to withdraw.

2.4. Data collection

The main author performed partial participant observations (Bourgeault et al. (2010) from April to October 2016. All staff with tasks related to medication management in the ward were observed during daytime shifts and evening shifts on weekdays. A few observations took place during night shifts. Most observations took place during daytime shifts in order to capture periods of high activity related to patient care and medication administration. While staff members performed tasks related to medication administration, the researcher took notes and paid attention to the various work system elements, such as the use of technology or how noise and interruptions affected their work. After each day of observations, the notes were transcribed by the researcher.

Halfway through the observation period, the staff members who met the inclusion criteria were interviewed. All observations (70 h) (See Appendix 1: Observation guide) and interviews followed guides based on the five elements of the SEIPS model: persons, physical environment, tasks, tools & technology and organisation. The interviews were semi-structured, lasting from 30 to 60 min, and were performed in a separate room in the nursing home facility (See Appendix 2: Interview guide). The goal of the interviews was to explore how the staff related to and experienced the medication administration process. The interviews were audio-recorded and transcribed partly by the researcher and by a professional transcription service.

After the interviews were conducted, the remaining period (July to October) of observation narrowed in its focus, seeking to refine specific elements in the MAP pinpointed in the interviews.

2.5. Trustworthiness

The use of a sole observer, an intensive care nurse by training, may cause bias, such as prior conditioning (Bourgeault et al., 2010). At the same time, familiarity with the setting and the medication administration process may lead to insights otherwise missed. The researcher was aware that the interaction with the participants could influence or bias the surroundings and the data collected (O'Brien et al., 2014). To limit bias, special attention was given to how data was interpreted. By introducing individual interviews of the stakeholders at the mid-point of the data collection period, member checks of early interpretations of the observation data helped clarify and elaborate identified issues. In the remaining observation period, the researcher's interpretations were refined and an accurate description of the medication administration process was arrived at. The research team, consisting of three professional researchers with a diverse background in nursing and engineering, had regular meetings during the data collection and analysis. They discussed key issues and performed iterative analytical reflections to ensure the reflexivity and trustworthiness of the findings. To ensure the dependability of the data, the observations were made by the same researcher throughout the six months, using an observation guide. Over time, the staff members grew used to a researcher being present and probably took less notice (Lincoln and Guba, 1985). Excerpts from the interviews and observation notes are included in the results section to increase the transferability of the findings.

2.6. Analysis and process map development

The transcribed observation notes and interviews were analysed using deductive content analysis (Elo and Kyngäs, 2008). A categorisation matrix based on the five elements of the SEIPS model (columns) and the six stages of the MAP (rows) formed the categories. The delineation between the different stages was mainly based on observations, together with descriptions of the MAP (Carayon et al., 2014). As activities in the ward were seldom linear, the building of the process model involved interpreting where certain activities belonged. For example, activities in stage one (ordering) and stage two (transcribing) often took place simultaneously.

The first part of the deductive content analysis involved the entire research team individually reading the entire data material to make sense of the data. Relevant parts of the material were marked, and the data were discussed to form an analytical approach to answer the research question. To identify relevant meaning units, the focus was on

[2] Both registered nurses and nurses with post-graduate education are described as RN's in the study.

the marked parts containing information that could assist in building an accurate description of the MAP, while also giving insights into possible facilitators and barriers that seemed relevant. A total of 274 meaning units that all the members of the research team agreed on were identified in the text material and placed in the matrix. One example was how "several interruptions during doctor pre-visitation" was placed in the nexus of "ordering" (stage one) and the "physical environment". The meaning units were then condensed into broader codes and provisionally identified by the main researcher either as a barrier or a facilitator.

A facilitator is defined as a trait or activity related to a specific work system element that promotes safe medication administration, while a barrier hinders safe medication administration. Hoonakker, Carayon, and Cartmill (2017) acknowledge that certain traits or activities can be perceived both as facilitators or barriers and use the term 'dimensions' to encompass both. This was also the case in the current study, but as some activities were clearly identified as either a barrier or a facilitator, the term dual trait is introduced to encompass those activities that can act as both. In three subsequent meetings, all the researchers went through the material and discussed the formation and placement of the individual codes in the process map. Some codes were difficult to identify either as a facilitator or a barrier. Since data from interviews and observations sometimes differed on the same subject, some of these instances were coded as dual traits. Placing the different codes under a specific work system element could also pose challenges. Examples are barriers placed under tools & and technology, such as the use of pen and paper, that may also fit under the work system element tasks. A consensus on how to define facilitators or barriers was reached through discussions and analytical triangulation in the final conceptual stage of the process map (Fig. 2) and the accompanying work system analysis (Table 1).

2.7. Ethics

Participation was voluntary, and all involved staff members received oral and written information about the study, including data confidentiality and the possibility to withdraw at any time. No one chose to withdraw. A form was distributed for participants to give their informed consent.

No patient sensitive information was documented or used in the analysis of the data, The Regional Committee for Medical and Health Research Ethics concluded that approval from the Norwegian Social Science Data Service (NSD) sufficed (No. 45389).

3. Results

3.1. The process map of the medication administration process

The results are presented as a process map (Fig. 2) and a work system analysis (Table 1). The process map visualizes the interconnectedness of the stakeholders, tasks and stages of the MAP, while the work system analysis identifies and describes work-system facilitators, barriers or dual traits to safe medication administration. Major stakeholders in the medication administration process (columns in Fig. 2) are registered nurses (RN), medical doctors (MD), other staff members, patients and the pharmacist. The RN with medication responsibility is involved in all stages of the process. The MD is involved in the ordering stage and the transcribing stage, in close collaboration with the RN and the patient. Other staff consist of RN's and nurse assistants and are peripherally involved in ordering and transcribing depending on need and circumstances. In addition, they are crucial in gathering clinical information and relaying this to the RN in charge of medication administration. They are also involved in delegated medication administration tasks such as delivering medicines to patients. The patients at the centre of the entire medication administration process are mostly active at the receiving end of the administering stage, while also playing a crucial part in imparting their clinical information to the staff in the first two stages. The pharmacist is only involved in the process when patients use multi-dosage orders. Symbols used in notes and computers indicate that some form of documentation occurs in all the stages of the MAP, predominantly in the ordering stage. The computer symbol (key in Fig. 2) indicates that staff members use eMAR to retrieve information or to document. The note/paper symbol (key in Fig. 2) indicates that staff members use analogue forms of documentation, often in the form of small notebooks, paper slips or forms.

The medication administration process commences with the RN gathering patient information from written documentation and talking to colleagues (activities 1–3, Fig. 2). While gathering information, he/she makes notes in a notebook or on a slip of paper (activity 4). When the MD arrives, they discuss each patient, talk to staff members and consult the patients (activities 5–8). Afterwards, they make actual changes in the documentation (activities 9–11), and patients may receive new medicines if needed (activities 12–13). The RN then makes the actual changes by checking the documentation and removing or adding medicines in the medicine dispensers (activities 14–16). If patients use multi-dosage medicines, new prescriptions are sent to the local pharmacy (activity 17). Before medicines are administered to the patients, the RN reviews patient clinical charts, talks to colleagues and assesses the patients (activities 18–20). Then the prescribed medications are checked against the medicine list and content of pill dispensers before being transferred to a suitable dispenser. In the cases where patients receive intravenous medicines, these are usually prepared in advance in the nurse station and double-checked before administered (activities 21–22). The RN brings the medicines to the patients and supervises while they ingest them, and documents the event afterwards (activities 23–25). All staff members are involved in observing and documenting the effects on the patients (activities 26–29).

3.2. Work system analysis

The study identified 60 work-system facilitators (fx1), barriers (fx2) or dual traits (fx3) across the five elements of the MA work system model (Table 1). Each of these is noted in the table according to their source data: *italic* font from observations, **bold** font from interviews and normal font when data derives from both sources.

There is a preponderance of identified barriers (38) in contrast to relatively few facilitators (13). Some activities show dual traits (9). Facilitators and Barriers are more common in the work system elements: tools & technology, organisation and tasks. The dual traits are found mostly in tools & technology and person(s). A majority of the barriers occur in stage 1 (ordering) of the MAP, while there are most facilitators in stage 1 (ordering) and stage 4 (preparing). All the stages, with the exception of stage 5 (administering), contain a few dual traits.

3.3. Facilitators for safe medication administration

In the opinion of staff members, the use of mobile devices with eMAR functionality would significantly enhance the MAP in both the ordering and preparing stages and be a major facilitator (activities 8, 18). An example of a discussion on documentation of medicines is described in the following excerpt from an observation note:

> "The nurse enters the nurse station and addresses the other nurse present, expressing how easier things could have been if they had access to an iPad to document their activities consecutively."

From an organisational point of view, staff consistency seems to be an overall decisive factor, allowing the staff to prepare for vulnerable shifts such as weekends (activity 6). This is exemplified in the following excerpt from an interview with a RN showing the importance of knowing each other:

> "So we understand when a vulnerable shift approaches and are able to plan accordingly."

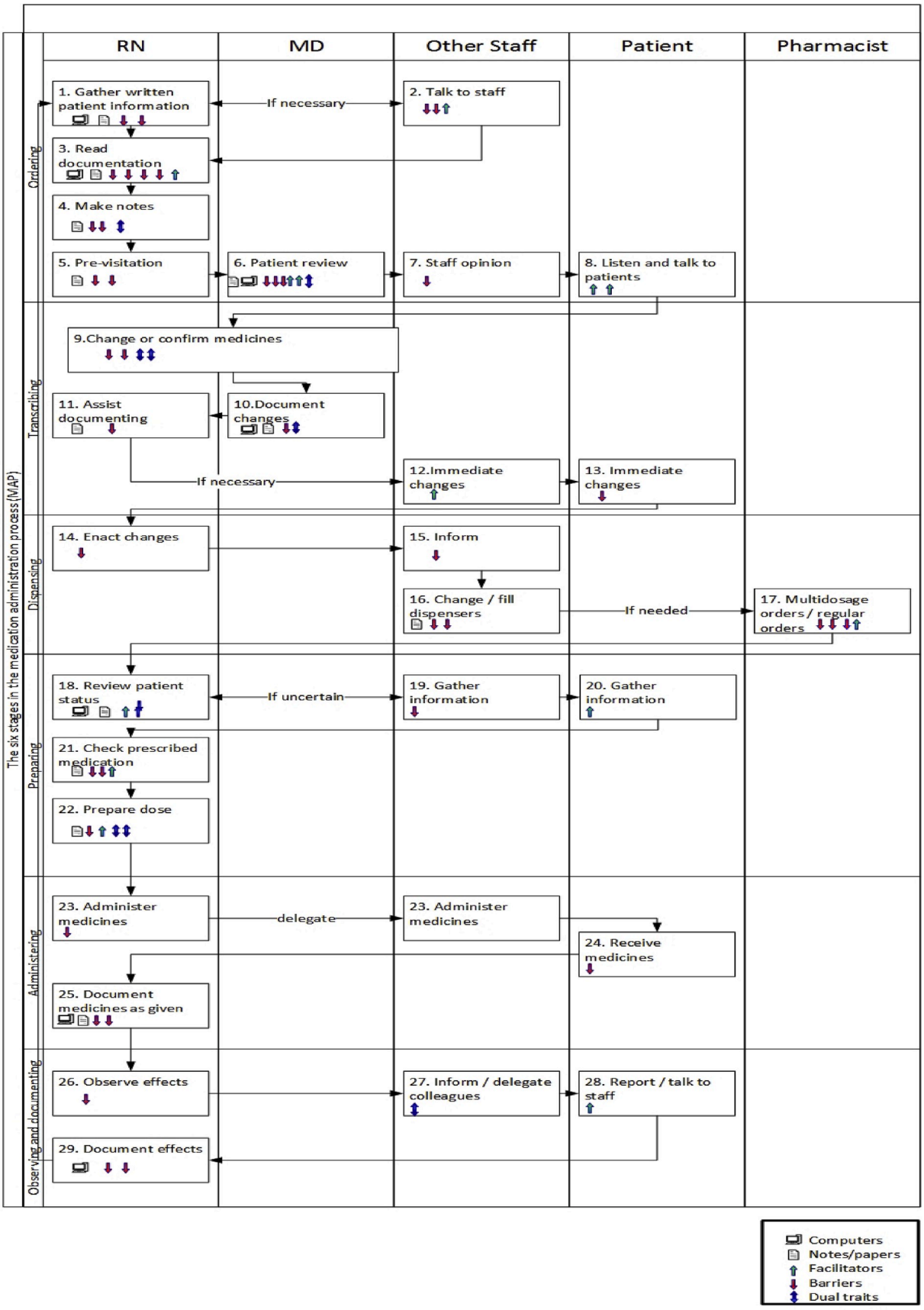

Fig. 2. SEIPS-based process map of the medication administration process.

Table 1
The work system analysis.

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
1	Gather written patient information	Finding clinical information from various sources; paper journals, patient folders.	*Relevant documents are located in different places distant to each other.*				*No guidelines exist on what to prepare for ward round.*	
2	Talk to staff	The nurse locates staff with updated knowledge of the patients and asks questions about the current clinical status.			*Time-consuming.*	Not always available.	**The staff feel appreciated, empowered.**	
3	Read documentation	Briefly reads highlights from last week. Thereafter looks up most recent notes and relevant documents in eMAR.	[1]Nurse station is small, noisy with several interruptions. *information is located in different places.*	Poor or lacking documentation. Lengthy login to computer and eMAR. *2 computers are available at the nurse station*				Barriers= 16 Facilitators=6 Dual traits=2
4	Make notes	Plans most salient issues to bring up when the doctor arrives and notes them in a notebook or on a slip of paper.		**Poor search function in eMAR** *Pen and paper easy to use. Uses a "black book" in addition.* *No formal archiving of plans.*				
5.	Pre-visitation	The doctor arrives and greets the staff. Informal talk. The nurse has a quick recap of last week's events and the status of patients.				*Staff member not always available, or busy.*	*No set time for arrival or preplanned schedule*	

[1] Interruptions and noise are recurrent throughout the MAP.

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
6.	Patient review	Login to eMAR Nurse and doctor systematically go through patient charts, discuss, and review medicines for each patient. They plan for eventualities until next visit is due.		*Slow login.* **Separate module for nurses and doctors in eMAR slows down the process.**	*MD documents in eMAR. Takes time.* (may be due to lack of familiarity with the process)	The n*urse has extensiveknowledge of all patients. Depends on the individual nurse. Depends on the nurse 's overview. Individual differences regarding knowledge and competence..*	Usually, the same persons doing ward rounds. Ensures continuity. Prepares for eventualities on weekends or vulnerable shifts, by considering hiring extra staff and ensuring adequate stock of medications. Staff consistency facilitates smooth collaboration.	
7.	Staff opinion	Staff members responsible for individual patients may be asked for the current patient status and their opinion.		**Mobile devices with eMAR would greatly enhance this activity**	*Time-consuming.*			
8.	Listen and talk to patients	Ward round. The nurse and MD may talk to some patients to get a better impression of clinical status before prescribing medicines.				*Patients partake in decisions.*		
			Barriers=3	Barriers=6 Facilitators=2 Dual traits=1	Barriers=3	Barriers=2 Facilitators=1 Dual traits=1	Barriers=2 Facilitators=3	
9.	Change or confirm medicines	The RN and MD agree on the change after an individual review of the patient.		**Often confusing medicine prescriptions from the hospital.**	*Some changes are made in advance and need confirmation or signature*	*Relies on the knowledge and competence of the staff members. Individual variations.*	**Sometimes a lack of communication with other institutions may lead to**	Barriers=5 Facilitators=1

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
					from MD.		**mistakes.**	
10.	Document changes	The MD changes prescriptions in the eMAR and prints an updated medication list for each patient.		**Codes in eMAR make adjustments easy if you know the codes by heart.**	*Time-consuming and leads to* double-documentation.			
11.	Assist in documenting	RN takes over the printed medication lists and replaces the old ones in folders with the new ones.			*Redundant to save paper copies of all medicine charts.*			
12.	Immediate changes	If there are changes the other staff members should know immediately, they are informed.		*Would benefit from an effective calling system.*				
13.	Immediate changes	If there are medicines the patients need urgently, they are administered.			May cause interruptions to other tasks.			
				Barriers=1 Facilitators=1 Dual traits=1	Barriers=3 Dual traits=1	Dual traits=1	Barriers=1	

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
14.	Enact changes	RN checks that MD signature is on all printed lists. Replaces old lists with new ones.			Double documentation and time-consuming.			
15.	Inform	Staff members responsible for individual patients are updated at change shift by a lead nurse.					*No system to how remaining staff members are informed of the changes made.*	
16.	Change/fill dispensers	Pill dispensers are refilled according to updated medicine charts.	*The medicine room is distant from the rest of the ward.*		*This is done manually, and is dependent on visual recognition to identify correct medications..*			
17.	Multidose orders	If patients use multi-dosage, an updated medicine chart is sent to the pharmacy. Existing multi-dosage packages are opened and changed according to the new prescription.	*The fax is located on another floor.*	**Uses fax to send signed medicine chart to the pharmacist. Then the nurse has to phone the pharmacist to verify the prescription.**	**There is a 1-2 week delay before updated multidoses arrive**. **Easy to use multidose if they are up to date.**			
			Barriers=2	Barriers=1	Barriers=2 Facilitators=1		Barriers =1	

Barriers=6 Facilitators=1 Dual traits=0

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
18.	Review patient status	Patient responsible nurse reviews clinical status and medicines given last 24 hours. Uses both eMAR and paper charts.		**Would benefit from a mobile device with integrated eMAR and medicine charts.**		**Dependent on first-hand patient knowledge of the patients and relevant competence.**		Barriers=4 Facilitators=4 Dual traits=3
19.	Gather information	Other staff members are conferred with if documentation is lacking or patient status is rapidly evolving.			*Time-consuming and may interrupt other tasks.*			
20.	Observe and talk to patients	Clinical status of patients is reviewed before administration. Strong painkillers may, for instance, have hemodynamic effects. Patients may be asked how they feel.				***The patients partake in decisions.***		
21.	Check prescribed medication	Checks content of pill dispenser against medicine chart.	*All medicines are readily available in a mobile medication trolley.*	*Uses printed medicine chart, with no information on current patient clinical status.*	*Complex task dependent on visual recognition of all tablets to ensure double control.*			
22.	Prepare dose	Tablets are transferred to a pill cup. Intravenous, patches or oral liquid medicines prepared.	*Medication trolley is mobile and allows for flexibility.*	*Medical calculations using whatever means available. Some have a calculator, some use a mobile device, some do calculations in their head or on a slip of paper.*	**Unchanged multi dosages are easy to use.**		**Double checks of on-demand medications are sporadic, dependent on adequate staffing and workload.**	
			Facilitators=1 Dual traits=1	Barriers=1 Facilitators=1 Dual traits=1	Barriers=2 Facilitators=1	Facilitators=1 Dual traits=1	Barriers=1	

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
23.	Administer medicines	Takes medicines to patients and confirms identity. Delegate to other staff members if necessary.	*Patients may be roaming about and can be time-consuming to locate.*					Barriers=4 Facilitators=0 Dual traits=0
24.	Receive medicines	Patients ingest medicines while supervised/observed by a staff member. Some patients may self-administer some medicines.					*Not all staff oversee the patients ingesting the medicines due to high workload or negligence of guidelines.*	
25.	Document medicines as given	Staff member documents medicines as taken in eMAR and on the printed medicine chart.		Login is lengthy, and some prefer to wait until the end of the shift with documentation tasks.	*Double documentation.*			
			Barriers=1	Barriers=1	Barriers=1		Barriers=1	

	Activity	Activity description	Physical environment	Tools & Technology	Tasks	Person(s)	Organisation	
26.	Observe effects	Whenever staff are in contact with patients, they continuously review clinical status regarding what medications they have received.					*No systematic observation tools or documentation in use.*	Barriers=3 Facilitators=1 Dual traits=1
27.	Inform/delegate to colleagues	Delegate or ask colleagues to observe patients for potential effects.				*Dependent on personnel's competence and knowledge of what to observe and pass on.*		
28.	Inform staff	Patients are informed of the potential effects and encouraged to report any changes to the staff.				Often valuable contributions to how various treatments affect patients.		
29.	Document effects	Effects of medications are documented in eMAR.		**eMAR provides a poor interface for documenting the effects of medicines.** Lengthy login process.				
				Barriers=2		Facilitators=1 Dual traits=1	Barriers=1	
			Total Barriers=6 Facilitators=1 Dual traits=1	**Total** Barriers=12 Facilitators=4 Dual traits=3	**Total** Barriers=11 Facilitators=2 Dual traits=1	**Total** Barriers=2 Facilitators=3 Dual traits=4	**Total** Barriers=7 Facilitators=3 Dual traits=0	

The staff also appreciate when their opinions are considered in medication-related decisions (activity 2). The nurse's competence and knowledge of patients and staff members is identified as a facilitator when reviewing patient status during the ordering and preparing stage (activities 6, 18). Excerpt from observation notes:

> "The nurse is well acquainted with all the patients now at the end of the week …. Whenever the doctor asks a question, he/she has a ready answer, and they often discuss how to proceed with the medications."

During the transcribing stage, all involved stakeholders would benefit from an effective calling system, ensuring staff availability when immediate medication changes are to be effectuated (activity 12). Finally, patient involvement may be a significant facilitator regarding how a patient's knowledge and self-observations positively affect the medication administration (activity 28).

3.4. Barriers to safe medication administration

Many of the barriers are related to the ordering stage of the MAP and are associated with the work system elements: physical environment, tools and technology and tasks. Most prominent is how noise and interruptions, tied to the physical location, affect the entire MAP. An example of this is illustrated in the following observation note from the MD's ward round in the nurse station:

> "…. The door opens 15 times. Five persons enter at different times to use the xerox-machine, six enter to retrieve different medications, four enter to get some papers from their mailbox. The telephone rings twice, and the nurse is interrupted several times to answer questions."

Problems associated with the electronic medication administration record (eMAR) are tied to tools and technology and tasks, exemplified by lengthy login times (activities 3, 6, 25, 29), poor search functionality (activity 4) and separate MD and RN modules (activity 6) prohibiting the sharing of specific information. This is exemplified in the following interview excerpt with the MD:

> "I am not happy about the eMAR we use! It has an exceptionally poor module for the doctors, and any tasks are laborious…... It is also a challenge regarding patient safety that all the information is not available to me when I need it."

These problems seem to spur the use of additional paper documentation (activities 4, 10, 14, 21, 25), increasing time consumption (activities 6, 10, 14) and difficulties retrieving relevant patient information in a timely fashion (activity 3).

3.5. Dual traits in respect of safe medication administration

These are concentrated around the work system elements: technology & tools, tasks and person(s). Examples are how the individual staff member's knowledge, personality and competence vary and influence how they perform their tasks in different situations.

Examples of dual traits are how the use of eMAR is tied to the staff's competence and training (activity 9). If staff know the codes by heart, the doctor finds it easy to document medication changes. If not, it can be taxing, since an index search must be done in advance (activity 10). Due to the barriers identified in the use of eMAR, all the staff members engage in auxiliary analogue documentation (activity 4). The staff perceive this as a helpful tool, while observations suggest this activity leads to double documentation and subsequent problems in retrieving essential patient information. An excerpt from an observation note exemplifies this:

> "During the ward round, the doctor documents all the changes in the eMAR, while the nurse uses an informal black book, several paper notes and occasional brief notes in the patient cardex."

Another example is how the staff make medication changes before conferring with the MD (activity 9). This may improve workflow but can also constitute a risk to medication administration as the MD is not involved in the decision process. The following excerpt from an interview with a nurse shows how staff members make independent decisions regarding the administration of insulin:

> "Last night it (the blood glucose) was low because he/she refused to eat, and we halved the dose. Then the blood glucose levels

normalised, and we gave the regular dose. Then his/her blood glucose levels suddenly had dropped again when we checked, and we had to make sure he/she ate something."

The use of a mobile medication trolley is another example. While providing mobility and flexibility; it is often stationed in busy environments such as the nurse station, which is prone to noise and interruptions (activity 22).

3.6. Dynamic interactions

Several barriers and facilitators interact across the elements of the work system. One example is how the distances in the ward (physical environment) and the storing of information in different places result in staff members using a book (tools and technology) to record and keep track of vital information, resulting in challenges to retrieve and document patient information properly. These challenges may follow indirectly from the lack of guidelines on what to prepare before ward rounds and uncertainty about when the doctor arrives (organisation). Subsequently, staff members may be unavailable when called upon for updates (person(s)). If the nurse is experienced (person(s)), it promotes an efficient ward round. The availability of experienced nurses and staff consistency facilitate a smooth workflow in the ward (organisation). If all the staff members are familiar with each other and the conditions of the patients, they are to some degree able to predict future vulnerable shifts and act in a preventive way.

The eMAR is documented as cumbersome to use and with lengthy login times (tools & technology). Regulations state that all staff member must log off when they are finished with a session. In periods of high activity in the ward, this often meant that the staff members document on paper (tasks) and postpone proper documentation in the eMAR until the end of their shift. In some cases, this may lead to poor or lacking documentation (physical environment), which again poses challenges in the next ward round.

4. Discussion

Human factors-based studies of the medication administration process have used diverse approaches. In the study of Wooldridge et al. (2017), three different settings (previsit planning, patient outreach and checkout) are analysed to show how SEIPS-based process modelling may enhance the understanding of clinical processes. Huang and Gramopadhye (2014), demonstrates how clinical activity linked to medication administration in rural healthcare facilities can be portrayed in extensive flowcharts and provide feedback to staff and management. Carayon et al., 2014a,b, display the medication administration process in intensive care units while analysing the number of MAE's and ADES's occurring in each stage of the process.

The current study adapted the process modelling technique proposed by Wooldridge et al. (2017), and may offer some new insights. This is the first SEIPS-based process modelling of a nursing home ward integrating the entire MAP into a conceptual model. It expands the knowledge of the complexity of the MAP in a nursing home setting by portraying the dynamic interactions between the major stakeholders in the work system, and the temporal flow of the activities involved. Secondly, it identifies facilitators, barriers and dual traits in the work system linked to the six stages of the MAP.

By systematically considering all work system elements when analysing the medication administration process in the current study, the work system analysis provided information about how the system may respond to inherent variations. Since multiple simultaneous configurations of the dynamic work system are possible, it is crucial to prioritise which possible interactions are relevant (Holden et al., 2013). The findings suggest that several activities in different work system elements interact and reinforce each other. Barriers in tools & technology, such as poorly designed eMAR, may alter the behaviour of the stakeholders prompting workarounds or ad-hoc solutions that affect other work system elements. The work system analysis (Table 1) documents a wide range of factors that may inhibit or strengthen the MAP at different points. Current research on factors contributing to adverse events in nursing homes lists various elements such as lack of competence, poor documentation, interruptions, teamwork failures, inadequate communication and failure to follow procedures as critical (Andersson et al., 2018). McLeod, Barber, and Franklin (2015) found that many subtle variations in available resources seemed to affect how nurses interact and behave, with both positive and negative unintentional consequences for medication safety. Furthermore, they suggest that efforts to reduce MAE's should focus on better medication systems, management of interruptions, and reinforcement of patient involvement where appropriate. How this should be managed is complex and Lapkin et al. (2016) conclude that more research is still needed.

An earlier study exploring the nurse role during medication administration in nursing homes (Odberg et al., 2019), found that the staff members were seldom aware of the risk of ADE's. In order to maintain effective operations, the nurses were flexible and had a shifting responsibility. They took on tasks beyond the job description and had more responsibility than intended. During specific shifts, the work team sometimes lack critical skills while the nurse in charge was often engaged in performing administrative tasks. This led to a dynamic situation where individuals always compensated for varying degrees of competence when acting in teams. These findings resonate with the current study. Also, the system for reporting ADE's was seldom used since the staff members perceived that the management seldom learned from the incidents or made any targeted quality improvement efforts based on these.

4.1. Facilitators, barriers and dual traits in the work system analysis

Most barriers and facilitators occur in the first few stages of the MAP, indicating a vulnerability. These barriers and facilitators are closely tied to documentation activities and the retrieval of critical information at the right time. MAE's at this stage could cause potential cascade effects leading to ADE's. MAE's committed in the first few stages may, therefore, be crucial for patient outcomes and depend on the nurses' vigilance in rectifying those errors before they affect the patient. A study from the intensive care setting also found the first two stages of the MAP to be particularly vulnerable (Carayon et al., 2014), indicating commonalities across healthcare settings.

The literature often describes the prescription of medicines as the sole domain of the MD (Carayon et al., 2014; Qian et al., 2018). This study documents how the RN performs a series of activities before the MD arrives. Arguably, an additional "pre-ordering stage" in the medication administration process exists where the RN in charge uses considerable time and resources preparing for the MD's round. Also, when the MD conducts her/his activities, there is a close collaboration before any decisions or changes are made. As the MD is present only at specific times during the week, the RNs operate fairly autonomously within pre-set limits. Some RNs adhere more strictly than others to guidelines, while others make medicinal decisions ordinarily made by the MD and await later approval and confirmation. This independent behaviour depends on the skills, training and competence of the RN. It is therefore crucial that a bond of trust exists between the MD and RN, allowing this flexibility, something also confirmed by Vogelsmeier (2014).

A silent agreement seems to exist between all staff members that certain shifts are vulnerable and that they prepare in advance. Such shifts may be night shifts or during weekends. The vulnerable shifts may entail unexpected events, stretching the limits of their resources. How well they cope with such situations is tied to the degree of competence and relevant training. Smeulers, Onderwater, Zwieten, and Vermeulen (2014) support this view and further indicate that given sufficient knowledge, nurses are in a pre-eminent position to enable safe

medication administration. Also, staff consistency emerges as important when doing ward rounds. Having staff members familiar with the current routines, guidelines and patients facilitates interprofessional collaboration and ensures a smooth workflow.

Interruptions are identified as negative in the current study, disrupting workflow and causing hindrances in work processes even though research suggests that interruptions can be categorised differently and that some interruptions are positive in the overall perspective (Anthony et al., 2010; Hopkinson and Jennings, 2013; Odberg et al., 2017; Rivera and Karsh, 2010). An example of dynamic interactions in the current study is apparent in the preparing stage, as the staff used a mobile medication trolley. The staff members often placed the trolley in areas of high activity, and it became a hub of social activity where different activities, both social and professional, were discussed. In some cases, the activity around the medication trolley thus facilitated important information sharing even though the staff members were vulnerable to interruptions.

4.2. Issues with documentation

The process map illuminates how eMAR acts as a barrier at several stages of the MAP. Poor interface, slow login, lack of user-friendliness and poor access to relevant information are the most pertinent elements, slowing down the overall workflow. Several studies have reported on similar findings, calling for more streamlined eMAR to facilitate care processes (Alenius and Graf, 2016; Baril et al., 2014; Beuscart-Zéphir et al., 2010; Choo et al., 2010). Issues related to eMAR are often accompanied by the staff engaging in double documentation, creating layers of information on top of the original intent. Double documentation may be perceived as beneficial for the staff members but can create vulnerabilities during the ordering and transcribing stages of the MAP. Some RN's wanted to use mobile devices to streamline medication administration. Navas et al. (2015) found that the use of mobile devices during preparing and administering medications could decrease the likelihood of medication administration errors.

4.3. Implications

Findings in the current study that may enhance the work system are that eMAR should be tailored to fit the needs of the involved stakeholders and that proper education should be given in advance. The introduction of mobile devices to document medication administration may result in increased flexibility and less double documentation. Also, the physical environment in which medication administration takes place seems to interact with other work system elements such as tasks & tools and technology. This suggests that the first stages in the MAP are vulnerable to MAE's. Attention should, therefore, be directed towards creating proper work environments to lessen noise and interruptions during the first two stages of the MAP. Efforts should also be made to increase the staff's competence in medication administration via regular on-site courses, while rules and guidelines should be updated and made visible. Staff consistency over time is reported as important, and management should invest resources in maintaining a stable staff.

4.4. Methodological process modelling issues

Changes beyond the original SEIPS process modelling described by Wooldridge et al. (2017) are partly methodological and partly about the visual layout. The data material was analysed employing a deductive content analysis with a categorisation matrix (Elo and Kyngäs, 2008) containing the six steps of the medication administration process and the work system elements. A categorisation matrix was valuable when constructing the process map, allowing for independent placement of the meaning units and subsequent agreement within the research group. Using a similar categorisation matrix during analysis may be beneficial for other researchers with comparable challenges. The layout of the process map (Fig. 2) is the same as in Wooldridge et al. (2017) but the symbols for facilitators and barriers are now represented as coloured arrows instead of coloured dots. Utilising dual traits (dual arrows) allows for elements that can represent both facilitators and barriers depending on the circumstances, thus introducing more flexibility.

Another change from Wooldridge et al. (2017) is the work system analysis (Table 1) which lists the elements of the work system in columns to show where the facilitators and the barriers may belong. Coding the different data sources (interviews and observations) allows for further interpretation of the results. What some informants describe as a facilitator in interviews was found to be interpreted as a barrier in the observations. Thus there are multiple perspectives that need consideration when identifying facilitators and barriers in the work system of the MAP.

One may argue that facilitators or barriers stemming from both data sources have a higher degree of confidence. Some data from the interviews and the observations on the same subject contrast, showing how important the data interpretation aspect is. By utilising observations and interviews, it is easier to identify proximal factors such as how staff document administration of morphine, rather than distal factors such as administrative leadership's allocation of funds to train staff (Wooldridge et al., 2017). This may be perceived as a weakness, as most of the activity documented in the study relates closely to clinical activity. Future research may consider the linking of the proximal and distal factors at different levels (Holden et al., 2013). Possible solutions could involve an analysis of strategic documents and structured interviews with administrative stakeholders.

4.5. Strengths and limitations

The study is innovative in being the first study to map the entire medication administration process in a nursing home ward, using SEIPS as a conceptual model. The study also points to potential ways of enhancing the work system to provide a safer environment for medication administration in nursing homes.

The process map is based on observations and interviews from one ward, and thus the results are not necessarily generalisable. One limitation may be that the data collection was conducted by one observer (first author), preventing the use of inter-rater reliability to assure the validity of the findings. To compensate for this, we used consensus meeting among the co-authors to discuss and reflect on how the elements in the work system analysis could be presented.

5. Conclusion

A SEIPS based process modelling technique is an appropriate tool when identifying facilitators and barriers to safe medication administration in nursing homes. There are a large number of identified barriers to safe medication administration in the work system. The barriers are found in all work system elements but are prevalent in the tools & technology and tasks categories during the first few stages of the medication administration process. Potential medication administration errors introduced initially in the medication administration process may cascade and cause adverse drug events.

The use of dual traits and separate data source coding allows for interpretational flexibility and elaborates on the dynamic interactions of all the stakeholders involved. The prominent role of the RN is evident in all the stages of the MAP.

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Declaration of competing interest

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Appendix A. Supplementary data

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