Modeling the Communications Dimension of Clinical Work and Medication Errors

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Abstract

Hospital medication errors continue to be a significant problem despite the targeted use of information and communications technology (ICT) interventions. In an ongoing program to add an 'in silico' dimension to our multi-method multilevel evaluations we are modelling the significant role of communications in medication error at the context, process and task interaction levels. This extends our previous long-term context and process interaction system dynamics model and adds agent based modelling to more naturally represent the process and task interaction level. The conceptual model integrates previous relevant communications, work and organisational context, task interruption and cognitive overload modelling. The prime focus is to understand and integrate the multiple effects of ICT interventions at multiple levels that can combine to produce unintended results, including new errors. It is being extended to provide a high fidelity systems simulation test bed for designing and testing ICT interventions to reduce medication errors. KEYWORDS: Hospital Medication Error, Communications, ICT, System Dynamics and Agent based modelling

Introduction

Medication errors are one of the most significant causes of iatrogenic injury and death for the Australian and international health care systems (Institute of Medicine, 2000; Thomas E et al., 1999). In the US it is estimated that over 770,000 people are injured or die each year in hospitals as a result of adverse drug events (ADEs). (Kaushal R and Bates D, 2001) US deaths from medication errors are estimated at around 7,000 each year and the number is reported to have increased by 250% between 1983 and 1993. (Phillips, D et al, 1998) In Australia, 2-3% of all admissions are medication-related, accounting for around 140,000 admissions in 1999-2000. (Runciman W et al., 2003) This compares with around 60,000 admissions for asthma and 42,000 for heart failure. The costs of these medication-related admissions are estimated to be $380 million annually. (Australian Institute for Health and Welfare, 2002)

The frequency of medication errors in hospital is increasing each year with a growing older and sicker population, with the prescribing of complex medication regimens and use of new, more potent medicines. (Lesar TS, Lomaestro BM, et al., 1997)
Of great concern is the growing body of anecdotal and empirical studies contradicting early results, showing new electronic medication management systems (e-MMSs) may actually increase the frequency of medication errors. (Ash J, Berg M et al., 2004; Berger R, Kichak BA, 2004) MedMax data from 570 US hospitals reported that 20% of hospital medication errors in 2003 involved computerisation or automation (US Pharmacopeia, 2005). A

nationwide field test of commercial e-MMSs in the US found only a small number of the systems alerted the users to potentially fatal prescription errors (Bates, DW, Cohen M et al, 2001). A recent study (Han YY, Carcillo JA et al, 2005) found that following the implementation of a computerized order entry system in a paediatric hospital in the US, there was an unexpected increase in deaths.

As Patterson et al. (2004), note, communication is frequently implicated as a major cause of medication errors. So, a reasonable strategy for reducing error rates is trying to improve communication practices. Therefore, in designing, implementing and evaluating ICT-interventions, we should focus on their impact on the communications dimension.

Background

Te'eni (2001) presents a cognitive-affective model of organizational communication that identifies two main outcomes for a communication process:

1. The mutual understanding among the participants in the communication process (the cognitive aspect of the model), and
2. The changes in the relationship between the participants (the affective aspect).

Both outcomes are driving forces for successful collaboration in organizations. In fact, the analysis presented by Patterson et al. (2004) of a specific medication error, demonstrates how not achieving these goals can hamper working together in a serious way. In this study we will restrict our attention to mutual understanding that is the cognitive aspect of the model.

Mutual understanding is a pre-requisite for the successful completion of two activities that are essential to collaborative work: instructing action (which includes requesting information), and managing interdependent action. If we look at the conceptual framework for medication management as proposed by Bell et al. (2004), we see that instances of both activities are included. The clinician 'instructs' the pharmacist to dispense the prescribed medication. And the clinician, patient and staff (e.g. nurse) are managing their interdependent execution of the monitoring task. Beuscart-Zéphir et al. (2005) argue that the prescribe-task is also an example of collaboration between the clinician and the nurse, and therefore an example of managing interdependent action.

What actually happens in both instructing action and managing interdependent action is the ***alignment*** of actor behaviours. Figure 1 below gives an abstracted view on the behaviours of both clinician and pharmacist, and the point at which these behaviours have to be aligned, by means of a UML-activity diagram.

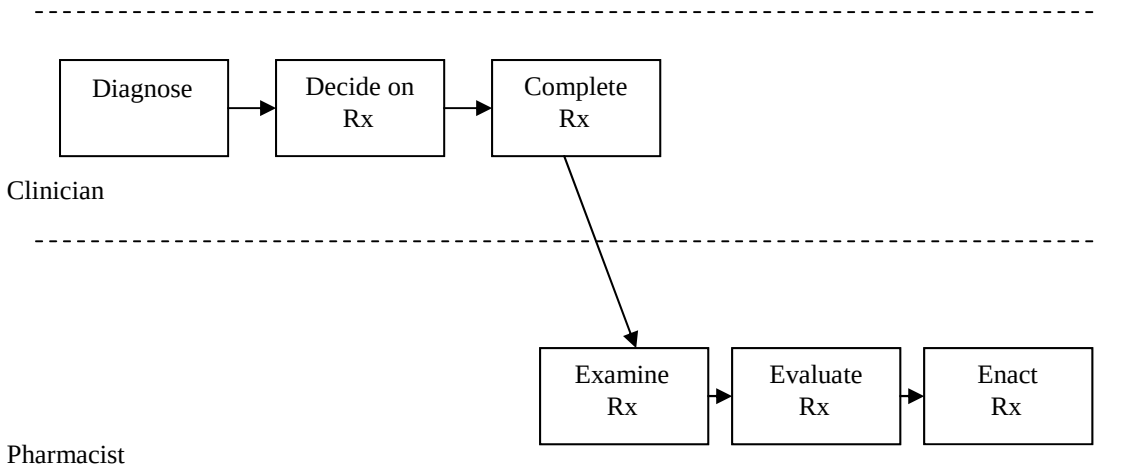

Figure 1: alignment between behaviours

The alignment is achieved by means of a communication process, and its success depends, according to Te'eni's model, on the level of mutual understanding that is reached. We will elaborate this by viewing this communication process as a **Speech Act**. This concept is well known from the pragmatics literature (e.g. Levinson (1983) and Thomas (1995)), while it originated from work within the philosophy of language (Austin (1961) and Searle (1969)). There are two dimensions with respect to the concept of 'speech act' worth discussing here. The first is the dimension of 'meaning'.

Thomas distinguishes two levels of meaning: **utterance or contextual meaning** and **Force.** Utterance meaning comes down to the semantic content of the words uttered in a specific context. In order to determine the utterance meaning of a sentence, a hearer has to resolve ambiguities in sense, reference and structure. In case of a sentence like: 'It is becoming hot in here', this means combining knowledge of the word meanings with knowledge of the time of uttering and the location indicated by 'here'. Force, has to do with speaker's communicative intention.

The contextual meaning and force of a speech act are determined by the participants on the basis of four sources:

1. **Linguistic behaviour** – what is actually said, the messages exchanged.
2. **Para-linguistic behaviour** – the way it is said, using: pitch, tone etc.
3. **Non-linguistic behaviour** – accompanying behaviour such as: gestures, facial expressions, etc.
4. **Contextual information** – this includes information about the location of the conversation, the time of the conversation and about the activities the speech act is to align.

The second dimension is that of the relation between a speech act and the utterances by means of which it is expressed. As is often remarked, presupposing a 1-to-1 relation

between a speech act and an expressing utterance is too restrictive. It is more common to see a speech act realized as a piece of situated discourse. Thomas gives two main reasons for this. The first one is that speech acts require preparation. Bluntly requesting something to be done is often not the way to make someone act. The request has to be accompanied by information that explains the reason (and maybe the urgency). The second reason is that speech acts are by nature collaborative, that is: the force of a speech act is often negotiable. As Thomas extensively shows, people are exploiting mechanisms of indirectness all the time in order to leave the force of their speech act undetermined until they are sure the addressee will take it up. If I utter the aforementioned utterance 'it is becoming hot in here', and my addressee responds 'I think it is perfect' and goes on working, my utterance will have received the force of a statement and not a request. For this reason, Thomas defines pragmatics as the study of meaning in interaction.

(Thomas, 1995, p.22): "Making meaning is a dynamic process, involving the negotiation of meaning between speaker and hearer, the context of utterance (physical, social and linguistic) and the meaning potential of an utterance."

Modelling Alignment Speech Acts

Given the role of an alignment speech act, as presented in the previous section, how can we characterize such a speech act? We stress that is features of the setting of language use we are interested in. These determine the success of an alignment speech act, and they are the ones that are affected by an ICT-mediated intervention.

The defining characteristic of an alignment speech act is its force. So, we will consider *situated discourse of single force*. In the example of the clinician instructing the pharmacist to dispense certain medication, as discussed above, the force is **ordering** or **requesting** to act. The discourse implementing the speech act can be fragmented into a form filled in, a phone call made and an information system accessed. We propose to describe this situated discourse of single force, by means of the following features, that are categorized into three separate categories. We will first present the features and give examples afterwards.

Participants

When we have identified an alignment speech act, we should list all the participants involved in it. Information resources consulted in the realization of the speech act are also considered as participants.

The second feature that is relevant can be referred to as *the social context* of the speech act. Clark (1996, Ch. 10) distinguishes three types of social contexts. The first type he refers to as ***closed***. In this situation participants have clear roles, and associated responsibilities. These roles do not have to be negotiated. A physician ordering a nurse to administer some drug is an example of a ***closed*** situation. In ***regular*** situations, the second type, most roles and responsibilities are clearly allocated, but some allocations must still be negotiated. The team conference described above is an example of such a

situation. The third type is called ***open***. In such a situation almost all roles and responsibilities must be negotiated. This is the most difficult situation for achieving speech act success.

In the context of our model we will restrict ourselves to communicative roles. A speech act of a certain force has a set of communicative roles that must be taken up in order to realize it. If the force is for example **requesting**, we have a requester-role and a responder-role. In a closed situation it is determined who takes which role, while in the open situation, the role allocation has to be determined in the course of the interaction.

The third feature relates to the body of knowledge shared by the group of participants. Clark (1996) refers to this as common ground; Te'eni (2001) discusses this point as the cognitive distance between the participants. The less common ground, the less change there is on speech act success.

The Causal Loop Diagram below summarizes the interactions between these features and their impact on speech act success.

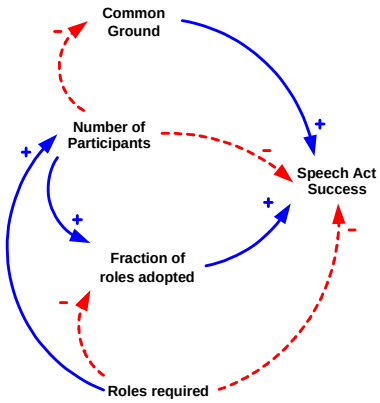

Figure 2: CLD for the participant features

Linguistic Behaviour

The linguistic behaviour being part of the speech act can be characterized by looking at its form and content. Both can be standardized. This restricts the structural and semantic means that participants can use to express themselves. We will refer to standardized form and content as ***scripted linguistic behaviour***. It has a positive effect on common ground, because the participants use the same linguistic apparatus, and therefore will be more able to interpret each others linguistic behaviour. However, the effect on speech act success can be negative, because the linguistic means by which both contextual meaning and force can be negotiated are reduced. Participants are less expressive in a scripted situation.

We add this to the CLD.

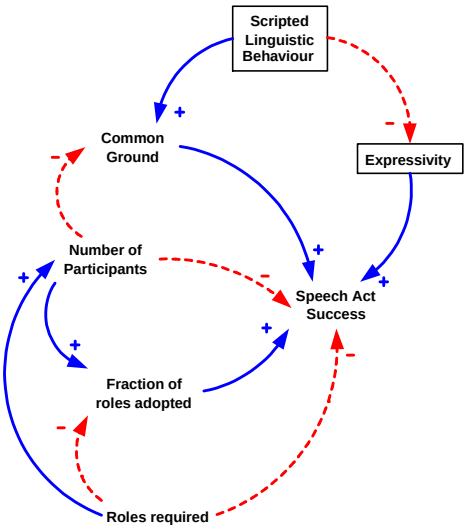

Figure 3: CLD with participant and linguistic behaviour features

Setting of language use

Clark (1996, p. 6-10) proposes 10 features for characterizing a setting of language use. In our opinion the first 4 are basic features and the others derivatives. He proposes to take the *face-to-face* conversation as the basic setting of language use. The main features of this setting are (p.9):

1. Co-presence — The participants share the same physical environment.
2. Visibility — The participants can see each other.
3. Audibility — The participants can hear each other.
4. Instantaneity — The participants perceive each other's actions at no perceptible delay.

These 4 features are referred to by Clark (p.10) as reflecting ***immediacy***. We will follow Clark where he states that each setting of language use can be best understood in terms of its deviation from the basic setting, e.g. face-to-face conversation.

The features relate to the sources that people use to negotiate contextual meaning and force. Lack of co-presence and instantaneity reduces the amount of contextual information the participants can use to negotiate meaning. Lack of visibility reduces the amount of non-linguistic information, and lack of audibility reduces the amount of para-linguistic information.

The effect of immediacy is expressed in the extended CLD.

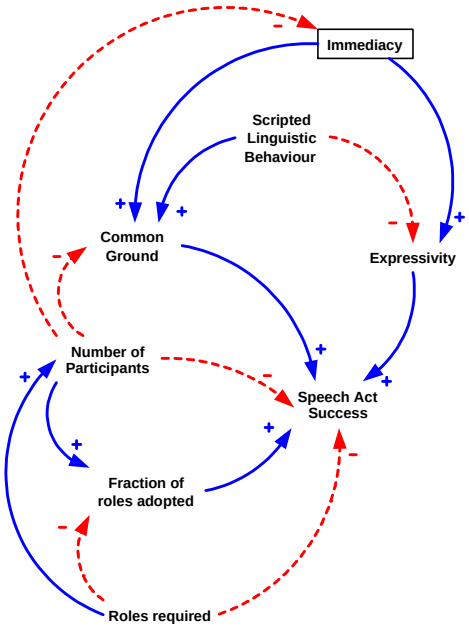

Figure 4: CLD with language use setting feature

By means of an example, we will work out the alignment speech act for the alignment of the activities of the clinician and pharmacist given above. We start with a (highly improbable) situation in which the clinician transmits the Rx in a face-to-face meeting with the pharmacist. The interaction can be described as:

Force	Order
Participants	Clinician (**requester, information provider**), Pharmacist (**responder, information seeker**), closed social situation, common ground is small because the pharmacist does not know the patient.
Linguistic Behaviour	Unscripted
Setting of language Use	Face-to-face, so it has: co-presence, visibility, audibility, and instantaneity.

The Force suits the alignment task. So, there is no need for change. If we look at the implementation features, than the only problem is the lack of common ground. This could be a reason for change.

From an organizational point of view, there are two more disadvantages of this implementation of the alignment speech act. The first one is the fact that the pharmacist is uniformed about the patient, and that the clinician has to provide the necessary information. So, 'expensive' expert time is spent on informing. The second disadvantage is that the clinician is actually 'trapped' in his sub behaviour 'Complete Rx', until the

pharmacist makes the transition to his sub behaviour 'Enact Rx'. The clinician cannot turn his attention to another patient (or something else) until the pharmacist 'releases' him, to say so.

We now turn to a different implementation that removes the identified disadvantages. In this case an electronic prescription application (e-Rx) is available, as well as an electronic patient record (EPR). The clinician sends the Rx to the pharmacist by means of the e-Rx. The pharmacist evaluates the Rx using information from the EPR.

Force	Order
Participants	Clinician (**requester**), Pharmacist (**responder, information seeker**), EPR (**information provider**), closed social situation, common ground is large (encoded in EPR).
Linguistic Behaviour	Scripted
Setting of language Use	Lack of immediacy, so: no co-presence, no visibility, no audibility, and no instantaneity.

In this implementation, both human actors only communicate in a highly decoupled fashion. This enables them to integrate the alignment task more smoothly into their other work processes. Although the force still suits the alignment task, the implementation features might increase the chance of interpretation problems due to the lack of immediacy. The success of the speech act will depend on the whether it is possible to script the linguistic behaviour in such a way that ambiguities are ruled out.

An architecture for a simulation model

In the previous section we have proposed a number of assumptions with respect to the effect of features on speech act success and the interactions between the features. These assumptions were expressed as relations in a CLD. Using validated simulation models, we could elaborate these relations.

Achieving speech act success is not a goal in itself. Nor is proper alignment, for that matter. In the end we would like to be able to relate these effects to measures of the outcome of clinical work, e.g. the percentage of adverse drug events occurring. Only then will it be possible to evaluate the contribution of changes in the speech act implementation to changes in relevant outcomes.

We propose an architecture that consists of three main components, or perspectives. These components have a certain structure (codified in the simulation model), and as a result of this structure **and** the interaction with the other components, a certain emerging

behaviour (demonstrated in the simulation run). Figure 5 below depicts the framework's architecture.

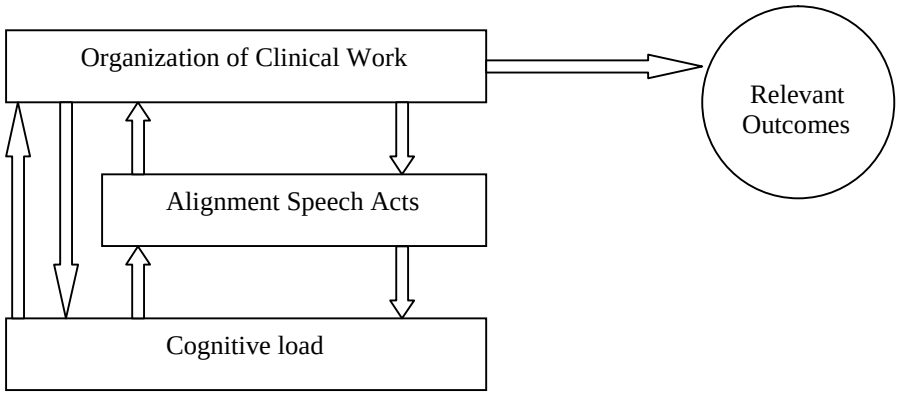

Figure 5: simulation framework

We will describe these components or perspectives from top to bottom.

1. **Relevant Outcomes –** these are the indicators for the success of the clinical work. It can encompass a variety of attributes, depending on the way success is defined. Some examples are: error rates, revenues, patient satisfaction and throughput rates.

2. **The organization of Clinical Work –** this component encompasses the descriptions of work processes, policies, organizational culture, etc. It interacts with the 'Alignment Speech Acts' component by defining alignment speech acts, based on identified alignment tasks. It interacts with the 'cognitive load' component by generating task lists for individual actors.

3. **Alignment Speech Acts –** this component models the communication perspective we have elaborated above. It views an organization as a set of alignment speech acts associated with alignments tasks. Based on their force and their individual features they have a chance to fail. The 'Alignment Speech Acts' component interacts with the 'organization of clinical work' component by generating alignment failures based on speech act success. This component interacts with the 'cognitive load' component by generating communication events.

4. **Cognitive load –** Individual agents are susceptible to making errors due to communicative and task overload. Communicative events and task lists are generated by the two other components in the framework. Based on these, actors generate error rates on task and speech act performance.

We intend to implement this framework by using both System-Dynamics and Agent-Based techniques. The components 1 and 2 are already (partly) implemented in the system

described in McDonnell and Heffernan. This SD model represents the longer term interaction between context and process errors. The extension focuses on the interplay between process errors and task interaction. Each process is enacted by various agents working as a team in a mixture of semi-structured and creative ways to jointly inform, decide and act, with the optional use of many speech alignment acts during these task interactions. This interactive individual behaviour has a good natural fit with agent based modelling techniques. The existing SD model is being extended by implementing components 3 and 4 using an Agent-Based approach.

Discussion

Communication practices play an important role the generation of medication errors. If we want to design and implement organisational interventions that change communication practices, with the aim of reducing medication error rates, we have to have a thorough understanding of the mechanisms involved. Observational studies can help, but, due to both costs and risks of real life implementations, the insight thus gained will be restricted. Simulation can help in offering an environment in which the impact of different interventions can be assessed, without disturbing clinical practice.

We have argued in this paper that a mixed approach of SD and AB techniques is needed in order to cover all aspects that play a role in the relation between communication practices and relevant outcomes.

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