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Unintended transformations of clinical relations with a computerized physician order entry system

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ABSTRACT

A socio-technical approach was used to study the qualitative effects of deploying a medication computerized physician order entry system (CPOE with no decision support) at two internal medical wards in a hospital in Denmark. Our results show spatial and temporal transformations of core acts and relations in medication work, i.e. of the intended use of the system inscribed in hardware and software, in the relations of care between doctors and patients, of collaboration between doctors and nurses, and prospectively of the patients' trajectories when readmitted to hospital or another health care institution, reusing data from the system. This study throws light on problems of continuity of patient care paths, patient-related and IT-system-related error handling and time spent on core activities—when ubiquitous IT is used locally in a real physical setting with specific traditions of performing or 'doing medication'. The paper argues for the project organization to support the local collaboration and renegotiation of time and place of enacting medication with CPOE, as well as set up feedback for maturation of the software for future clinical use.

1. Introduction

This study pays special attention to the technique and role of a computerized order entry system (CPOE) in the work processes of medication at two wards of internal medicine in a middle-sized Danish hospital. From the view of health care management, "the cockpit crew" [1], CPOE systems are expected to reduce errors and medical costs, give better quality and continuity of care and improve cooperation between health care professionals [2]. The aim of the qualitative study presented here, though, is to bring in the view of the "fire brigade" [1], the clinicians responsible for the medication outcome, and to support their articulation of experiences as the primary users of the system. These articulations might, in spite of their local, qualitative origin, be of interest to other implementers and developers of CPOE systems, as learning on design, change management and the nature of clinical work [3,4] seem to be the imperative of improving information systems in health care. Classen et al. state that evaluation of CPOE installation in individual organizations is more pressing than ever [5, p. 51]. "All organizations will need to perform ongoing evaluation of their CPOE applications and their electronic health record (EHR) if the potential benefits of these technologies are to be actually realized" [6, p. 53]. Georgiou et al. concluded that further research is needed, especially as "(f)ew data are available regarding the impact of CPOE on patient outcomes" [6, p. 514]. Pragmatic discussions on health care improvements from CPOE call for more attention to detail and appropriate support to clinicians' workflow [7]. The following ethnographic study illuminates usability and utility problems of clinicians interacting with CPOE in real life settings.

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1.1. Background

The theoretical background is socio-technical understanding of work processes, which basically means that work processes do not take place automatically, controlled more or less by either the technologies at hand or the professionals in place. Instead, technological artefacts and human actors are closely intertwined, and will be analyzed accordingly. Medication processes include a variety of persons and techniques, from patients, physicians, doctors' rounds, writing tools, note books, etc. They are also termed 'actants', as they all – humans as well as techniques – contribute to the production or 'enactment' of medication as an ongoing activity in concrete temporal and material settings [8,9].

2. Materials and method

The *object of study* is the medication process with a CPOE system in two Danish internal medical wards. Qualitative methods have been used for in-depth analysis of 48 h observation, six semi-structured interviews with primary users (two physicians and four nurses) and an analysis of the user interface and of other documents. Based on the observations, three use scenarios for central events in the medication process were constructed. The *actants* were among others drugs, physicians, nurses and the CPOE system. *The CPOE system*, at this stage of development, is only handling the "bookkeeping" of medication. It is not offering any decision support, and is developed by a professional vendor (Systematic Software Inc., Aarhus, DK) in close cooperation with the responsible Health Maintenance Organization (HMO) (Aarhus County, DK), who have supplied clinicians to the development project. At the time of the study, the CPOE had been in use for 8 months in the participating hospital wards, replacing a paper medication scheme, called MOS. Other actants were the pharmacy system (electronic Danish Physicians Desk Reference (PDR)), handbooks on medication, PC tables, other staff groups and techniques.

2.1. The medication process

Medication (treatment with drugs) in hospital settings can be understood as a process that begins with the patient's diagnosis and ends, at best, when the patient is discharged from hospital or is no longer in need of the drug. This overall *programme of action for carrying out medication* consists of a minimum of seven subprogrammes of actions that are essential for medication to take place [10]:

1. The indication of treatment.
2. 'Prescription', i.e. the choice of treatment and the patient's consent hereof.
3. 'Order', i.e. entry of clinical choice of treatment into the CPOE system.
4. 'Dispensing', i.e. the drug is made ready for consumption.
5. 'Administration', i.e. the patient is given the drug.
6. 'Assessment' of the drug's effect on the patient.
7. Considerations on how to precede, i.e. whether to continue or withdraw the drug.

These *subprogrammes of medication* are elementary, core events in medication work. They are continuously repeated, with ongoing adjustments within a 24 h rhythm, 365 days a year. Danish clinicians commonly understand *the goals of the subprogrammes* as 'the five right': the right drug, to the right patient, at the right time, in the right dose, in the right way (e.g. orally or intravenously). Any deviation from these goals is considered to be an error of medication.

Apart from being used for drug orders (3), the CPOE was an active part in the subprogrammes of prescription (2), dispensing (4) and continuity of treatment (7). The observations were condensed, verified by users and generalized in the construction of *three use scenarios* that confirmed transformation in vital elements of health care: (a) in the doctor's relation to the patient and other techniques (especially a clumsy PC table and stationary dictaphone for the patient record), (b) in the doctors' and nurses' coordination work, and (c) in the possibilities of the patient's further trajectory and future medication care path.

3. Results

The following shows how the CPOE system participates in the transformation of three central relations for enacting right medication, i.e. between doctor and patient treatment when prescribing and ordering drugs, between doctor and nurse and their collaboration around ordering and decisions on proper dosage for the patient, and in the coordination between hospital and future situations of treatment. These transformations point to unintended consequences that cannot alone, though, be reduced to either the system or social factors but are in many ways sensible outcomes of concrete situations of interaction. The use scenarios showed that the system's success or failure in use could not be assessed isolated from the environment in which it participates. The social culture and the materiality of space and things challenge the use of the CPOE system.

3.1. Transformation of prescription (2) and drug order (3) on doctor's rounds

On doctor's rounds 'a detour' [6] or work around occurred in making prescriptions and entering orders in the system. This was due to long walking distances between the patients' beds and the stationary dictaphone in the hallway for making prescriptions in the patient's medical record and subsequently, a clumsy PC table with the otherwise portable CPOE (Fig. 1). The doctor would therefore memorize three or four patients at a time before (s)he would, first, dictate the patients' diagnoses, indications and prescriptions for the patients' records and then enter the drug orders in the system. In other words, the space and distance between hospital beds, PC tables and a stationary dictaphone decide what is accessed, when, in what order and how. The CPOE may be, therefore, technically ubiquitous in the sense that it provides users with global access to patients' medication across hospital wards and other health care institutions in the county. Though in its local use other actants such as the stationary dictaphone, the clumsy mobile PC table (Fig. 1), the endurance of the laptop computers and the

Fig. 1 – PC table and patient paper records of both nurses and doctors.

walking distance between the different interactions of talking to the patient, dictating the diagnosis for the patient record and prescribing medicine for treatment in the CPOE, play a decisive role in how and what medicine is actually performed. Alas, the best working conditions for the users were at the stationary PCs in the ward office away from the patients and the drug storage.

3.1.1. *The figuration of a collective e-patient for drug orders*

The term 'figuration' means the formation and appearance of another meaning and identity in the given context [11]. In this case, a more 'collective e-patient' appeared in the physician's way of coordinating doctor's rounds, with the activities of recording diagnostic information on the dictaphone for the patient record and ordering prescriptions in the CPOE. The physician would start/continue treatment of the individual patient on the background of an encounter of three or four patients at a time, before (s)he would do the drug orders collectively. The health care treatment and trust relation between the human actants, therefore, to a higher degree depends on the doctor's memory and ability to keep the different patients' diagnoses, prescriptions, other treatments and plans of action apart.

3.2. *Transformation of drug order (3) and dispensing (4) with the CPOE system*

The CPOE software contains no facilities for computer-enhanced 'collaborative working environments'. Using the paper-based system, the doctor and nurse were able to collaborate, correct and negotiate patient treatments and each other's work tasks in achieving the 'five right'. With the CPOE, this cooperation still exists, but has spread out in time, space and numbers of persons and thereby gives less foundation for securing quality, negotiations and discussions.

3.2.1. *Deconstructing user rights and configuring a clinical e-team user*

The model of medication work built in the system, logons and user rights (during the development process with cooperation between the vendor and the clinical representatives of the HMO) did not correspond to the actual work practice and led to a transformation of both actants: system and clinicians. The users' practice was reconfigured as well as the system being used differently from how it was prescribed in the system design. According to the model of medication inscribed in the CPOE, only doctors can perform certain tasks: among others, approve prescriptions. Physicians and nurses, therefore, have individual passwords and different user rights in the system. In case patients need changes in medication, the nurses can register the changes, but the physician needs to log in and approve them. In practice, another work division and for a different reason was observed. Logon procedures were time-consuming and prescription, orders, changes in dosage, administration and assessment are done more fluently and ad hoc, according to the situation. The system was not flexible enough for supporting the mutual dependencies of physicians and nurses for making requisitions and continuing and withdrawing medication. In order for the work to flow, some physicians would log in and let the nurses continue the medication work with a doctor's user rights. Thereby, personal login and user rights mask clinical team users making workflow differently from the formal design. The following reasons for this transformation of formal and individualized user rights to clinical e-team user occurred.

3.2.2. *Inflexibilities and displacements in the use of the CPOE hardware and software*

Login procedures demanded a patience of the user that fits badly with the normal pace of hospital work, and a 'team login' in line with the mode of work described above was not possible. 'Irrationalities' of the system, the use and error messages were observed. A line of technical problems on hardware also had a considerable impact on contextual use and trust in the system. Too few computers queued up the users and demanded a physical separation of the work tasks and the information needed to perform them adequately, relying on users' abilities to memorize specific combinations of drugs, doses and patients. The CPOE system used – as the key for patient identification – the 10-digit Danish Civil Registration number. This number had to be keyed in on every access to a specific patient. On laptops with no numeric keypad, this work was time-consuming and prone to mistyping.

3.2.3. *Enrolling an 'old technique': the paper medication order scheme*

For backup reasons, paper copies of the CPOE content were printed every 24 h. Due to the instability of the system in the study period, these were in use for medication proce-

dures on average twice a week for hours. This was actually affecting the overall safety performance of drug dispensing and gave a lot of additional work with no extra gain, thus invalidating many of the reasons for implementing a CPOE.

3.2.4. *Problems with a unified and inflexible CPOE medication model*

The model in the software program contained very strict timing and inflexible control facilities designed around medication rounds four times within 24 h (three times for intravenous medicine). This was in contrast to the dynamic medication procedures needed and the work plan of the nurses that imposed the night nurse to dispense the medicine for the next day in special trays. If the prescription of the drug was altered during the round, a nurse had to identify the tray with that drug and change the dose of the drugs accordingly. When prescribing drugs in the CPOE system, users can choose whether to prescribe drugs in, e.g. mg, g or in number of pills. To avoid misinterpretations, users are urged to register the drug doses in mg. Since the interface is not so clear in this respect, this was a (novel) source of errors not experienced (to that extent) with a paper-based system, although in principle it contains the same flexibility. The basic problem was that the database underlying the CPOE system was for pharmacy use, focused on package variations and prices. The database contained no uniform way of declaration of strength, thus allowing for the variation in the interface as well, giving rise to errors and confusion in the work processes.

3.3. *Transformation of continuing medication (7) with the CPOE system*

The use scenario of 'considerations for continuation of patient care and treatment' showed considerable changes with the CPOE in two situations of use: when the patient was discharged and in need of information on how to continue medication at home, and according to the status of the patient in the CPOE in the case of the patient being re-hospitalized.

3.3.1. *Discharging patients with CPOE*

With the CPOE system, an automatic medication guide is printed for discharged patients who have to continue taking medicine in their homes. This guide includes details that are not comprehensible for the patient, for two reasons. The name of the drug may have changed when the patient picks it up from the pharmacy, because the pharmacy uses a product from a different company than the hospital.[1] The guide is a copy of the medication information in the CPOE and, therefore, the prescribed drugs are typically listed in mg and g and not in number of pills. The patients would therefore have to complete the task of converting the mg and g to the correct number of pills. As a solution, some nurses have started to write an additional medication guide that enables the patient to dispense and take his/her own medicine, regardless of the drugs handed out by the hospital and/or the pharmacy. Another new technique in nursing was included for doing this: a word processor.

3.3.2. *Withdrawal or discontinuous patient trajectories with the CPOE*

Traditionally, the paper medication scheme puts a material limit on how many drugs and for how many days the consumption continues. Because of the virtuality of electronic documents, a transformation in the continuation of medication was observed with the CPOE and the medication model of the system. Medications not specifically terminated at the previous discharge were listed as active treatments on readmittance. This is an important issue, because it shows the hidden aspects of the new possibilities of coordinating patient care paths and trajectories virtually with information technologies: errors can 'live longer' and reappear in different, future health care settings, and are difficult to discover. As clean-ups and withdrawal are not routinely and/or automatically done with a non-paper-based system, the CPOE assigned new tasks to users.

3.3.3. *New tasks and demands on the clinicians from doing medication with the CPOE*

The study showed a higher cognitive pressure on the physicians' and nurses' memory skills and competences of temporal and spatial coordination. The system offered no decision support, apart from a list of approved drugs to choose from. There were no CAVE-alarms (previous adverse effects) and no warnings of potential interactions. Pocketbooks (paper) were still an important technique in the medication work. Drug orders, which have not been withdrawn from the CPOE are potential adverse effects of medication, that also delegate new work tasks. The collective use of the CPOE in order to support workflow makes the actual collaboration in medication work more invisible. Communication between physicians, nurses and patients was not supported but demanded considerable work around including old and new techniques.

4. Discussion

The role of CPOE systems in fostering new errors as well as reducing old ones is known [3,12] and forms the debate on IT development in health care as such [1,5–7,12–15]. The point seems to be that, despite disappointments in improving the quality of health care with information technology, HIT [16], including CPOE systems, is indispensable to modern health care. It also follows that the complexities of health care make flawless systems a priori impossible [7,16,17]. Arguing along the line of either the system [18] or system developers/organization [19] being solely responsible for the user's resistance is a modernistic conception of rationality [20], that cannot grasp the transformative character of IT implementation on communication and sense-making. Instead, more iterative design processes that include the domain knowledge of the end-users [4,7,16,20] are required. Interdisciplinary research in human–computer interaction in hospital settings can inform on more clinical sensitive and iterative design

[1] Danish pharmacies are obliged by health care authorities to recommend comparable drugs at the lowest price.

processes [1,5,6,15,16]. Here, quality of health care depends heavily on the inclusion of the end-users' domain knowledge in more iterative design processes [7,17,21]. The argument is that transformations of medication processes, also outlined above, touch upon many actants that all have responsible roles to play in the overall goal of medication, i.e. the right – and safe – treatment of individual patients. 'Errors' are, therefore, not an impediment to HIT-mediated health care, but can be seen as something to learn from [22] when new understandings and solutions are equally integrated into the system design and work processes.

This study confirms numerous usability problems that also affect the overall quality of health care and is of consequence to professionals. One important issue concerns the technical maturity in relation to stability and functionalities, and the CPOE system in this study is fairly unripe. Another important issue is the rationality of the system as reflecting different understandings of work division. In this study, the deconstruction of the formal user rights and of the individualized logon to a clinical team user, working under the rights and responsibilities of a physician, showed a lack of correspondence between work division inscribed in the system, and the actual use of the system for medication work. This 'gap' between formal understandings of what nurses and doctors are trained and licensed to do, inscribed in the software, and how these roles are played out as teamwork to smooth the process in a real clinical setting, stays open, and has not yet been bridged. Among the Danish public, this issue is in general discussed as either a technical problem of making a faster and unbreakable login [23], a jurisdictional problem of health care authorities to secure and punish misuse of patient data more firmly [24], or as problems of the hegemony of the clinical professions. The authority and right of the physician to delegate tasks, and the duty of the nursing profession to protect care obligations from new tasks and workloads are diluted. These issues point to implementation problems that transcend the knowledge domain of the vendor and hospital owners, as they touch upon power relations and core duties and responsibilities of health care professionals. Additionally, it can therefore be asked who is responsible, or can be made responsible, for these transformations of core relations in patient treatment with the CPOE systems.

5. Conclusion

Expectations of more quality and continuity in health care from simply implementing vendor-built CPOE systems are naive and bound to be disappointed. 'Rational medication' can never be detached from local interactions between wide ranges of actants. System design and implementation has to take the pragmatic rationalities of concrete tempo-spatial interaction into consideration and negotiation. The presented study points to critical situations of enacting medication with CPOE, that demands more flexible functionalities, vendors adherence to general recommendations for human–computer interaction, more attention to change management by the project organization, but also to political and ethical issues on among whom and how responsibilities for health care are to be shared.

Summary points

Three to five bullets showing what was known before the study:

- Hospital information systems affect and change clinical practice differently than the rationality designed for.
- Science–technology–sociology studies can inform on human–computer interaction for politics of design.
- The actual effect of any technique arises in the concrete use situations, therefore – according to the complexity of reality – it can never be fully predictable and designed for in advance.

Three to five bullets showing what the study has added to the body of knowledge:

- The outcome of a CPOE system designed for improving individual patient safety in medication might empirically transform the physician's treatment of individual patients to drug orders for groups of patients at a time, including new risks of medication errors in relation to supporting patient care paths across health care providers and re-hospitalization, and transform the formal work division between doctors and nurses inscribed in the system but surpassed or deconstructed by a group of clinicians working under an individual login.
- Project organizations have to plan and screen for the unexpected consequences of CPOE systems, and leave the design of CPOE and rationality of clinical practice open for socio-technical renegotiation.

REFERENCES

[1] R. Koppel, A.R. Localio, A. Cohen, B. Strom, Neither panacea nor black box: responding to three Journal of Biomedical Informatics papers on computerized physician order entry systems, J. Biomed. Inform. 38 (4) (2005) 267–269.
[2] Indenrigs- og Sundhedsministeriet. National IT-strategi for sundhedsvæsenet 2003–2007. 2003.
[3] E.M. Cambell, D.F. Sittig, J.S. Ash, K.P. Guappone, R.H. Dykstra, Types of unintended consequences related to computerized provider order entry, J. Am. Med. Inform. Assoc. 13 (5) (2006) 547–556.
[4] J.E. Bardam, H. Baldus, J. Favela, Pervasive computing in hospitals, in: J.E. Bardram, et al. (Eds.), Pervasive Computing in Health Care, CRC Press, 2006, pp. 49–78.
[5] D.C. Classen, A.J. Avery, D.W. Bates, Evaluation and certification of computerized provider order entry systems, J. Am. Med. Inform. Assoc. 14 (2007) 48–55.
[6] A. Georgiou, M. Willianson, J.I. Westbrook, S. Ray, The impact of computerized physicians order entry systems on pathology services: a systematic review, Int. J. Med. Inform. 76 (2007) 514–529.
[7] P.A. Gross, D.W. Bates, A pragmatic approach to implementing best practices for clinical decision support systems in computerized provider order entry systems, J. Am. Med. Inform. Assoc. 14 (1) (2007) 25–28.

[8] M. Akrich, B. Latour, A summary of a convenient vocabulary for the semiotics of human and nonhuman assemblies, in: W.E. Bijker, J. Law (Eds.), Shaping Technology/Building Society: Studies in Sociotechnical Change, MIT Press, Cambridge, MA, 1992, pp. 259–264.
[9] B. Latour, Reassembling the Social—An Introduction to Actor-Network-Theory, Oxford University Press, 2005.
[10] Lægemiddelstyrelsen. Brug medicinen bedre—Perspektiver i klinisk farmaci. <http://www.laegemiddelstyrelsen.dk/publikationer/netpub/rapporter/brug_medicin_bedre/>, 2005 (accessed 20.09.05).
[11] D. Chandler, Semiotics for Beginners, Rhetorical Tropes. <http://www.aber.ac.uk/media/Documents/S4B/sem07.html> (accessed 16.06.07).
[12] J.S. Ash, B. Berg, E. Coiera, Some unintended consequences of information technology in health care, J. Am. Med. Inform. Assoc. 11 (2004) 104–112.
[13] R.G. Berger, J.P. Kichak, Computerized physician order entry: helpful or harmful? J. Am. Med. Inform. Assoc. 11 (2004) 100–103.
[14] E.H. Shortliffe, CPOE and the facilitation of medication errors, J. Biomed. Inform. 38 (2005) 257–258 (Editorial).
[15] J. Horsky, J. Zhang, V.L. Patel, To err is not entirely human: complex technology and user cognition, J. Biomed. Inform. 38 (2005) 264–266.
[16] R.L. Wears, M. Berg, Computer technology and clinical work. Still waiting for Godot, JAMIA 293 (10) (2005) 1261–1263.
[17] M. Berg, C. Langenberg, I. Berg, J. Kwakkernaat, Considerations for sociotechnical design: experiences with an EPR in a clinical context, Int. J. Med. Inform. 52 (1998) 243–251.
[18] Y.Y. Han, J.A. Carcillo, S.T. Venkataraman, R.S.B. Clark, R.S. Watson, T.C. Nguyen, H. Bayir, R.A. Orr, Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system, Pediatrics 116 (6) (2005) 1506–1512.
[19] M.A. Del Beccaro, H.E. Jeffries, M.A. Eisenberg, E.D. Harry, Increased mortality rates in an intensive care unit: no association with computerized provider order entry implementation, Pediatrics 118 (1) (2006) 290–295.
[20] B. Latour, We Have Never Been Modern, Harvester Wheatsheaf, New York, 1993.
[21] C. Nemeth, R. Cook, Hiding in plain sight: What Koppel et al. tell us about healthcare IT, J. Biomed. Inform. 38 (4) (2005) 262–263.
[22] M. Cole, E. Engeström, A cultural–historical approach to distributed cognition, in: G. Salomon (Ed.), Distributed Cognitions, Cambridge University Press, Cambridge, MA, 1993.
[23] J.E. Bardram, The trouble with login—on usability and computer security in ubiquitous computing, Pers. Ubiquit. Comput. 9 (6) (2005) 357–367.
[24] B. Bundgaard, F. Klamer, Jeg kan se, at du har været inde at kigge, Ugeskr Læger 169 (16) (2007) 1494.