Healthcare Information Technology's Relativity Challenges: Distortions Created by Patients' Physical Reality versus Clinicians' Mental Models and Healthcare Electronic Records

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Abstract: This paper examines the inconsistencies or distortions among three medical realities: patients' physical reality (as reflected in clinical observations, lab reports, and other "objective" measures); clinicians' mental models of patients' conditions; and how that information is represented in the patient's electronic chart—the electronic health record (EHR). We created a typology based on the semiotic triangle of "symbol," "thought or reference," and "referent."

Differing perspectives (or realities) are illustrated with examples from our observations in hospitals and medical facilities, interviews with clinicians, IT personnel and IT vendors, computer logs, and error reports. Scenarios/models enumerate how the differing perspectives can misalign to produce distortions in comprehension and treatment. These are categorized according to an emergent typology derived from the cases themselves and refined based on insights gained from the literature on interactive sociotechnical systems analysis, decision support science, and human-computer interaction.

The scenarios reflect the misalignment between patients' physical realities, clinicians' mental models, and EHRs, identifying five types of misrepresentation: IT data too narrowly focused; IT data too broadly focused; EHRs miss critical reality; data multiplicities—perhaps contradictory or confusing; distortions from data reflected back and forth across users, sensors, and others.

Conclusion: With humans, there is a physical reality and actors' mental models of that reality. In healthcare, there is another player: the EHR/healthcare IT, which implicitly and explicitly reflects many mental models, facets of reality, and measures thereof that vary in reliability and consistency. EHRs are both microcosms and shapers of medical care.

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In sociology, we often compare differing views of reality. In medicine, however, there is an assumption that we shall eventually find the truth; and differing views will coalesce around this truth. This paper examines how differing perspectives of medical "truth" are altered when we add the electronic health record (EHR)—the digital system that combines the clinical perspectives (called physician or nurse notes, any clinician's notes) with assumed objective measures (the lab reports and other measures, such as vitals, X-rays, MRIs, etc.). That is, the EHR becomes another player, and often the most important player, in the diagnosis and treatment of patients, in how clinical work is evaluated, how costs are billed, how the illness is labeled, and how the medical profession understands its actions and outcome. Here, we focus on distortions that often occur when we seek to integrate the technology with the other data. More, we seek to catalog and organize these distortions, and perhaps illuminate the structures underlying them.

Ostensibly, Healthcare Information Technology (HIT) directly embodies all the relevant features of a given medical reality and directly corresponds to clinicians' mental models (since the clinicians must work with it). But no one, not even HIT vendors, believes the HIT's design and populated data could correspond to the many differing clinicians' mental models, or even to any one clinician's mental model.

We first offer a typology of misunderstandings between patients' realities, clinicians' mental models of those realities, and representations of those realities within HIT—usually EHRs (also called Electronic Medical Records [EMRs]). Inspired by Norman (2002), we use the term "mental model" in the general sense, as the way clinicians internally represent and then reason about actions in their clinical world. We then use this framework to examine different sets of troublesome but generic use cases. Last, we consider limitations and the next steps.

Methods

Our scenarios, or use cases, were based on: the research literature, 27 years of our direct observations, work with our research partners, logs from hospital and clinic IT departments, implementation teams' reports, the U.S. Agency for Healthcare Research and Quality (AHRQ)'s *Guide to Reducing Unintended Consequences* (Jones et al. 2011), personal communications by users, attendance at several HIT vendor forums, hospital computer user help desk logs and discussions with help desk staff, the U.S. FDA's Center for Devices and Radiological Health reports and logs (which has reports of problems with healthcare IT),[1] participation in Institute of Medicine—and the American Medical Informatics Association (AMIA)—task forces on usability (Sinsky et al. 2012; Middleton et al. 2013), AMIA's implementation forum (where medical informatics experts and clinicians discuss these issues), and additional reports from the field. Rather unexpectedly, the vendors of this equipment, which is advertised as over 99% foolproof, had many insights about the workaround used by clinicians to make the system function in the real world.

[1] See: U.S. Food and Drug Administration. CDRH Reports (http://www.fda.gov/AboutFDA/CentersOffices/OfficeofMedicalProductsandTobacco/CDRH/CDRHReports/default.htm; retrieved August 31, 2022) and U.S. Food and Drug Administration. Manufacturer and User Facility Device Experience Database (MAUDE) (http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/PostmarketRequirements/ReportingAdverseEvents/ucm127891.htm; retrieved August 31, 2022).

We also participated in scores of hospital sessions called "Failure Mode and Effects Analysis" (FMEA) meetings, where errors are discussed, their causes explored, and improvements offered. These are standard events in hospitals that are seeking to understand why a piece of equipment or a process has not worked as expected. Often these occur after a consequential error is unearthed.

In addition, as in most U.S. hospitals, there are Mortality and Morbidity (M&M) conferences. These are a required gathering of the clinical and technical staff whenever a patient is significantly harmed or killed. Recent trends seek to make these meetings learning experiences without blaming staff. The theory is to encourage open discussion in a non-punitive form. This perspective fits with the human-computer interaction perspective, which prefers the term "use error" rather than "user error." The term is valuable in that it acknowledges that most errors are, in fact, due to poor device design rather than lazy or careless users. Of course, the non-blaming ethic is sometimes violated.

Note also that the literature on the transition from paper to computers is no longer relevant to this research. That shift occurred more than a decade ago in all of our observation sites. There were no paper documents involved in this research. Even the MAR (previously the nurses' paper guide to medication administration) was replaced by the eMAR, the computerized task list for nurses. The only paper involved were labels—the paper inserted into patients' wrist bands or occasional paper labels attached to IV bags or the envelopes housing the medication.

Triangulation beyond the semiotic triangle: The work reflects a very intentional triangulation of 1. observations, 2. interviews (with vendors, clinicians, IT personnel, and trainers), 3. shadowing, and 4. systematic data analysis of over half-a-million scans of patients' wrist bands and medication labels in addition to the tens of thousands of documented reasons for overrides of / workarounds to the system (typed by nurses and others to explain why the system did not work as designed). These are the critical workarounds that allow patient care to continue in the face of inadequate software design or rigid procedure manuals that fail to reflect the reality of care. We also participated in the many meetings noted above, which we augmented with later interviews with the clinicians and technology staff.

Central to all of our analyses were the underlying theories of how technology is used in any organization, often called Socio-Technical Analysis (Harrison, Koppel, and Bar-Lev 2007; Jones et al. 2011; Sinsky et al. 2012), which recognized that "technology-in-use" is never static and that there are recursive interactions between the organization, its rules, its devices, and the personnel who are the actors in this setting. Technology changes the organization, its processes, and its rules, while it is being changed by all of those factors. Moreover, because most of the study team were sociologists (2) or industrial engineers (1), the nurses, who are the primary users of the technology, felt it was safer to talk to us than to the usual hospital hierarchy of physicians and administrators. Also, these interactions—among the clinicians, between the clinicians and patients, and between the objects (e.g., barcoded medications and the computer system)—are classic examples of symbolic interaction's underlying premises on the role of individual interpretations of any action and the role of context in interpreting behavior. The workarounds make sense in the landscape of the mission of the hospital, healthcare, and clinicians, even if they violate the designated part of the task the nurses are fulfilling. Meaning, as always, is negotiated in contexts.

Constructing the typology: To construct our typology, we employed a *grounded theory* approach, amassing many scenarios/problem cases, and then categorizing them according to an emergent typology derived from the cases themselves. This was followed by iterative re-examinations incorporating insights from: Interactive Sociotechnical Systems Analysis (ISTA) (Harrison et al. 2007), with its emphasis on the recursive nature of HIT and workflow; from Decision Support Science's rigorous examination of parameters, constraints, and optimizations (Culnan 1987; Mingers and Stowell 1997; Kagolovsky et al. 1998); and from the Human-Computer Interaction literature (HCI) (Jansen, Spink, and Saracevic 2000; Norman 2002; Wickens et al. 2004; Solskinnsbakk and Gulla 2010; Kaptelinin n.d.), a natural fit with our focus on usability, flexibility, and adaptability. Typical of grounded theory methods, the categories underwent repeated modifications.

A Typology

We offer five types (categories) of miscommunication among: 1. the patient's physical reality, 2. clinician's mental models, and 3. HIT. Undoubtedly, there are areas of possible overlap, but we have made every effort to disambiguate and clarify.

Note: Almost all of our examples are directly from EHRs/EMRs, but a few are from their digital partners, collectively called HIT. These are: *Computerized Provider (Physician) Order Entry (CPOE)* systems, the *Barcoded Medication Administration (BCMA)* technology, and the *electronic Medication Administration Record (e-MAR*). Where appropriate, we name the specific sub-system, but for the sake of consistency, we generally use the terms "EHR," "EMR," or "HIT."

We generally understand physical reality through our mental models of that reality. As noted, modern healthcare settings have another player: the HIT, which implicitly and explicitly reflects many mental models, facets of reality, and measures thereof that vary in reliability and validity. The HIT, thus, is both a medium of communication and a representation of much information—some of which is conflicting, some of which is missing, and all of which interacts with the mental models of designers and users. It is both a microcosm of medical care and it shapes medical care.

Looking at our initial set of trouble scenarios, we illustrated the types of mis-correspondence and provided a structured way of organizing them.

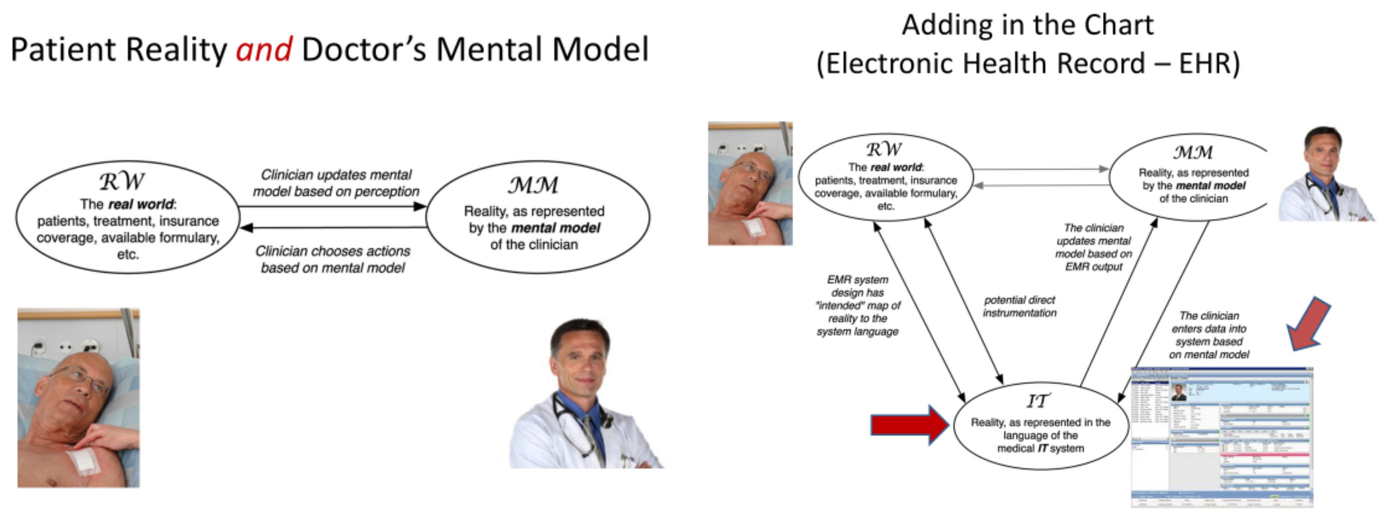
- Let RW denote the space of underlying patient realities in the real world—usually the patient's condition, vitals, and test results.
- Let MM denote the space of clinician mental models. [Where relevant, we will add a subscript to indicate the clinician involved.]
- Let IT denote the data and language of the EHR.

Strictly speaking, our representation of the "real world" contrasts with clinician mental models and the EHR since we focus on how these two (MM and IT) correspond or mis-correspond to the underlying medical reality, the "real world" here. Of course, all three are parts of reality.

Moreover, we note that the three-part model outlined above is a simplified version of many differing perspectives and hierarchies. That is, in almost all cases, more than one physician is involved in the patient's care, each with a differing perspective, specialist focus with accompanying different sets of medical images and lab results. Often, also, there is more than one institution (e.g., previous hospitalizations, other clinicians, history of other treatments, etc.). In the U.S., also, hospitals have extensive administrative leadership that sets policy and budgets. Last, and often most powerful, the final decider about treatment is frequently the patient's insurance company. Each insurance company has different cost arrangements with the hospitals for what and how much is funded; and for what treatments and pharmaceutical choices are allowed. The insurance rules often determine the care.

To the underlying models: Figure 1 shows the initial situation where the clinician works with the underlying medical reality via their mental model. Figure 2 shows the more complicated picture when we add HIT.

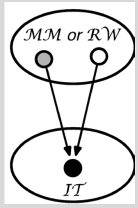
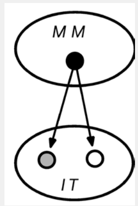
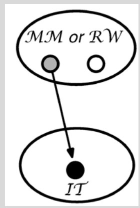
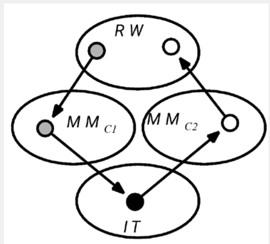
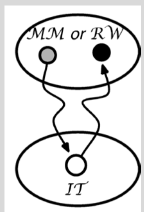
Figures 1 and 2. Clinician mental models of patient conditions and their interaction with EHRs



Source: Self-elaboration (diagrams credit: Sean W. Smith; images: found and adapted by Ross Koppel).

What is relevant here are the nuances of the various *mappings* between the spaces. When a clinician sees some particular EHR screen or menu from the IT, what model (MM) do they construct? Does this model correspond usefully to the reality (RW) that generated this mental model? Furthermore, if two different clinicians see the same EHR screen, will they draw the same conclusions about the correspondence to reality? Within a typical hospital, there will be thousands of clinicians in many different groupings. There may also be 150 to 400 different IT systems communicating with the HIT. Table 1 presents the problems with these mappings and provides a way to organize the trouble scenarios we discuss below.

Table 1. Mapping distortions and trouble scenarios

Distortion Categories		
Incompatibility Type	***Incompatibility Description***	***Sketch***
Type I: IT ***too coarse***	Significantly different scenarios in RW and/or MM are represented in the same way in IT. [Examples: 1. Problem lists that do not permit sufficient qualification or classifications, for example, left side CVA (cerebrovascular accident) vs. just stroke, or inactive asthma. Or, 2. only indicating the patient has cancer is woefully insufficient to be useful to oncologists.]	
Type II: IT ***too fine***	Scenarios identical to the clinician are represented significantly differently in IT [Examples: 1. Very granular categories within ICD-10 may reflect a level of certainty or understanding that does not exist for a specific patient. The (false) specificity may misguide other clinicians. 2. Unconfirmed suggestions of one very specific subcategory of several possible cancers may lead to premature closure of analysis.]	
Type III: ***missing reality***	Scenarios or scenario details significant to the clinician are not represented at all in IT. [Examples: 1. Only lab reports and medications are listed; not symptoms or history. 2. The EMR implicitly assumes COWs (computers on wheels) are always network-connected, but the clinician encounters a reality where they are not.]	
Type IV: ***multiplicity***	Different communities of clinicians may construct different mental models (and hence infer different realities) from the same representation in the IT. [Example: the EMR reflects misleading/distracting judgments by staff or family members in addition to many lab reports with alternative interpretations.]	
Type V: ***looking glass***	When a clinician scenario is reflected into the IT and back, it becomes something rather different and surprising. [Example: clearly incorrect sensor data, which a clinician would reject, becomes enshrined in the EMR, which now describes a reality that never existed.]	

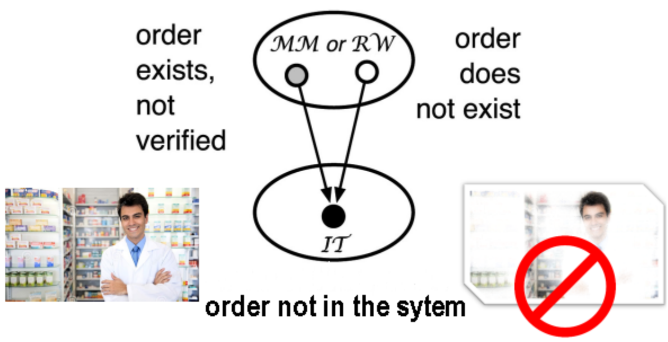
Note: the scenarios shown below are selected from among 45 developed by Smith and Koppel (2014). Readers may wish to refer to that paper to view the full set of scenarios.

Source: Self-elaboration (diagrams credit: Sean W. Smith).

The scenarios presented below mirror the many sorts of errors reflected in the typology—illustrating actual examples of patient harm or potential harm caused by the distortions. Later, we expand the scenarios to consider additional participants, that is, additional clinicians, EHRs from other hospitals or institutions, family members of the patients, and, of course, the patients themselves, as they are not allowed to view and comment on their electronic health records.

Schrodinger's Pharmacy: Doctor ordered a medicine, but it has not yet been "verified" (approved) by the pharmacy. The order exists, but some EHR screens do not show that (because the pharmacist did not yet say OK). The order exists, and the order does not exist. Alas, another doctor, not seeing the first order, can order twice the amount ("double-dosed").

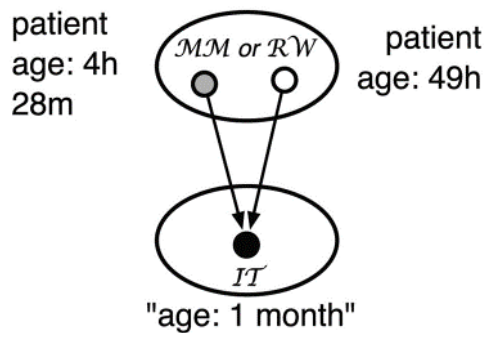
Figure 3. Schrodinger's pharmacy: ordered medication not yet visible to the doctor



Source: Self-elaboration (diagram credit: Sean W. Smith; images: found and adapted by Ross Koppel).

Baby Age/Ages: For newborn babies, precise age (in hours or minutes) is often needed to determine treatment, such as medication dosage. However, EHRs often do not allow fine-grained age information, just the number of months or years.

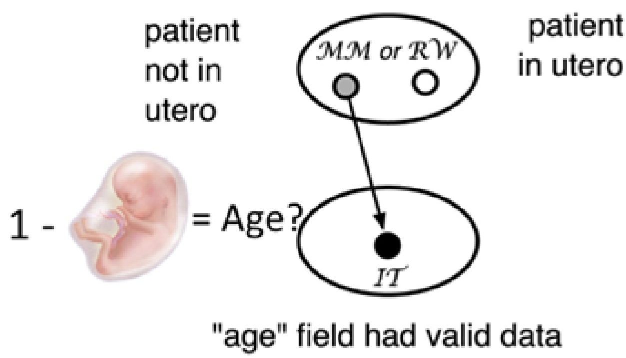
Figure 4. Baby ages: lack of fine-needed metrics for baby ages



Source: Self-elaboration (diagram credit: Sean W. Smith).

Negative Age: When treated in utero, a fetus may need to be represented in EHR as a patient. But, the EHR age category does not have negative ages, that is, "three months before birth" (age = - 3). Some systems use gestational age, but there is no consistent metric for that.

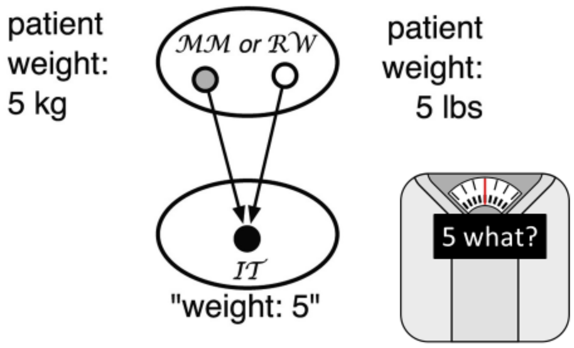
Figure 5. Inability to insert age of patient for in utero treatment, that is, negative age



Source: Self-elaboration (diagram credit: Sean W. Smith; image: found and adapted by Ross Koppel).

Patient Weight(s)? In the U.S., patients typically give weights in pounds; but for kids, all medications use the metric system. Failure to specify can lead to 2.2-fold overdosing. For babies, this equals death.

Figure 6. Errors from the use of both metric and imperial measures

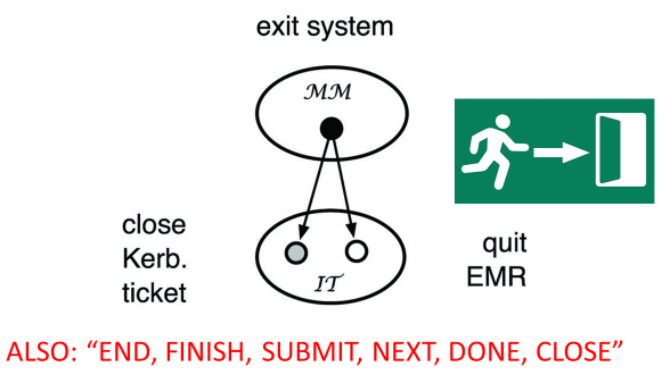


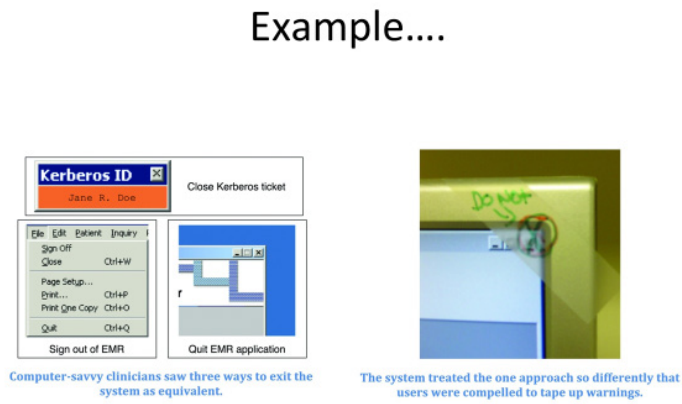
Source: Self-elaboration (diagram credit: Sean W. Smith; image: found and adapted by Ross Koppel).

How to End? Doctors see several ways to exit the EMR system: CLOSE; EXIT, QUIT, et cetera, but each has a very different meaning to the EHR. Are data saved or not? Is the new information now part of the record, or not?

Who Is the "Patient"? Is it the IVF zygote (in vitro fertilization), later fetus in utero, and later, the baby born; all the same person, but may have three different records in the EHR.

Figure 7. Confusing terms to end EHR sessions

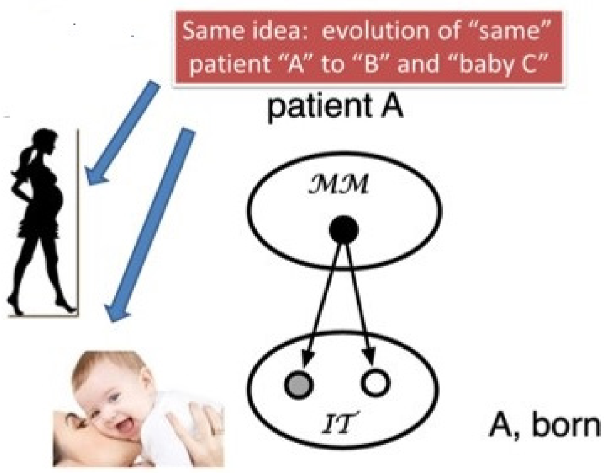




Source: Self-elaboration (diagram credit: Sean W. Smith; images: found and adapted by Ross Koppel).

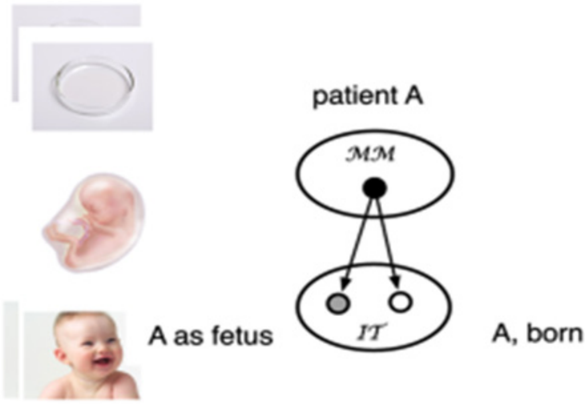
Same or New or Two Patients? Similarly, in many medical facilities, a woman may be seen as general patient A, a maternity patient B, and then a mother with a new baby C, who becomes a patient at the facility—and the EHR has three separate records.

Figure 8. Different terms for the same patient: zygote, fetus, baby



Source: Self-elaboration (diagram credit: Sean W. Smith; images: found and adapted by Ross Koppel).

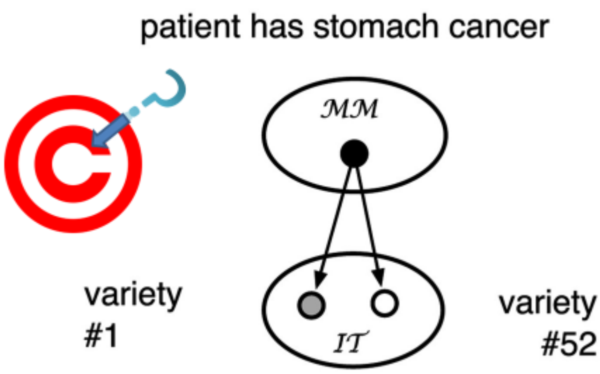
Figure 9. Emerging terms for emerging patients: "patient," "maternity patient," "baby"



Source: Self-elaboration (diagram credit: Sean W. Smith; images: found and adapted by Ross Koppel).

What Cancer? Which Cancer? This is a real case of false specificity: The doctor says his patient has stomach cancer and sends the patient to a specialist. But, EHR requires the doctor to pick **a** stomach cancer from a drop-down menu of scores of different varieties of stomach cancer. No option for "I don't know—that's why I am referring the patient to a specialist" will probably misdirect the oncologist.

Figure 10. False specificity of diagnoses



Source: Self-elaboration (diagram credit: Sean W. Smith; image: found and adapted by Ross Koppel).

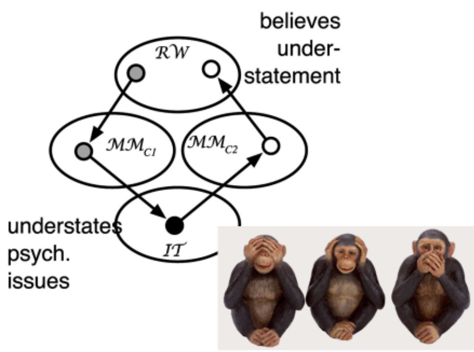
The smell of Breath: Doctors have been using the smell of breath for thousands of years to diagnose illness. But, EHR categories do not include that option. Note: with a paper system, doctors could write it on their notes.

Figure 11. Missing categories in EHRs

Source: Self-elaboration (images: found and adapted by Ross Koppel).

Intentional Understatement: Sometimes doctors lie or distort to protect patients, for example, to help get the patient's insurance to cover their convalescence for another week or two, to avoid jail (e.g., drug use), to hide pregnancy, to help a worker get a job, or to avoid a kind of work the patient cannot perform.

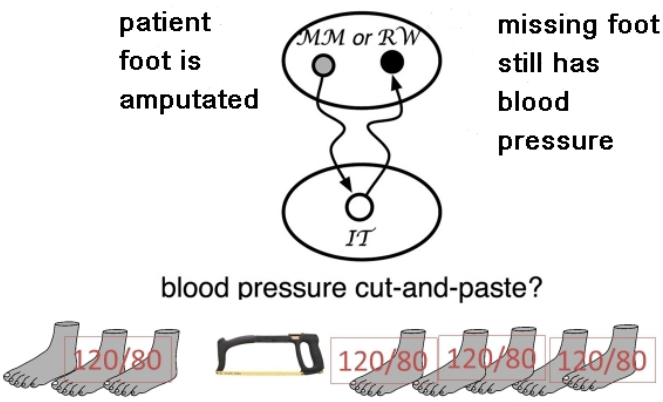
Figure 12. Intentional understatement or deception of diagnoses or treatment time



Source: Self-elaboration (diagram credit: Sean W. Smith; image: found and adapted by Ross Koppel).

Duplication and Paste/Cut and Paste/Amputate and Paste: The ease of "copy-and-paste" with digital data creates errors. One patient's EHR data showed three weeks of the exact same foot blood pressure readings. But, the nurse had just re-entered the same earlier blood pressure 21 times over. Alas, that foot had been amputated. It was the same blood pressure, but it should have been zero, not the blood pressure from before the operation.

Figure 13. Copy and paste errors or deception

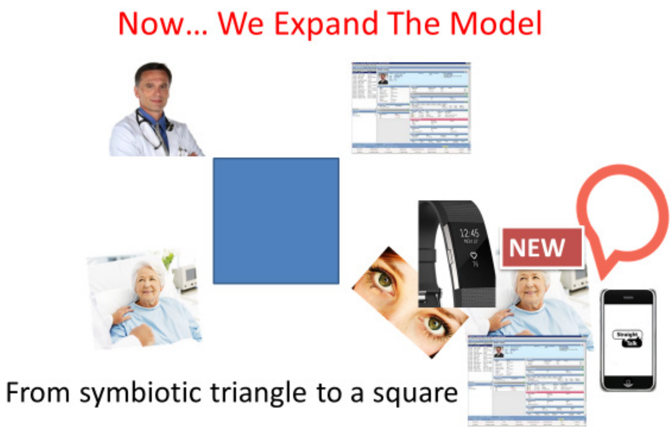


Source: Self-elaboration (diagram credit: Sean W. Smith; images: found and adapted by Ross Koppel).

Expanding the Model from Three to Four Elements

Here, we expand the model to include a new, but essential, player in the process: The patient! It is no longer a triangle, but a square, where the patient has a role in addition to the physician, the lab reports, and the EHR.

Figure 14. From symbiotic triangle to four elements, that is, adding the patient's perspective



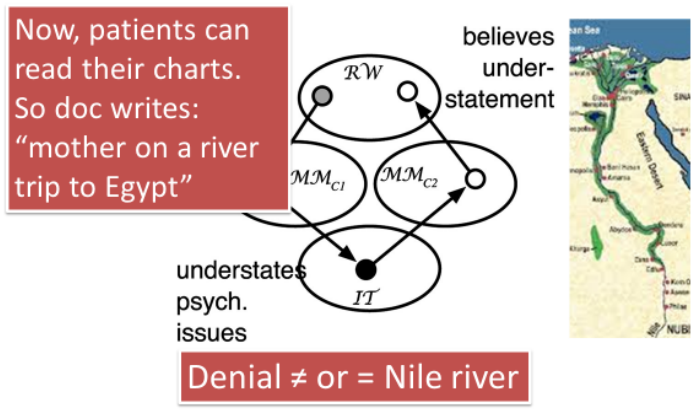
Source: Self-elaboration (images: found and adapted by Ross Koppel).

In our first scenario of this expanded model, the new element—the patient—presents a conflict because the patient's involvement may compromise the treatment process. That is, new laws in the U.S. dictate that the patient has the right to see the doctor's notes. This has many advantages, and some dangers. On the plus side, it gives the patient the opportunity to better understand what the doctor is thinking and conveying to their colleagues. It also gives the patient an opportunity to review their data and correct errors. Patients may also use the information to search the web for more information or to consult with other clinicians. On the negative side, doctors may not feel free to fully explain what they want to convey to their colleagues and insert it into the medical record, the failure of which may seriously compromise the patient's care and, indeed, well-being. Also, there is a danger that a family member may see information that should be confidential between doctor and patient. Perhaps worse, patients may be horrified to learn via a web link that they have cancer or that they have been classified as "morbidly obese." Last, a lot of medical terminology and acronyms are unknown to patients. The term SOB commonly refers to someone who is difficult or nasty, that is, a son of a bitch. But, in medical terms, it means shortness of breath. Similarly, some medical phrasing appears hostile, for example, it is common to see a text such as "patient denies smoking" or "patient denies drug abuse." This is frequently misunderstood as the doctor doubting the patient's statements. In reality, it is an attempt to convey the uncertainty of any patient's claims about their lives. There is also a danger of patients' not understanding the complexity of a diagnosis. Some seemingly dire laboratory reports may be benign, for example, some cancers are easily removed and do not affect the patient's well-being. Other reports from radiologists or pathologists may require more information to understand, for example, additional data from linked laboratory reports.

Intentional Understatement (Another Scenario): The first case is from a psychiatrist who was seeking to explain to her colleagues that the mother was in denial about the daughter's (the patient's) condition. The psychiatrist was cryptic and wrote: "the mother was on a river trip in Egypt," to convey—via the pun between the word for the river "Nile" and the English word "denial" that the patient's mother did not recognize her daughter's condition. Alas, the patient read the chart and insisted her mother had never been to Africa and that the doctor was wrong.

Another big problem is the disclosure of medical information about teenagers, where the parents may have the right to see the record that may contain private information.

Figure 15. Intentional deception in the EHR to alert colleagues, but not alert the patient or her family



Source: Self-elaboration (diagram credit: Sean W. Smith; image: found and adapted by Ross Koppel).

Figure 16. Possible conflicts of information access: Keeping teenager's medical data from parents

Source: Self-elaboration (image: found and adapted by Ross Koppel).

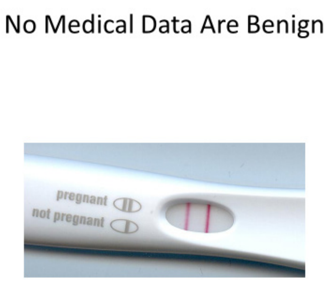
Yet another aspect of patient involvement that is both a blessing and a curse is the digital self—where patients' watches and other devices report medical information to the EHR constantly. The data load may be overwhelming, and it would be understandable for clinicians to miss critical information in the avalanche of constant information, most of which is of little interest.

On the other hand, no medical information is necessarily benign. A woman may have had a pregnancy test in the hope that she was not pregnant; seemingly good news. But, if the woman is not having sex with her current partner, the fact that she has ordered a test—even if negative—is hardly neutral information.

Figure 17. The digital self: problems of incorporating and analyzing self-reported data

Source: Self-elaboration (image: found and adapted by Ross Koppel).

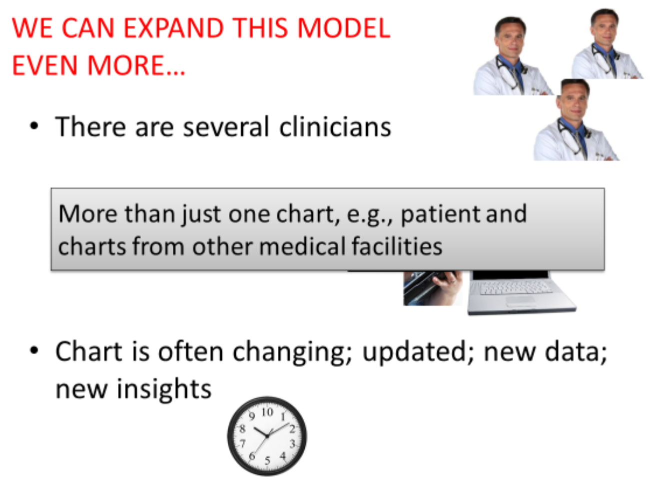
Figure18. Dangers of displaying any medical data to families or caregivers



Source: Self-elaboration (image: found and adapted by Ross Koppel).

Now, we explore the consequences of expanding the model even more. Beyond considering the complications and advantages when we include the patient, we include other clinicians and other EHRs (patient records and charts) from other medical institutions. This also highlights the fact that the chart is always changing, with new data added and corrections to the existing data. It is hard enough with one chart. But, with more charts, some reflecting other days and times, the possibility of confusion and error is magnified.

Figure 19. Added complexity when including several clinicians and data updates in the EHR



Source: Self-elaboration (images: found and adapted by Ross Koppel).

Thus, we must also incorporate the mental models and the data from other clinicians and other laboratories. We, now, often have conflicting perspectives and differing datasets. Last, the patient may have family and other people who have additional perspectives and desired outcomes. For example, the family may wish to stop treatment and have their relative return home or be placed in a different institution.

Discussion

There is a growing literature on HIT dissatisfaction (Harrison et al. 2007; Cimino 2013), and industry practitioners worry that 70% of such installations fail ("IT Projects Have a 70% Failure Rate: Don't Let Your Hospital IT Projects Fail" 2012). Analyzing these scenarios suggests at least one common thread is woven by IT systems that fail to correspond to the medical workflow: implementing EHRs introduces an additional representation of reality—one that comes between the clinician and the patient and exists in manifold forms among the many clinicians treating patients. When these representations fail to match the patients' conditions and clinicians' mental models, EHRs can distort reality, which it nevertheless continues to neatly array in specified columns and rows.

We do not fault the EHRs for any of these difficulties. Any representation distorts, be it paper, logs, reports, or even ontologies designed to reduce confusion. But, what may be different about computerized HIT as compared to earlier paper-based systems (built with and on the natural affordances of paper) is the rapid permeation of interconnected IT into the medical workflow, coupled with the relative inflexibility of computerized systems, which do not know "when to look the other way" (Felten 2002). In addition, HIT is freighted with additional and extraordinary requirements of documentation, categorization, ordering, responding to (and generating) alerts of varying utility, accommodating legacy limitations, and billing. Moreover, HIT must also operate in a diverse interdisciplinary environment dictated by professional societies, state and federal boards, payers, unpredictability, no control over inputs (patients and their severity), limited control over patients' actions, and innumerable unknowns and unreliable data. We add, lastly, that many of the key players are untrained in the HIT's use and may be mastering a complex subject while learning to operate the HIT, which is itself undergoing frequent modifications. All of these factors limit user interface flexibilities and thus may influence responsiveness to clinicians' mental models and patients' always-emergent realities.

Moreover, many times the EHRs do a dramatically better job of reflecting reality than paper ever could. The instant availability of graphic representations that would be nearly impossible to construct with paper records offers alternative views of laboratory reports (e.g., shifting timelines or overlays of results); omnipresent data means consultants and others can view records anywhere and anytime; and laboratory results and medical images can be sent to several clinicians simultaneously. Supervision by experienced clinicians no longer needs to be constrained by physical space.

Another approach might be to look at how the heterogeneity of medical workflows may require each HIT system to be custom-engineered, hindering the economies of engineering investment that benefit IT by supporting more homogeneous and universal tasks, such as word processing. As the line goes, "if you've seen one EHR installation, you've seen one EHR installation." In addition, even if workflows were similar from institution to institution, the number and types of other IT systems that link with any given EHR installation are vast, numbering in the hundreds, with each requiring special codes and connecting algorithms. Every EHR, no matter how similar to its sister, will be different when running in a different institution.

In response to these challenges, our work centered on cataloging these "hard-to-use cases" (instead of the more typical focus on "use cases"). Prior work on computer decision support for clinicians (DSS) (e.g., Culnan 1987; Mingers and Stowell 1997; Kagolovsky et al. 1998; Harrison et al. 2007) was beneficial by emphasizing the interaction of workflow and HIT, which is a major theme of the clusters. Prior work on HIT (e.g., Jansen et al. 2000; Norman 2002; Wickens et al. 2004; Solskinnsbakk and Gulla 2010; Kaptelinin n.d.) led us to consider the role of the EHR user's mental model concerning the EHR system itself and the medical reality in which the user must act. The work by Harrison, Koppel, and Bar-Lev (2007), Heath and Mondada (2019), and Luff, Heath, and Sanchez Svensson (2008) stressed the need for, and absence of, the malleability of the software. In this sense, the previous theories helped us in generating the clusters of hard-to-use cases, and of our resulting typology, which builds on and extends the prior work.

To help solve these problems, we need to better identify and reduce incorrect mappings between HIT and patients' bodies and between HIT and clinicians' mental models. For example, suppose the clinician could press a button, take a screenshot (e.g., Cooley and Smith 2012), and scribble on it with a magic stylus. Clinicians could then correct or annotate the EHR to reflect distortions, for example:

- Type I: When the IT language is too coarse: clinicians could circle the checkbox and say, "there are more things in heaven and earth than your model allows."
- Type II: When the IT language is too fine: clinicians could circle several items on the EHR's screen and annotate, "it's one of these, but not just 'this one.'"
- Type III: When the IT language is missing or "too small": clinicians could say, "you're missing this thing I care about."
- Type IV: When the IT language lends itself to a multiplicity of interpretations: things are trickier; maybe the second clinician could note, "this is what I thought this meant," and the system could forward this back to a representative of the first clinician.
- Type V: When the IT offers a distorted-looking glass reflection: clinicians could note, "this is very, very wrong."

Such an approach could also help with ambiguities and provide the affordances of paper, so lacking in most digital interfaces. When clinicians are uncertain and/or the data are ambiguous (as is often the case), clinicians could reflect on the ambiguity and suggest a range of possible options. When clinicians were uncertain about the most appropriate consultant, they could indicate the ambiguity and request clarification by specialists.

HIT will also benefit by improving how we discover and remediate these problems (Koppel 2013). This requires work by local IT teams, requests to vendors, analyses of linkages with other IT systems, ongoing observations of clinicians' work, focus groups, interviews, et cetera—or, most probably, a combination of these methods. Remediation will require working with all parties and, perhaps more importantly, empowering clinicians and others to observe problems and request changes and improvements. Most important, problems that have been reported and requests for improvements or modifications must be addressed. Adding enhanced awareness of difficulties to the existing frustration will only increase alienation and learned helplessness. Encouraging clinicians to act without subsequent action on the IT side is perhaps worse than doing nothing.

As discussed above, we also need to recognize and address the role of the myriad other IT systems that interact with each HIT system. Problem-solving often requires understanding how several IT systems work together or do not.

We need to recognize the role of workarounds as both needed solutions and as symptoms not of user laziness, but system design failure, or at least system non-responsiveness—and we need to figure out how to fix these designs.

Limitations

There is no listing of distortions generated by the interactions of patients' physical reality, clinicians' mental models, and HIT. We used many information sources, but there are inevitably hundreds of additional examples and scores of more use case scenarios that will emerge. We, therefore, make no claims of completeness. Also, given the delicacy of some of the situations and the contractual restrictions preventing users of commercial HIT systems from publicly discussing "flaws" (Koppel and Kreda 2009), a systematic collection of these examples is probably impossible. In that, this paper is a conceptual typology of problem scenarios, data source limitations are obvious, but only temporarily problematic. A new scenario will be offered and evaluated. If they do not apply, they will be quickly removed from consideration. If they are helpful in improving HIT, they will be included.

Another limitation is that we did not extend this analysis to include the perspectives of patients, their families, and the many other clinicians who may have competing, supportive, or very divergent views and desired outcomes. Including these additional—and often critically important perspectives and data—would expand the model from the triangle we present here to a very different shape, perhaps extending to hyperspace. But, the reality of healthcare indeed extends to these additional dimensions, and we encourage others to pursue such new models.

To our knowledge, this is a new typology, incorporating the commonalities of HIT functions and medical workflow. There are, therefore, undoubtedly overlaps or missing elements in our typology. We assume further refinements are probable. Also, we did not include a separate node for patients' mental models—a most worthy addition, which we hope will be addressed in future research.

Conclusion

We have tried to present our methodology for the discovery and documentation of a process that claimed almost perfect accuracy when followed according to the listed procedures using the technology as presented. In contrast, our several methods of observation, interviews, and data analysis revealed that relying on the technology and the rules would prevent hundreds of patients every day from receiving their needed medications. Our effort was an attempt to attenuate the gaps among patients' realities, clinicians' mental models, and representations of those realities in EHRs—and perhaps to offer some insights into how clinicians gather information about patients' conditions via EHRs. We also hope our typology and scenarios enable HIT designers and implementers to reduce their systems' ambiguities, missing elements, over-generalized or too granular categories, obfuscated data, and uncertain navigation. The scenarios we present, then, are intended to guide both our understanding of misrepresentations (the typologies) and as tools for addressing each distortion or inadequate presentation of reality. The typology is, thus, a first step to making HIT work better with patients, clinicians' cognitive models, data (structured, unstructured, misclassified), and our representations of all three.

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References

Cimino, James J. 2013. "Improving the Electronic Health Record—Are Clinicians Getting What They Wished For?" *Journal of the American Medical Association* 309(10):991-992.

Cooley, Joseph and Sean Smith. 2012. *Privacy-Preserving Screen Capture: Closing the Loop for Medical Informatics Usability.* Computer Science Technical Report. Retrieved August 31, 2022 (https://digitalcommons.dartmouth.edu/cs_tr/358/).

Culnan, Mary J. 1987. "Mapping the Intellectual Structure of MIS, 1980-1985: A Co-Citation Analysis." *MIS Quarterly* 11(3):341-35.

Felten, Ed. 2002. "Too Stupid to Look the Other Way." *Freedom to Tinker*, October 29. Retrieved August 31, 2022 (https://freedom-to-tinker.com/2002/10/29/too-stupid-look-other-way/).

Harrison, Michael I., Ross Koppel, and Shirly Bar-Lev. 2007. "Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis." *Journal of the American Medical Informatics Association* 14(5):542-549.

Heath, Christian and Lorenza Mondada. 2019. "Transparency and Embodied Action: Turn Organization and Fairness in Complex Institutional Environments." *Social Psychology Quarterly* 82(3):274-302.

"IT Projects Have a 70% Failure Rate: Don't Let Your Hospital IT Projects Fail." *HIMSS Industry Solution Webinar*. November 2012.

Jansen, Bernard J., Amanda Spink, and Tefko Saracevic. 2000. "Real Life, Real Users, and Real Needs: A Study and Analysis of User Queries on the Web." *Information Processing & Management* 36(2):207-227.

Jones, Spencer S. et al. 2011. *Guide to Reducing Unintended Consequences of Electronic Health Records*. Retrieved August 31, 2022 (https://digital.ahrq.gov/sites/default/files/docs/publication/guide-to-reducing-unintended-consequences-of-electronic-health-records.pdf).

Kagolovsky, Yuri et al. 1998. "Towards Improved Information Retrieval from Medical Sources." *International Journal of Medical Informatics* 51(2-3):181-195.

Kaptelinin, Victor. n.d. "Activity Theory." In *Encyclopedia of Human-Computer Interaction*, 2nd ed., edited by M. Soegaard and R. F. Dam. Interaction Design Foundation. Retrieved August 31, 2022 (http://www.interaction-design.org/encyclopedia/activity_theory.html).

Koppel, Ross. 2013. "Foreword." Pp. xi-xiv in *HIT or Miss: Lessons Learned from Health Information Technology Implementations*, 2nd ed., edited by J. Leviss, P. Charney, and C. Corbit. Chicago: Ahima Press.

Koppel, Ross and David Kreda. 2009. "Health Care Information Technology Vendor's 'Hold Harmless' Clause: Implications for Patients and Clinicians." *Journal of the American Medical Association* 301(12):1276-1278.

Luff, Paul, Christian Heath, and Marcus Sanchez Svensson. 2007. "Discriminating Conduct: Deploying Systems to Support Awareness in Organizations." *International Journal of Human Computer Studies* 24(4). doi: https://doi.org/10.1080/10447310801920490.

Middleton, Blackford et al. 2013. "Enhancing Patient Safety and Quality of Care by Improving the Usability of Electronic Health Record Systems: Recommendations from AMIA." *Journal of the American Medical Informatics Association* 20(e1)e2-8.

Mingers, John and Frank Stowell, eds. 1997. *Information Systems: An Emerging Discipline?* London: McGraw- Hill.

Norman, Don. 2002. *The Design of Everyday Things*. New York: Basic Books.

Sinsky, Christine A. et al. 2012. "Comparative User Experiences of Health IT Products: How User Experiences Would Be Reported and Used." Retrieved August 31, 2022 (https://nam.edu/perspectives-2012-comparative-user-experiences-of-health-it-products-how-user-experiences-would-be-reported-and-used/).

Smith, Sean W. and Ross Koppel. 2014. "Healthcare Information Technology's Relativity Problems: A Typology of How Patients' Physical Reality, Clinicians' Mental Models, and Healthcare Information Technology Differ." *Journal of the American Medical Informatics Association* 21(1):117-131.

Solskinnsbakk, Geir and Jon Atle Gulla. 2010. "Combining Ontological Profiles with Context in Information Retrieval." *Data & Knowledge Engineering* 69(3):251-260.

Wickens, Christopher et al. 2004. *An Introduction to Human Factors Engineering*, 2nd ed. Harlow: Pearson.

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