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Viewpoint ■

When Conversation Is Better Than Computation

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Abstract While largely ignored in informatics thinking, the clinical communication space accounts for the major part of the information flow in health care. Growing evidence indicates that errors in communication give rise to substantial clinical morbidity and mortality. This paper explores the implications of acknowledging the primacy of the communication space in informatics and explores some solutions to communication difficulties. It also examines whether understanding the dynamics of communication between human beings can also improve the way we design information systems in health care. Using the concept of common ground in conversation, proposals are suggested for modeling the common ground between a system and human users. Such models provide insights into when communication or computational systems are better suited to solving information problems.

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The current decision-support paradigm in health informatics is a computational one. The computer sits at the center of information systems that acquire, manipulate, store, and present data to clinicians. Computational models of clinical problems allow computers to make inferences and create views on data or perhaps prompt, critique, or actually make clinical decisions.

In this computational paradigm, human information processes are shaped into a form dictated by technologic structure. Yet we know empirically that the development of technology is actually socially shaped.[1] The value of any particular information technology can be determined only with reference to the social context in which it is used and, more precisely, with reference to those who use it.[2,3] For example, in one study the strongest predictor of e-mail adoption in an organization had nothing to do with system design or function, but with whether the e-mail user's manager also used e-mail.[4] Furthermore, a highly structured view of human processes sits uneasily with the clinical workplace. It is not just that people have difficulty accepting information technology in a social setting because their interactions are loosely structured. We know that people will treat computers and media as if they *were* people.[5] Consequently, they superimpose social expectations on technologic interactions.

So, should we recast the tasks of acquiring and presenting clinical information socially? In the computational paradigm, clinicians faced with a decision problem turn to computer-based systems for support. However, if we examine what actually happens clinically, it is clear that people preferentially turn to each other for information and decision support. It is through the multitude of conversations that pepper the clinical day that clinicians examine, present, and

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interpret clinical data and ultimately decide on clinical actions. In contrast to the computational view of decision support, this conversational view emphasizes social interaction in health care and sees the sharing and interpretation of information as an interactive process that emerges out of communication. Rather than "acquiring" and "presenting" data in some mechanistic way, conversations are better characterized by the fluid and interactive notions of asking and telling, inquiring and explaining.

Although few studies have attempted to quantify directly the size of the communication space that contains the direct interactions between clinicians, those that have all paint a similar picture. Covell et al.[6] reported that colleagues, rather than document sources, met about 50 percent of information requests by clinicians in clinic. In a similar study, Tang et al.[7] found that about 60 percent of clinician time in clinic is devoted to talk. Safran et al.,[8] reviewing the information transactions in a hospital with a mature computer-based record system, still found that about 50 percent of information transactions occurred face-to-face between colleagues, with e-mail and voicemail accounting for about another quarter of the total. Only about 10 percent of the information transactions occurred through the electronic medical record.

Not only is the communication space huge in terms of the total information transactions and clinician time, it is also a source of significant morbidity and mortality. Communication failures are a large contributor to adverse clinical events and outcomes. In a retrospective review of 14,000 in-hospital deaths, communication errors were found to be the lead cause, twice as frequent as errors due to inadequate clinical skill.[9] Furthermore, about 50 percent of all adverse events detected in a study of primary care physicians were associated with communication difficulties.[10] If we look beyond the raw numbers, the clinical communication space is interruption-driven and has poor communication systems and poor practices.[11]

In summary, the communication space is apparently the largest part of the health system's information space. It contains a substantial proportion of the health system information "pathology" but is usually ignored in our informatics thinking. Yet it seems to be where most of the information in the clinical workplace is acquired and presented. The biggest information repository in health care lies in the people working in it, and the biggest information system is the web of conversations that link the actions of these individuals.

Possible Responses to the Communication Paradigm

How do we respond to the idea that information exchanges in the social communication space are primary and, therefore, that this is where substantial informatics efforts need to be focused? There seem to be four plausible responses, depending on how one views communication tasks and what technical interventions are considered to support those tasks:

- *Identity: Communication tasks are replaceable with information tasks*. In this view, the problem is the size and behavior of the communication space, and the solution is to transform communication interactions into information transactions. For example, we replace information-seeking questions that currently occur in conversation with queries to databases. The identity response implies a 1:1 correspondence hypothesis, that all communication tasks can be replaced by computational tasks. It is similar to the so-called strong hypothesis in artificial intelligence, which states that human intelligence can be directly simulated in a computational system. The strong hypothesis is a matter of ongoing debate in the artificial intelligence community. For our purposes, it should be sufficient to say that pragmatically we do not currently have the technology capable of transforming any arbitrary conversation between humans into identical human–computer interactions. Consequently, we must for now dismiss the identity response.
- *Exclusivity: Communication tasks are necessary and not replaceable*. This view emphasizes the necessity for communication and considers the size of the communication space to be natural and appropriate. Communication tasks are essentially "different" from the ones we currently support with information systems and, consequently, accomplish different things and need to be supported in different ways. For example, the informal and interactive nature of most conversations is essential, since the types of questions we seek to answer might be poorly structured and become clear only through the act of conversation. The idea that a query to a database could replace a conversation is meaningless, because the query only comes into existence as a result of the discussion. The exclusivity of communication response suggests that problems in the communication space arise because of the way we support these tasks, either ignoring them completely or shoe-horning them into formal information technology solutions that misunderstand the nature and role of communicative interaction.

- *Mixed: Some but not all tasks can be satisfied in either the information or the communication space.* Attempting to find common ground between the previous identity and exclusivity responses, the mixed hypothesis suggests that some communication tasks should be replaced by information systems. For example, information requests that occur frequently in the communication space, such as requests for laboratory results or drug information, could be gainfully replaced by information systems. The regularity of these requests permits them to be modeled accurately and serviced by a formal information system. The mixed response is probably the status quo viewpoint in informatics thinking, albeit an implicit one, since active consideration of tasks in the communication space is rare.
- *Continuum: Communication and information tasks are related but drawn from different parts of a task space.* This view holds that, while there are essential differences between what happens in an informal conversation and what happens in a formal information system transaction, these differences are simply those we find at different ends of the same continuum. Unlike the previous responses, the continuum view sees the whole information-communication task problem as a false dichotomy, perpetrated in part by technology. We see information and communication interactions as different only because we support them with different tools. While the telephone and the computer might rightly be seen as supporting one or the other type of task, a complex system like the Web begs classification and can support both communication and information tasks. As a result, the continuum view aims to understand which specific task characteristics would indicate where along the technologic continuum we look for solutions. However, to build tools tuned to the specific needs of information and communication tasks, we need to more precisely characterize this continuum. For example, is there some parameter in a clinical process that we could measure to help us decide when communication is better than computation? Without such precision, we are left to rely on rules of thumb or case lore and have progressed only little beyond the mixed hypothesis.

Two implications arise from the above analysis. First, and pragmatically, on the basis of either the exclusivity (necessity-of-communication) response or the mixed hypothesis, we need to recognize the importance of the informal transactions that occur in the communication space. Direct support of the communication between clinicians should substantially improve how our organizations acquire, present, and use information. By recognizing the communication space as an essential part of any organization's information systems, we avoid depending solely on the computational paradigm, which can end up shaping our view of how clinical decisions are made and cause us to ignore features of clinical practice that sit outside it. Thinking only in computational terms, we run the risk of becoming focused exclusively on re-engineering all clinical work into formal behaviors that are suitable for computational treatment.

Second, the continuum view suggests that developing a richer understanding of communication tasks should help us more appropriately craft and target information and communication technologies for our organizational information needs. Both of these implications will now be examined in turn.

Supporting Clinical Communication

To create processes and technologies that support the communication space, we first need to characterize the activities that occur within it and understand where improvement is needed. While much has been written about the dynamics of patient–clinician communication, very little is known about the way clinicians communicate with each other. More pertinently, the studies of communication processes from the wider perspective of the clinical organization are almost nonexistent. Perhaps the only shining exception here is the development of the structured clinical interview and problem-oriented medical record. These are communication innovations as much as information ones. They ensure that messages between clinicians are well formed and maximize the likelihood that critical information is "sent" and "received" via the reliable communication channel that we call the medical record.

What we do know about clinical communication systems in an organization like a hospital is that they carry a heavy burden of traffic and create an interrupt-driven workplace.[12] Clinical tasks generate many communication requests, and inefficiencies in communication system design, technology, and clinical behavior lead to an apparently much higher level of interaction than is necessary.

It is only by delving into the details of the specific conversations that we can start to understand who is responsible for the high level of traffic across communication systems and what the reasons for it are. In one analysis of a U.K. hospital, doctors were found to be the highest generator of communication traffic, sending almost twice as many messages as they received.[11] Furthermore, doctor–doctor interactions made up more than 40 percent of the calls made by the doctors in the study, denying the truism that medical staff suffer constant interruption because of the actions of other clinical staff in the hospital.

Of concern is that the high level of interruption, whatever its source or reason, may lead to errors by clinical staff. Well-known cognitive costs are associated with interruption, leading to diversion of attention, forgetfulness, and errors.[13–15] Furthermore, interruption often requires rescheduling of work plans. The interrupt-driven nature of the hospital work environment thus has the potential to generate extra costs in staff time and efficiency.

There are many potential reasons for the high level of call traffic in an organization. Many are specific to the systems in place in particular organizations, but others are general characteristics of clinical work and human interaction. Some potential causes of the high level of call traffic in hospitals include[11]:

- *Synchronous bias*. People seem to favor interruptive communication mechanisms, such as face-to-face discussion, paging, and the telephone, over less interruptive methods that are available to them. This may be because, in busy environments, tasks need to be "ticked off the list" once completed, to reduce cognitive load. For example, asking someone directly to complete a task produces immediate acknowledgment that the hand-over has occurred, but asynchronous channels like e-mail, voicemail, or notes are usually not designed to deliver the appropriate acknowledgment of message receipt and task acceptance.
- *Information seeking from humans*. The reliance of clinicians on discussion to resolve information needs has suggested to some that this is in response to poor printed or computer-based information sources.[6] Another hypothesis is that communication is actually the preferred mechanism for information gathering. Clinical problems are often poorly defined, and clarification can be obtained through conversation. Thus, clinical staff may opportunistically interrupt each other because face-to-face discussion is highly valued but difficult to schedule, and any opportunity is avidly seized.
- *Poor directory information about roles and responsibilities*. Up to a quarter of calls in hospital may be associated with identifying the name of an individual occupying a specific role. This suggests that poor support for identifying role occupants contributes significantly to overall call traffic.
- *Failure to reason about the impact of individual behavior*. Most clinicians seek to maximize their personal efficiency in serving their patients but do not seem to consider the consequences of their behavior on the overall operational efficiency of their organizations. However, the consequence of interrupting colleagues to satisfy individual needs may be a far more inefficient organization overall. This is analogous to a situation in which everyone elects to drive a car rather than take public transport, because the car is more convenient personally, but the overall impact is congested roads and slower transport times for all on the road.

While it is clear that much more research is needed into the nature of clinical communication processes, we can begin to outline the types of intervention that should lead to improved communications.

Nontechnical Interventions

Although it is tempting to immediately suggest new technical solutions, a variety of powerful nontechnical interventions can profoundly alter the communication dynamics of an organization. First, communication behaviors can be altered. Individuals can be encouraged to regard communication behaviors not as a personal style choice but as a professional skill. Educational programs can emphasize the individual and organizational costs of interruption, and staff can be trained to consider the costs and benefits of different communication channels and services. Second, communication policies can be altered. Beyond educational interventions, organizations have some power to institute mandatory policies that constrain professional behavior involving poor communication practice. For example, it might be reasonable to prohibit the sending of e-mail organizationwide unless strict criteria are met.

Technical Interventions

With the merging of information and communication technologies into new classes of communication networks and devices, the opportunity to innovate technically to improve communication is enormous. When faced with a communication task, system designers have the opportunity to introduce a variety of different interventions:

- *Channels*. One of the simplest interventions is to improve organizational infrastructure by introducing new channels for staff. For example, the introduction of pagers, mobile phones, or e-mail offers new options for interaction among staff who might otherwise have difficulty contacting each other. When faced with apparent difficulties in information flows in an organization, one should remember that communication channels are prime bearers of information and are a part of the solution to information problems—the telephone is an information system, too! For example, members of a clinical team may spend much of their days geographically separated. Providing team members with an asynchronous channel like a shared "to-do" list on a wireless palmtop device would allow team members to track one anothers' activities and prevent duplication of tasks as well as provide a check to ensure that all team tasks are completed.

- *Communication services*. Communication channels can bear a variety of different services or applications on top of them.[16] The telephone channel, for example, can bear voice, fax, and e-mail services. Thus, if analysis of organization call traffic reveals that many calls are attempting to identify who occupies a specific role or that errors occur because of a failure to contact an individual in a role, then a role-based call-forwarding service might help.[12,17] Teams of individuals can also be coordinated using complex role-based calling services. For example, calls to a medical emergency team can be managed by a system that uses knowledge of team roles to ensure that someone in each designated role is called and acknowledges receipt of a call.[12] Such information-enhanced communication systems use specific knowledge about communication patterns and users to optimize the routing and management of messages.

- *Types of message*. Fine-grained analysis of communication traffic may reveal that certain classes of message may benefit from automation. For example, computer-generated alerts can be sent to physicians to notify them of significant clinical events, with substantial clinical benefit.[18] Computer-based notification systems thus integrate with the communication infrastructure of an organization and offer a mechanism to extend the level of interaction between traditional information systems and clinicians.[19] Sometimes, even simpler methods of sending messages can help. For example, individuals in specific roles can be routinely interrupted with the same request from different individuals. The number of calls they receive could be reduced by providing a page of information on a Web-based local directory with answers to these frequent questions.

- *Agents*. The notion that some computational services can act as semi-autonomous proxies for their owners is now well established. Agents responsible for creating, receiving, or filtering messages can be created. As with human beings, interesting conflicts arise between the needs of individuals and the needs of organizations. For example, clinicians may wish to instruct an agent to filter certain classes of message they consider annoying, but organizational policy may wish to override such individual preferences when wider concerns are taken into account.

Typically, a communication system will introduce a bundle of new interventions into an organization, each with different effects. For example, introducing a computer-based notification system for alerts will have channel, service, and message effects. The channel effect may be positive, by permitting a shift of existing events from the synchronous to the asynchronous domain, reducing the number of interruptions. Thus, rather than receiving pages from laboratories or the pharmacy, a clinician will instead receive e-mail that can be read at the time of the clinician's choosing. However, the message effect of introducing a new communication system may be to generate new types of events in the asynchronous domain. This could increase the overall message load, with consequent increases in demand on user time and effort. Such systems thus have the potential to either harm or help, depending on which of the effects dominates and the state of the local environment.

The Continuum View

The continuum view suggests that developing a richer understanding of the connection between communication and information tasks should help in the design and blending of information and communication technologies. It is easy to construct specific examples, in which a solution to a problem can be engineered using different mixes of computational or communication technologies. For example, to minimize the efforts of clinical staff in learning to use an electronic record system, one might use speech recognition and synthesis technologies. Alternatively, using a communication channel like the phone, and alternative structuring of processes and roles, staff can dictate notes and send orders via trained computer operators[20] (Figure 1).

The challenge is to develop a set of principles that permit choices between such alternatives to be made rationally and to guide the design and implementation of systems along different points of the continuum. From an informatics viewpoint, we can take a first-principle approach, which regards all informatics tasks as model construction and application.[16] It makes sense, therefore, to look at how models are handled in information and communication technologies.

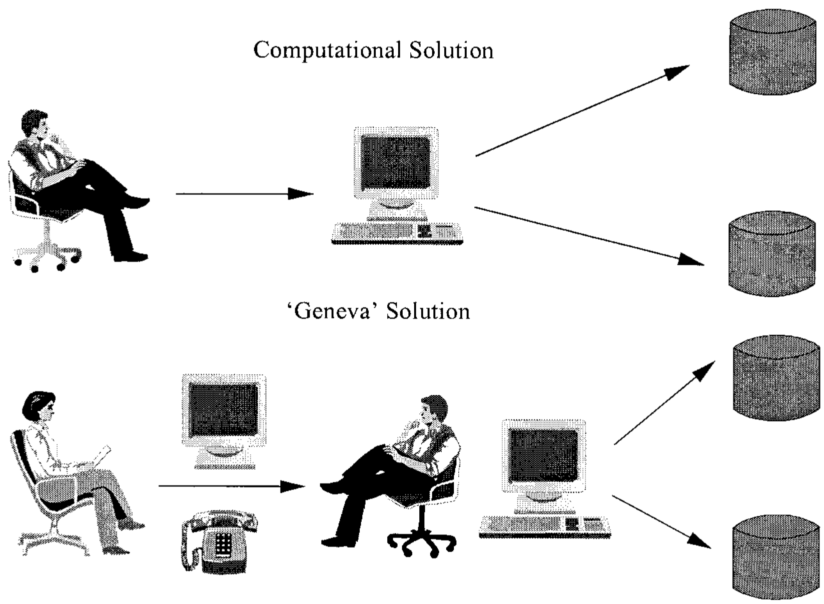

Figure 1 A voice-driven interface to an electronic medical record system can use a computational solution relying on speech technologies or a hybrid approach using communication and information technology. One design solution developed at the University Hospital in Geneva allowed clinical staff to interact with the medical record via a telephone pool of trained operators.

In simple terms, we can say that information technologies require explicit formalizations of information processes for them to operate, whereas communication systems remain relatively informal to process models.[21] A telephone, for example, needs no model of the conversation that occurs across it to operate. In contrast, a computer system would need to explicitly model any dialog that occurs across it. From this point of view, we can say that a continuum of possible model formalization is available to us. For a given task, system designers make an explicit choice to model some or all of a process, based on their perception of costs and benefits. When the choice is to formalize the process substantially, computational solutions are sometimes used. When the task is left informal, we find instead that communication solutions are required.

Searching for a similar characterization of the continuum, one can turn to the literature in psychology and linguistics. While much communication research is focused on the specifics of conversational structure, some work does step back and look at the underlying notions of how much of a conversation has been explicitly modeled. In particular, the psychological notion of *common ground* is a strong match with the notion of relative formality of model construction.

Common ground refers to the knowledge shared by two communicating agents.[22] For a conversation to occur, agents have to share knowledge about language as well as knowledge about the subject under discussion. We know intuitively, for example, that discussing a medical problem with a clinical colleague or with a patient results in very different conversations. While messages can be concise and much mutual knowledge can be assumed between colleagues, explaining an issue to a nonexpert requires the main message to be sent along with the background knowledge needed to make the message understandable.

Unsurprisingly then, human agents communicate more easily with others of similar occupation and educational background, since they have similar experiences, beliefs, and knowledge.[23] Furthermore, the more individuals communicate, the more similar they become.[24] We can recognize the sharing of common ground as a key reason that similar agents find it easy to converse with each other. In addition, two separate streams of dialogue actually occur during any given conversation. The first is concerned with the specifics of the conversation, while the second is devoted to checking that messages have been understood, and may result in the sharing of common ground when it is clear that assumptions about shared knowledge do not hold.[25] Thus, building common ground requires mutual effort and consent between participating agents.

The notion of common ground holds whether we are discussing a conversational interaction between human beings or a human–computer interaction. For a computationally rendered information system, the system designer must create a model of what the user will want to do with the application. For their part, users have to learn a model of how to operate the computer application. When both computer and user share this common ground, the interaction should be succinct and effective. When the user and system do not share mutual knowledge, we run into difficulty. If the user lacks knowledge of the system's operation, the human–computer dialogue will be ineffective. On the other hand, a system that does not model its context of use will be regarded as an inappropriate intrusion into the workplace.

Building common ground incurs costs for the participating agents. For example, a computer user spends some time up front learning the functions of a system in anticipation of having to use them for future interactions. Inevitably, not everything that can be "said" to the computer is learned in this way, and users also typically learn new features of a system as they interact with it for particular tasks. This means that agents have two broad classes of grounding choice:

- *Pre-emptive grounding*. Agents can share knowledge prior to a specific conversational task, assuming that it will be needed in the future. They elect to bear the grounding cost ahead of time and risk the effort being wasted if it is never used. This is a good strategy when task time is limited. For example, if a rare event is nonetheless an urgent one, preparation is essential. Thus, pilots, nuclear power plant operators, and clinicians all train rigorously for rare but mission-critical events, since failure to prepare has potentially catastrophic consequences. Training a medical emergency team on how to interact with each other makes sense because at the time of a real clinical emergency, there is no time for individuals to question each other to understand the meaning of any specific orders or requests. Pre-emptive grounding is a bad strategy when the shared knowledge is never used and the time and effort in grounding becomes wasted. For example, training students with knowledge that is unlikely to be used when they face a task in the workplace is usually a poor allocation of resources. From first principles, the cost of pre-emptive grounding is proportionate to the amount of common ground an agent has to learn. For example, the length of messages increases, as does the cost of checking and maintaining the currency of the knowledge once received (Figure 2)
- *Just-in-time grounding*. Agents can choose to share only specific task knowledge at the time they have a discussion. This is a good strategy when there are no other reasons to talk to an agent. For example, if the task or encounter is rare, it probably does not make sense to expend resources in the anticipation of an unlikely event. Conversely, it is a bad strategy when there is limited task time for grounding at the time of the conversation. Just-in-time grounding is also a poor strategy if one of the agents involved in the dialogue is reluctant to expend energy learning. Thus, computer system designers might face difficulties if they assume that users are willing to spend time during the routine course of their day learning new features of their system, when the users are already overcommitted to other tasks. The cost of just-in-time grounding is inversely proportional to the amount of prior shared knowledge between agents. For example, a message between agents with a high degree of common ground will be very terse, but the length (and thus cost) of transmitting a message to an agent with little common ground will be greater (Figure 3).

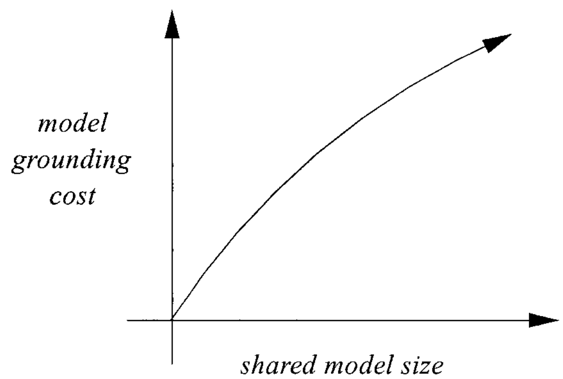

Figure 2 The cost of pre-emptive grounding increases with the amount of knowledge agents share: The more we share, the greater the cost of telling and maintaining.

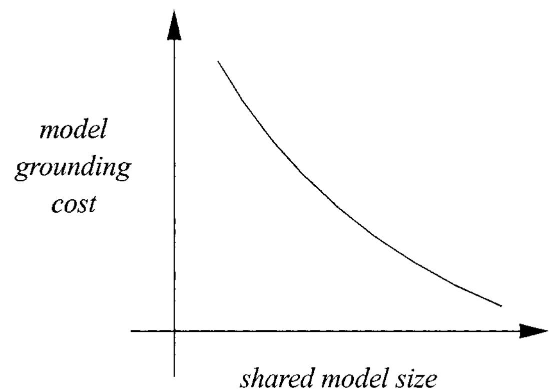

Figure 3 The cost of "just-in-time" grounding decreases with the amount of prior knowledge agents already share about a task: The less we share, the more I have to share now.

Any given interaction between two agents usually involves costs borne at the time of the conversation, as well as costs borne previously in pre-emptive groundings (Figure 4). Information system designers thus have choices about the amount of grounding they expect of the agents who will participate in organizational interactions. At the "solid-ground" end of the spectrum, the effective or efficient completion of tasks requires agents to share knowledge ahead of time. At the other end of the spectrum, on "shifting ground,"

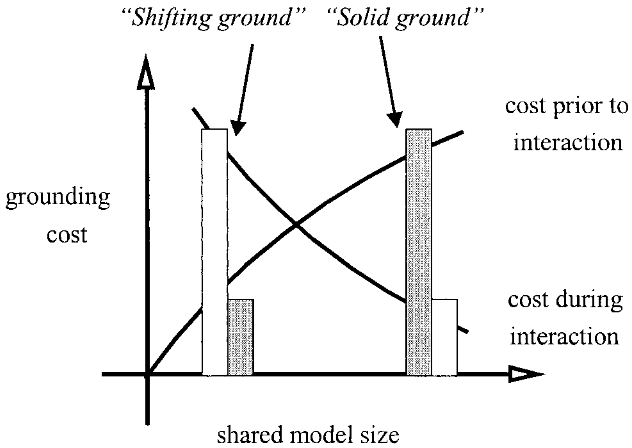

Figure 4 For any given interaction, some of the grounding costs are borne at the time of the interaction and some have been borne earlier. This means that an information system designer has a spectrum of options for designing the interaction between computer and user.

it is hard or uneconomic to decide what ground should be pre-emptively shared.

Thus, with solid-ground interactions, a user is expected to have learned most of the formalities of an information system or, conversely, the system is expected to have adapted to the needs of the users. On shifting ground, the information system is designed to handle interactions that require new knowledge to be exchanged at the time of interaction. This may be in the form of online help to the user or the acquisition of data from the user.

When Is Conversation Better than Computation?

Common ground is a candidate for the continuum parameter, which links information and communication system design. It offers us an operational measurement that can be used to define the characteristics of specific interactions between agents, whether they are human or computational. Using it, we should be able to analyze the specifics of a particular set of interactions and make broad choices about whether they would be better served by communication or computational systems. It should also allow us to make finer-grained distinctions about the dynamics of such interactions as, for example with regard to the amount of grounding that needs to be supported in a specific human–machine conversation.

With this in mind, we can now simply regard information models as part of the common ground of an organization and its members. We can choose to model any interaction across a spectrum from zero to a "complete" formal description (Figure 5). Furthermore, the models of our organizational systems have value only when we interact with them through our information or communication systems. In other words, for computational tools to be of value, they have to share ground with human beings. Users need to know how to use the system, and the system needs to be fashioned to users' needs. If an information system is perfectly crafted to model the processes of an organization but not the resource constraints of those who will need to learn to use it, the logic that predicts its failure is inevitable. Consequently, we should no longer consider information models in isolation but rather include the models that users will need to carry with them. Simply building an information model without regard to how it will be shared with those who interact with it ignores the complex realities of the workplace and does not factor in the costs and benefits of using the model for individuals.

"Pure" communication tools such as the telephone can now be seen to be neutral in any particular conversation that occurs over them, and they need no common ground with the agents using them. As such, they are well suited to support poorly grounded conversations, when it is hard to predict ahead of time what knowledge needs to be shared. We thus favor the use of communication tools across shifting ground with a high just-in-time grounding component. This may be because the interacting agents do not share sufficient ground, or it may be because it simply is not economic to do the modeling. The transacted information is thus often personal, local, informal, or rare. It is up to the agents having the discussion to share knowledge. The channel simple provides basic

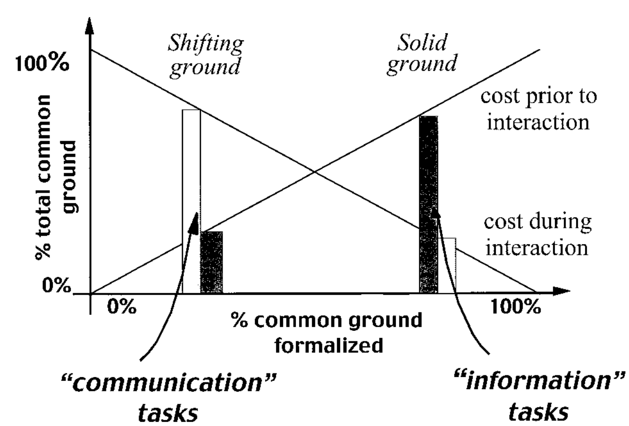

Figure 5 A continuum of common ground between agents defines how much of the interaction can be modeled formally ahead of time and how much needs to be left informal until the time of the interaction. Computational systems work well when substantial modeling can occur ahead of time, while communication systems can be used when agents are unable to reliably model their interactions ahead of time.

support to ensure that the conversation takes place. Communication channels are thus used de facto when no computational tools exist to support the interaction.

Furthermore, for highly grounded conversations, we know that the agents will be able to have succinct conversations. One can predict that they will need lower bandwidth channels than if the message exchange were poorly grounded. Poorly grounded conversations, in contrast, need a higher bandwidth, since more information has to be exchanged between the conversing agents. Building such common ground between agents may require the sharing of information objects such as images and designs.[26]

In contrast, we favor computational tools when it is appropriate to formalize interactions ahead of time and when the users of the system are willing, able, and resourced to build common ground with the tool. Such interactions occur over solid ground, having a high pre-emptive grounding component. The information exchanged in such situations is worth formalizing, perhaps because it is stable, repetitive, archival, or critical but rare. The computational system moves from being a passive channel to the interaction to either modifying what is said or becoming a conversational agent itself.

An information system designer also needs to take into account the common ground that is expected of the system users. For example, the voice-driven electronic record system illustrated in Figure 1 requires users to understand both their clinical task ground and the operation of the electronic tool. For complicated systems, the resource implications of mastering both clinical task and tool ground can be unacceptable to users. In contrast, using operators to drive the computer system allows the clinical users to master only their clinical tasks, leaving mastery of the computational system to the operators. Thus, clinicians can devote most of their pre-emptive efforts to clinical tasks and learn most about the specifics of the computational tool on a needs-only basis during interactions.

For computational tools, choices also need to be made between the traditional process of information modeling prior to system construction and a more interactive approach to building models. Thus, a system designer may try to model all the user needs prior to the construction of a system or engineer some flexibility into the architecture that will allow personalization of the interaction for specific users. For example, a system may gather data about the frequency of different requests from a specific user and customize its behavior to optimize for the most frequent requests of the individual, rather than the population as a whole. Such computational systems build common ground with their users in a just-in-time fashion, as well as having pre-emptive modeling to cover the most common features users will need.

Conclusion

The communication space is the largest part of the health information space and seems to contain a substantial proportion of the health system's information "pathology." Nevertheless, it has been largely ignored in our informatics thinking. In this paper, two implications of acknowledging the primacy of communication have been explored. First, there is an immediate need to support communication in our health care organizations, since this should lead to substantial improvements in organizational efficiency and effectiveness as well as offering a genuine opportunity to improve patient care. To do this we need to develop a richer understanding of the specific communication systems in our health care organizations. With such an understanding, a variety of technical and nontechnical interventions can be brought into play to improve poor communication processes.

Communication research is also important for developing our understanding of the basic principles of informatics. Understanding the interrelationship between communication and information tasks may help us re-evaluate the role of technologic support. Common ground is a powerful candidate concept that may help unify our understanding of information and communication in just such a way.

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