

On Distribution, Drift and the Electronic Medical Record

Some Tools for a Sociology of the Formal

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Abstract: Formal tools (i.e., tools that operate on circumscribed input using rules, and that contain a model of the workplace in which are to function) are attributed central roles in organizing work within many modern workplaces. How to comprehend the power of these tools? Taking the (electronic) medical record as an example, this paper builds upon recent calls to overcome the dichotomy between the Formal and the Informal and proposes an understanding of the generative power of such tools which does not attribute mythical capacities to either tool or human work. The concrete, real-time use of formal tools is the starting point. These steps towards a sociology of the formal are crucial for a more comprehensive understanding and evaluation of such systems.

Introduction

Through offering abstracted models of the work, and/or through the processing of input into output, formal tools are attributed central roles in organizing work within just about any modern workplace. What is it that these tools do in practice? How do they add to or interfere in the work performed? Answers to these questions are highly relevant for all those who believe that technology design might be improved through theoretical insight into the processes of everyday work. Yet any answer has to sail a risky course between either granting too much power and self-sufficiency to the tool at the expense of the workers (and thus replicating the rationalist discourses of 'naïve formalists' (Star, 1995)) or overly stressing the versatile and creative skill of the human workers versus the 'rigidity' of the formal tool. Both alternatives overlook how it is in the *interrelation* of the tool's functioning with the

human workers' work that new potentialities emerge. Through this interlocking, for example, new competences for workers can be achieved, higher levels of complexity in work tasks can be reached, and activities can be coordinated over time and place (Bowers, 1992; Suchman, 1993; Robinson, 1994; Berg, 1997).

Yet what does this interrelation look like? How does it yield new workplaces? The danger of speaking of 'interrelation' is that one may be seen to end up in some middle ground, taking over too many assumptions from the naïve formalist's position and its 'naïve informalists'' sibling. In fact, this is what often occurs in much recent work on the interrelation of formal tools and work practices. Yet how can we grasp the generative power of these techniques without having to assume the superiority of their models, or the purity of their logic? Likewise, how can we account for functioning tools without having to fall back on the interpretative skills or superior flexibility of human workers as the bottom-line explanation? Either of these two options would re-invoke the grand categories of the Formal or the Informal, and would draw on *a priori*'s questioned in recent science and technology studies (e.g. Haraway, 1991; Latour, 1994). This would constrain our analytical understanding of such workplaces, and would ultimately limit the innovative contributions that can be made to technology design. Building upon recent work in science and technology studies and related fields, then, I will propose a more mundane understanding, and touch - in the limited space available - upon the differences such an understanding could make.

The route into this analysis investigates the real-time work of and with formal tools in current practice.¹ The materials presented here are taken from an ongoing study of the construction, implementation and use of an electronic medical record system in an intensive care unit (ICU) in a research hospital in the Netherlands. This system was thoroughly adapted from the generic, commercial version by two nurses and an anesthesiologist, all working on the ICU. At this moment it has all but completely replaced the 'paper' record, functioning as *the* patient record for both nurses and physicians: a rather unique situation.

Distribution

Only as part of a concrete work practice does a formal tool come to life. By itself it does not do anything: people must turn on the computer to use the record. Organizational routines, instruments, specific forms: all will have to be in circulation, interlocking with the tool for it 'to work'. This is not a deep metaphysical point: it is like saying that a bicycle doesn't work unless someone sits on it, and you have a road, a pump for your tires, gravity, an urge to cycle, and so

¹ . This paper is adapted from a larger paper (forthcoming in *Science, Technology and Human Values*), in which I also explore a historical route, asking how the current map and terrain have been co-produced through time.

The fluid balance is the ultimately formal: the rendering of a range of sufferings and activities into a single number, ready for further manipulation. How is this formal rendering produced? It is not simply 'inferred' from the practice by the formal tools that are in place: intricate nursing routines are required to get the right numbers in their right places. Is it, then, humans performing the active translation, producing a number out of a dense ensemble of bodies, tubes, containers and paperwork? Yes, in a way: if the nurses didn't do their work, nothing could be written in the record. Yet the gap between the formal representation (the *map*) and the actual sphere of work (the *terrain*) is not crossed in one step. Rather, we see a *chain of re-representations* (Star, 1989; Bowers, 1992): a series of intermediate, representational activities performed by *materially heterogeneous entities*. At each step, input from the territory is condensed, elaborated and transformed until it matches the abstract level of detail of the map.

First, the nurses' work already *begins* with many numbers. The first step from the 'empirical' to the 'formal' is performed, for instance, by using precisely dosed infusion bags, by letting the patient drink from cups and glasses whose contents (in milliliters) are known, and by collecting the urine, through a catheter, in a container which indicates the produced quantity. The cup, bag and container each perform parts of the miraculous jump across the gap, from 'informal' to 'formal': these artifacts themselves already transform the unmediated, empirical realm into a number - into an element of the calculation that will produce the day's fluid balance. The drips of fluid are transformed, through the shape and transparency of the container, into an indicator. The fluid becomes a pointer on a dial: a fine line moving up and down a series of other fine lines indicating quantities. The task of producing a formal representation is partially *delegated* to mundane artifacts which perform, in Latour's terms, 'the practical task of abstraction' (1994). Moving from the empirical to the formal, here, is not a step wholly provided for by the formal tool. Nor, however, is it a human act of interpretation: providing meaning to the world is not the sole task of humans. We leave, here, the question of how language can be said to speak for the world and turn to its forgotten other half: how the *world* is stirred and thus *becomes* discourse itself (*ibid.*). These artifacts perform the first re-representation. The nurses' task is to perform the second: to transport the numbers produced by the artifacts to the appropriate fields in the record - meanwhile checking whether the current reading is possible in the light of the previous one, and whether the urine container has not been emptied by accident.

In the paper record, the tabular form of the recorded numbers performs yet another small crossing (see Figure 1). Here as well, a simple artifact actively participates in the production of a formal representation. Horizontally, these forms map the passing of time, and vertically, they list the different means fluid can enter or leave the body. Because of this spatial layout, the numbers end up in rows and columns which now merely need to be added. Moreover, the special configuration

of the form (see the IN and UIT [out] columns) constrains the placing of the calculated results, and affords the production of a total fluid balance much like an accountant keeps track of the in- and out-going flow of money.

Crossing the gap, then, is an intricate achievement - but it is not an achievement of the formal tool, nor is it a task of human interpretation or abstraction. Rather, the ensemble of heterogeneous entities performing the chain of re-representations *as a whole* crosses the gap. In the historical production of this work practice, the nurses' task has been transformed and displaced to the much smaller subtask of re-representing the data on the form or into the computer (Hutchins, 1995).

To take this point further, the capacities and characteristics that formalists and their opponents attribute to the formal tool or to a human agent appear to be highly distributed.² One may point to the electronic medical record and state that that is the formal tool we are discussing, but one should not forget the simple, low-tech urine container hanging at the bedside which also enters into the production of the formal representation. The work that is performed in this way, then, is highly distributed. Calculating, decision making, controlling - are these done by the formal tool (the record, the spreadsheet)? Or is it in fact the human agent who ends up in control, who does the skilled, 'cultural' part of calculation while delegating the 'mechanical' part of it to a machine (see e.g. Collins, 1990)?

Neither position holds much ground. The 'calculation' of the fluid balance is the *total net effect* performed by this hybrid. If one enters the network itself, however, one sees a chain of small re-representational tasks being performed by a series of heterogeneous entities none of which resembles anything like 'doing a fluid balance'. This is an activity that only occurs at the level of the whole hybrid.³ The particular position of the formal tool is not that it is in control, doing the calculation while the other elements in the network merely bring it some input, and process its output. Neither should we say that these technologies make it 'easier' for humans to do this task. Both formulations overlook that the urine container and the form already do some of the calculations. Not only does the container transform the urine produced by the patient into the required numerical datum: through its intricate design, it also rounds off the measurement appropriately. Slight urine production is measured in 2 milliliter steps, while more profuse production is rounded off to steps of 10 to even 50 milliliters. Similarly, the paper form first establishes the formal equivalences of such variable substances as blood, glucose solution, feces, and sweat - and it subsequently materially *contains* the required relations between the isolated observations.

² . See also e.g. Lave (1988) on the social, non-individual nature of cognition. Hutchins' work is exemplary in focusing on the role of non-human actants in distributed cognition.

³ . This formulation is reminiscent of Activity Theory, which argues that the unit of analysis in studies of work should be the complex of humans, tools, the organization of work, and so forth which constitute the Activity System (see e.g. Engeström, 1990). From the perspective of this paper, however, Activity Theory's explicit underwriting of the a priori asymmetry between humans and non-humans is problematic.

The nurses or physicians, in their turn, transfer numbers from displays to the form, compare them, and add up rows. They perform small tasks, interlocking with the other small tasks performed by the container and the form. They do not use these artifacts to calculate the fluid balance. A phrase like that assumes that the essence of the calculating activity remains in the hands (or heads) of the human; as if nurses and physicians can simply choose whether to use an artifact. But the very task they perform has been transformed and displaced by the artifacts mentioned. These are a crucial part of the network, not just 'tools' which the nurses can draw upon as they see fit. As Hutchins phrases it in his study of Navy navigation, these 'mediating technologies do not stand between the user and the task. Rather, they stand with the user as resources used in the regulation of behavior' so that the chain of small tasks performed interlock and together produce the calculation (1995). The tools' re-representation work sets constraints on the nurses' subsequent task - constraints which render their subtask do-able, but which also render it a component of the overall process. Likewise, the computer based record performs fragments of the total calculation: it adds up the entered figures. But the whole calculation is done by the network as a whole. All the small subtasks requires in- and output - and the chaining together of these steps (i.e., the organization of the hybrid) produces the net effect: the fluid balance.

This also implies that no one or no thing is 'in control'. Nurses, physicians, the formal tool - all have only partial knowledge of the intricacies of the work of other entities. In Hutchins' terms, 'an interlocking set of partial procedures can produce the overall [task] without there being a representation of that overall [task] anywhere in the system' (1995). They react upon what they receive as input, and work from there. No single element is master: the configuration is neither subjected to humans fulfilling their task, nor to the formal tool. The electronic record controls the nurse: as soon as s/he tries to enter an infusion dosage the computer considers 'too high', the computer emits a red warning signal. Likewise, it checks the input: one cannot enter non-numerical characters when entering the blood pressure, and one can only pick from a list of some eight options to describe the heart rhythm. Moreover, the entry fields have circumscribed lengths, and they remain visibly empty when not filled in. Yet the staff members control the computer: nurses have to validate every piece of data the computer draws from the monitor, and nurses and doctors can add remarks to all the computer data. Yet in its turn, the computer again controls the nurse whether indeed s/he has validated the data: if not, the numbers remain in italic font. And the computer controls all modifications made by automatically registering who changed what and when. Now who controls what? These relations cannot be captured hierarchically: they are *non-transitive*. There is no one center of control, not one core figure (whether formal tool or human) around who or what the whole activity is organized.

One point requires clarification here. Crossing the gap is often seen to be about (the possibility of) producing or applying an *accurate representation*. However,

'accuracy' is not the point - if with that is meant 'closeness' to some reality residing outside the ongoing interlocking of subtasks. For the agents performing these tasks, the goal is to maintain the flow through the chains of re-representations; to perform the subtasks in response to and required by other subtasks. Only on the level of the whole hybrid can 'accuracy' become a meaningful notion. But then it can no longer be seen as referring to some inherent quality of the tool's representation: it can only reflect the *achieved* fit of the map with the historically re-written work practice.

The formal tool, then, is an active element within the practice, and it performs subtasks in the production of, for example, the fluid balance. Yet whether we are referring to the production of a numerical representation of a state of the body or to the act of calculation, the powerful net effect a formal tool can produce is not due solely to this isolated element. But neither is this effect 'in the end' due to skillful humans. By zooming in on the way tool and work practice are interwoven, the distributed nature of the tasks comes into view - and thereby the way control and responsibility are transformed and dispersed over the heterogeneous assembly. We witness a myriad of little powers, together exhibiting capacities which the formalists would want to grant to the Formal tool, and their opponents would like to keep apart for the Human. The formal tools themselves are infinitely less powerful than the former would argue - but infinitely more than the latter claim.

Drift

Speaking about distribution in the way I have done so far, however, leaves some important questions unaddressed. How can the individual subtasks and their interlockings be characterized? Does the whole practice now function as a large formal Machine, with subtasks efficiently being performed according to pre-set rules? Does speaking about a territory re-written in the light of the map imply that the whole practice has been captured in the iron, instrumental rationality of Taylorism?

This interpretation would be a misunderstanding: there is nothing 'formal' about the way these networks actually operate. Before elaborating on this, however, it is interesting to note that several central traditions within the field of science and technology studies actually seem to collude with this image. Studies within the framework of SCOT or actor-network theory generally demonstrate the social nature of a technology through a study of its production: focusing on technologies-in-the-making allows one to highlight the negotiated and contingent history of their emergence. Yet in the operation of this focus, all too often the *ready-made* technology is reified, 'black-boxed'. In the argumentative move to demonstrate how Efficiency is an *effect*, not an a priori asset of Technology, the smooth functioning of the produced technology is taken for granted. It has become a Machine, in Latour's terms; 'where borrowed forces keep one another in check so that none can fly apart from the group' (1987). The Machine, the heterogeneous network that is

put and kept in place, produces the effect of Efficiency; it is the illusion of instrumental reason *made* true (Bowker, 1994). In creating this new opposition ('in production' - 'ready made'), however, the illusion of Efficiency now recurs at the level of the 'ready-made' technology, the technology-in-use: it has only been displaced. This rhetorical move thereby glosses over the fundamental issues at stake in the real-time functioning of the hybrid. I want to argue that *in studying technologies-in-use we should not grant them qualities that we would withhold while studying their production*. Actual machines-in-use are not Machines, and instrumental reason is not what makes these hybrids tick.

The notions of 'heterogeneous elements keeping each other in check', or of a network of smoothly and efficiently interlocking subtasks, are ideal images, indeed colluding with the formalist dream of total order. They downplay the processes of internal corrosion, of drift, which characterize the dynamics of these hybrids. As Jordan and Lynch point out, speaking about 'technologies' as 'black boxes' 'does not attend to the continual genesis of incoherence and fragmentation within the relatively settled development of an established technology' (1992). This point is not limited to formal technologies. A focus on such tools, however, is an interesting, hard case to start with - if any technologies-in-use could be characterized by instrumental rationality and efficiency it would surely be these. Yet this is not the case.

First, the different 'points' in the network, the different intermediaries aligned, *themselves* tend to drift apart from each other (Dodier, 1995). Each actant does more than its specific position in the network calls for: since it is always also tied up into other, cross-secting networks, its concrete form will always *overflow* its definition in the particular network under study. For the electronic medical record, for example, so-called electronic data exchange procedures are crucial for the record to function: they allow the laboratory results to be imported directly from the Hospital Information System. They were developed by the vendor's representative as part of another project, and have been incorporated into this record system. They translate the data unhesitatingly - in that sense they are fully docile actants. Yet the combined effect of the hundreds of laboratory results processed each morning leads to the - unexpected - result of irritating waiting times, and moments the record system seems 'locked'. That the exchange procedures take their time exchanging had never been a problem in the other networks in which they functioned. Yet here, given the unforeseen peak of laboratory results coming in at the same time, they turned into important obstructers of the network's smooth functioning.

Likewise, multiplying the number of cups and glasses drunk by their measured capacity is a practical way to measure the fluid taken in 'orally'. Yet cups and glasses are familiar objects to patients and family members, who refill half-emptied cups, throw away stale drinks - as they are used to doing. Overflowing their definition as 'standardized input measurement', the way family members and patients deal with them tends to render the fluid intake measurement imprecise.

As a final example, the record could not function without the physicians working with it and entering their data. Yet to them, the electronic medical record is only one of a whole array of exigencies they have to cater to. Residents have to 'do' each patient before the daily grand round at 11:30 am⁴, they have to coordinate the activities of the different specialists involved in a case, and they have to talk to patients' families. Often, they skip entries, do not fill in forms, or work from a small piece of paper they carry around rather than deal with the computer. Similarly, consultants often do not work in the intensive care unit, but are just called in to give an advice on a specific patient. They have many other priorities than 'learning to type', as one anesthesiologist ironically put it. Many just continue to write down their remarks on the traditional, paper consultation forms. Physicians, then, have to be made part of the network for the record to become a reality - yet in taking them aboard, a tendency of the network to erode itself from within is introduced as well.

This phenomenon holds whether we are talking about the individual components that constitute the electronic medical record *as artifact* (its wiring, its screens, its software), or whether we are talking about the heterogeneous network within which this artifact comes to life. In both cases, the individual elements that constitute the larger whole have additional tendencies, desires, urges, which together create a centrifugal pull. A computer program may be meticulously designed - yet it inevitably contains features that nobody has foreseen, or that end up working against its functioning. The electronic record made log files of all the operations it performed. Since the way the program was implemented in this hospital yielded a very large number of operations, it created huge log files that slowed overall performance considerably. Moreover, a program as complex as a computer medical record is the result of a collaborative effort, where specifications are stipulated which must be met by the different programming groups that construe the program's subparts. These groups have different goals, may be in conflict or competition with each other, have only a limited amount of resources to work with, and have to fulfill criteria that to them might be opaque. These processes, which iterate through time (through different upgrades, new versions, debugging, and so forth), result in a program whose detailed functioning can never be fully predicted (Weizenbaum, 1976; Berg, 1997).

Every network, then, has the tendency to fall apart, to contain glitches, and to behave unexpectedly. We do not witness the polished, smooth functioning that would characterize a practice or tool where instrumental rationality reigns. The 'borrowed forces that keep each other in check' are *themselves* in constant motion.

Having dispelled this misunderstanding, however, another problem arises. If these configurations tend to fall apart, what keeps them going, if they do? Recent ethnographies of (formal) technologies-in-use (e.g. Button, 1993), demonstrating the fragility of these configurations, give us clues to start from. The following

⁴ I.e., they have to update the record, get an impression of the current state of the patient, and order tests and changes in policy.

vignettes can illustrate these insights, as well as an important danger we encounter here:

John, a nurse, is entering a new patient in the computer: the doctor's orders, the medication for today, and so forth. When entering the vital signs he says: 'This takes so much time I have to validate every data item I enter. When a patient is unstable, when the vital signs differ from one moment to the next, you're constantly typing in your code... it drives you crazy. So I just scribble it all down on a little paper, and fill in some of these data afterwards. You have to re-set the time when you do that, because you're feeding data in retrospectively'. He goes further, and gets irritated by the fact that he has to open different windows to find information he needs. The system only supports one open window at the time: to get the doctor's policy in the nursing work-list, John has to quit that worklist, open the physician's progress form, write down the policy, quit the progress form, open the work-list again, move to the field where he had left off, and enter the policy. After he has done this twice, he grabs the terminal standing near the next bed and opens the physician's progress form there. 'Now I no longer have to jump back and forth all the time', he mutters.

Agnes, a resident, is filling in the physician's progress form. This form is implemented so that the progress notes are entered in the *same* fields, every day: to enter new data, old data first have to be removed. The progress form is printed every night ('to keep a record'), and the residents change daily whatever they feel needs to be changed to 'update' it. Agnes does not change the X-ray reading which was jotted down yesterday: since she hasn't heard about another X-ray, that reading still stands. The working diagnosis, the cardiac findings: all that she leaves unchanged. And although the blood pressure monitor says '125/65' she does not change the reading in the progress form, which is '136/72'. Under 'remarks' it is written 'tracheotomy yesterday'. She sighs. 'Well, that's confusing. That is the day before yesterday, now. And that .. [she points to a remark saying 'attempt detubation tomorrow'] should be today..'. She changes the references to dates ('yesterday' becoming 25/9, 'today' becoming 26/9). Filling in the current date she runs into trouble: the computer accepts only a standard format (it accepts '25sep95', and not '25/9'). The progress form cannot be stored until this field is filled in properly.

The first vignette depicts what might be called a classic example in these ethnographies: a nurse *works around* the limitations of the formal tool (Gasser, 1986; Button and Harper, 1993). Following the exigencies of the tool would stand in the way of his primary task - dealing with an acute patient. So he performs a detour, satisfying both this acute need and (albeit post-hoc and cursory) the record's demands. The nurse re-establishes 'compatibility' between the different exigencies of the different networks he is a part of (Dodier 1995). It is this type of example Star (1989) and Bowers (1992) focus on when they argue that in moving out of the self-contained sphere of the formal, the effect of 'deletion' is inevitably felt. Tension arises between the tool's model and what it models: since the record embodies an impoverished version of what nursing work is like, humans working with the tool need to re-add detail, or to repair the tools' functioning when it is used in practice (Collins, 1990).

Working around, tinkering with the tool, are omnipresent features of these

hybrids. However, selectively focusing on these, and showing how humans 'save' the faltering formal tools and keep these configurations going runs the danger to again pit the former against the latter. We hover dangerously close to the informalists' discourse here: reinstalling the informal in its privileged position to overcome the limitations of the formal. Yet we do not have to interpret these moments as instances where the formal is 'rescued' by the informal. We can also understand the persistence of these configurations in a different way. When John grabs a second terminal to facilitate his work, he is indeed working around the system's limitations. But the fact that the system can only have one window open at the time has nothing to do with specific characteristics of 'the formal': we see, rather, a nurse making do with what everybody involved sees as an idiosyncratic, stupid limitation of the program. Moreover, in the second example Agnes is not repairing the system - she is repairing what she calls 'unthoughtful' work of her colleagues. Relative temporal references such as 'yesterday' or 'today' are confusing in a form which is re-used the next day.

This is not, then, an argument about humans 're-appropriating' or 'saving' the technology. Humans are not pitted against the formal: the tinkering activity is directed at mending the drift in *all* juxtaposed elements. In addition, speaking about humans 'saving' or 'repairing' the formal tool re-installs the human in a position of control and oversight, and that is not what we encounter here. Nurses and physicians' perform their subtasks, and tinker with upcoming problems and glitches as they present themselves in the performance of their subtasks (see e.g. Hughes and King, 1992). John is not 'taking control' over the system when he pulls a second terminal towards him: he is simply tinkering to get his job done. Within the work, the 'oversight' that would be required for staff-members to 'appropriate' formal tools, to 'use' them at will, is nonexistent. As Hutchins would argue, it is *because* of the very shallow insight into the 'inner details' of the other elements' functioning that the performance of their subtasks remains do-able (1995).

To speak about 'repair' or 'appropriation', moreover, suggests a return to some original state: to the technology's 'proper' functioning, or, more often, to the original aims and ways of the practice. Yet this disregards the *transformation* of these 'original states'. When John has a new, unstable patient, his routine is to scribble data on a piece of paper, and enter these into the record afterwards. This detour fulfills the conflicting demands of the record system and of his acute need to care for the patient. Yet his activity is not so much a repair but a *balancing act* between two cross-cutting networks - which are changed in the process. He does not tinker with the record to restore some 'informal', prior-to-the-tool practice: as argued, the tool is part and parcel of this practice, and has fundamentally changed its working patterns. John does not 'undo' this. But neither does he 'save' the tool's pre-determined mode of functioning: he fills in the data afterwards, and makes a rough selection of the monitor readings to create an indication of the unstable period. In this filtering and post hoc entry of the data, the record's original

functioning is altered as well: what was meant to be complete, direct input, only checked upon by the nurse, now becomes an abbreviated set of data, filled in by the nurse as a summarized, second order entry.⁵

The same can be said for Agnes' intervention. In her dealing with the computerized progress notes she is *learning* how to deal with a novel means of writing. She is no longer filling in an empty, unstructured sheet of paper, but a pre-structured form which is already completed - with yesterday's notes. In selectively leaving pieces of text on the form and deleting and adding fragments, residents change their own progress note writing habits, learning that terms like 'yesterday' are not very practical on such forms. Yet they thereby also transform the ideals of this electronic medical record. By just editing the filled form, data and information are accepted which were accurate yesterday but may be just 'approximately' so today (Agnes, for example, does not change the now-different blood pressure reading) - curbing the record designer's hopes for 'exact' and 'complete' data.

The consultant's paper forms, finally, are stored in a paper, 'shadow' record, together with the printed progress notes. The residents enter summaries of the consultant's findings into the computerized progress notes. Doing so, they may be said to 'repair' the specialists' hesitancy about typing - but they thereby also take over the responsibility to convey this information from the record, and thus erode the record's position as source of all 'primary' data.

The persistence of these fragile configurations, then, is not due to skillful humans mending the formal tools' shortcomings: such a description overestimates the mastery human worker, and overlooks the drift in all other elements. It further overlooks how artifacts situated at the crossroads between networks also perform balancing acts. To balance the busy day-to-day demands of nursing work with the unstructured, large number of printing options the program offers, a written protocol exactly prescribes what to print when a patient is transferred to a different ward; what to print every Friday; and what to print every day. Similarly, notes (listing observation categories) are taped to the computer screens to aid nurses fill in their observation forms.

If the network persists, it is because the exigencies of the other, cross-cutting networks balance out against the exigencies of the network in question. This is not some mechanistic play of static forces: the network itself is in constant transformation due to these ongoing balancing acts. At the intersection of two cross-cutting networks, the conflicting exigencies transform *both* the operation of the tool-in-use, and the primary work tasks of nurses, residents and consultants.

To round off this discussion on drift it is important to return to Hutchins' marvelous study of navigation, in which he (amongst other things) demonstrates the phenomenon of distribution discussed above. Hutchins' networks are depicted as smoothly operating and as pre-designed by Navy-officials. The subtasks are

5. This is what I have elsewhere called the process of *localization* of a formal tool (Berg 1997).

meticulously aligned, and the way they are to interrelate laid down in extensive protocols. Doing so, Hutchins denies the existence of central, planning and controlling agencies at the level of the actual work of navigation. However, he implicitly re-invokes this agency at the next higher level of aggregation: the overall task seems to be organized, designed, set up by just the centralized Agency that he is at pain to dispel elsewhere. In this paper, however, there is no such Agency either designing these networks from above - nor 'saving' them from below. Rather, we witness a fragile, never static equilibrium, characterized by never ending frictions, loose ends, and unforeseen consequences. Tricks, devices or routines may be created to 'fix' recurrent tensions - but these will also produce new problems. New intermediaries will inevitably yield new diffractions: every time, every new actant does more than it was called upon to do. Moreover, it is important to recall that there are multiple actants performing these balancing acts. This it is yet another reason for the persistence of the drift described - for the continuation of a phenomenon these interventions at the same time attempt to counter. Nurses, protocols, but also the record's vendor and the programming nurses are constantly working to balance the differently pulling exigencies and desires. But the vendor is also constantly tinkering with the system: to deal with complaints, or to implement improvements. Given the history of protracted negotiations between multiple, hetero-geneous elements (wires, people, hospital boards, computer vendors...), given the distributed nature of the tasks performed, and given the multiple goals that went and go into the construction and functioning of this hybrid, it would be an illusion to believe that 'control' or 'redesign' would or even could be done from one, central position.

Conclusions

The generative power of formal tools, then, lies in the very existence of the gap between the workpractice and its formal representation. Through deleting detail the map is functional in tracking a route between distant sites: the record feeds into the separating and linking of different organ systems, and into the planning of complex treatments (Wood, 1992; Robinson, 1994, Berg, 1996). The electronic fluid balance's manipulation of the input data affords a more continuous and more precise monitoring, while taking some chores out of the hands of personnel. Yet the consequential role such formal tools may play is not due to some inherent superiority of the formal, nor to the repair and interpretative work of humans. A formal tool performs a crucial role in many work practices, yet to understand its functioning we do not have to leave the domain of the ordinary: it selects, deletes, summarizes; it adds, subtracts, multiplies. These simple subtasks have become so consequential because they interlock with a historically evolved, increasingly elaborate network of other subtasks: nurses filling in the data in the balance sheet,

complex fluid containers, organizational routines, and so forth. This description does not imply that the number representing the fluid balance and the computerized progress notes are produced through the fully disciplined behavior of actants captured in some iron logic. Nor does it imply that the elaborate whole of interlocking subtasks is centrally (re-)designed. The networks develop in piece-meal fashion, through a complex interplay of driving forces, and partly through the ongoing balancing acts that occur wherever cross-cutting networks intersect.

The work performed and its formal rendering, then, are the *outcome* of historical and real-time processes. In real time, the difference between the drunk, spilled and expelled fluids and the single number blinking on the screen is produced by the articulation of subtasks and balancing acts: these processes bring the map to life, and allow it to function as a representation of the terrain. These very same processes also *bridge* the gap: they produce the ongoing flow of re-representations which link the map to the terrain, and which allow the generative power of these tools to exert itself.

This focus allows one to study the transformations of work practices that occur as the intertwinement between tool and practice evolves (Simone and Schmidt, 1993; Star, 1995; Berg, 1997). Will the final record be more congenial to the nurses' demand for practicality and simplicity of use or to the specialists' desire for research data? What type of body is produced when we shift from a paper-kept fluid balance to an electronic one, where the balance is now 'continuous'? How is the hierarchy between junior and senior doctors affected when the progress notes become increasingly pre-specified and accessible to all? How is the decision-responsibility distributed over the different elements that perform the overall task? To address these questions in the formalists' or informalists' vocabularies (or in a combination of these) restricts our understanding of these processes since so much explanatory power is invested in the capabilities of either the tool or the worker - or both. This is crucial, since a finetuned appropriation of the generative power of formal tools can only evolve from an equally finetuned understanding of how this power emerges and operates!

The conceptual tools developed here, then, might contribute to a better analytical grasp on the workings (and failings) of formal tools in workplaces. The relationships between junior and senior doctors, for example, will surely change through the implementation of the electronic medical record - but the concepts introduced here make clear that a simple increase or decrease in hierarchy or efficiency will be the exception rather than the rule. And rather than getting 'more' or 'less', it could be the very *meaning* of 'hierarchy' or 'efficiency' in this setting that might change.

Moreover, the analytical tools developed here offer the opportunity to address these questions while avoiding the pre-set evaluative axes that accompany the vocabularies mentioned (Berg, forthcoming). Speaking about the generative power of formal tools, of distribution and drift opens up the possibility of scrutinizing

configurations of artifacts and personnel without im- or explicitly projecting the direction of these changes in terms of either efficiency and accuracy, or (de)humanization and (de)skilling. These axes too often still structure the debates around formal tools, even if the caricatured discourses themselves are said to be left behind. This does not mean abandoning a political stance - rather, it allows new issues for debate and design (such as the shape of the heterogeneous distribution of responsibility, the different meanings of 'efficiency', or the patient's body that is implied in these configurations).

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