INTEGRATING MICRO- AND MACRO-ERGONOMICS

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ABSTRACT
Understanding how a new piece of technology fits into a user's working environment is perhaps the classic definition of human factors or ergonomics — a view which fails to address the role of the organization in optimizing this fit. This paper presents a framework which tries to address this failure. The framework (the Dynamic Dilemmas model) is dynamic in that components of the framework are responding in real time to the behavior of other components — over and above any natural tendency they may have to develop and change on their own. And it is dilemma-based in that each component has its own needs and limits, not all of which can be met simultaneously, creating tricky choices concerning accommodation and optimization.

In this framework traditional usability is a part of a complex process optimizing the three-way fit between people, technology and organizations, with the fit being assessed in relation to the activities, skills, limits, needs, philosophy and whims of the people, technology and organization.

A USABILITY PROBLEM?

A few years ago, while helping a national organization (in the UK) to manage its failures of information technology, the first author noticed how most of their problems stemmed from the poor usability and inadequate functionality of the main software supporting their work activities. However, unlike many other such cases the software in question was an off-the-shelf package which was in use in many other places and which was presumably not crippling every organization which used it.

In an attempt to try and understand this, we contacted the national User Group for the software and through them were able to visit ten other companies using the same software. What we found was that the same features and usability flaws that were crippling one organization appeared to have little impact in others. The key differences were related to organizational structure and culture — an organization where people were flexible in their ways of performing their activities was much more able to cope with the poor software, than was a more rigidly structured and less-empowered organization.

Whilst not wishing to make any strong claims about these particular variables, the general lesson that usability (and its impact on an organization) could be mediated by organizational culture is very important. It has led us to explore more fully the conventional notions of usability, of organizational behavior and of context. This paper is our first presentation of the results of this inquiry and it includes a new framework for considering the nature of human factors and usability.

AN HISTORICAL PERSPECTIVE

Understanding how a new piece of technology will fit to a person and their working environment is perhaps the classic definition of human factors or ergonomics. And yet, setting aside for the moment the existence of the HFES' Macro-ergonomics group, the classical view of human factors generally fails to address the role of the organization in contributing to this fit between the user and the technology.

There is (in Europe especially) a strong tradition of studying the organizational impact of information technology, independently of the influence of the user upon the organization or the technology (see for example, Blackler and Oborne, 1987, or Eason, 1988). And then there are also, of course, the traditional areas of organizational psychology and organizational development, which include the study of the relationships between the organization and the employees, with less concern for the role of the information technology.

Although there has recently been considerable movement in all these areas towards recognizing the role of the third party in the equation, there are few models to guide a coherent, systemic approach to the problem. However, Majchrzak and Finley (1995), for example, write explicitly about the need to address the integration of social and organizational factors during the implementation of technological change in an organization.

The existence of the HFES' Macro-ergonomics group is another indicator of the recognition that the problem is larger than the classical views permit.

In the area of human-computer interaction there has been a substantial movement towards CSCW, situated action and activity theory (see, for example, Nardi, 1996), with a much greater concern for the context in which the computer use occurs (for example, contextual inquiry, Beyer & Holtzblatt, 1997). However, very little, if any, of this work has included discussion of the relationship between these new ideas and traditional approaches to human factors and human-computer interaction. Indeed, Seely-Brown (1992) claimed that addressing the social and organizational factors was all that mattered — that once these were solved, the traditional cognitive concerns would have vanished.

In a more public domain, a variety of books have been published recently cataloguing significant technological failures and disasters (e.g. Casey, 1998; Flowers, 1996). One feature which these volumes have in common is that their tales describe complex interactions of organizational, technological and human error. In many respects these stories have captured the systemic nature of technological failure more effectively than most of the academic disciplines.

This paper therefore aims to present our current views on an integrative framework for the macro- and micro-ergonomic issues in technological development. The ideas are still under development and the framework is intended to stimulate discussion about this and other possible integrative perspectives.

Before describing the framework, it seems useful to return briefly to the story with which we began this paper (and others which have inspired us) and to draw out some of the key properties of that story — we believe these recur sufficiently often that they will resonate for most readers.

LESSONS FROM CASE STUDIES

Support for the following comments can be found in many of the examples provided by Casey and by Flowers (op. cit.). However, (demonstrating the power of experiential learning) the lessons were derived primarily from two case studies conducted while the first author was on the faculty at the University of Nottingham (UK). One is the story with which we began this paper and the other concerned the procurement of a new system by a very small company supplying goods to a major chain of supermarkets.

The important lessons from all these taken together were:—

1) The ability of technology to fit successfully with the needs and limits of the organization is not the same as its ability to fit with those of the users — and overall effectiveness depends upon both (and more).

2) Where technology does not fit the needs and limits of the users (for example), they may make changes to their working practices which can impact upon the organization (both positively and negatively). Particularly when this impact is negative, it is possible for the organization to then adjust its activities in turn, maybe thus changing its own fit to the technology.

3) The impact of software with poor usability is moderated by organizational factors. For example, flexibility in work allocation enables the organization to manage changes in people's activities before the software imposes changes on the users.

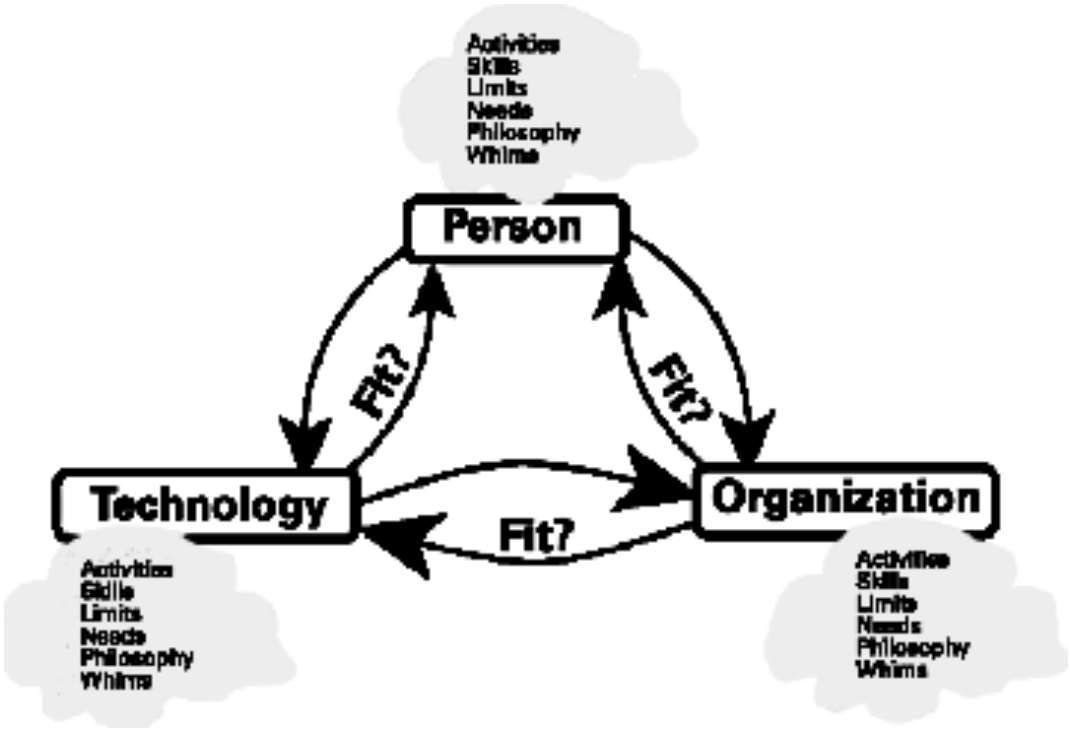
4) An organization may have good reason to choose software which it knows is not optimal for the individual users, but which does meet its own needs. Whether such a system succeeds or fails may not be predictable initially, since the outcome will depend upon many varied aspects of post-implementation behavior.

Emergent from these four key lessons is the realization that the whole process can be seen as being both dynamic and dilemma-based. It is dynamic in two ways — firstly that each of the components has a natural tendency to develop and change on its own (for example, technology has to be upgraded) and secondly that components of the system are responding in real time to the behavior of other components

The process is dilemma-based in that each of the components has its own needs and limits, not all of which can be met simultaneously, creating tricky choices concerning accommodation and optimization.

THE DYNAMIC DILEMMAS MODEL OF HUMAN FACTORS

In this model (shown in Figure 1), human factors is depicted as a three-way balancing of the fit between people, technology and organizations, thereby encompassing more than usually comes under the heading of human factors. The criteria of fit are indicated along the sides of the model. The particular nature of these criteria is very different between the three components — some examples are given below.



Micro-ergonomics is one side of the triangular model — the one indicating the fit between the person and the technology. The other two sides include the area which has been termed macro-ergonomics. The important feature here is the combination of micro- and macro-ergonomics into a common framework.

The use of the term 'fit' is deliberately loose, encompassing both the traditional human factors sense of physical fit (cf. sizes in clothing) and the more cultural, philosophical sense of the word. For example, Henning (1997) uses fit to refer to the congruence between managers and staff in relation to their views on issues such as authority and responsibility at work.

Furthermore, this move towards a systemic view reveals the inevitable dynamic nature of the process. Any poor fit between two components will lead to adjustments, which will in turn lead to changes in the fit to the remaining component. And that is in addition to the natural change and development of each of the components alone.

Also, as we strive to maximize the fit between any two components, we cannot avoid altering the fit with the third component, creating dilemmas as we discover that the key criteria of fit do not correspond between the components. For example, although we want to fit (for example) along the dimension of needs and limitations, the needs and limits of people are very different from the needs and limits of organizations, which are different from those of the technology.

This further indicates how the concept of 'fit' is a broad one, covering both the 'matching' and the 'complementary' sense of the word. Thus one might design for a reasonable match between the activities of the technology, the people and the organization, while at the same time trying to ensure a complementary fit of skills and limits.

THE CRITERIA OF FIT

The fit between components in the model can be assessed in relation to a set of six criteria, which are described briefly in Table 1. Each component has generic values on these criteria as well as situation specific ones. Table 1 gives some examples of generic values.

The generic values are those which commonly occur, not necessarily those which always occur. In some respects, they can be thought of as default assumptions if we have no situation specific information to guide us. The distinction

between generic values and situational values can be clarified with the example of human skills and limitations. There are generic human skills and limitations which we all generally share (e.g. difficulty in processing negative information, ease of processing information which has a personal meaning for us) but within any given situation the range of skills and limitations increases (for example, to include particular task-related skills).

In some cases we may be able only to identify important aspects of a fit criterion without being able to specify any generic value. For example, many organizations have a need for confidentiality, which needs to fit with the people and the technology. But there is no sense in which we can state this as a general property of organizations — we can simply state the view that, within any given situation, the organization's need for confidentiality should be assessed.

Some of the six criteria are very familiar — activities, skills and limits for example — and probably need little or no explanation. The study of email software and its use (Whittaker and Sidner, 1996) provides an excellent example of a misfit in relation to activities. They noted that email clients are based on an assumption that email is a transient communication (read, replied to and then deleted or filed). However, they found that email systems were used as address books (keeping each person's most recent email in the InBox) and 'To Do' lists (keeping active responsibilities in the InBox). Furthermore, the lack of support for these activities in email clients caused much difficulty (errors and delay) for people, but did not cause them to change their use of email.

However, our inclusion of needs, philosophy and whims, which may be more controversial, is very deliberate. From the cases we've seen and read about these criteria have to be included. For example, in the story we began with the activities supported by the technology were not appropriate but the 'fit' was enabled in some cases by the people and the organization sharing a philosophy of flexibly adapting, but blocked where the people or the organization did not have this philosophy.

Some aspects of these fit criteria are very well understood while some others are much less so. For example, the relationship between the skills and limits of people and technology is described in most ergonomic textbooks, under the title of 'task allocation' (e.g. Oborne, 1995, p. 17-19). However, the relationship between, for example, the whims of the technology and the organization is much less well understood.

THE ISSUE OF CONTEXT

The development of situated action, contextual inquiry and related ideas all have a tendency to make us think in terms of a piece of technology, its users and their context. One of the striking things about the model presented here is that it moves us away from this description to a whole system model. If we examine it from the perspective of a traditional human factors, or micro-ergonomics professional, then the person-technology fit is seen in greatest detail, with the organization appearing more contextual. Although this view isn't wrong, it can prevent us appreciating that this is simply the view from our perspective. For example an organizational development consultant might view technology as a contextual factor impairing the relationship between an organization and its employees, whereas a management information systems expert may view the people as a contextual issue in getting technology to work effectively for an organization.

Each of these individual perspectives is missing something — the system view which recognizes that it is the relationships between components of a system which produce behavior rather than any individual component (Senge, 1990). The systems perspective enables us to see that the success of an enterprise depends upon the whole system in Figure 1. The technology may indeed have very poor human factors, but the impact of that on the performance of the business depends upon properties of the whole system — the relationships and fit between the people, the technology and the organization.

Looking at the three types of fit independently is an example of what Senge calls "detail complexity", in which we focus upon the complexity resulting from the details in a problem and strive to understand these static details individually. The contrast to this is to focus upon the dynamic system, striving to understand the subtle problems of "dynamic complexity". The model presented in this paper is intended to help us discuss and debate the role of these types of complexity in our work.

DISCUSSION

Micro-ergonomics is clearly an example of a detail-focus, but macro-ergonomics is more ambiguous. If macro-ergonomics is seen as equivalent to organizational design and management, then it too will tend to have a detail focus, but if we view macro-ergonomics as a whole system-perspective, then it can focus on the dynamic complexity and be a true complement to micro-ergonomics.

Important within this framework (and present in Senge's writings) is the view that both detail and dynamic complexity are equally important. In particular the details contribute much of the content to our understanding of the dynamic complexity.

Since we developed the framework presented here we have become aware of others developing similar viewpoints. For example, Majchrzak and Finley (1995) argued for an integrative approach to technological change. They explain how a traditional, component centered approach "ignores the reality that all elements of an organizational system are highly intertwined such that impacting one will, by fiat, affect others." A key implication of this, they argue, is that there is no 'silver bullet' solution — every situation requires its own integrative approach. This conclusion has an echo in the frustration many human factors professionals feel with the silver bullet known as the GUI (graphical user interface), which frequently fails to address the user's goals, knowledge and beliefs, let alone their social or organizational context.

One of the key challenges from this kind of framework is translating the ideas into a form which can support the design process. This is complicated for us by the emphasis on the system's dynamic nature. Given that each component, as well as the overall system, has a propensity to change, it seems challenging to translate the framework into recommendations for the design process.

One important insight is that the dynamic nature can be seen as liberating, rather than complicating. Our goal is not to find the 'silver bullet' design, but to come up with a best approximation given our understanding of the system. Critical to this understanding will be, for example,

- an understanding of the flexibility of the system — where is it most likely to change?
- an understanding of vulnerability in the system — which parts can least manage change?
- where is the commitment / compliance to change — which part will control / dictate the changes?

Thus, designing a system for a flexible organization with a committed workforce, who are doing a non-critical task, may not require the same degree of human factors investment as for an inflexible organization with a compliant staff working at a safety critical task. This in essence, takes us back to the scenario with which we began the paper — the poorly designed software nearly brought down the rigid, bureaucratic organization, with a disillusioned workforce, performing a safety critical function, whereas the same software worked successfully in a company doing analogous, but not life-threatening work, with a staff who felt empowered to adjust their ways of working to suit the technological limitations.

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