For a psycho-engineering approach to HCI

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N° 2215
Mars 1994

PROGRAMME 3

Intelligence artificielle,
systèmes cognitifs et
interaction homme-machine

Rapport de recherche

1994

INRIA
ROCQUENCOURT

-- Projet de Psychologie Ergonomique pour l'Informatique --

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Pour une psycho-ingénierie des interfaces utilisateurs

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FOR A PSYCHO-ENGINEERING APPROACH TO HCI (*)

Abstract

This paper presents a critical view of the field of HCI ergonomics and describes some of the research conducted at INRIA on the topic of HCI design and evaluation methodologies. The paper provides a few definitions and describes some of the current methodological approaches. Introducing the debate about the nature and role of HCI ergonomics, the paper discusses some of the limits of the laboratory only approach and of the field only approach, as well as the limits of the current cognitive modelling approaches. More specifically, several points are discussed: the problem of modelling interface objects; the problem of knowledge organization of available results in the domain; the problem of formal task modelling; and the problem of HCI expertise. The discussion and conclusion provide items for the debate on future research needs for building a unified domain of psycho-engineering of HCI.

Keywords : human-computer interfaces; user interfaces; interactive software; evaluation and design methods; user modelling; task modelling; psycho-engineering, ergonomics.

POUR UNE PSYCHO-INGÉNIERIE DES INTERFACES UTILISATEURS

Résumé

Ce rapport présente une vue critique du domaine de l'ergonomie des interfaces utilisateurs et décrit certaines des recherches menées à l'INRIA en matière de méthodologies d'évaluation et de conception d'interfaces. Tout d'abord sont proposées quelques définitions et une revue des approches méthodologiques actuelles. En évoquant les débats sur la nature et le rôle de l'ergonomie, ce rapport discute de certaines des limites de l'approche uniquement laboratoire et de l'approche uniquement terrain, ainsi que des limites de la modélisation cognitive. Plus particulièrement, plusieurs points sont évoqués: le problème de la modélisation des objets de l'interface, le problème de l'organisation des connaissances du domaine, le problème de la modélisation formelle des tâches, et le problème de l'expertise ergonomique. La discussion et la conclusion proposent des éléments de débat sur les besoins de la recherche afin de construire un domaine unitaire en psycho-ingénierie des interfaces.

Mots-clés : interfaces homme-ordinateur ; interfaces utilisateurs ; logiciels interactifs ; méthodes de conception et d'évaluation ; modélisation de l'utilisateur ; modélisation des tâches ; psycho-ingénierie, ergonomie.

(*) This text is an edited version of an invited conference given at the *II Congresso Latino Americano e VI Seminario Brasileiro de Ergonomia*, October 10-13, 1993, Florianopolis, Brasil.

What are the consequences of bad design? Typical consequences are extra effort needed from the user (added procedures), limited use or non-use of computer facilities, regression to manual use, doing things twice (with the computer, plus with other means), usage of an intermediary between the system and the user, modification of the task, frustration, disinterest, rejection, high error rate, poor performance, in the end, decreased performance of the Human-Computer System. The characteristics of design flaws are mainly a lack of knowledge on users and tasks; a lack of HCI design methodology; a functional rather than operational design orientation; a lack of evaluation of the combinatory consequences of dialogue transactions; a lack of human errors forecasting. The performance criteria are system criteria rather than users goals; often all "thinkable" functions are provided, rather than the appropriate ones; all available information is provided, rather than the one necessary for the task at hand; the computer is considered as an end by itself rather than a tool for some goal.

The increased importance of taking into consideration HCI aspects comes mainly from the reduction in hardware costs, the increase in power and functionality, the fact that more resources are dedicated to the interface without sacrificing functionality, the evolution of computers from data processing centers to the office, the house, the classroom, the industry, the fact that users are not any more only computer specialists. There is a striving need for more and more efficiency and accuracy, which of course, can only be attained if there is some symbiosis between the human and the system. In addition to safety reasons (which allowed ergonomics to pioneer in the areas of aerospace, energy, and the military) now economical reasons also are part of the managers' interest in ergonomics: they are very sensitive to cost/benefit analyses. For instance, taking a population of 100 users (which is a small sample), assuming that each one has about 50 interactions per day with a few main screens, and assuming that good ergonomics allows even only a gain of 5 seconds on each screen (e.g., with a form-filling dialogue), the yearly savings in labor cost is close to $ 35,000 (using 250 days of work per year and an hourly salary rate of $ 20); and this is without even considering reduction of errors!

Looking at the history and evolution of the domain, one can distinguish two periods: the 80's and the 90's. Before and until the early 80's, the users were mainly programmers; the systems were slow, the dialogue types, and input/output devices were limited; ergonomics concerned (without mentioning hardware-related studies) mainly the identification of research issues (e.g., Scapin, 1981), with empirical experiments, many studies of programming. Getting to the 90's, the users population started to be constituted mainly with non-specialists in computers but specialists of other domains; the systems became faster, with many dialogue types and input/output devices, manufacturers' interface style guides appeared, architectures started to distinguish interface/application levels allowing some independence in the design, prototyping tools became numerous; ergonomics provided lots of experimental results, as well as theories and models, lots of recommendations were produced, as well as handbooks and in-house interface style guides. Conferences and tutorials in HCI Ergonomics were getting popular, including in computer science departments; computer science books started to include ergonomics (Barthet, 1988; Coutaz, 1989; Meinadier, 1991). However, let us not be too optimistic for the users and for the domain! First, if the emerging interface standards (from manufacturers such as CUA (1991), or from international standards such as OSF/MOTIF (1990)) did indeed bring some consistency to the presentation and behavior of interfaces ("look and feel"), it did not fully improve the characteristics of the interfaces available, especially from an "utility" point of view. After all, consistency (Grudin, 1989) is not the only issue! Another issue of more concern is that ergonomics is not included in the current computer science methods, and very few are the examples of such attempts (see for instance the DIANE method, particularly designed for organizational applications, Barthet, 1988). The situation just described must lead ergonomists to wonder about their own contributions.

2 THE VARIOUS METHODOLOGICAL APPROACHES

Of course, HCI ergonomics can be quite complex. The evaluation of a concept, object or model can be considered as a comparative diagnosis based on a particular dimension or model, using in some cases tools such as measurement tools. This definition of evaluation concerns many domains. For instance, one can evaluate the moving speed of an object. This is achieved along the dimension velocity, using various tools such as a speedometer. Such a tool can be precisely scaled, a time measure is computed and referred to a distance between two specific points. It is therefore possible to compare the speed of two mobiles in order to select the fastest one; a standard speed can be chosen and used as a reference to assess how close speeds are to that value, etc. Speed is a measurable physics quantity, it has units. While it may not be divided into sub-dimensions, the various factors applying on speed are well know (e.g., slope of the distance, weight of the object, gravity, air characteristics and coefficient of drag, etc.). Concerning HCI, the situation is less well-known. Interface usability is not such a well-defined concept. It has several facets: usability can be described by ease of learning curves or ease of use, which can themselves be described using learning time, usage time, number of errors, satisfaction, etc. Such elements are indeed not similar to directly measurable physics quantities, except the ones that refer to physiological aspects (e.g., for hardware: luminance, contrast, etc.). Usability is not evaluated on a distance/time dimension, but along several sub-areas of behaviour corresponding to various psychological processes such as: memory, problem-solving, decision making, language understanding, etc. Such sub-areas are difficult to model and to measure; the processes are also quite variable from one subject to the other; and they also both depend on several conditions which characterize usage situation (e.g., type of software environment, type of work context, type of performance constraints). A very large body of research work has been carried out to face such a complexity. In terms of available methods for the evaluation and design of interfaces, one can distinguisn several approaches: principles, expert judgements, empirical approaches and analytical approaches.

Numerous *design principles* can be found in the human factors literature, especially handbooks (e.g., Wasserman, 1973; Norman, 1983; Shneiderman, 1987). They include some very useful concepts and design dimensions; they point out the most salient aspects of the interface from a human factors point of view. However, most design principles remain very general, without providing methods. Two prerequisites are often mentioned as crucial for any interface design: the users and the task. Concerning the task, it seems that there is not yet satisfying methods that can include tasks characteristics into the design of interfaces. Concerning users, two observations are often made: a single interface cannot be adapted at the same time to all its potential users, and users characteristics will evolve while they increase their experience with the system(s) and the interface(s) they use. However, user types are often distinguished only according to very general categories.

Expert judgements are often requested for quick interface evaluations. The expert provides a judgement that depends on his/her skills and experience, and on good reference material, when available. Despite its advantages (e.g., in terms of time and cost) and besides the fact that such experts are not always available, studies question the completeness of their approach, and point at the variability of the format and strategies of their diagnosis (Hammond et al., 1983, 1985; Molich & Nielsen, 1990; Nielsen, 1992a, 1992b; Nielsen & Molich, 1990; Pollier, 1989, 1992; Rosson et al., 1988). The material used by experts (e.g., heuristics, guidelines, standards) may itself be too high level, incomplete, its level of detail may not be sufficient. More generally, the evaluative approach is dependent on the expert's own strategies, rather than on a more systematic approach. One good reason for that process not being systematic is probably that the domain itself does not provide such global and systematic methods.

Empirical approaches are based on the users' performance or opinions (a posteriori). For evaluation, the goal is to define the ergonomic quality of an interface through various behavioral dimensions as they can be measured from usage. Even though user testing can be set up at various stages of the design, it is an a posteriori evaluation in the sense that it concerns observations or measures established from the usage by human subjects, once the interface is well enough specified (or prototyped). This approach is well described in Senach (1990) or MacLeod (1992). Such approaches can vary a lot, depending, for instance, on the context (real work situation or constructed laboratory situations); on the types of measures whether there are objective measures (e.g., learning curves, error rates, recall performance) or subjective measures (e.g., preferences, opinions on usability), on the types of data gathering techniques (e.g., task analysis, critical incidents, automatic logs of actual use) and on the experimental situations (e.g., simulation, wizard of Oz). Even though, in some cases, such approaches, conducted either in the field or in the laboratory, are the only available ones to answer new problems, they lead to several major drawbacks: their usually large cost, the availability of real adequate users, the need for specialists to ensure user testing is appropriately run, the time necessary to conduct extensive field studies or sophisticated experiments, etc. On the other hand, their great advantage is its potential realism, its computable (if not measurable) characteristics.

Analytical approaches are based on existing knowledge, not on live users' performance. For the evaluation, the goal is to define the ergonomic quality of an interface from its examination and comparison with existing data, such as models, recommendations, criteria, etc. It is an a priori approach in the sense that it does not require real usage, that it can start as soon as some features of the interface are described. Of course, such an approach can also be applied to different stages of the design; the nature of the items looked at will then be quite different (e.g., interface concepts and structure at early stages, graphical characteristics at later stages). Two types of analytical approaches can be distinguished: analytical approaches based on theory and analytical approaches based on results or data.

Analytical approaches based on Theory: various theoretical elaborations and HCI models have been conducted on the topic of human-computer interaction (see Hoppe et al., 1986; Scapin et al., 1988; de Haan et al., 1991). *Cognitive theories* such as the theory of action (Norman, 1986) or the communication-based design theory (Thomas & Carroll, 1981) are interesting ways of looking at the factors leading to a good interface, even though they do not result in formal models. Designing friendly interfaces has been defined (Norman, 1986), as being a problem of designing logical systems, allowing conceptualizations by the user through mental models coherent with the designer's model.

Norman' s theory, which distinguishes interaction steps, represents ways of conceptualizing the problem of interface design; it is a framework for thinking of the problems in terms of cognitive representations, not a method that can be directly applied for defining the parameters of a good interface. Human-computer interaction can also be viewed as a communication in which each participant has his/her own goals (Thomas & Carroll, 1981). The advantage of such a perspective is to consider interface design the same way as other aspects of design. Even though the authors' main points of interest concern naming and language syntax, the communication metaphor appears to be appropriate for thinking in terms of design; that conceptual framework can be considered to create tools that may enhance the designer/user communication thus improving interface design. Various *human-computer interaction models* such as KLM (Card & Moran, 1980), CLG (Moran, 1981), GOMS (Card et al., 1983), CCT (Kieras & Polson, 1983), ALG (Reisner, 1984), TAG (Payne, 1984), ETAG (Tauber, 1990) have been also proposed. Such models explicitly aim at describing the user' s behavior, in relationship with the interface. Among these models, very few of them mention explicitly the problem of interface design, but many deal with very low level user and interface behaviors. Besides, most models are difficult to apply, and furthermore difficult to implement. For instance, Coutaz (1988) mentions that design methods are not appropriate (in the sense that they are not engineering tools), that the models investigated are either too limited (restricted to low level issues), too informal (i.e., no underlying formal model), or too difficult (in fact, too general). Another type of models (abstract layered models) offers interesting perspectives by structuring the interface into layers that allow to envision the design at different levels (e.g., Foley & Van Dam, 1973; Buxton, 1983; Nielsen, 1986). Such models remain very general, especially concerning the most abstract levels. Their main usage is classificatory, but they are fruitful frameworks to describe the interface.

Analytical approaches based on Results or Data: in the literature, there is a continuous increase in the various forms of recommendations and guidelines for the design of user interfaces (e.g., Smith & Mosier, 1986a; Bodart & Vanderdonckt, 1993). Four different forms can be distinguished (e.g., Smith & Mosier, 1986b): design standards for which their use for good design is still questioned; design guides constituted from series of recommendations, but their structure, mode of access and sometimes terminology lead to serious difficulties; design rules which are in-house "style guides", a little more specific than guides; design algorithms constituted by a set of implementation rules for controlling the production of user interface software; among other things, this approach requires solving the problems of coherence, applicability and implementation of human factors recommendations.

3 DEBATES ABOUT HCI ERGONOMICS

In April 83, a workshop was held to discuss where human factors in computer systems research and development should be heading in the next decade (Vail, 1983). Some issues were selected as most important: providing tools to system designers that will aid in more effectively integrating human factors knowledge and techniques into the system design process (most frequently mentioned issue); designing an expert system to completely handle certain human factors issues was already mentioned, knowledge-based prototyping tools; developing procedures and metrics for the evaluation of human factors issues; providing models of the users of interactive systems. A very useful distinction was made between two kinds of models: the models that are built by psychologists to describe human behavior (cognitive models) and those built by a designer to convey to the user an understanding of the behavior of the system (user conceptual models). Other issues were mentioned: devising a development process such that the behavioral issues would be included; finding better ways to describe tasks, providing task taxonomies, etc. This attempt at identifying research issues for the future resulted in extremely good guesses since these issues are very current and could characterize most of the topics involved in HCI research nowadays. However, these issues, especially the first ones, are far from being resolved, even though one can notice a very strong tendency to concentrate on methodological aspects.

There are probably many reasons for such a slow evolution towards really usable methods. In addition to its inherent complexity, an explanation may relate to the way the domain of HCI ergonomics is viewed and which priorities are chosen.

As expressed by Amalberti (1993), ergonomics of HCI is in a crisis state; there are still too many misunderstandings about the role of ergonomics and its very nature. Issues are being debated within ergonomics societies about what ergonomics is and should be; for instance, within SELF[2] (e.g., Hubault, 1993), questions are put forward about knowledge vs. practice, art vs. science, task vs. activity, about the nature of research vs. practice, the importance of a holistic approach, etc. To the outsider (and maybe sometimes even to the insider), the field of HCI ergonomics does not present a very neat and united view, which may be harmful for its credibility by other disciplines.

For instance, some strong oppositions are expressed between the "human factors" approach and the "cognitive" approach. A very common distinction (especially within the French speaking community) is well described by De Montmollin (1992) who distinguishes three types of ergonomics: *human factors*, which is described as first aid, application of

[2] Société d'Ergonomie de Langue Française

knowledge, concerning the characteristics and limits of human beings; *activity oriented ergonomics*, where there is no salvation outside the field, where the process prevails over the structures, where the emphasis is on work analysis rather than on task analysis; *macroscopic/global aspects of work*, i.e., macro ergonomics which promotes a holistic approach, where " the new hero .... is not the scientist ... but the consultant", but also where the weaknesses of current methods can be stressed. A similar distinction comes from an historical view presented by Amalberti (1993) who sees three steps in the evolution of ergonomics: *health and safety*, *human factors*, and *cognitive ergonomics.*: the distinction between the latter two approaches lies mainly in their orientation: unlike human factors, cognitive ergonomics does not start from the dialogue tools to generate usability issues, but uses the opposite approach: its is more qualitative than quantitative and it does not distinguish clearly between task oriented ergonomics and HCI ergonomics.

One could wonder if such distinctions are really still accurate now that the Human Factors Society (HFS) itself decided to change its name to the Human Factors and Ergonomics Society (see the reactions following of members in the HFS Bulletin of April 1992; and for the fun, H. M. Parson's poem reproduction in the HFS Bulletin of October 92). Of course, the real reason for that name change may well be, as mentioned by Laughery (1992), that the name ergonomics has become better known, with a higher "recognition quotient", while the term human factors does not have a well-defined literal meaning. "Let's face it, it can mean a lot of things !"

Two criticisms about human factors (as opposed to cognitive ergonomics) are that it starts mainly (in the laboratory) from the limits of the human beings rather than from field studies (activity analysis) and that it starts from the interface devices characteristics (e.g., dialogue techniques) rather than from the users' characteristics. Our very ecumenical view is that both approaches are needed and complementary: knowing the systems (and their impact) and knowing the human should be requirements for better human-machine system symbiosis! Our point is really that both approaches are recommended as long as their contributions are explicit and their limits are recognized. Unfortunately, this is where the trouble is.

3.1 Orientation of HCI studies

Along these lines, there are many debates in the HCI community. Several issues seem to be good candidates for the discussion. Without mentioning again the debate on the real differences between the task versus activity approaches, and similarly the differences between the French-speaking approach vs. the Anglo-saxon approach, we wish to set the debate around the research needs in HCI. What is research in HCI ergonomics? It goes from "research is whatever I do with real users" to "research is only the limited models I build." Let us consider a few items we feel are important:

- the orientation of HCI studies: laboratory and field studies. What are the limits of both orientations?

- the theoretical approaches of HCI studies. What are the limits of cognition and cognitive models?

3.1.1 Laboratory studies and the usability of their output

Criticism about laboratory studies are well-known. One criticism is lack of realism (some say real situations are much more complex). "Theories and models developed in the calm of the laboratory often need to be stretched to find their limits" (Green & Hoc, 1991). However, doesn't science consist of dividing (problems) to conquer (solutions to simpler problems)? On the other hand, because the situations are too restricted, only intended to support hypotheses or to show what went wrong, studies are sometimes limited in the generalization of their results. Taking a global view on the field, one can add another serious criticism, not as often mentioned, which is that the design of experiments may have included very little consideration to its place within a co-ordinated advancement of the domain, with an organized view of the sub-field considered. There has been a considerable gain in knowledge from laboratory experiments in HCI, but the way it has been performed has been so disorderly that with the benefit of hindsight, some efforts appear to be fruitless. In addition, that very large amount of data available is not obvious to use due to a lack of underlying organization, and because of difficulties in comparing available results.

3.1.1.1 The case of menu systems

A good example of the lack of an organized approach in empirical research concerns studies on menus based dialogues. Not mentioning the difficulties to design a structure following a consensus on recommendations extracted for ISO Standards (e.g., ISO 9241 Part 14), building a workable model out of available data on menus has been a difficult task (Gibbons, 1991, 1992). The study started with the goal of defining some implementable structure of interface objects that would allow some kind of semi-automatic ergonomics reasoning (e.g., using expert systems). In order to access and to apply recommendations, it is indeed necessary to know precisely which part of the interface they concern. A set of objects and descriptors was first defined (Scapin, 1989). Two approaches have then been used to look at possible structures: one based on the examination of action theory. One of the issues is really the need to consider the usability of standards, including their legibility which may be impaired by editing rules from standard organizations (such as no indentation!). When assessing the benefits of such dimensions, one must address a number of issues: what is their level, e.g., can they be used by themselves; are they complete; are they independent, distinct; should they all be applied; what is the consistency of their assignment, etc. Concerning standard principles, there is not yet much data to answer these questions. On the question of independence /distinctiveness, the answer comes from the standard itself: " standard principles proposed are not completely independent and some degree of overlap should be assumed", which obviously prevents the evaluator from using them as a metric or just as a conformance method. Concerning overall applicability of the principles, even though a statement like "all principles should be considered " is not really that much of a constraint, one can wonder about its appropriateness. For instance, it may be dangerous to suggest the designer or the evaluator to attempt applying the principle "suitability for individualization" since it contradicts with multi-users situations and may lead to unmanageable interface changes. On consistency of assignment, discussions on other parts of the ISO standard dedicated to specific dialogue types (such as Part 14 previously mentioned) showed indeed that principles could not be assigned consistently nor uniquely to individual recommendations, which is an important limitation in the usefulness of the principles.

Overall, little knowledge on understanding / usage of the principles is available. Data on the usability of standards are available, however such studies concern detailed standards containing individual guidelines (such as Part 14) not the principles themselves. Interestingly, a study is under way to assess the value of the principles through an international survey. Such a questionnaire-based method will certainly assess the acceptability of such principles in the experts community, but it may not provide full insight on the real usage of the principles.

The *empirical approach* starts from individual data. In a study (Aschehoug et Scapin, 1991) about 800 recommendations extracted from the literature were organized into groups using a deciphering format (Scapin, 1990a, 1990b) that included normative dimensions called "criteria" (Scapin, 1990b, 1990c) which were supposed to best describe the rationale for using such recommendations (initially as a way of accessing a data base). A number of iterations, as well as group agreement decisions were necessary before the criteria were settled in their first version. The criteria consist of eight main (first level) criteria (Guidance, User workload, User explicit control, Adaptability, Error management, Consistency, Significance of codes, Compatibility). Three of these criteria *(Consistency, Significance of codes, Compatibility*) were not subdivided and are considered as elementary. The five other first level criteria were subdivided into two or more sub-criteria for a total of 13 second level criteria (*Prompting*, Grouping and distinguishing items, *Immediate feedback*, *Legibility*, Brevity, *Information density*, *Explicit actions*, *User control*, *Flexibility*, *Users' experience management*, *Error protection* , *Quality of error messages*, *Error correction*). Two of those criteria were again subdivided into a set of third level sub-criteria (*Grouping by location*, *Grouping by format*, *Concision*, *Minimal actions*). There is a total of 18 elementary[5] criteria. Each criterion is illustrated by a definition, a rationale and some examples.

In the literature criteria are often loosely defined; they are not used in a consistent manner and they may overlap. In general, no method is used for their specification. To avoid these flaws, our approach has been to define as explicitly as possible the criteria, but also to evaluate them, from the point of view of accuracy and understandability. In a study (Bastien & Scapin, 1992), the criteria were tested in a concept identification task. After a learning phase where the 24 subjects (one group of experts and one group of novices) were invited to read a document containing the criteria, their definitions, rationale and examples, the subjects were asked to match criteria and definitions with a set of usability problems collected from a real application interface. The results show no differences between groups of subjects in terms of correct assignment. The performance times did not vary significantly either. The overall assignment performance between the elementary criteria and the problems is above average, even though the experimental situation was quite restrictive (the subjects were only provided with the definitions and had no opportunity to look at the rationale or at the examples). A more detailed examination of the data allowed to identify categories of criteria and definitions that potentially need improvements. This research shows that the understanding of ergonomic criteria and the knowledge of the content to which they refer may not in fact be as obvious as it is generally assumed.

Even though this experiment seemed to support the feasibility of defining explicitly criteria, a second experiment (Bastien & Scapin, 1993) was designed to assess the effectiveness and usability of these criteria as an aid for the interface evaluation diagnosis. Two groups of experts (19 usability specialists) evaluated the interface of a musical database application ("HyperManip", Scapin, 1992). After an exploration-diagnosis phase, the participants evaluated the same interface states (through the replay of their previous interactions) with or without ergonomic criteria. Preliminary results show that in the first phase, the number of usability problems detected and the proportions of usability problems with respect to the size of the aggregates were similar for both groups. In the second phase, the use of criteria increased both the evaluation diagnosis and the proportions of problems with respect to the size of the aggregates: the difference is significant in the second phase

[5] *The elementary criteria are in italics*

($F(1, 37) = 39.618$; $p = .0001$). Participants uncovered 93.90 ($SD = 14.66$) and 113.00 ($SD = 11.69$) problems in the Control and Criteria group respectively. In phase 2, aggregating the individual evaluations from both groups resulted in a total of 326 different usability problems. The proportions of usability problems found as a function of the size of the aggregates are greater in the Criteria group. To uncover about 50% of the problems, it is necessary to aggregate 3 evaluations in the Criteria group and 5 in the Control group. The proportions of common problems tend to be greater in the Criteria group. These results indicate that the use of ergonomic criteria, compared to the sole expertise, helps evaluators uncover more usability problems; to diagnose the same proportions of problems, fewer aggregates are necessary when evaluations are conducted with the criteria. Even though experimental data must be further investigated (e.g., importance and ease of detection of the problems, characteristics of most common problems, detection range of the various criteria, etc.), the effectiveness of the criteria as suggested by the preliminary results has important implications in terms of cost-benefit analysis. The final version of the criteria is presented in Bastien & Scapin (1993). Such criteria have been used in part to support the organization of the most recent and largest set of interface recommendations (Bodart & Vanderdonckt, 1993); also the criteria have been the basis for the standard document AFNOR-Z67-133-1 (1992).

In summary, the criteria have been built from a large base of results which somewhat guarantees their completeness; their distinctiveness and the consistency in their assignment has also been demonstrated. However, in order to offer a real method and some metrics, further research work will be needed to define more explicit and operational ways of applying the criteria (e.g., by increasing their level of detail), to compare the criteria with other evaluation methods (such as in Jeffries et al., 1991; Karat et al., 1992; or Desurvire et al., 1992), to assess the criteria as a guide for writing evaluation reports, to investigate criteria usability by non-specialists, etc.

3.1.2 Field studies

There are also limits to the field approach, especially if conducted by itself only. A usual criticism of field studies is that not much can be applied to other situations because the situation is too specific, too rich, not well enough controlled. However, such approaches are the only way to be sure of the ecological validity of the issues tackled. As usual, the solution is probably in-between. Amalberti (1993) opposes two approaches that should be co-ordinated: those who want to develop generic concepts but who do not care for observation of real situations, and those who only start from the field, from which they infer properties. It is indeed a very strong need to have these two approaches co-ordinated.

The goal should be to aim for generic concepts extracted from real situations. There is a good description of ergonomics with a practitioner's view in Christol et Mazeau (1991). The main features of the practitioner's activity are its integration in a multidisciplinary project team and the many aspects that are looked at (e.g., the organization, the communications, the physical layout, the relationships). The ergonomist is viewed by the authors as the physician or the engineer, which corresponds very well to the belief (a true one this time) that ergonomics is an art! From looking at the state-of-the-art, one can easily admit that view; however, the danger is to also consider that this situation is going to be that way for ever, and that the relative lack of tools (if compared with the engineer's mathematical tools and models) is something that cannot be improved. Our view is that it would be an extremely useful contribution to increase and improve the tools and methods for the ergonomist. While we agree with the analogy of the practitioners with the physician, research in HCI ergonomics could be viewed partly as being similar to the research in the various domains related to medicine, such as pharmacy which studies some limited aspects of biology, chemistry, etc. with the goal of providing the physician with new molecules, new drugs, and new ways of using them; or as being similar to research in sophisticated computer imaging in order to bring new chest or brain investigation methods. Analogies though have always their limits. A difference between ergonomics and medicine is a matter of age, especially in terms of teaching: ergonomics is a domain that certainly needs to be taught but for which the knowledge is very dispersed. In ergonomics, sometimes, one can feel that we are still at the Diafoirus stages! (from the name of the very pretentious and ignorant physicians in Molière's play "Le malade imaginaire") .

In any case, even if the practitioner is the best person to develop a holistic approach that includes motivation, environment, software interactions, etc., it does not mean that the approach by itself is always appropriate. On the contrary, even limited but well controlled contributions from laboratory studies should be welcomed by practitioners, even so called "discount methods" (e.g., Nielsen, 1989) in order to be more explicit and more standard about their results, not mentioning saving time, and concentrating on real new ergonomic problems. A great danger the field is facing is to consider that there is no salvation outside from the field. As we said before, generalization from field studies to other situations is often quite difficult (mainly because there are so many factors). Doing an activity analysis does not represent a full warranty for the design specifications; if well conducted, it may only improve our knowledge of a specific situation. The main concern here is the fact that just being "in the field" does not insure any sound and appropriate methodology. As a matter of fact, one of the problems of presenting field studies to the "customers" (especially the designers) is that they don't see (or can't read) what the results are, either because of the format in which it is delivered, or because of the variations from one specialist to the other.

The opposition between research and practice is really a matter of cost vs. benefit and of taking chances. Field ergonomics (by practitioners), often because of time and cost constraints, because of limited usage of state-of-the-art references, limited usage of sophisticated (but sometimes hard to use) methods or simply because limited usage of experimental methods for problems that are not solved yet, consists of making the best with what is available, i.e., the practitioner's knowledge and know-how (which is very variable) and the situations (users, tasks, activities, etc.). It means that the options offered by the ergonomist are the best ones under these conditions, i.e., with decisions that may have a low percentage of certainty (no test is conducted): the choices are "best guesses". On the other hand, the more generic, more academic, more research oriented ergonomics may provide answers with a higher percentage of certainty and may guarantee some control over the validity of the hypotheses. However, besides wondering if the questions asked are appropriate in the first place, this goes with a considerable reduction of the situation.

Another view of the pre-eminence of field studies is that everything should come from the users' views, but it should be done with some caution. A very good advice comes from Cazamian (1992) who suggests to focus on the users' operativity. A lot of interesting work has indeed come from such a perspective; however, it has not been only through field studies, but also from experiments, in situations controlling the validity of the users' data, not only from users' opinions. Ergonomics should definitely be imaginative, both identifying and creating heuristics, but not restricting itself only to extracting users' imagination! This is another reason for a more engineering view, where the ergonomist is also a designer!

Let us go now to two criticisms of the field approach: its lack of formal, reusable, comparable descriptions and the variations of expertise.

3.1.2.1 The case of task formalization

Tasks and activities analyses are recommended by most practitioners, as well as in scientific papers, guidelines and handbooks; it is taught in universities. The notion of user task is of central importance. A lot has been said on how to perform such analyses, from the point of view of data gathering techniques, but not much is said about what to do with the data obtained to help the HCI design process. In addition, there is not much consistency in practice, the descriptions are not standardized and are delivered in various formats; one can observe (e.g., when assessing task analysis documents; or when re-engineering interfaces) that task analyses are not always complete to answer design questions, and sometimes specific to the analyst. One reason may be that such descriptions are usually in plain natural language which makes them difficult to read by the ergonomist who did not perform the analysis, but more importantly difficult to read and understand by HCI designers. In addition, task analyses are much more reports on situations than indications of needs and constraints, at least not explicitly.

Our hypothesis (Scapin et al., 1988) is that the obstacles encountered in including ergonomics in the early stages of design are largely due to the lack of consistency and formalization in the area of task description. An attempt at defining a description formalism that would integrate the task information necessary for the early design of interfaces has been carried out. The MAD formalism described in Scapin & Pierret (1990), Pierret et al. (1990) and for its implemented version in Delouis et al. (1991) aims to provide stable and complete descriptions of the activity from work analysis techniques that are centred on user representations. Most features from MAD are extracted from the examination of task related concerns expressed in recommendations from the literature. MAD offers an extension of the key concept of hierarchy (see also Sebillotte, 1988), of levels of abstraction, using logic-and-time graphs of objects, from the most general (root) to the most specific (task leaves, i.e., elementary tasks). In addition, an object-based structure has been chosen to offer both declarative and procedural statements; each object is an independent entity. The main component of MAD is the task-object. This object is characterized by the following elements: an initial state, a final state, a goal, pre-conditions, post-conditions. Two types of task-objects are defined: the elementary task class which corresponds to an action, and the composite task class which is described by a structure. A structure consists of constructors and their parameters. The constructors are: SEQ(uential), PAR(allel), ALT(lternate), LOOP, OP(tional), OR.

A set of studies has been carried out in complex situations (air-traffic control), with the goal to test MAD, together with semi-directed interviews as suggested in Sebillotte (1991), and to extract from the task descriptions data for helping the design/evaluation of a future air-traffic control workstation that will integrate in a single control position all the vizualization and dialogue functions which are currently distributed over a number of independent devices. Some methodological conclusions are drawn in Sebillotte & Scapin (1993). MAD certainly proved a convenient means of obtaining a large amount of information in a systematic and relatively complete way. The method is practical in that it is standardized and allows a comparison between a large number of tasks and "faster" descriptions; MAD can also be used as a tool for validating descriptions already obtained from tasks studied previously. By following the task tree structure and the definitions of the task-objects, the consistency and completeness of the description can be assured. However, this set of studies also brought to light several shortcomings in the model (e.g. managing interruptions, multi-user situations, etc.). A new version of the model is currently being defined in order to characterize its content in a more detailed manner. A great deal of research work remains to be carried out in order to obtain valid, usable results : gathering rules, identifying task configurations, matching the rules, building a data base of rules, designing application software, etc. Efforts are currently devoted towards a design method goal, by formalizing task oriented rules and by developing a methodological approach. In the first case, a study aims to identify some task related constraints and to express them in the form of production rules (premises describing a particular configuration of the users' tasks and conclusions that indicate specific interface requirements); data obtained from the air-traffic control activity is currently examined to draw out some examples concerning future interfaces of the controllers' new workstations. In the second case the study concerns a methodological approach which would allows to map a structured task model to a highly abstract user interface specification (Hammouche, 1993; Hammouche & Scapin, 1994). This approach involves three steps: first, an object-oriented structure models the tasks obtained from MAD; second, a structure of the user interface defines the concepts involved ("conceptual user interface"[6]); third, mechanisms and heuristics that explicit and justify an incremental path from a user task model to an appropriate model of the user interface. The output of this approach can be used two ways, which correspond to two major steps of the user interface specification process at an early stage: as a formal specification of user interface conceptual entities (static aspect); and as a way of setting up the relationships between these entities (dynamic aspect).

Another research avenue concerns language extensions to MAD (in the context of fire situations management on ships). In a project aiming at facilitating multimodal retrieval of data in multimedia data bases (text, graphics, videos, factual data, etc.) a study is focusing on the relationship between the concept of sub-language (Dachelet & Taleb, 1993) and the context of tasks as described in MAD.

3.1.2.2 The case of HCI expertise

Providing what was mentioned before, i.e., that ergonomics is not formally included in the design methods, how do people manage to include these aspects? Some studies have investigated the design process (e.g., Smith & Mosier, 1984; Hammond et al., 1983;

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[6] Definition: the conceptual interface consists of all software characteristics that have a direct relationship with the users' task goals. In other words, the conceptual interface concerns all high abstraction level aspects of an interface (conceptual and semantic), but also the lower abstraction levels as long as they have a direct relationship with the tasks (e.g., topologic relationships for coordinated tasks, graphical codes illustrating task links, etc.)
This definition is larger than than usual interface definitions in computer science (which include often only the most directly visible aspects; which distinguish strictly betwen interface and application), but the definition is less broad than some ergonomics definitions (which include aspects independent from the tasks)

Hammond et al., 1987). It is usually described as complex, dynamic, cyclic and evolutionary, rarely linear or sequential, and opportunistic. Designers attempt to take into account ergonomics aspects, but in most cases, do not have or ignore the resources available to solve these questions; they are dependent on their logical analysis phase and on both their intuitions about the users' needs and capabilities, and about the way the users structure their goals. The main problem is that designers differ considerably on these intuitions and the logical analysis of the task may not correspond to the users' conceptualizations. The other thing designers can do is to call for some HCI ergonomics specialists. What are the characteristics of these specialists? With the goal to study expertise in order to design evaluations methods or at least to design methods that would be compatible with their behavior, two studies should be mentioned.

A study (Pollier, 1992) concerned the observation of four subjects experienced in ergonomics involved in a real evaluation situation of an existing system (a multimedia communication system). The goal of the study was to investigate the types of expert diagnoses (characteristics and variability) produced as well as the patterns of their behavior, i.e., their strategies (how is the interface examination organized, which dimensions are considered, what are the priorities?). Results show that the degree of community of the problems diagnosed is quite small (6% of common problems; an average of 42% of the problems diagnosed by individual subjects; 3 experts are needed to get a diagnosis on 80% of the problems). Even if the experts evaluation are efficient, there is a very large diversity of focus depending on the subjects, on their areas of expertise, their knowledge of the applications. These results confirm other results in the literature (e.g., Jeffries et al., 1991; Nielsen, 1992). This phenomenon is of course not specific to ergonomists (it has also been observed for computer scientists, e.g., Nielsen & Molich, op. cit.). However, one could argue that such variable patterns result partly from the very fact that the domain is not characterized by a well developed and well accepted set of evaluation measurements (except maybe for user testing). Another contribution of this study has been to bring new light about expert diagnosis strategies. Five very intricate strategies have been identified: along usage goals, interface structure, levels of abstraction, interface objects classes, and criteria. Very important individual variations were observed concerning the priorities in the examination of the interface (in depth vs. in width approaches; top-down vs. bottom-up vs. mixed approaches). Basically, the experts' behavior is not systematic nor complete, and rather opportunistic in nature.

These results support the need to define some methods that would allow a more systematic approach to interface evaluation. One of the research directions considered is to see if methods based on some of the strategies can be of any use to the evaluator. The idea here is also that several "point of view" can be taken to look at an interface, and that these different points of view may correspond to different classes of interface usability diagnoses. Usually, an interface (except in the specification phases) is shown to the evaluator in its "live" version, from the initial display to the others, depending on user and system events. One can imagine other ways of describing an interface that could facilitate the diagnosis along the lines of the strategies observed: for instance presenting the interface through a set of usage goals, or through a model of the interface states, or through levels of abstraction, or through categories of interface objects classes, or through the use of evaluation dimensions such as the criteria previously described.

Another study has been recently conducted in order to precise our knowledge of the experts strategies (using a larger group of subjects), but also to evaluate the efficiency of one of the "points of view", the usage goals. To support such a point of view, a set of six scenarios was built, illustrating the main goals a user would select for running the application. The scenarios constituted a potential structure for discovering the interface. The hypothesis was that such a method would increase the consistency of diagnoses between the various experts and that it would increase the proportion of high level problems (i.e., task and goal related problems, some of which can be among the most important ones). Eighteen experienced subjects participated to the study. One of the major features of this experiment is that the application used ("HyperManip", Scapin, op. cit.) was controlled as much as possible: not too complex, the application was a musical database which required little specific domain knowledge (every one has at home some CDs, LPs and tapes, organized in some way); a set of ergonomic design flaws was purposely introduced in a somewhat systematic way according to interface states, types of objects, categories of problems, which resulted in 346 types of problems, with 503 instances. A group of nine subjects (control group) evaluated the interface without any constraints, except to think aloud. A group of nine subjects (scenarios group) worked in two phases: an evaluation from a guided tour of the interface through the scenarios of usage; an evaluation without any constraints. In the first phase the subjects were able to stop and resume their examination of the interface. All sessions were recorded on video tape as well as for the software transactions. The results are being analysed. However some preliminary results can be mentioned.

This study confirms the need for several evaluations to get to 80% of the problems diagnosed by the subjects (which is different from the total number of existing problems). Comparison of the two groups shows that 3 experts are needed in the Scenario Group to reach that level, while 4 experts are needed in the Control Group. The study also shows a higher performance of the Scenarios Group over the Control Group in terms of problems diagnosed as well as for the category of high abstraction level problems (conceptual and semantic, i.e., task related, Manova $P < .05$). For high level problems, the Scenario Group has a higher performance than the Control group (Anova P <.05) while this difference is not significant for lower level problems. Also, the study supports differences concerning the types of problems diagnosed, for instance according to the type of criteria favored: there are more diagnosis in the Scenario Group for some criteria (Clarity, Mental load, Concision, Compatibility), but for other criteria (Protection from errors, Error messages, Error correction), there are more diagnosis in the Control Group, while it is similar for the other criteria. Another result is that quite few diagnoses were provided by the subjects about cases of user errors and error recovery.

These preliminary results demonstrate the interest of a scenario based method to help optimize the interface evaluation diagnoses, and particularly to make such diagnoses more consistent. However, other types of mini-methods must be also investigated along the idea of points of view. Besides, there is a need to intermingle and harmonize these different potential methods in order to provide a well defined set of tools for the evaluation. Another very important question is whether or not such methods can also help non specialists in ergonomics.

3.2 Limits of cognition and cognitive models

Let us now move to the debate about HCI ergonomics, from the point of view of cognitive models.

Indeed, one can easily admit when looking at some cognitive models that complex concepts do not necessarily mean accurate and useful knowledge (for HCI design). An excellent excerpt from Stuart Mill (cited in Fuld, 1993) expresses just that: "The tendency as always been strong to believe that whatever received a name must be an entity or being .... And if no real entity answering to the name could be found, men did not ... suppose that none existed, but (instead) imagined that it was something ... abstruse and mysterious".

There are several criticisms that can be addressed to cognition and cognitive models, either per se, i.e., with a different theoretical or epistemological view, or with from the point of view of their usage in ergonomics.

In the first case, numerous criticisms can be found in a manifesto against cognitivism presented in Still & Costall (1991). For instance, the argument of Bolton (1991) is that "... cognitivism is an abstraction from experience that study mental processes as abstractions. It thus shows a false picture of psychological phenomena, because abstraction needs to be placed within the context of experience...". One can also retain the criticism of metaphors, especially the computer metaphor, which is well illustrated by a quote from Boyd (1979), cited by Costall (1991). "... (A) concern with exploring analogies, or similarities between men and computational devices has been the most important single factor influencing postbehaviorist cognitive psychology. Even among psychologists who dispair of actual machine simulation of human cognition, computer metaphors may have an indispensable role in the formulation and articulation of theoretical positions. These metaphors have provided much of the basic theoretical vocabulary of contemporary psychologists:..". This state of affairs may actually be challenged with the development in computer science of parallel distributed processing, which may even threaten the alliance between computers and cognitive psychology (Costall, 1991). From the very interesting distinction presented by Richelle (1985) between the types of cognitivism, one can mention the strong criticism of the "radical cognitivisms" which not only try to infer reasonably mental processes or organizations underlying the observed behaviour, but tend to assign these inferences a very privileged status: these internal phenomena, these "mental objects", are proposed as the very material of psychology; the behavior is reduced to simple indicators of mental objects. Even though the author mentions the suicidal character of such an evolution, we will not here concern ourselves with the real veracity, certainty or validity of models, nor with their future, but question their contribution to HCI ergonomics.

Concerning neo-behaviorism models, not much can be said so far about their impact on ergonomics since the literature is very poor in that area. Now, concerning cognitive models for HCI, one can discuss a few other criticisms:

One can argue about their originality: as already criticized by behaviorists, one can wonder if psychological models are coming from field studies or novel psychological concepts or from new architectures or concepts from computer science (e.g., the analogies with the types of memories, the type of processing, the knowledge bases, the types of networks; now, after the blackboard architecture, parallelism is becoming very popular as a paradigm for cognition!). More importantly, one can criticize the fact that ergonomics studies (and not only models) are following technology, and that few models allow any predictions. Ergonomics is becoming reactive rather than proactive (Sheridan, 1991); new paradigms are needed (one-person stimulus-response is not enough).

The computer metaphor is also criticized within the HCI ergonomics community. For instance, there are some dangers in considering the human being as an automaton or a machine. Hollnagel (1993) notes that it is even worse to assume that the human being is an information processing system (as exemplified in Newell, 1990), one strong argument being the lack of consideration of user adaptation.

Another issue is the focus of the studies: there are probably not enough studies about long term learning and usage of computers, while HCI ergonomics can be viewed two ways: adapting the software to the user and improving that adaptation through training of users.

There is the problem of trade-offs between adapting the interface to the user and adapting the user to the interface. Indeed, current models do not incorporate well the difficulty of making behavioral predictions on the way the user-interface interaction will occur while the design and evaluation is done from an existing situation, not the future usage situation. Particularly for process control, the need for evolutionary models, as well as their contextual nature, is also described in De Keyser (1991).

There are so many field studies that one would hope that some generalities could be extracted from that large body of knowledge. Unfortunately, it is quite frequent that studies have to be run again because of no design answer is provided yet. Often, because people are changing, technologies are changing, a new study is needed to answer precisely to the challenge. However, as expressed by Chapanis (1992), we should not be apologetic about doing more studies: designers themselves do not come up directly with a full-scale production of a finished product!

One can also argue about the scope of models: the risk is indeed to build more and more models of the human cognition that are so constrained in the experimental approach, and so reduced in the size of the problem tackled, that it will not only prove to be unuseful for the human condition, but also that it will not increase much our scientific knowledge. One can also question their explanatory character: "certain domains in cognitive psychology, such as problem solving are still very descriptive and not explanatory enough" (Hoc, 1989).

Taking the example of user models, one can question their generic character. While they may work at the specific level of a very limited work situation, they don't seem to work as general models of human behavior (Staggers & Norcio, 1993). The history of the concept of mental model can be traced to Craik's (1948) (cited by Staggers & Norcio, op. cit.). The notion of users' mental models is a widely accepted concept, however, authors use various terms to describe this notion; besides, "most cognitive psychologists are comfortable with the theory of mental models, but only indirect evidence is available for their existence."; "no one, of course, knows exactly how mental models are formed". Except for the fact that most authors generally agree that it is easier to give users a conceptual model than to have them infer one, how mental models are constructed is not known. There is some agreement about the nature of mental models, but "the resulting model is a private enterprise, an individualist phenomenon". This means that generic models may be quite questionable. During the 1980s, authors created a number of terms which refer to the notion of mental models; rather than being meaningless, these interrelated terms have intuitive appeal, which may be a partial reason for the extensive adoption of that notion. A number of needs can be identified, such as: clarification of the definitions, of the differences concerning the way mental models are stored as compared to any knowledge stored in the human brain;

study of information processing or "chunking", study of general concepts learning; identification of the relationship with current thinking in brain physiology and neural networks, etc. "Perhaps we are thinking too rigidly and simplistically about mental models" (Staggers & Norcio, op. cit.).

One can question the models as a starting point: often, the model is the basis for research (especially user models based on human-to-human models). As Hollnagel (1992) puts it "the risk with starting from the model is that it limits the perspective and the possibilities". "Most experiments and reports conclude by either confirming the model and the hypothesis that go with it or by pin-pointing the circumstances and conditions that prevented that. Too few lead to the rejection of the model, or even consider what role it may have played". His advice is the following: cognitive psychology ought to change the focus to events which are truly representative of human performance, as found in the practical problems that are typical of the environments we work and live in. In other words, we need to temporarily set aside our favourite theories and models and enmesh ourselves in the abundance of empirical results that have been collected for decades. One could also add that errors are not well taken into consideration: most research treated errors as if they were the results of a user problem, when, in fact, it may be an interaction effect of design and user.

On the issue of searching for theories, there are various opinions: for instance, a goal set by Barnard (1991) is "bridging between specifically cognitive theory and behavior in HCI" while Landauer (1991) says "for the most part, useful theory is impossible, because the behavior of human-computer systems is chaotic or worse, highly complex, dependant on many unpredictable variables or just too hard to understand... (theories) will yield little advantage over empirical methods". Others (Kuutti & Bannon, 1993) think it is not so utopian, but their review of the interface concept demonstrates how variable the concept is.

Three issues are interrelated:

- one is to get closer to software engineering as mentioned by Barnard (op. cit.) "there is a need to develop bridging representations that will enable us to interrelate models of user cognition with the formal models being developed to support design by software designers";

- the second issue is a prerequisite to the first one: it is only by providing generic and formal models of human behavior that there may be a chance that the co-operation with software engineering will be strengthen. This issue is a challenge for the field of psychology! Let us (psychologists) have some humility; cognition has become much of a buzzword. Mainly because users activities are cognitive (vs. mechanical), everyone adopted the term and sometimes the concepts of cognition. However, just using the term may not be sufficient to demonstrate that the work one is doing is appropriate, truthful, reliable, and most of all, useful;

- the third issue is a prerequisite to the second one: cognitive models are certainly good food for thought; they can lead to a number of clarifications when they are general enough and testable, but this should not let us forget that research in HCI ergonomics should always ask itself first: what are the design problems (even generic) for which an answer is needed? Being "quite interesting" is just not enough!

4 DISCUSSION

As we have seen, there are many different trends and approaches about HCI ergonomics. The domain can be viewed (Long & Dowell, 1989): as a craft, an applied science, engineering. One can agree with the authors who recommend mutual support of different conceptions of HCI, but there is probably a need for more convergence. There are also many "cognitive sciences", psychology, computer science, linguistics, philosophy. It is a current question to wonder if there is a common core for these domains to build a common field of cognitive science. One pessimistic view would be that the models are so different that a common core is difficult to achieve.

People in the field of HCI ergonomics should be very cautious about their contributions. In some cases (fortunately very few) practitioners, but also researchers have created bad reputations for themselves, but more importantly for the field of ergonomics.

- practitioners because of the lack of convincing presentation of demonstrable results (often due to lack or poor methodology),
- researchers because they have promised to bring ergonomic contributions (sometimes because it is easier to sell) while they merely produced just another unusable user model.

Both types of specialists (which are the same ones, in some cases), should be more open to other endeavours, for instance:

- practitioners should admit that, even though a holistic approach is of course commendable (everything counts), it should not prevent them from using explicit and formal methodologies; it should also be perfectly acceptable to reduce somewhat a situation in order to study a particular aspect for the advance knowledge or methodologies;

- researchers, particularly cognitive psychologists, should admit that even though everything is so complex, useful results and advice can be obtained, not only from extremely poor and limited situations.

Our stand is that if we ergonomists, as a profession, do not work at building a real engineering field, HCI ergonomics will get ignored or absorbed in its most reduced version in regular design practice, i.e., sometimes in a very superficial fashion. If there is not a coherent field, the risk is that designers (e.g., computer scientists) will easily think that just reading a few papers on ergonomics will makes them good human factors specialists (it is already very common to see products with unjustified ergonomics advertising!).

we will argue that the field is currently at risk if there is not more cumulative results, shared general models, reliable and explicit methodologies and if research in ergonomics does not bring some sound and applicable results either by better knowledge or by better methodologies. Some unity should also prevail in the teaching of the field: ergonomics should be considered as an independent discipline, taught as such in universities. There is also a need to provide measurements and to cost/justify HCI ergonomics in the design of systems (Karat, 1992). This will facilitates ergonomics to become part of design process.

The priority is to wonder what will be gained rather than the only intellectual satisfaction ("I am interested in!") or the follow-up ("my thesis advisor has worked on such topic, so I should follow!"), or the inertia ("I have done such work and got some results and a good academic position, so let's continue!").

We believe that ergonomics research should make sure that anything we do is either going to bring increased knowledge (e.g., about the human) or is going to prove its utility (i.e., provide systems that are more secure, more efficient, more satisfactory). Not enough attempts have been made yet at providing methods: it may be where the future (if any) of the field is! Chapanis (op. cit.) who defends a real engineering position for human factors even suggested to include a final section on design implications in every manuscript submitted to the Human Factors Journal. To this good idea corresponds, we believe, a good solution for the future of ergonomics in HCI: show what is gained in design by using ergonomics! Let researchers show how good they are at applying theoretical elaborations to the real world! Of course, there is a danger in that, which is to have only a very limited "product" view. In order to avoid that, a very important contribution of ergonomics should be to provide explicit methods, i.e., as stated in (Hollnagel, 1991): identify or predict the situations where problems arise; describe the conditions that may either be the cause of problems or have a significant effect on how the situations develop; prescribe the means by which such situations can either be avoided or their impact reduced; all that should be viewed with some humility: "For the time being the imprecise knowledge of psychology does not seem to support anything more elevated than the notion of approximate cognition."

5 CONCLUSION

We are convinced that there is a need for many types of ergonomics contributions, that should benefit each other, including:

- quick, limited and not so sure answer to design problems, which is needed because if not done, then no ergonomics at all will be done (and we know that in some cases, just doing a little bit of ergonomics can have a serious impact on overall quality);
- general answers to new technological problems (e.g., new input medium);
- more far-sighted ergonomics: (1) general characteristics of human psychology (which can be applied to several situations and problems, including new ones) and (2) general methodologies which can be applied in a wide range of situations, which allows to really compare results, to explicit them, etc.

In order to strengthen the ergonomics approach for HCI, co-ordinated efforts have to be made:

- to provide real answers to real design questions;
- to provide generic results about human behavior in real contexts;
- to provide methods and tools from existing knowledge.

Some work has been dedicated to some of these goals at INRIA, in general with an approach which is not laboratory only, nor field only, but a joint venture and iterations between the two, trying to make ergonomics knowledge available to designers. Four problem areas have been looked at:

- how to take into account the conceptual and semantic aspects of interfaces, which resulted in task formalization work and generation of the conceptual interface;
- how to take into account the lexical and syntactic aspects of interfaces, which resulted in some organization of the recommendations, especially around tested and validated criteria;

- how to take into account the dynamics of evaluation and design, which resulted in the idea of points of view, tested particularly for the users goals scenarios;
- how to structure and characterize the user interface and its elements, which resulted in interface objects models.

Of course, this paper provided a limited view of the field. Many other research topics are of interest; just glancing at recent conferences in the field shows the large spectrum of the work: it can concern very specific issues or very general ones, particular populations, new methodologies, it may have to do with psychology or with computer science: HCI research is really a multiform area! For instance, there is a growing interest in ethnography, CSCW[7] and teamwork; more studies comparing various types of keyboards; exciting and exotic studies on 3-Dimension manipulation, virtual reality and spaces, study of new entry modes, study of multimodal and multimedia systems, usage of gesture-recognition, voice output, facial displays, sign language, earcons, graphical maps, interfaces for the physically impaired, prototyping, UIMS, toolboxes, interface tools. There is also strong interest in users' data capture, interface usability measurements issues, design methodologies.

Providing these limits in scope, we hope the arguments we developed as well as the research we described explain by now the title we have chosen for this paper.

Knowing (see Boorstin, 1986) that it is a very difficult task to make any predictions about the evolution of a scientific domain, that epistemological twists in history may be due to chance; that often, these changes are contradictory with the majority's views; and that things take time, we have limited the usage of the term "psycho-engineering of HCI" to the title and abstract. But maybe the term and orientations will catch on?

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[7] Computer Supported Cooperative Work

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ISSN 0249 - 6399

RR_2215