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Prolegomenon To Cognitive Task Design

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Abstract

The design of artefacts, and in particular artefacts involving computing technology, is usually focused on how the artefact should be used. The aim of Cognitive Task Design (CTD) is to go beyond that by emphasising the need of considering not only how an artefact is used, but also how the use of the artefact changes the way we think about it and work with it. This is similar to the envisioned world problem, i.e., the paradox that the artefacts we design change the very assumptions on which they were designed. The ambition is not to make CTD a new discipline or methodology, but rather to offer a unified perspective on existing models, theories, and methods that can be instrumental in developing improved systems. In this context cognition is not defined as a psychological process unique to humans, but as a characteristic of system performance, namely the ability to maintain control. The focus of CTD is therefore the joint cognitive system, rather than the individual user. CTD has the same roots as Cognitive Task Analysis, but the focus is on macro-cognition rather than micro-cognition, i.e., the requisite variety of the joint system, rather than the knowledge, thought processes, and goal structures of the humans in the system.

What Is Cognitive Task Design?

In a Handbook of Cognitive Task Design (CTD) it is reasonable to begin by defining what CTD is. To do so it is useful first to make clear what it is not! CTD is not a new scientific discipline or academic field, neither is it a unique methodology.

CTD Is Not A New Scientific Or Academic Field

Since the mid 1970s, the terms *cognitive* and *cognition* have come to be used in so many different ways, that they have nearly lost their meaning. There has in particular been an abundance of more or less formal proposals for lines of activity or directions of study that as a common feature have included the terms *cognitive* and *cognition* in one way or another. These range from cognitive ergonomics, cognitive systems engineering, and cognitive work analysis to cognitive tools, cognitive task analysis, cognitive function analysis, cognitive technologies, cognitive agents, and cognitive reliability – to mention just a few.

Some of these have thrived and by their survival justified their coming into the world as well as established an apparent consensus about what *cognitive* means. Others have been less successful and have in some cases languished uneasily between survival and demise for years. The situation does not in any way seem to improve, since the terms *cognitive* and *cognition* are used with ever increasing frequency and, inevitably, diminishing precision – although at times with considerably success in obtaining funding.

Cognitive Task Design is not put forward in the hope that it will become a new scientific field. Indeed, was that to be the case it would signify failure rather than success. As this Handbook hopefully will make clear, CTD is something that we already do – or should be doing – although we may bee lacking a precise name for it.

CTD Is Not A Unique Methodology

The widespread use of the terms *cognitive* and *cognition* is, of course, not the result of a whim but does indicate that there is an actual problem. Indeed, many people are genuinely concerned about such issues as, for instance, cognitive tasks and cognitive reliability, since these are salient aspects of human behaviour in situations of work, as well as of human behaviour in general.

It is because of such concerns that a number of specific methodologies have emerged over the years. A case in point is the development of cognitive task analysis as an "extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance" (Chipman et al., 2000, p. 3). Even though cognitive task analysis is used as a common name for a body of methods that may vary considerably in their aim and scope – partly due to the imprecision of the term *cognitive* – they do represent a common thrust and as such a distinct methodology.

Whereas cognitive task analysis is aimed at analysing cognitive tasks, i.e., "knowledge, thought processes, and goal structures", Cognitive Task Design is not aimed at designing cognitive tasks as such, at least not in the precise sense implied by Chipman et al. Instead of being a unique design methodology, CTD is proposed as a unified perspective or point of view that can be combined with a number of different methods. This is explained in the next section.

CTD Is A Unified Perspective On Design

By saying that CTD is a perspective I mean that it designates a specific way of looking at or thinking about design. More particularly, it is a specific way of thinking about the design of systems where humans and technology collaborate to achieve a common goal. These systems are called *joint cognitive systems*, a concept that will be explained later in this prolegomenon. The way of thinking that is represented by CTD can be expressed by a number of principles:

- Every artefact that we design and build has consequences for how it is used. This goes for technological artefacts (gadgets, devices, machines, interfaces, complex processes) as well as social artefacts (rules, rituals, procedures, social structures and organisations).
- The consequences for use can be seen both in the direct and concrete (physical) interaction with the artefact (predominantly manual work) as well as in how the use or interaction with the artefact is planned and organised (predominantly cognitive work). Thus, introducing a new "tool" not only affects how work is done, but also how it is conceived of and organised. This will in most cases have consequences for other parts of work, and may lead to unforeseen changes with either manifest or latent effects.
- The primary target of design is often the direct interaction with or use of the artefact - as in Human-Computer Interaction and Human-Machine Interaction. Interface design, instruction manuals and procedures typically describe how an artefact should be used, but not how we should plan or organise the use of it. Yet the realisation of the artefact may affect the latter as much – or even more – than the former.
- As a definition, the aim of Cognitive Task Design is to focus on the consequences that artefacts have for how they are used, and how this use changes the way we think about them and work with them – on the individual as well as organisational level. The ambition is to ensure that Cognitive Task Design is an explicit part of the design activity, rather

than something that is done fortuitously and in an unsystematic manner.

Cognitive Task Design is not new, since many of the principles have been recognised and used before. Some may be found among the roots of Cognitive Task Analysis, as described below. Two more recent examples are the concept of "design for quality-in-use" (Ehn & Löwgren, 1997) and the notion of task tailoring (Cook & Woods, 1996). It is also a postulate that this perspective is unified. Perhaps it would be more correct to say that CTD should **become** a unified perspective on design. The argument of this prolegomenon, and of many of the chapters that follow, is that the design of artefacts and systems very often has neglected the aspect of cognitive tasks in the above sense, i.e., as the way we think about artefacts rather than as the way we use them. A considerable amount of work has been done on issues of usability and usefulness, and several schools of thought have established themselves. Yet both usability and usefulness focus more on the direct use of artefacts than on how that use by itself changes how we come to see them.

The Need Of Cognitive Task Design

The 20th Century has witnessed dramatic changes to the nature of human work, particularly since the 1950s. These changes led to the emergence of human factors engineering, ergonomics and later developments such as cognitive ergonomics and cognitive systems engineering. The extent of the changes is amply demonstrated by tomes such as the Handbook of Human-Computer Interaction (Helander et al., 1997) and the Handbook of Human Factors and Ergonomics (Salvendy, 1997). In relation to CTD, the following two changes were particularly important.

Firstly, work went from being predominantly manual work – or work with the body – to being predominantly cognitive work – or work with the mind. Many manual tasks have disappeared while new cognitive tasks have emerged. For those manual tasks that remain, technology has often changed them considerably.

This change to the nature of human work is the logical continuation of the development that gained speed with the industrial revolution, the essence of which is that machines or technology are used to amplify and/or replace human functions. Modern information technology has significantly increased the speed by which this development takes place and the types of work that are affected. Even for the kinds of work that are still largely manual, technology or machinery are usually involved in some way. (A checkout counter at a supermarket is a good example of that.) Today there are, indeed, very few types of work that depend on human physical power and abilities alone. Machines and technology have effectively become part of everything we do whether at work or at home. This means that cognitive tasks are everywhere, and work design is therefore effectively cognitive task design.

Secondly, cognitive tasks – even loosely defined – are no longer the prerogative of humans, but can also be carried out by a growing number of technological artefacts. Machines and information technology devices have, in fact, for many years been capable of taking over not just manual but also mental work. In other words, the ability to amplify human functions has migrated from the physical (motor) to the cognitive parts of work. It is not just that work has become more cognitive, but also that humans have lost their monopoly of doing cognitive work or cognitive tasks. When we conceive of and build machines, we must therefore also in many cases consider cognitive task design.

The changes to the nature of human work need corresponding changes to the methods by which work is described, analysed and designed. The cognitive aspects of work have traditionally been addressed by cognitive task analysis, as an extension of classical task analysis. But cognitive tasks are more than just an addition to manual tasks, and the changes affect work as a whole rather than what humans do as part of work. In order to be able to build efficient and safe socio-technical systems, we must be concerned about cognitive task design from the point of view of the individual who carries out the work as well as of the work system. Cognitive task design thus comprise the study of cognitive work – by humans, by machines, and by human-machine ensembles – and covers the whole life-cycle of work from pre-analysis, specification, design, risk assessment, implementation, training, daily operation, fault finding, maintenance, and upgrading. Cognitive task design is about the nature of work as it is now and as we want it to be in the future.

The Meaning Of Cognition

As argued out above, the terms *cognitive* and *cognition* have generally been used without much precision, and Wilson et al. make the same point in their chapter in this Handbook. It is therefore necessary to provide a more precise definition of what *cognition* means. This is not an easy task since etymology, semantics, and practice may be at odds with each other. While it is tempting to accept Jim Reason's definition of cognition as that which goes on “between the ears”, it behoves an editor to sound more scientific. This leads to the following line of reasoning.

- Cognition is a term used to describe the psychological processes involved in the acquisition, organisation and use of knowledge – emphasising the rational rather than the emotional characteristics. Etymologically it is derived from the Latin word *cognoscere*: to learn, which in turn is based on *gnoscere*: to know. Following the example of Mr. Pott in the Pickwick Papers (Dickens, 1837, cognitive tasks could then be defined as those tasks that require or include cognition.
- This easily leads to an axiomatic position, which starts from the fact that humans are cognitive beings (or that humans have cognition), hence that human performance has a cognitive component. However, following the same line of reasoning one could also argue that human actions are driven by motives and emotions, and that human performance therefore has a motivational and an emotional component – which indeed it has. While it is evidently true that humans have cognition, the axiomatic position makes it difficult to extend the notion of cognition to other entities, such as technological artefacts and organisations. It also begs the question of what cognition really is.
- An alternative is to use a more pragmatic definition, which is based on the characteristics of certain types of performance. Human performance is typically both orderly (systematic and organised) and goal directed. This can be used as a provisional definition of cognition, and be extended to require that cognitive tasks have the following characteristics:

•Cognitive tasks are driven by goals (purposes, intentions) rather than by events. They include cause-based (feedforward) control as well as error-based (feedback) control. Cognitive tasks are therefore not merely responses based on algorithmic combinations of predefined elements, but require thinking ahead or planning over and above complex reactions.

•Cognitive tasks are not limited to humans; cognitive tasks can be found in the functioning of organisations, of certain artefacts (a growing number, but still not many), and of animals.

- Polemically, the issue is whether the definition of cognitive tasks is based on an axiomatic definition of cognition, or a pragmatic characterisation of performance. In other words, cognitive tasks could be defined as tasks performed by a system that has cognition – which presumably only humans have(?). Alternatively, cognition could be defined as a quality of any system that has certain performance characteristics, and which therefore can be said to do cognitive tasks.

This would base the definition on the characteristics of the tasks and of system performance, rather than on the possible constituents and explanations of internal mechanisms.

- From this perspective, cognitive tasks are characteristic of humans, organisations, and some artefacts. (I shall leave out animals in this context.) Since cognitive tasks only exist in a field of practice, they cannot be studied separate from that. Cognitive task design is consequently concerned with how functions and structures – of a cognitive system proper and of its environment – can be designed to further the system's ability to perform in a purposeful manner and to let it keep control of what it is doing. Looked at in this way cognitive task design refers to (joint) cognitive systems as a whole, whether they are biological individuals, artificial intelligences, or organisations. Cognitive task design clearly also goes beyond cognitive tasks analysis, as the emphasis is on the potential (future) rather than the actual (past and present) performance.
- The importance of cognitive task design stems from the fact that any change to a system – such as the introduction of new technology, improved functionality, or organisational changes – inevitably changes the working conditions for the people in the system, hence their cognitive tasks. All design is therefore implicitly or explicitly cognitive task design. This is obviously the case for technological artefacts and information devices, since these directly affect user tasks. A little thought makes it clear that the same is true for any kind of design or intentional change to a system, since the use of the system, i.e., the way in which functions are accomplished and tasks carried out, will be affected. Cognitive task design comprises the study of how intentional changes to system functions and structures affect the conditions for work, hence on the cognitive tasks, and the development of concepts and methods that can be used to improve design practices.

The outcome of this line of reasoning is that cognition is not defined as a psychological process, unique to humans, but as a characteristic of system performance, namely the ability to maintain control. Any system that can maintain control is therefore potentially cognitive or has cognition. In this way the focus of cognitive task design is not just on the characteristics of putative human information processing or capabilities such as recognition, discrimination and decision-making that normally are seen as components of cognitive work. The focus is rather on descriptions of the performance of cognitive systems in the complex sociotechnical networks that provide the foundation of our societies, and how this performance must change to enable the systems to stay in control. CTD therefore struggles with the dilemma known as the envisioned word problem (Woods, 1998), i.e., how the results of a cognitive task analysis that characterises cognitive and cooperative activities in a field of practice can be applied to the design process, since the introduction of new technology will transform the nature of practice! Or put more directly, the paradox of CTD is that the artefacts we design change the very assumptions on which they were designed.

Cognitive Systems And Joint Cognitive Systems

The concept of a Joint Cognitive System (JCS) has already been mentioned several times. While classical ergonomics and human factors engineering have often emphasise the necessity of viewing humans and machines as parts of a larger system, the analysis nevertheless remains focused on the level of elements of the larger system, specifically humans and machines. A consequence of this seemingly innocuous and "natural" decomposition is that the interaction between human and machine becomes the most important thing to study. Cognitive Systems Engineering (CSE; Hollnagel & Woods, 1983) instead argues that the focus should be shifted from the internal functions of either humans or machines to the external functions of the Joint Cognitive System (JCS). This change is consistent with the idea that humans and machines are "equal" partners, and that they therefore should be described on equal terms. Humans should not be described as if they were machines, neither should machines be described as if they were humans. While the former has been the case so often that it practically has become the norm, the latter is only occasionally suggested or practised. (Some elementary examples would be anthropomorphism and animism. Thus most people tend to ascribe psychological qualities to machines. More deliberate trends can be found in the fields of robotics and affective computing.)

An important consequence of focusing the description on the JCS is that the boundaries must be made explicit, both the boundaries between the system and its context or environment, and the boundaries between the elements or parts of the system. A system can be generally defined as "a set of objects together with relationships between the objects and between their attributes" (Hall & Fagen, 1969, p. 81) – or even as anything that consists of parts connected together. In this definition, the nature of the whole is arbitrary, and the boundary of the system is therefore also arbitrary. This is illustrated by the following delightful quote:

> "It is legitimate to call a pair of scissors a system. But the expanded system of a woman cutting with a pair of scissors is also itself a

genuine system. In turn, however, the woman-with-scissors system is part of a larger manufacturing system – and so on. The universe seems to be made up of sets of systems, each contained within a somewhat bigger, like a set of hollow building blocks."

(Beer, 1959, p. 9)

As this examples shows, it is insufficient to describe only one level of the system – for instance, that of the woman using the pair of scissors. The woman-*cum*-scissors is in turn a part of the local manufacturing system, which may be a part of a larger production system and so on. If for some reason the people cutting the cloth are given a better pair of scissors, or even a laser cutting tool, this will clearly have effects beyond the cutting itself. The design or improvement of the cutting artefacts must acknowledge this and include it into the design as far as necessary. Failing to do so will render the design basis invalid to some degree, hence possibly jeopardise the outcome.

For joint cognitive systems, the boundary clearly depends on the purpose of the analysis and thereby also on the purpose of the JCS. Consider, for instance, a pilot flying an aeroplane (Figure 1). The traditional ergonomic approach would focus on the pilot in the cockpit, and the way in which the interface is designed. This addresses issues such as information presentation, information access, automation, communication, and the manual and cognitive tasks required by flying as such. The ergonomic approach is based on decomposing the system into is basic elements, the pilot and the cockpit, taking certain physical boundaries for granted.

In a CSE-based approach, the pilot-plane ensemble clearly constitutes a JCS, which exists within the larger air traffic environment. It makes sense to consider the pilot-plane ensemble as a JCS and to analyse, e.g., how well it is able to attain its goals, such as arriving at the destination at the scheduled time. Alternatively, the pilots in the cockpit can also be considered as a JCS that is studied separately, such as in Cockpit or Crew Resource Management (Helmreich et al., 1997. The environment of the pilot-plane or crew-plane ensemble is, however, not just the atmosphere and the weather, but also the air traffic management system, specifically the air traffic controllers. It may therefore in many cases make sense to consider the pilot-plane-ATM ensemble as a JCS, and modify the boundaries to correspond to that. In this case the context may be the airline companies. The whole of aviation transportation may also be considered a JCS, and in this case the context could be the national aviation authority and the regulators, and so on. (Figure 1 intends to illustrate how JCSs can be described on different levels, but the rendering of linear separable layers is, of course, an unrealistic simplification.)

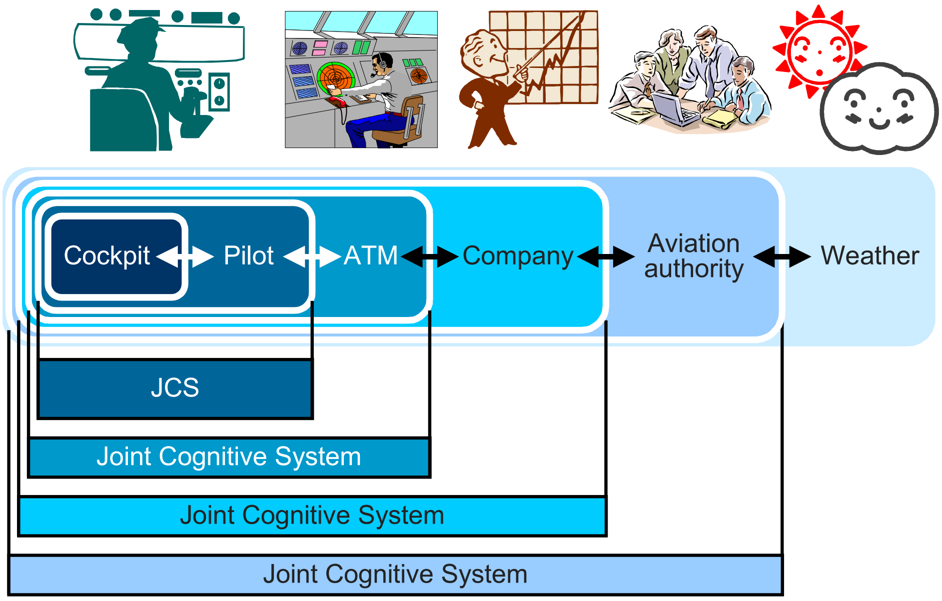

Figure 1: Levels of Joint Cognitive Systems

From the general systems point of view the environment is that which provides inputs to the system and which (hopefully) reacts to outputs from the system. A more formal definition is as follows:

> "For a given system, the environment is the set of all objects a change in whose attributes affect the system and also those objects whose attributes are changed by the behavior of the system."
> (Hall & Fagen, 1969, p. 83)

Translated into Cognitive Task Design terms this means that CTD should consider all objects or factors that may affect the use of the artefact as well as all objects and factors that are changed by the functions and use of the artefact. These principles are summarised in Table 1.

Table 1: A pragmatic definition of the JCS boundary.

	Objects or factors that may affect the use of the artefact.	Objects or factors that do not affect the use of the artefact.
Objects or factors that are changed by the use of the artefact.	Must be considered by CTD	Should be considered by CTD
Objects or factors that are not changed by the use of the artefact.	Should be considered by CTD	Need not be considered by CTD

Cognitive Task Analysis and Cognitive Task Design

Even though Cognitive Task Analysis (CTA) and CTD are fundamentally different in their objectives, they do have several things in common. Most importantly, CTA is an important stepping-stone for and complement to CTD.

The label Cognitive Task Analysis was coined in 1981-82 to describe the endeavour to understand the cognitive activities required of a man-machine system. It was used in print in a technical report (Risø-M-2330) in February 1982, which later appeared in journal form as Hollnagel and Woods (1983), and it was a major explicit part of the discussions at the workshop in August 1982 on cognitive modelling of nuclear power plant control room operators (Abbott, 1982).

Looking back at the developments then, five threads or approaches to CTA can be seen as emerging roughly in parallel in the early 1980s. (The following list is borrowed with kind permission from Woods et al., 2002.)

1) *Functionalism.* The need to aid human cognition and performance in complex high-consequence settings gave rise to what might be labelled a functionalist cognitive engineering thread. The goal of CTA here was to discover how the behaviour of practitioners adapted to the constraints imposed by the domain, organizational goals and pressures, and characteristics of the artefacts available (Rasmussen and Lind, 1981; Hollnagel and Woods, 1983; Rasmussen, 1986).
2) *The basis for expertise.* The need to expand expertise via new forms of training led to studies of the basis for expertise and the knowledge organization of people at different stages of acquiring expertise – what might be labelled a cognitive learning thread (e.g., Chi et al., 1981; McKeithen et al. 1981), later transforming into knowledge engineering.
3) *Cognitive architectures.* The need to understand work through a computer and to support the design of human-computer interfaces led to work that mapped mechanisms of the individual's micro-cognition onto specific tasks that centred on interaction with computers and computerized devices – what also might be called a cognitive simulation thread (e.g., Card et al., 1983; Kieras, 1988).
4) *Ethnography of workplaces.* The need to understand work cultures as a result of the consequences of technology change led to field observation of practitioners at work in their world and ethnographies of work – what might be called an ethnography of work thread (e.g., Suchman 1987; Hutchins, 1980; 1990; 1995; Jordan and Henderson, 1995).

5) *Naturalistic decision-making.* Attempts to apply decision making to complex settings led to observations of people at work and critical incident studies. Observing people at work challenged assumptions about human decision-making leading to new models (Klein et al., 1993).

Each of these threads included an approach to bring concepts and methods about cognition to work. In one way or another they all tried to account for operational systems (people, technology, policies and procedures) in terms of cognitive concepts. All of them also used CTA, or similar labels, as a pointer to develop a research base of cognition at work – even though that term had not itself become in vogue. Finally, they all wrestled with how to apply results from CTA to design.

Of the five threads mentioned above, only some are important for CTD. Since the purpose of CTD is to account for how the use of artefacts affects the ways in which they are understood, neither the acquisition of experience nor the match to human information processing are essential. What remains important are the functional approach and the strong anchoring in practice, i.e., the link to macro cognition, rather than micro cognition. The concern has also changed from that of yielding information about knowledge and thought processes, to providing a comprehensive foundation for the design of artefacts and how they are used. In a historical context, CTD brings to the fore the struggle to apply CTA to design that was present already in the early 1980s. One ambition of this Handbook is indeed to demonstrate how CTA can be used for CTD, and to argue that the design of any system, or of any detail of a system be it hardware, software, or "liveware", inevitably also affects the tasks of the people involved (the chapter by Kevin Corker being a good example of that).

Design And Cognitive Task Design

Design is the deliberate and thoughtful creation of something to fulfil a specific function. Design is therefore usually focused on the actual purpose and use of the artefact, and every effort is made to ensure that the design objectives are achieved. A number of competing design schools exist, ranging from usability engineering and problem-oriented practice to user-centred, participatory and situated design (e.g., Carroll, 2000; Dowell & Long, 1989; Greenbaum & Kyng, 1991; Nielsen, 1993; Norman & Draper, 1986; Winograd & Flores, 1986). Common to them all is a focus on the artefact in use.

The design of technological and social artefacts – ranging from simple tools used in the home, over complex machines used at work, to rules and regulations governing communication and co-operation – must consider both how the artefact is to be used, and how this use affects the established practice of work. As a simple example of the latter, just think of how the introduction of a new and faster photocopier may change the work routines of the people who use it.

It is important for CTD to acknowledge that the use of an artefact may affect the systems in ways that were not among the primary concerns of the designer. Any change to a system will affect the established practice of work. Some of the consequences are desired, and indeed constitute the rationale for the design. Other consequences may be unwanted and represent unanticipated and adverse – or even harmful – side effects. If the artefact is well designed, the changes will be minimal and the unanticipated side effects may be negligible. But if the design is incomplete or inadequate in one or more ways, the unanticipated side effects may be considerable.

In most cases people adapt to the artefact after a while, and develop new working practices. This involves learning how to use the artefact, possibly via some system tailoring (Cook & Woods, 1996), agreeing on norms and criteria for its usefulness, developing new practices, task tailoring, etc. As pointed out by the envisioned world dilemma, these responses transform the nature of practice, which may render invalid the criteria for quality-in-use that were the basis for the design. This is illustrated by Figure 2, which shows a progression of steady or stable states of use, in contrast to a simple change from an “old” to a “new” system configuration. These issues become even more pronounced when the design concerns the organisation itself such as role assignments, rules for communication and control, administrative and work procedures, etc.

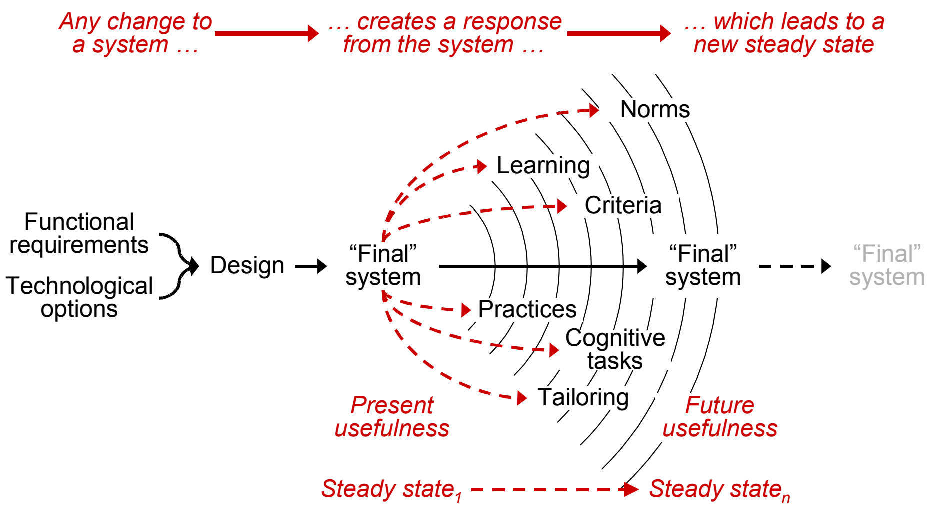

Figure 2: The context of cognitive task design.

It is necessary that the design methodology is able to anticipate and account for these changes. In the words of David Woods, "design is telling stories about the future" – where the future may change as a result of the users' coping with complexity. To achieve that is obviously easier said than done, since predicting the future notably is a difficult business. CTD does not provide the final methodology to do that, but it does propose a new perspective on system design as a necessary first step.

Examples

So far this prolegomenon has tried to describe what CTD is in an analytical manner. To complement that, a few examples may be of use.

An Analogy: The Road Effect Zone (REZ)

One way of understanding the meaning of cognitive task design is to consider the analogy of the Road Effect Zone (REZ). A road is usually built to meet specific objectives, i.e., to allow a certain volume of traffic to move efficiently from point A to point B. But whenever a road is built, there are also consequences for the existing wildlife, i.e., the ecology. A road thus has an influence that goes beyond its pavement (Aschwanden, 2001).

This is described by the term Road Effect Zone. The REZ is defined as the total area over which a road exerts its ecological influence. The REZ is irregularly shaped, and is determined by factors such as topography, landscape, land use, and waterways. Roads have normally been built without considering the REZ, and the result has often been devastating for the ecology and fauna. But by carefully planning the road, and considering the REZ, ecological costs can be reduced.

When we design an artefact – as e.g. hardware, software, or rules for work and collaboration – it is not sufficient to ensure that the objectives for designing the artefact are achieved. Since the artefact will have consequences for the structure of work itself – in a sense the "social ecology" – it is necessary to consider this as part of the design. In other words, we need something akin to a Work Effect Zone, defined as the total range of work over which the artefact has an influence. To find effective ways of doing this is a primary objective for cognitive task design.

Digital pictures as cognitive artefacts

One of the more recent examples of how information technology affects daily life is the use of digital photography, which broke into the mass consumer market in 1997. From a technological point of view this can be seen as no more than replacing photographic film with a charge-coupled device (CCD). The primary advantage is that there is no need to develop the film and make copies, which saves both time and money. The main disadvantage was – and is – that the resolution of the picture is considerably less than for a conventional camera.

Digital photography is, however, not just the replacement of one technology with another, but a complete revolution in the way we use pictures. For professional news photographers (if one dare still use that word), the change to digital pictures was accompanied by a wide-ranging change in how pictures are used affecting not only how the picture is taken, but also how it is distributed, stored, edited, etc. For other professions, such as dentists, doctors, and real estate agents, there are equally large changes, although they are taking place more slowly. For private consumers, digital photography brings about a new way of thinking about pictures; since there is no need to worry about cost, one can afford to take many pictures and throw away the bad ones either on the spot or at a later time. This essentially amounts to a completely new practice of picture taking, as well as of storing.

Yet another effect is that pictures from digital cameras can be used as a complement to symbols in communication for people with cognitive disabilities (e.g. Jönsson & Svensk, 1995; Svensk, 2001. Pictures can, for instance, replace verbal descriptions both in remembering the past and in communicating with others and thereby help people with aphasia or other disabilities.

As these few examples show, the introduction of a new artefact – the digital camera – has wide-ranging consequences for how we think about the function that it provides (taking pictures), and may lead to innovative applications. The extensive use of digital photography also causes major changes in organisations of many types and on many levels, from camera and film producers to news agencies. While some of these changes may have been anticipated, it is a fair bet that most of them have not and that even now we do not appreciate the full impact of digital photography on our daily lives. This example illustrates that the design of the artefact is woefully incomplete if it is focused just on taking the pictures. Digital cameras affect the ways in which we use pictures, and thereby change some of the basis for designing the cameras in the first place.

Email as bookkeeping

A different and more straightforward example is the use of electronic mail. From a bumpy beginning in the mid 1980s, email has now become the practical standard for communication – business as well as private. The design of email systems has also converged towards a common style of interface, which usually includes some kind of list or overview of the emails that remain in the inbox.

While the primary purpose of such a list is to show the emails that have arrived recently or since the service was last used, the emails that have been received usually remain on the list until the user actively deletes them. In this way the list can be used to keep track of emails that have been received but not yet acted upon. Many people, myself included, use the inbox list as a bookkeeping device and as a way of managing correspondence and activities. In this way the artefact – the email system – changes the way in which I work over and above what was intended. It does not just make it faster and easier to receive and send messages, but is also serves as a reasonably effective to-do list.

Other, and perhaps more serious, consequences of the use email are to the way information is archived and events are documented. A number of court cases in around the world have shown that this is not an easy problem to solve. This goes way beyond the aim of the example here – email as bookkeeping – but it illustrates in a dramatic sense that the change from one way of doing things to another, in this case the change from physical to electronic media, has far-reaching consequences. To design a good email system therefore requires more than understanding the knowledge and thought processes of individual users; it requires sufficient imagination to anticipate how the artefact will be used, how it will be brought into established practices, and how the whole fabric of activity will be changed as a result of that.

About the Handbook

While it is common to end an introduction by providing a summary of the contents of the rest of the work, I have chosen not to do that. One reason is that each chapter has its own abstract, which the reader can use quickly to get an impression of what the chapter is about. Another reason is that the chapters are so diverse that they are difficult to put into well-defined groups.

As a consequence of that, the Handbook is simply organised in three major parts called Theory, Methods, and Field Studies, respectively. The various chapters have been put into one of these parts based on whether their main thrust is on theory, methods, or applications. Although several chapters with some justification could put in a different category, the need to achieve some kind of order has dictated the final choice. In this, as in many other cases, the linear ordering imposed by a printed document cannot do justice to the multifariousness of the contents. In any case, there is no single ordering that can satisfy the needs of all readers. So rather than trying to solve an impossible problem, this prolegomenon has been provided to offer a basic outline of what CTD is. Although the reasoning presented here has developed with the Handbook, the outline has in an earlier version been the basis for selecting and reviewing the individual contributions; it is my hope that it will also enable readers to find those chapters that are particularly relevant to their own problems and to make use of the knowledge and experience that these pages offer.

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Epilogue – Mr. Pott's Approach

Mr. Pott looked dubiously at Bob Sawyer for some seconds, and, turning to Mr. Pickwick, said:

"You have seen the literary articles which have appeared at intervals in the Eatanswill Gazette in the course of the last three months, and which have excited such general - I may say such universal - attention and admiration?"

"Why," replied Mr. Pickwick, slightly embarrassed by the question, "the fact is, I have been so much engaged in other ways, that I really have not had an opportunity of perusing them."

"You should do so, sir," said Pott, with a severe countenance. "I will," said Mr. Pickwick.

"They appeared in the form of a copious review of a work on Chinese metaphysics, sir," said Pott.

"Oh," observed Mr. Pickwick; "from your pen, I hope?"

"From the pen of my critic, sir," rejoined Pott with dignity. "An abstruse subject I should conceive," said Mr. Pickwick.

"Very, sir," responded Pott, looking intensely sage. "He 'crammed' for it, to use a technical but expressive term; he read up for the subject, at my desire in the 'Encyclopaedia Britannica'."

"Indeed!" said Mr. Pickwick; "I was not aware that that valuable work contained any information respecting Chinese metaphysics."

"He read, sir," rejoined Pott, laying his hand on Mr. Pickwick's knee, and looking round with a smile of intellectual superiority, "he read for metaphysics under the letter M, and for China under the letter C, and combined his information, sir?"