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Putting the Horse Before the Cart: Formulating and exploring methods for studying Cognitive Technology.

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The University of Hong Kong

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Odense University

1. Introduction

The First International Conference on Cognitive Technology (CT'95, Hong Kong, 1995) explored a radically new way of thinking about the impact computer technology has on humans, especially on the human mind. Our main aim at that time was a consideration of these effects with respect to rendering the interface between people and computers more humane. And we exemplified our approach by pointing to existing trends and tendencies in the vast new loosely organized field of research often referred to as ‘HCI’ (‘Human Computer Interaction; the replacement for the politically and factually “incorrect” MMI, ‘Man Machine Interface’).

2. Current trends in HCI

Recent approaches to design in Human Computer Interaction, in particular those of Cognitive Engineering ([55], [58], [73]) Cognitive Ergonomics ([7], [64]), and Engineering Psychology ([71], [67]), stress the need for tool designs which are characterized by interfaces which facilitate better user comprehension of the full effects of their actions on application systems. The goal is to optimize the coupling of system performed and user performed tasks during complex problem solving. In attempting to adapt technological equipment and environments to people, the emphasis has been on using the psychological profiles of users to determine design flaws in order to understand why particular problems in user-tool interactions occur. It has been assumed that success in achieving this understanding will lead to more effective HCI design processes which are able to target those tasks that map primarily to human cognitive and physical capabilities. The intention has been to increase overall system performance by eliminating the dissonance between natural human capability and the demands of technology mediated activity. Consequently, the approaches assume that human cognition is established as the basis from which technological progress launched.

Cognition oriented approaches to HCI research a development have led to a large number of information technology applications which feel good and comfortable to use. However, such approaches generally fail to adequately integrate directly into the design process a consideration of the negative and undesirable short and long term effects these technologies may have on humans. It is not unreasonable to postulate that the greater the functional rewards offered by using modern, computer mediated tools, the greater the cost in impact we humans are likely to pay. These costs have been noted by several researchers (e.g., [2], [9], [10], [15], [16], [18], [25], [27], [28], [34], [40], [41], [53], [59], [61], [65], [66], [68], [69], [72]). Table 1 presents a summary of possible cost/reward tradeoffs.
<table>
<thead>
<tr>
<th>aspect</th>
<th>rewards</th>
<th>costs</th>
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<tbody>
<tr>
<td>place</td>
<td>global access to interacting agents</td>
<td>global displacement of interacting agents</td>
</tr>
<tr>
<td>identity</td>
<td>ease of unconstrained and unchecked intimacy with numerous locutors</td>
<td>multiple personality disorders</td>
</tr>
<tr>
<td>community</td>
<td>new international, intercontinental social groups</td>
<td>local individual isolation and alienation</td>
</tr>
<tr>
<td>knowledge</td>
<td>instant retrieval and storage of vast, encyclopedic knowledge</td>
<td>epistemic disruption</td>
</tr>
<tr>
<td>processing speeds</td>
<td>thought expression: slower interaction frame</td>
<td>diminished coherence and/or depth of interaction</td>
</tr>
<tr>
<td></td>
<td>during discourse: e-mail &amp; thought processing: faster interaction frame</td>
<td>in natural environments.</td>
</tr>
<tr>
<td></td>
<td>during action: games</td>
<td>confusion of a game/reality distinction (killing,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>zapping, blasting, etc.)</td>
</tr>
<tr>
<td>interaction</td>
<td>increased visual and acoustic stimulation</td>
<td>diminished tactile contact with other human beings</td>
</tr>
<tr>
<td>adaptation</td>
<td>unconscious induction of the relatively simplistic but strongly</td>
<td>inability to relate to the highly complex but weakly</td>
</tr>
<tr>
<td></td>
<td>deterministic dynamism of computerized environments</td>
<td>deterministic dynamism of natural environments</td>
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</table>

Table 1. The cost/reward tradeoffs inherent within current advances to information technology.

3. Humane approach to tool design

By contrast to the above mentioned trends in HCI, a truly humane approach to tool design must take as its driving force real human need. It must take into consideration the processes (both physical and cognitive) by which humans adapt to environments. Thus, the focus of design needs to be reversed. Technology must be developed to enhance human capabilities rather than human capabilities used to condition and inform technological development. The differences between these points of departure are summarized in table 2.

3.1 Current Advances in CT

Cognitive Technology, despite its being a ‘young’ discipline, has already made a few important claims in the domain usually described as ‘HCI’. By putting the computer in its place, a human, humanized, and necessarily humanizable tool, it simultaneously has put the human user in charge, and the interactional horse before the technological cart. In this section, we provide examples of this approach in theory-informed applications within a variety of areas in which CT has had an impact. These include the augmentation of human cognitive potential, the alleviation of human impairments and handicaps, and interactive learning.

<table>
<thead>
<tr>
<th>Cognitive Technology</th>
<th>Cognitive approaches within HCI</th>
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<tr>
<td>serving the interests of people</td>
<td>serving the interests of computing technology or academic pursuits of cognitive science or business oriented organizations</td>
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<tr>
<td>improving human cognitive capacity by means of transcending human cognitive closures (= cognitive prosthetic)</td>
<td>improving overall system performance by optimizing effectiveness and efficiency of human agents due to minimized stress and fatigue and maximized comfort, safety, and job satisfaction</td>
</tr>
<tr>
<td>investigating ways of how people adapt to the demands of technology</td>
<td>investigating ways of how technology can adapt to the demands of people</td>
</tr>
<tr>
<td>investigating holistic integration between human mental processes and technological progress</td>
<td>investigating dichotomous interactions between human mental processes and technological outputs</td>
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Table 2. Different points of departure for CT and HCI
3.1.1 Cognitive augmentation

In his critique of Kantian ([36]) and Whorfian ([70]) models of human intelligence, Roger Lindsay has suggested that the main advantage of computer technology, given its capacity to respond to a real human need to amplify cognition, is its capacity to make the impossible possible. Due to advances in technology we are now in a position to transcend human cognitive limits by constructing tools for implementing plans whose execution takes us beyond the normal reach of our cognitive resources. This type of technology has been termed cognitive prosthetics. Cognitive prosthetics can take various forms, some of which are briefly described below.

Overcoming Impairment

Developments of concrete CT technologies which deal with impairments have aimed at increasing the quality of life for those individuals which suffer from a lack of sight, hearing, or full linguistic ability. Notable examples are Sylloid - a device which can be used for teaching syllogistic thinking to the blind ([14]), a TDD - Chinese Character Based Telecommunication Device for the Deaf ([8]) providing an appropriate interactive telecommunication service which allows the hearing impaired access to information networks, and a vibrotactile stimulation device ([48]) for teaching linguistically impaired adults to better express themselves. This latter device can easily be adopted to the learning of foreign languages.

Interactive Learning

A domain which invites little dispute with regard to the use of technologies producing desirable mind change is education. At the Institute for the Learning Sciences at Northwestern University, USA, in collaboration with the University of Chicago, research into and development of computer teaching aids, so-called ‘goal-based scenarios’ (GBS) ([62]) or ‘learning support systems for interactions with simulated characters’ (Casper) ([37]), have focused on restoring students’ desire for effective learning by creating environments interesting enough to prompt good questions ([61]). At both Yale and John Hopkins Universities, USA, planning aids have been implemented that collaborate with humans in mixed-initiative planning and expert decision making, respectively ([5], [32]). These systems fall into the CT paradigm because they simulate real life experiences in ways which channel users’ attention to purposely made salient environmental cues that positively affect the cognitive processes of generating effective action schemas. Creativity enhancement in humans as a result of interacting with computer software has also been reported by Calvert et. al. ([6]; cf. [3]).

3.1.2 Cognitive regression

Technology as a cognitive microscope

A different, but methodologically related, facet of structured learning environment has been proposed by Kunii ([39]), who has exploited machine vision in teaching the martial art Shorinji Kempo. The underlying assumption has been that the users can easily recognize what the computer has brought to a level best suited for human perception. In this system, modern technology is used to translate video recordings of winning box positions of expert masters (which prevent the aggressor smooth and continuous body movement) during real life performances into graphical body configurations of screens for learners to align themselves with. The significance of this type of technological intervention in the learning process in relation to the aims and objectives of CT is that it is entirely free from forming a long lit dependency relationship between the human user and the available tools, as opposed to, e.g., word processors which are now a sine qua non in generating texts. It still remains unresolved, however, how shortening the time master winning techniques will affect the nature of the martial arts with respect to the renowned potential of character formation in those who master them.

Technology as a tool for the scientific study of the mind

Studying human computer interaction may help explain how human cognition works. Hermann et. al. ([33]) have been studying how reminding devices affect people who use them to keep their appointments. Pattern observed in their experimental data may shed light on how the memory of intention in humans is organized.

While the augmentation of cognition by means of technology can find concrete expression in the current products of design, a technology induced regression cognition can only be demonstrated by means of methods carefully designed to uncover the true nature of the integrative processes which occur at the interface of the physical with the mental.

In this connection, progress to date has or been noticeable in research which has brought attention to a large number of perceivable inter- and intra-person behavioral “symptoms” (listed in table 1) that people have been noticed to exhibit as a result of frequent exposure to tool use. Turkle ([68, 69]) and Slouka ([6] have provided ample evidence showing that play in computer games and surfing on the Internet can lead to serious personality disorders, which in turn affect social infrastructures. Janney ([34]) has pointed out that an unwarranted degree of intimacy, far exceeding the norm, often rapidly develops between total strangers due to the ease with which we can now establish contact and communicate without restrictions, over the e-mail.
David Good ([15,16]) conjectures that one reason for this phenomenon is an ever diminishing authority and control of the speaker/hearer over how technology structures the environment, in particular those aspects of normative social interaction which affect the contexts under which interpretative communication occurs. In particular, the elimination of the physical cues which establish the intended meanings that normally exist in face-to-face communication, has a profound effect on how humans now develop pragmatic mechanisms for dealing with incomplete information. Thus, for example, what may appear beneficial in academic polemics in quote/commenting over the e-mail (since exact verbal expressions are delivered and processed closer to the natural speed of thought ([30])), proves to be detrimental to personal ‘virtual partnerships’ formation and maintenance.

Problems also arise when the computer technology plays the role of an equal partner in group communication. Roberts ([59]) has gathered experimental evidence for an earlier observation ([72], [17]) that a label such as ‘expert systems’ (which carries the entailment of ‘knowing better’ than some lay user) have a disruptive bearing on how humans engage in conversation. The communication impedance caused by computerized tools mediating human interactions has been discussed by Eisenhardt and Littman ([9]), who explain that this occurs because computers lack the human capacity to detect potential communication failures before they arise.

Claims of apparent gains to humans such as 1) increased natural readability due to hypertext ([45]) and text-to-speech conversion systems ([40]), and 2) increased skills in self-expression due to Electronic Argumentation Environments ([65]) have been found premature and not fully supported by empirical data. Kirkeby and Malmborg ([38]) have wondered whether different degrees of immersion in multi-media technology, ranging from interactive systems to full-blown virtual realities that support different mental processes, can each destroy the cognitive effects that the other has produced. The skepticism culminates in Biocca’s ([2:71]) pertinent question regarding the ‘teleological’ orientation of the intelligence augmentation hypotheses postulated by researchers in VR labs around the world: if “... we hardly know what ‘intelligence’ is, how can we hope to ‘augment’ it?”

4. Towards a unified theory of adaptation

The issues pertaining to the products of design cannot be considered disjointedly from the processes by which design occurs. Rather, one is always informed by the other. This particular interrelationship comes about due to the dialectic nature of the adaptive process ([49], [25]). Our mind, via its outputs, fabricates and changes its own environment in order to decrease the complexity of the problems we have to deal with ([18], [43]) and to execute otherwise impossible plans; the fabricated environment, in its turn, recursively conditions the mind. While in the human processes of externalization and internalization everything comes together, for methodological reasons these two types of processes constitute related but distinct areas of investigation. To this effect, Gorayska and Marsh ([22]) have proposed to reserve the term Cognitive Technology to refer to methodological matters of tool design, and proposed the term Technological Cognition (TC) to refer to theoretical explorations of the ways in which tool use affects the formation of human internal mechanisms that govern the way humans behave and think.

Our primary concern is thus with the identification, mapping, and evaluation of the relationship between technological products and the processes by which our cognitive structures adapt through exposure to the heuristics governing the highly ordered information structures of an intensely technological environment. Of particular interest to us is how the mind becomes a product of the tasks it performs and the technological resources it exploits, i.e. how it becomes technologized in ways not necessarily beneficial to the humans themselves.

A unified theoretical framework for empirical investigation into the processes of mental and physical adaptation has to integrate several conceptually connected phenomena which up to this day have only received separate treatment. Our own work on the issues now brought together under the umbrella of Cognitive Technology began with the Fabricated World Hypothesis of Gorayska and Lindsay ([18,43]), who postulated that the ways in which people structure their habitats have major influence on which cognitive mechanisms may operate inside of those habitats. In their paper they conjectured that structured habitats are externalizations of human memory which serve two major purposes: they facilitate simple but sufficient algorithms for dealing with the complexities of the material world; at the same time they act as reminders for intention directed behavior. That is, the spatial and organizational relations between objects present in those habitats dictate which goals are to be pursued and which plans-action sets will effectively achieve them. It follows from the Fabricated World Hypothesis that, if the human mind and the external world are interrelated in intricate and inseparable ways, the structure given to the human fabricated environment must have a profound influence on the organization of the mind. This thesis has since become one of the major areas for explorations in CT ([24])

We speculate that the orientation of human habitats towards functional goals supports people in the generation and recovery of problem spaces which comprise elements interconnected by relevance relationships ([18], [19], [21]). The cognitive mechanism for processing relevance relationships, (conceptualized as a relevance meta-function) provides an interface between motivation, situation, and action systems (cf. [25]). It is understood to be responsible for governing how unconscious motivation is cognized, how external situations are perceived, and
how effectively our sensori-motor movements are integrated with these two seemingly independent contexts.

The processing of relevance is closely linked to the phenomena of attention and external priming ([22]). Attention and external priming are driven by both linguistic and non-linguistic communication. When communicating, people perform pragmatic acts ([51]), i.e., they purposely set up scenarios which increase the probability of some intended events - the so-called 'take ups' by targeted participants in a dialogue - to occur. Pragmatic acts are therefore a behavioral equivalent of the fabrication of external reality. The analogy can be further extended to include natural language as a spontaneously evolving technology which externalizes the mind, amplifying and, at the same time, constraining its internal operations ([25], [27], [42], [29]).

Within psychology, two frameworks have been proposed which are pertinent to the above issues: Ecological Perception ([12]) and Symbol Grounding ([30]). With respect to the former, Gibson argued that within a perceivable external reality only a finite set of experiences are possible. He conceived that human perception involves two interrelated processes: recognition of the invariant properties of objects in unstable environments and recognition of the actions these objects can afford. However, he claimed that it is possible to understand human perception without considering linguistic and cultural mediation. Hence, he rejected any link between perception and mental representation, postulating that mentation is purely reactive and occurs as a direct exposure of the mind to its environment.

Hamad [30] calls into question the purely reactive, Gibsonian way of perceiving the invariant properties of perceivable external objects. For him, every act of symbolically mediated perceiving needs to be 'grounded', that is, the representations of our perceptions must have some ultimate foundation in invariant properties. This symbol grounding problem, as he calls it, can only be solved by examining cognitive processes by means of which the invariant properties of objects are picked out, and which are incorporated as an integral part of categorical perception mediated by language. As Hamad is mainly concerned with how natural language expressions come to be properly understood, he does not extend his theory beyond the relationship of language to the external world. However, this provides no explanation for how affordances affect the selective recognition of invariants. Consequently, researchers who have taken on the symbol grounding problem, when dealing with the question of how (basic) concepts are internally formed, are guilty of a similar omission (e.g., [54]).

While Hamad has directed attention to the internal perceptual processes necessary for dealing with the invariants of objects, the internal dynamics governing the perception and recognition of these objects' affordance potential remains unresolved. Here, Gibsonian theory may help. What is needed is an empirically viable, process-oriented footing on which to base Gibson's affordance theory. This need begins to be addressed by Brook ([4]), who advocates a 'subsumption model' for meaningful perceptual interpretation without intermediate representation, which is basically Gibsonian in nature. However, affordance perception cannot be considered a simply passive and deterministic (the lectio passima - the Gibsonian model). Affordances must be envisioned as virtual structures that can be recovered in ways suitable for human perception and cognition. Structures which mediate in human interaction with the external world.

It is not surprising that the computer science and A community, rather than accept the 'natural', ecologic model proposed by Gibson, adopted the cognitiv framework proposed by Marr ([46]). Marr, unlike Gibson, provided a procedural dimension for dealing with an testing simulated models of visual perception. To ect Hamad's argument for the symbol grounding problem, is not enough simply to know what affordances can be perceived in interactive environments (as discussed e.g., [57], [11]). Nor is it enough to know what the nature may be (namely, individual attributes of external objects) and how they are distributed in pragmatic model of representation ([35]). What we have to establish fit and foremost is how those affordances are actively reified both in the material and the cognitive world.

4.1 The affordance activation problem

Highly dynamic environments rely on invaria characteristics which are perceived as constant. Accordin to Gibson, these invariants reside in optic array accessible to sensory inputs of a (moving) perceiving agent. Morphing of multiple views of objects in the environments allows us to pick up the invariants with them. Hence, invariants are relational. A single instance viewing cannot and does not facilitate establish invariants as characteristic features of external object. Negative and positive feedback is necessary to reinforce the choice of affordable invariants. But where do the affordances reside and how do they emerge?

We believe that the external world provides only potential for affordance (cf. [11]); that affordance is not unique nor complete. Affordance potential also exists individual perceiving agents. Upon contact with an affordance potential in the environment the afford potential in the individual perceiving agents reifies the affordance. This leads to the construction of a meaning action trigger. Action, in turn, has a recursive effect motivational states and the environment. The afford activation problem is thus an instance of how relevar relations (comprising fine tuned complexes of goal actions, and perceived objects) come to be determined, internalized, recursively modified, and externalized living organisms in order to ensure their self-regulated equilibria.

Let's go back for one moment to the relevance me function that we introduced earlier. And let's suppr
further that we indeed are able to define and handle an archetypal relevance meta-function, both conceptually and procedurally. That would mean that we could establish the relevance of the internal processes that steer motivational states and environments, as well as the necessary interaction between the two, and that furthermore, we are able to procedurally determine the vectors controlling those processes.

The question then arises: Doing this, have we established a working CT model? Vice versa, will this conceptual arrangement affect our vision of CT, and how? Will it become fruitful for tool design? And so on.

In particular, the question needs to be raised whether such knowledge, combined with its applications, will allow us to answer some important empirical questions, such as the ones listed below (see also [28]):

1. Which manifestations of evolutionary mind change can be monitored?
2. Does the process of human mental adaptation vary significantly with respect to natural and/or highly technological environments? If so, in what ways?
3. What kinds of evidence can help find the answers to questions 1 and 2 above? and
4. What methods and practices are appropriate to gather this evidence?

It goes without saying that the notion of relevance as discussed here, cannot properly be situated in a societal context without appealing to concepts such as discussed here, cannot properly be situated in a societal context without appealing to concepts such as control (whoever is in power decides on relevance) ethics (whose relevance is more relevant: that of the producer or of the user of technology), and the all-encompassing issue of locating relevance in the conditions governing our cognition and its use through environmental awareness. We have touched upon these matters in earlier publications ([17], [27], [41], [50], [53], [63]).

References