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

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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 tł success in achieving this understanding will lead to mc effective HCI design processes which are able to tarş those tasks that map primarily to human cognitive a physical capabilities. The intention has been to increa overall system performance by eliminating the dissonan between natural human capability and the demands technologically mediated activity. Consequently, the approaches assume that human cognition is establish as the basis from which technological progress launched.

Cognition oriented approaches to HCI research a development have led to a large number of informati technology applications which feel good and comfortable to use. However, such approaches genera fail to adequately integrate directly into the design proc a consideration of the negative and undesirable short a long term effects these technologies may have on huma It is not unreasonable to postulate that the greater functional rewards offered by using modern, compu mediated tools, the greater the cost in impact we humans are likely to pay. These costs have been noted several researchers (e.g., [2], [9], [10], [15], [16], [1 [24], [25], [27], [28], [34], [40], [41], [53], [59], [6 [65], [66], [68], [69], [72]). Table 1 presents a summ of possible cost/reward tradeoffs.

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aspect	rewards	costs
place	global access to interacting agents	global displacement of interacting agents
identity	ease of unconstrained and unchecked intimacy with numerous locutors	multiple personality disorders
community	new international, intercontinental social groups	local individual isolation and alienation
knowledge	instant retrieval and storage of vast, encyclopedic knowledge	epistemic disruption
processing speeds	*thought expression*: slower interaction frame during discourse: e-mail & *thought processing*: faster interaction frame during action: games	diminished coherence and/or depth of interaction in natural environments. confusion of a game/reality distinction (killing, zapping, blasting, etc.)
interaction	increased visual and acoustic stimulation	diminished tactile contact with other human beings
adaptation	unconscious induction of the relatively simplistic but strongly deterministic dynamism of computerized environments	inability to relate to the highly complex but weakly deterministic dynamism of natural environments

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.

Cognitive Technology	Cognitive approaches within HCI
serving the interests of people	serving the interests of computing technology or academic pursuits of cognitive science or business oriented organizations
improving human cognitive capacity by means of transcending human cognitive closures (= cognitive prosthetic)	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
investigating ways of how people adapt to the demands of technology	investigating ways of how technology can adapt to the demands of people
investigating holistic integration between human mental processes and technological progress	investigating dichotomous interactions between human mental processes and technological outputs

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 impairment 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])

Technology as a cognitive microscope

A different, but methodologically related, facet of structured learning environment has been proposed b Kunii ([39]), who has exploited machine vision i teaching the martial art Shorinji Kempo. The underlyin assumption has been that the users can easily recogni what the computer has brought to a level best suited f human perception. In this system, modern technology used to translate video recordings of winning bod positions of expert masters (which prevent the aggressor smooth and continuous body movement) during real li performances into graphical body configurations c screens for learners to align themselves with. Tl significance of this type of technological intervention the learning process in relation to the aims and objectiv of CT is that it is entirely free from forming a long li dependency relationship between the human user and tl available tools, as opposed to, e.g., word processo which are now a *sine qua non* in generating texts. It sti remains unresolved, however, how shortening the time master winning techniques will affect the nature of tl martial arts with respect to the renowned potential 1 character formation in those who master them.

Technology as a tool for the scientific study of tl mind

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

3.1.2 Cognitive regression

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

In this connection, progress to date has o been noticeable in research which has brought attention a large number of perceivable inter- and intra-perso behavioral "symptoms" (listed in table 1) that peo have been noticed to exhibit as a result of frequ exposure to tool use. Turkle ([68, 69]) and Slouka ([6 have provided ample evidence showing that playi computer games and surfing on the Internet can lead serious personality disorders, which in turn affect socie infrastructures. Janney ([34]) has pointed out that unwarranted degree of intimacy, far exceeding the norr threshold, often rapidly develops between total strang due to the ease with which we can now establish conta and communicate without restrictions, over the e-m

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. [35]). 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 nonlinguistic 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.

Harnad [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 Harnad 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 Harnad 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 affordanc theory. This need begins to be addressed by Brook ([4]), who advocates a 'subsumption model' fc meaningful perceptual interpretation without interna representation, which is basically Gibsonian in natur However, affordance perception cannot be considered a simply passive and deterministic (the *lectio passima* c the Gibsonian model). Affordances must be envisioned a virtual structures that can be recovered in ways suitable fc *human* perception and cognition. Structures whic 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 Gibsoi provided a procedural dimension for dealing with an testing simulated models of visual perception. To ech Harnad's argument for the symbol grounding problem, is not enough simply to know what affordances can b perceived in interactive environments (as discussed i e.g., [57], [11]). Nor is it enough to know what the nature may be (namely, individual attributes of extern objects) and how they are distributed in pragmatic mod of representation ([35]). What we have to establish fi and foremost is how those affordances are actively reifie 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. Accordi to Gibson, these invariants reside in optic arra accessible to sensory inputs of a (moving) perceivi 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 establishi invariants as characteristic features of external objec Negative and positive feedback is necessary to reinfo 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 neit unique nor complete. Affordance potential also exists individual perceiving agents. Upon contact with t affordance potential in the environment the affordar potential in the individual perceiving agents reifies t affordance. This leads to the construction of a meaning action trigger. Action, in turn, has a recursive effect motivational states and the environment. The affordar activation problem is thus an instance of how relevar relations (comprising fine tuned complexes of goa actions, and perceived objects) come to be determin internalized, recursively modified, and externalized living organisms in order to ensure their self-regulati equilibria.

Let's go back for one moment to the relevance me function that we introduced earlier. And let's supp 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 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]).

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