The Potential Societal Impact of Augmented Cognition

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Abstract

Of necessity, the Augmented Cognition (AugCog) research program, in order to be pursued successfully, likely will provoke important and far-reaching developments in cognitive science, as spin-off products. These include a theoretical clarification of 'cognitive status/state' and 'cognitive process/function,' and improved methods of measuring these constructs. A brain mapping project on the scale (and the payoff) of the Human Genome Project will also spin off of the AugCog research; said spin-off may itself lead to a major development in artificial intelligence. Finally, the relationship of cognition, affect, motivation, and personality will of necessity be clarified in the process of pursuing the AugCog program.

1 Introduction

Let us begin with a statement of the goals and program of Augmented Cognition (AugCog):

> Augmented Cognition research includes the study of methods for addressing cognitive bottlenecks via technologies that assess the user's cognitive status in real time. A computational interaction employing such a system monitors the state of the user, through behavioral, psychophysiological and/or neurophysiological data acquired from the user in real time, and adapts or augments the computational interface to significantly improve their performance on the task at hand.
> (Schmorrow & Kruse, 2004, p. 1)

It is understandable why cognitive bottlenecks should be of interest to the U.S. Department of Defense. Military service has always placed a strong demand upon members of the armed forces for cognitive and behavioral performance. In addition, several emerging trends in American military operations are converging in such a way as to increase the cognitive demands made upon the individual warfighter. To mention only a few such trends:

- Network Centric Warfare, in which tactical information is exchanged in real time among ground, sea, air, and space platforms (U.S. Department of Defense, 2003);
- the Army's Future Force Warrior program, in which soldiers are to be outfitted with extensive electronic sensors, and directed by command far from the field through telecommunications (U.S. Army Natick Soldier Center, 2004); and,
- the increasing use of advanced human-computer interaction in military contexts.

Given the cognitive demands made by traditional requirements and emerging trends in military service, it is crucial that military personnel perform optimally at cognitive tasks (e.g., correctly perceiving signals, making decisions, etc.). However, human information processing is marked by surprisingly narrow constraints. For example, visual short-term memory appears to have an upper bound of only four or five objects (Alvarez & Cavanagh, 2004). More broadly, some findings suggest, juggling four variables simultaneously is stretching the limit of overall human information processing capacity (Halford, Baker, McCredden, & Bain, 2005). Approaches such as Network Centric Warfare, and programs such as Future Force Warrior, will place demands on human information processing capacity that extend to the limit of currently available capacity—and perhaps beyond.

Given these interests in the military domain, it is reasonable to project that the AugCog program will ultimately be successful, through being granted the resources that it requires. However, even if only to consider the wisdom of committing such resources to this project, the question must be asked: in the great grand scheme of things, what difference would it make? My position here is that it will make a great deal of difference. More specifically, AugCog will have a major positive impact on cognitive science and human society.

No doubt some of those attracted to this presentation by its title are expecting something in the spirit of the 1964 World's Fair: *"Behold, the bright world of tomorrow!"* This is not that kind of presentation. This is more about the work that needs to be done in order to *have* a "bright world" tomorrow. Rather than a tour of Tomorrowland, this presentation is in the nature of a more positively minded version of the Ghost of Christmas Yet to Come, from Charles Dickens's novel, *A Christmas Carol*. It will be remembered that this was the visitor to Ebenezer Scrooge whose purpose was to show what the future might hold, so that Scrooge could take action to affect that future. In Dickens's novel, the future that the Ghost showed was a bleak one, and the point was to encourage Scrooge to change his ways. I, too, wish to encourage Augmented Cognition researchers to change their ways, not to avert a bleak future, but to bring about what could be a very bright one. AugCog has the potential to have some very positive societal effects; however, it will take a concerted effort to bring this about, an effort that will in some ways involve a departure from business as usual in AugCog research.

There are two types of societal impacts that any technology has, the direct and the indirect. The former involves the effect of using the technology itself in its developed state. The anticipated effects of the achievement of AugCog are well-documented in the literature (e.g., Schmorrow & Kruse, 2004, and related material found in *Augmented Cognition International Quarterly* and on various websites). I will focus here on the latter, indirect effects.

Indirect effects result from the fact that technology does not emerge into the world fully formed, like the Greek goddess Athena, who was said to have sprung into the world in a full set of armor, right from the brow of Zeus. Rather, during the development of any technology, there are sets of theoretical and technological challenges that must be engaged, and problems that must be solved. In some cases, addressing these challenges and problems creates spin-off benefits that rival or even outweigh the direct benefits of the technology itself. A case in point would be the manned near-space exploration program of the 1960's. Sorry as one must be to say this, in terms of direct and tangible societal benefit, we have very little to show from the Mercury, Gemini, and Apollo programs.[1] However, the indirect benefits of these programs have been enormous. It can be argued that the boost that these programs gave to computer technology alone more than justified the cost of these programs. Similarly, on the way to achieving AugCog's goals, researchers will have to grapple with problems; the outcome of this effort may have a tremendous impact on science and society—if these problems are addressed in certain ways.

2 Cognitive Status and Function: Construct Clarification and Measurement

In order to meet AugCog's goals (as outlined in the quotation from Schmorrow and Kruse, above), several theoretical and technological achievements must come first. Perhaps the most fundamental of these involve a clearer understanding of the constructs "cognitive status" (or state) and "cognitive process" (or function). To understand the relevant issues here, it may be helpful to compare electronic data processing and human cognitive processing at different levels of abstraction, as shown in Table 1.[2] There are at least two aspects of Table 1 (in both its explicit and implicit facets) that are worthy of consideration here.

First, what is meant by the "status" of the system (either electronic or human) differs, depending on the level of abstraction being considered. The implication of this for AugCog researchers is that they must specify what level of abstraction they are addressing in any discussion of "cognitive status."

Second, there is an inherent asymmetry that is masked by the structure of Table 1. In electronic data processing, status indicators at lower levels of abstraction map directly onto status indicators at higher levels of abstraction. That is, the status of the system at the level of hardware, as indicated by a core dump, directly maps onto the status of the system at the level of software program function, which in turn directly maps onto the status of the system at the level of the user interface.

[1] Arguably, this lack of benefit resulted from the premature termination of both Apollo and serious efforts at manned interplanetary exploration.
[2] I do not mean to imply that these two systems, electronic and human, map into each other or are directly analogous. It is still useful, however, to compare system functioning across broad levels of abstraction.

Table 1: Comparison of Electronic Data Processing and Human Cognitive Processing

	Electronic Data Processing		Human Cognitive Processing	
Level of Abstraction	**Description**	**Example of Status Indicator/Gauge**	**Description**	**Example of Status Indicator/Gauge**
Highest	User Interface	User-Intelligible Message (e.g., "Your balance: $_")	Behavior/ Performance Conscious Experience	Speed and accuracy of high-level task performance Self-report
Middle	Software Program Function	Programmer-Intelligible Message (e.g., "Error #139: Stack Overflow")	Mental Processes	Speed and accuracy of fundamental task performance
Lowest	Hardware Electron flow among switches	Core Dump	Neural structures Specific neural impulses	Cerebral blood flow

However, within the boundaries of current knowledge, the same cannot be said for human cognitive processing. It is true that great strides are being made in attempting to map brain function to specific domains of performance, through the subdiscipline of neuroergonomics (Hancock & Szalma, 2003; Parasuraman, 2003; Parasuraman & Hancock, 2004). However, at least anecdotally, AugCog researchers have been heard to complain about what they term an "individual differences problem," in which different people with similar status indications (or gauges, in AugCog parlance) seem to be showing very different cognitive states. My contention is that this is really not an "individual differences problem," at least not in the sense that the term 'individual differences' is used in psychology generally. What we are encountering here is one or more of at least two other problems involving construct validity:

- *Faulty operationalization:* That is, researchers are attempting to capture the status of human cognition at a given level of abstraction with indicators that are insufficiently sophisticated or valid. This would be the case, for example, if researchers are trying to capture cognitive status at the lowest level of abstraction, with an aggregate index combining, say, cerebral blood flow indicators, reaction time, and eye pupillometry, *and if* in fact this were not a valid way to capture cognitive status at this level.

- *Faulty understanding of levels of abstraction:* That is, researchers are attempting to capture the status of human cognition at one level of abstraction with indicators that are more appropriate to *another* level of abstraction. This would be the case, for example, *if* researchers are trying to capture cognitive status at a middle level of abstraction, using indicators that are more appropriate to a lower level of abstraction.

Thus, to meet the ambitious goals set by the founders of AugCog, the field is going to have to bring to a much more sophisticated level our understanding of what is meant by terms such as "cognitive status/state" and "cognitive process/function," and will have to make much more sophisticated our operationalization or measurement of these constructs. This would be a major advance for cognitive science; this alone would be worth the price of admission, as it were.

However, to bring about this major advance, AugCog researchers are going to have to recognize that the tasks of construct definition and clarification, and construct operationalization, are indeed problems to be faced. Then they will have to put their best theoretical abilities to bear on these issues. This is the price to be paid, in advance, for making a leap in the advance of cognitive science.

3 Brain Structure and Activity Mapped to Cognitive Status and Function

In order to meet their ambitious goals, AugCog researchers are going to have to advance, by a quantum leap, the task of mapping brain structure and neural activity to cognitive status and function. It is no exaggeration to say that this is a task with the potential impact (and the magnitude of effort) of the Human Genome Project.

No doubt this project will seem hopelessly (if not psychotically) grandiose to some of those reading this presentation. Ever worse, perhaps, this idea might seem to put AugCog forever out of reach. After all, with billions of neurons and an astronomical number of dendritic connections, the human brain, it has been said, is more complicated than the interior of a star, the most complex object upon which physical science focuses. What hope could we possibly have to do the sort of mapping that I am calling for, within the foreseeable future?

It would be worthwhile for the potential naysayer to keep a couple of factors in mind in considering this task:

- *The true scope of the task:* No one is suggesting that we need to map *all* neurons and their activity with *all* cognitive function. Certainly there are some cognitive functions that are more important than others for the military contexts where support for AugCog research is the strongest. For any given cognitive function or subfunction, what is needed is to map the most crucial neuronal centers and their activity with this cognitive function. Although still a daunting task, given the distributed nature of brain function, this perspective still cuts down the amount of mapping required considerably, for any one task.

- *Need breeds innovation*: Although in many ways a very different project, the history of the Human Genome Project (e.g., Davies, 2001; Shreve, 2004) is most instructive. To oversimplify greatly, one set of researchers had been working at a certain pace, a pace dictated largely by the limitations of the accepted procedures of the day. Another set of researchers, not satisfied with this pace, and wanting to gain the financial rewards that would come of genomic research, developed radically different ways to sequencing the genome that cut the time required greatly. (Perhaps I should have written "need *plus greed* breeds innovation.") In this context, *both* sets of researchers wound up sequencing the genome much quicker than expected. Similarly, I would predict that, if greater emphasis were put on this topic, innovative methods would be developed that would greatly advance the progress of brain mapping. (What would greater emphasis be? In short, establish a Human Brain Function Mapping Project, parallel in stature to the Human Genome Research Project. The latter was directed, for a variety of arcane reasons, in the U.S. Department of Energy. The Human Brain Function Mapping Project ["Human Brain Project," for short] could be placed under the direction of the Department of Defense.)

Thus, to meet the ambitious goals set by the founders of AugCog, the field is going to have to bring to a much more sophisticated level our understanding of the mapping of brain function into cognitive function. To say that this would be a major advance for cognitive science would be almost a criminal understatement; it would be the crowning achievement of neuroscience to date. However, to bring about this major advance, AugCog researchers are going to have to recognize that this task, too, must be grappled with, and, here again, must bring their best research abilities to bear on these issues. This, too, is the price to be paid, in advance, for making this titanic leap in the advance of cognitive science and neuroscience. This particular impact, however, has an especially important secondary impact of its own, to which I next direct your attention.

4 Quantum-Leap Advance in Development of Artificial Intelligence

As it happens, with the completion of the Human Genome Project, we are in a position to learn a great deal about the genetic basis of fundamental cognitive functions. Some such research, carried out with innovative methodology, is already beginning to appear (e.g., Parasuraman, Greenwood, Kumar, & Fosella, 2005). Combine this with the knowledge we will have of brain-to-cognition mapping, as mentioned above, and we will be in a position, ultimately, to design brains-to-order, as it were. This is a project for the distant future, of course—say, thirty years.

The impact that such a development would have on artificial intelligence (AI) would be enormous: we would literally be developing artificial brains, artificially embodied intelligence, actual but artificial "meat machines," to put a spin on Marvin Minsky's phrase. We are talking the creation of neural nets—with real neurons. The ability to develop fine-tunable neural hardware—perhaps with enhancements beyond current human capacity—would bring AI into very exciting domains.

5 Understanding the Intertwined Nature of Cognitive, Affective, Motivational, and Personological Processes

Elsewhere (Koltko-Rivera, 2005b, this volume), I have noted that AugCog researchers, in order to enhance human cognitive processing, are going to have to come to grips with the fact that cognitive processes are inextricably intertwined with affect, motivation, and personological processes, even at the neurological level. This proposition is evidenced by a growing body of research conducted across specialties, demonstrating, for example, that there is an obsessive-compulsive style to visual attention (Yovel, Revelle, & Mineka, 2005). Enhancing cognition in the context of affect, motivation, and personality, and understanding how these interact at the neurological level, will do much to promote a more comprehensive understanding of the human organism, an approach that is emerging as a new paradigm in behavioral science (Koltko-Rivera, 2005a). In the process, this activity will further the advancement of psychology as a unified science (Sternberg & Grigorenko, 2001).

6 Conclusion

To attain the goals of the AugCog program, researchers will have to address certain theoretical and methodological challenges. In the course of addressing these challenges, various spin-off developments seem almost inevitable. These include a clarification of the constructs 'cognitive status/state' and 'cognitive process/function,' and improved methods of measurement for these constructs. A brain mapping project on the scale (and the payoff) of the Human Genome Project will also spin off of the AugCog research, a spin-off with the potential of leading to a major development in the area of artificial intelligence. Finally, the relationship of cognition, affect, motivation, and personality will of necessity be clarified in the process of pursuing the AugCog program. Surely these spin-off products make the AugCog program of great scientific and commercial importance.

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