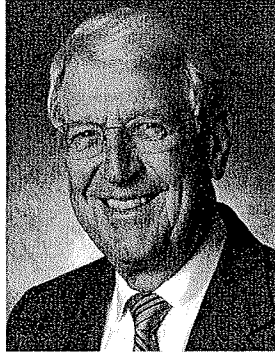


# A Case for Operational Approach in Advanced Research Projects—The Augmented Cognition Story



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THE THEME of this special supplement, “Operational Applications of Cognitive Performance Enhancement Technologies,” as you will quickly discern from this introductory piece, is of great interest to me. Seeking to apply new technologies to military operational problems has consumed the majority of my working hours since arriving in Washington, DC, in 1971. This involvement has led to a wide range of exposures in diverse fields with an emphasis on multidisciplinary approaches and solutions. My most recent exposure with such efforts began in 1998, with the germination of an idea that focused on augmenting human cognitive capability and which eventually became a funded program (which is always a good thing). Before I delve further into those details, I would like to provide some motivating background information on what has sparked my interest in cognitive performance enhancement technologies from the onset.

In 1998 my undisciplined, somewhat indiscriminate, and roving interest was aroused by the problem of interfacing human and computer-based systems. Earlier, in 1981 to be precise, I had exposure while at the Office of Naval Research (ONR) to one of the earliest applications of the personal computer, an interconnected office system—what is referred to today as a LAN (Local Area Network). Providing an inter-office messaging system was the centerpiece of this application. ONR had installed such a system based on a remote server (800 miles distant in another city). It was state-of-the-art at the time but far from intuitive to use, as it was based on a Command Line Interface which

required far too many key entries to link and send a message. In my judgment, this inter-office mail system was a failure primarily due a lack of real-world user operational testing before the product was offered to its customers.

Additionally, about 10 years ago at the end of the previous century, web-based systems and search engines with various features and functions became all the rage on the consumer and developer scene. The user interface was dominated by what was available from Microsoft at the time. While nothing is wrong with that from a market standpoint, it seemed to me we could do better in terms of innovative user interfaces that were needed to keep pace with the innovative tools and technologies beginning to emerge. The WIMP (windows, icons, menus, and pointers) interface represented the state-of-the-art at the time, and is still the most widely accepted interface standard. However, what was pointed out in a perceptive doctoral thesis (1,2) and struck my immediate attention and line of thinking at the time, was the assertion that the WIMP design is not well suited to supporting the development of electrophysiological-based interactive computer systems, let alone neurophysiologic-based systems—both of which were beginning to emerge by the dawn of the new millennium. Advanced computing technologies for

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monitoring the human “state” [e.g., using galvanic skin response (GSR), Electro-encephalogram (EEG), Electrocardiogram (ECG), video and kinesthetic-based monitoring of keyboard strokes and mouse clicks, etc.] were becoming more prevalent among the various R&D fields based on human-system computing concepts. The idea of developing non-invasive, electro-physiological, and possibly neurophysiologic-based human-system interfaces that could be used in operational environments seemed realizable, and I found myself right in the middle of the notion of it all—wondering how to gather just the right minds to help advance this notion further into actualized technologies.

To borrow a thought from Ray Kurzweil’s provocative 1999 book (3), “The Age of Spiritual Machines: When Computers Exceed Human Intelligence”:

Although computers still lack a sense of humor, a gift for small talk, and other endearing qualities of human thought, they are nonetheless mastering an increasingly diverse array of tasks that previously required human intelligence.

Now, how could we harness this increasingly capable computing power with a similarly powerful human-system interface? As it turns out [and not too unusual in the Defense Advanced Research Projects Agency’s (DARPA) history], a program in Cybernetics, which had its beginning more than 20 years earlier, had addressed this question with the ‘then’ generation of neurophysiologic instrumentation and sensors of the time. However, the science and technology (S&T) emerging from the federally-funded “Decade of the Brain” project in the 1990s showed some real advances in real-time monitoring of human cognitive activity. Although the DARPA Cybernetics program showed great potential, it failed to achieve the results that are being realized today by current DARPA investments in neuroscience, brain signal sensors, physiological monitors, and computer algorithmic understanding and responses to the human cognitive state (workload) in real time. This musing, coincidentally, brings me back to my original storyline and the details of my experiences with scientists aiming to augment human cognition, which led to the birth of a new DARPA program and the emergence of the now burgeoning field of Augmented Cognition.

The seminal work in (military) operational application of cognitive performance enhancement technologies, as represented by the DARPA Augmented Cognition-based program now called the Improving Warfighter Information Intake Under Stress (IWIIUS) Program, has interesting beginnings. In 1999 I began collaborating with LT Dylan Schmorrow (now CDR) of the U.S. Naval Research Laboratory (NRL) on how individuals could benefit from performance-enhancing technology. During our initial discussions, I learned that LT Schmorrow had previously explored the concept of “cognitive prosthetics,” namely a prosthetic that would help an individual with perceiving, interpreting, and acting on information in the same transparent manner as someone wearing eyeglasses can see more clearly and effortlessly. That is, one should be able to simply don a “cognitive prosthetic” device and then be able to think and handle information more efficiently. LT

Schmorrow originally started down this line of thinking during his time while serving as a cognitive science post-doctoral fellow at the Naval Post-Graduate School (NPS) when he first began meeting with and discussing such concepts in 1996 with Dr. Kenneth Ford, who was a NASA-Ames director at that time. When LT Schmorrow and I hooked up in 1999 and our mutual lines of thinking converged, we began participating together in numerous brainstorming sessions and workshops, which included meetings such as DARPA’s Information Science and Technology (ISAT) Study Groups and other DoD-sponsored idea-sharing events. The most fruitful of these meetings was a brainstorming session that was largely responsible for helping initiate the effort to develop a research program that DARPA might fund. This sprouted not from a profound “*Ah-ha!*” but rather from a collection of insightful observations gathered during various discussions in a brainstorming session we had with Dr. Denny Proffitt of the University of Virginia and Dr. Randy Pausch of Carnegie Melon University. The results of these discussions later stimulated early seedling investment by DARPA on the basis that augmenting the human to increase performance had been going on for centuries—binoculars, eye glasses, false teeth, bow and arrows, rifles, vehicles, telephones, cell phones, etc., etc.—so why not augment the human brain to enhance human performance?

The first seedling prototype—the InfoCockpit—was demonstrated to a prestigious group of researchers at an annual meeting in Woods Hole, MA, in 1999. The prototype using multiple displays and a wrap-around oval screen formed a holo-deck inspired by the Star Wars and Star Trek sci-fi series phenomena. Experiments run using the InfoCockpit demonstrated that human memory performance could be improved by over 100%. The concept of “Augmented Cognition” was coming to fruition right before our eyes and a new DARPA program was soon to emerge. It was not the first thought when the program was being planned to have a strong operational application focus. That idea came about as a result of a rather tense, week long, e-mail negotiation with the new (at the time) DARPA Director, Dr. Tony Tether. It was his proclivity as a research manager and developer that programs under his leadership be aimed from the outset at operational problems and this specific concept of Augmented Cognition should be aimed at military applications. Further, he mandated that the military service’s collaboration be codified in Memoranda of Understanding, which was a powerful influence on how this new program’s technical approach would take shape. Lest you think that this approach is peculiar to Dr. Tether or DARPA, it might be appropriate to consider a recent look at the vaunted Bell Labs, as published in a Wall Street Journal lead article (4), which noted the institutional change at the Bell Labs from a pure basic research approach to one where the emphasis was on commercialization. The new Bell labs leadership was directed to “...set more of its scientific stars to work on breakthrough technologies that could turn quickly into businesses. . . .” This approach is conceptually the same as Dr Tether’s—accelerate emerging basic research products into useful opera-

tional capabilities. Dr. Tether had one more dictum, the “Go–No Go” criteria for program continuation, which became a true *sine qua non* where the period for progress assessment was directed to be about 12 months or at the most 18 months.

This approach is not as daunting as it might appear. For instance, the first phase of the Augmented Cognition program in 2001 was the development and evaluation of the state-of-the-art in cognitive workload measurement technology and a test of the feasibility of interoperating multiple sensors to achieve a common objective—measurement of cognitive state (workload). This was in essence a base lining of the capability of basic research tools and the development of gauge-like measuring capability. The first phase consumed 18 months. The second phase, also 18 months, was devoted to understanding and developing techniques to overcome four primary cognitive bottlenecks (i.e. working memory, executive function, sensory input, and attention). The bottlenecks were parsed out to each of four teams during Phase 2, with a collaborative inter-team approach to obtain a system that could handle all four bottlenecks. Specific “Go–No Go” metrics were assigned as objectives for each team. In both initial phases of the program, basic research tasks were being performed, software and human factors engineers were introduced to neuroscience and vice versa, and the resulting intra-disciplinary teams inculcated in operational environments requiring innovative experimental techniques. At the end of Phase 2, feasibility had been clearly established, specific military applications selected, and service sponsors signed up to help support the next phases of the program. More importantly, the cognitive bottlenecks had been overcome by each Augmented Cognition team via their development of neurophysiologic-driven mitigation strategies—this became a key to pushing their technology to operational application levels in the next phases of the program.

In Phase 3, the operational application inspired prototypes that had emerged during Phase 2 were scaled up to include the added element of operational stress. Could the prototypes stand up to the more realistic operational environment demands? During this phase the requirements for the experiments and demonstrations were jointly developed with the service sponsors. The environments became as close to real as was possible. At the same time, the cognitive state assessment sensors, mitigation strategies, and system architectures of each team were still being evaluated and improved.

For the Augmented Cognition (AugCog)-based IWIIUS program’s final phase, Phase 4, which will have ended by the time this special supplement has been published in early 2007, the service sponsors have focused each team’s objectives on a final “operational

demonstration.” The operational demonstrations include: a “combat assault” vehicle demonstration on a military evaluation range in the California desert; a platoon 24-hour take and hold exercise in an instrumented MOUT (Military Operations on Urban Terrain) environment; overlaying a demonstration on an operational missile system test and evaluation; and using a prototype advanced unmanned aircraft control system. As I write this introduction knowing the DARPA program is not yet finished, there is clear indication that three of four prototypes will be continued by their service sponsors after the program ends. Further, a fifth team has recently been added to the program and seeks to use the techniques demonstrated by the other four teams and demonstrate AugCog performance enhancement technologies in a closed-loop aircraft cockpit. When the final program report is published, there is no doubt in my mind that it will reflect positively on early operator/user involvement and the pressure imposed by the “Go–No Go” criteria, schedule milestones, and the service sponsor imposed objectives.

This brief historical overview and technical approach summary may seem overly regimented in the telling, but, in practice, the process generated a very salubrious collaborative environment. After my experiences being part of this AugCog-inspired program at DARPA, it has never been more apparent to me than now how the joint development of objectives with service sponsors and the motivation to develop something ‘that really worked’ were essential to the ultimate success of this program. Furthermore, the interdisciplinary approaches to operational application were essential—the achievement of the program goals realized by the program could not have been accomplished by research psychologists, neuroscientists, or human factors experimenters alone.

As presented by my colleagues in the next two introductory segments and by the contributing authors of each of the articles in this supplement, today’s cognitive performance enhancement technologies continue to emerge and mature as a result of the continued successful collaborations of scientists and program managers across the services and scientific disciplines. I can’t wait to see what the next chapter in our human-system computing history delivers.

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