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From Associate Systems to Augmented Cognition: 25 Years of User Adaptation in High Criticality Systems

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Abstract

Beginning in the early 1980s, the U.S. Air Force initiated the development of a human-adaptive, information and automation management technology that came to be known as the "Pilot's Associate" (PA). Associate Systems technologies and approaches went on to be used in more than 15 major programs (in at least 5 countries and costing a, conservatively estimated, $US 240M). In many significant ways, associate systems were and are the predecessors of augmented cognition technologies. Both are seeking to solve the same problem (enhancing human + machine performance in high-criticality domains) via methods (ongoing awareness of context, state and operator intent coupled with adaptive modification of information presentation and/or automation behavior) that are, if not identical, certainly similar. Hence, it is important to ask how the approaches are similar and different, how augmented cognition approaches might solve problems inherent in prior associate system work, how they might fall prey to known pitfalls and how lessons learned from the wealth of effort invested in developing associate systems might apply to AugCog innovations. In this paper, the authors briefly review the two largest associate systems development efforts, cite lessons learned from their own observations of those efforts, and then compare and contrast those efforts to the AugCog development goals and methods, and suggest lessons for the growth of AugCog technologies.

1 INTRODUCTION

Beginning in the early 1980s, the U.S. Air Force initiated the development of a human-adaptive, information and automation management technology that came to be known as the "Pilot's Associate" (PA). PA, and all of the subsequent associate systems, consisted of an integrated suite of intelligent subsystems that were designed to share (among themselves and with the pilot) a common understanding of the mission, the current state of the world, the aircraft and the pilot him- or herself. Associate systems then use that shared knowledge to plan and suggest courses of action and to adapt cockpit information displays and the behavior of aircraft automation to better serve the inferred pilot intent and needs.

Since the early 80s, more than 15 major programs (in at least 5 countries and costing a, conservatively estimated, $US 240M) have sought to apply associate systems concepts in different domains and applications. An associate system was extensively tested in over 90 flight tests as a part of the Rotorcraft Pilot's Associate program and associate systems technologies are being incorporated into the F-22 Raptor (ISX Corporation, 2004). Lessons learned (and in some cases, specific code and algorithms) from the associate programs have been incorporated into adaptive, assisting automation in domains as diverse as software design, oil refinery operations, network bandwidth allocation and in-home care and monitoring for the elderly and cognitively disabled.

Augmented Cognition is defined as "… an emerging field of science that seeks to extend a user's abilities via computational technologies, which are explicitly designed to address bottlenecks, limitations, and biases in cognition and to improve decision making capabilities." (Augmented Cognition International, 2006). The aim of augmented cognition is to use physiological and neurophysiological sensors to detect states where human cognitive resources may be inadequate to cope with mission relevant demands. The goal is to enhance human performance when task-related demands surpass the human's current cognitive capacity, which fluctuates subject to fatigue, stress, overload, or boredom. Efforts have focused on ways to leverage cognitive state information to drive adaptive systems to manage information flow when detected human cognitive resources may be inadequate for the tasks at hand (Dorneich et al, in preparation).

In many significant ways, associate systems were and are the predecessors of augmented cognition technologies. Both are seeking to solve the same problem (enhancing human + machine performance in high-criticality domains) via methods (ongoing awareness of context, state and operator intent coupled with adaptive modification of information presentation and/or automation behavior) that are, if not identical, certainly similar. Hence, it is important to ask how the approaches are similar and different, how augmented cognition approaches might solve problems inherent in prior associate system work, how they might fall prey to known pitfalls and how lessons learned from the wealth of effort invested in developing associate systems might apply to AugCog innovations.

In this paper, we will describe the general concept and goals of the associate system approach and will briefly describe some of the major research efforts conducted in that tradition (with emphasis on military aviation applications). We will discuss the similarities and differences between associate systems and augmented cognition systems. We will review general lessons learned from associate system research with emphasis on their applicability to augmented cognition approaches.

2 ASSOCIATE SYSTEMS DEVELOPMENT EFFORTS

The associate concept was designed to further the capabilities of fighter aircraft, to reduce or eliminate what was seen as the problem of "information overload" in advanced military systems of all types, and to exploit emerging capabilities in high speed data processing and artificial intelligence (expert) systems. "The Pilots Associate concept developed as a set of cooperating, knowledge-based subsystems: two assessor and two planning subsystems, and a pilot interface" (Banks & Lizza, 1991, p. 18). The concept of an "associate" system designed to intelligently, but semi-autonomously aid the pilot of an advanced aircraft was first conceived in work by Reising (1978). The Pilot's Associate program "… began in February, 1986 as an application demonstration for DARPA's strategic computing initiative." (Ibid., p. 18).

Two large, government-sponsored efforts can be characterized as representing the primary sources of development of the associate system concept and of specific associate technologies. These two programs can be singled out not only on the basis of the size of their efforts (in terms of both dollars and labor hours invested), but also because they have most consciously embraced the "associate system" label and philosophy and because they have taken the concept furthest toward practical implementation and usage. These are the U.S.A.F. and DARPA's Pilot's Associate (PA) program and the U.S. Army's Rotorcraft Pilot's Associate (RPA) program. The PA program (Banks and Lizza, 1991) was initiated in 1985 with two parallel development awards, each approximately $40M in value, to Lockheed and to McDonnell-Douglas. PA focused on the development of an associate for single-seat fighter aircraft. By 1991, each team had completed a simulated full mission demonstration. The RPA program (Colucci, 1999) was awarded to McDonnell-Douglas (soon to merge with Boeing) in 1995 and ran through 1999 when it culminated with a twelve-month series of live flight tests in a modified Longbow Apache aircraft (Robertson, 2000). RPA focused on the development of an associate system for attack/scout helicopter operations in vehicles with two pilots. At nearly $80M, RPA represented the Army's single largest R&D program throughout much of its duration (Colucci, 1999).

In addition to the above efforts, there have been a wide range of research and development efforts, both within the U.S. and abroad, and within both government and industry, which have been influenced by the associate system efforts and/or which have shared its goals. A sampling of such programs includes:

- *Ongoing major platform work:* In a direct lineage from the RPA work, Boeing and the U.S. Army are continuing to apply RPA's associate system and cognitive decision aiding technologies in related programs such as the Warfighter's Associate, Mobile Commander's Associate, Hunter Standoff-Killer Team (HSKT) (Wright & Kuck, 2001) and, ultimately, elements of the Future Combat System's Warfighter-Machine Interface through cognitive decision aiding work done on the Crewman's Associate (Tierney, 2003).
- *Major international development efforts:* UK Cognitive Cockpit (Taylor, 2001) leading to Qinetic's AugCog cockpit (Adams, 2005), France's Copilot Electronique (e.g., Reising and Taylor, 1997),

Germany's Reiner Onken/Axel Schutte work (DAISY, CASSY, etc.-- e.g., Reising and Taylor, 1997), Canada's IAI (Hou and Kobierski, 2005), etc.

- *Less major government-sponsored industry efforts:* A large number of such efforts have been sponsored and, in the interests of space, only program names will be listed here: D/NAPS, LSPA, PADC, Hazard Monitor, Designer's Associate, Submarine Commander's Associate, Crewman's Associate
- *Government sponsored academic research:* While there have been a host of academic research involving, explicitly or implicitly, the associate concept, one of the earliest, most extensive and most influential was that sponsored by Jefferey Morrison of the Naval Air Weapons Center (Parasuraman, et al., 1992).
- *Industry driven work (Honeywell):* Undoubtedly, multiple industries have made use of the associate systems technologies for non-military applications, but the authors are most familiar with the work of Honeywell which includes associate-like applications for petrochemical plants (AEGIS—Cochran, Miller and Bullemer, 1996), in-home monitoring and caregiving for the elderly (I.L.S.A.—Miller, et al., 2004), and design assistance for building fire, security and ventilation systems (IDS—Raymond, 2001).

Special mention should be made of what is obviously the largest and most fully deployed associate system effort to date: Microsoft's Office Assistants™—the infamous "Clippy" which was initially shipped with versions of Office95™. While the Office Assistants were developed under internal Microsoft funding (the Lumiere project, Horvitz, et al., 1998) and there was little or no explicit interchange with research efforts, or individual researchers, in the associate tradition, nevertheless the goals and even many of the specific implementation methods used in Office Assistants are similar to those used in associate system efforts.

3 ASSOCIATE DEFINITIONS

Various definitions of an associate system exist in the literature. These include:

- Banks and Lizza (1991) call an associate "a cooperative, knowledge-based system application" and say "The Air Force wanted to explore the potential of intelligent systems to improve the effectiveness and survivability of post-1995 fighter aircraft." (p. 18) and "The creation of an associate must be driven by requirements to support human decision-making capabilities…" (p. 20).
- Colucci (1995) quotes Program Director Bruce Tenney as describing the RPA thus: "The whole technology thrust behind the RPA program is to apply computer intelligence to serve as a buffer between all these various subsystems…to insert this computer into the loop with the crewmember." Colucci goes on to label RPA as "The Third Crewmember" and say "RPA is an information and action management system for the pilot." (p. 16).
- Miller (1999) described associate systems as "collections of intelligent aiding systems that, collectively, exhibit the behavior of a capable human … They can (a) perform roughly the same breadth of activities as a human expert operation in the domain; (b) take initiative when necessary, though they generally follow a human colleague's lead; and (c) integrate over ongoing activities to exhibit robust, coordinated, appropriate behavior." (p. 443).
- Miller and Riley (1994) defined the associate relationship as "… is characterized by a mixed-initiative approach to collaborative problem solving between one or more human actors and a subordinate but semi-autonomous computer system with sufficient depth and range of intelligence and capabilities to encompass a full task domain."

The goals of the original Pilot's Associate system effort were " … to advance the [Strategic Computing Initiatives] technology base, principally in the area of real-time, cooperating knowledge-based, systems. The Air Force wanted to explore the potential of intelligent systems application to improve the effectiveness and survivability of post-1995 fighter aircraft." (Banks and Lizza, 1991).

Within the context of the initial development effort, as well as subsequent efforts, the designation "associate" was carefully and consciously chosen in contrast to refer to a specific relationship that was sought between human and automation—one in which the machine was highly competent and had some authority to initiate its own or even interrupt human activity, but one in which both human and machine shared the same goals in the domain and would work together to achieve them. The term was contrasted to other potential relationships which could exist: "drone", "assistant", "coach", etc. It was recognized that, in order to provide substantial benefit, aiding automation had to be:

- Aware of the world around it, including the state of the operator
- Aware of the mission goals, and aware of the operator's current goals within that broader set of mission goals
- Able to determine how current world and operator state affected overall mission goals, as well as how they affected (and perhaps changed) current operator goals.
- Aware of the capabilities of the mechanical system (e.g., aircraft), its subsystems and of the operator
- Able to plan how those capabilities might be exercised to achieve mission goals
- Able take actions to affect the state of the world or of the operator—this could include autonomously affecting ship's systems, autonomously affecting the operator's displays and controls, or recommending actions via the displays for the operator to either take or authorize the associate to take.
- While some degree of autonomous and adaptive action on the part of the associate was understood to be required to achieve maximal payoff, this action was always to be in the service of the operator's goals and, whenever feasible, to be authorized by the operator—either during the mission, immediately prior to execution, or pre-mission, in a pre-authorization mode.

4 ASSOCIATES AND AUGCOG: COMPARE AND CONTRAST

In the remainder of this paper, the authors will be expressing personal opinions about the goals and lessons learned from the associate systems effort and their implications for AugCog. The first author, Dr. Miller, has 17 years working with associate systems technologies and has participated in most of the programs described above. Dr. Dorneich has been involved in the AugCog program as a part of Honeywell's effort since its inception. While this gives us a good basis from which to begin our analysis of the two technologies, we cannot claim to have comprehensive knowledge of either. The analysis presented here must be regarded as our opinion only.

Augmented Cognition is defined as "… an emerging field of science that seeks to extend a user's abilities via computational technologies, which are explicitly designed to address bottlenecks, limitations, and biases in cognition and to improve decision making capabilities. The goal of AugCog science and technology is to develop computational methods and neurotech tools that can account for and accommodate information processing bottlenecks inherent in human-system interaction." (Augmented Cognition International, 2006).

These goals have strong echoes in the motivations, and even the specific approaches and technologies of the associate system efforts. For example, Bruce Tenney, the director of the RPA program for the Army, stated RPA's goals as (from Colucci, 1995): "We do a really good job of generating information and making it available to [the pilot], but in the end, he still has to absorb it… The problem is there's a very fundamental limit on this guy's ability to absorb that much information in a short period of time." In fact, it is telling that in the largest recent associate system development effort (RPA, concluding in 1999), the advanced reasoning, assessment, advising and information management portions of the overall RPA system were referred to as a "Cognitive Decision Aiding System." In other words, the associate existed to aid (or, if you will, to "augment") the user's cognition.

There were, nevertheless, some significant differences between the efforts.

- *Neurophysiological Assessment*—AugCog approaches have made heavy use of neurophysiological approaches to infer operator state and adapt onboard systems accordingly. By contrast, the primary means used in both the PA and RPA programs to infer operator intent was logical deduction based on knowledge of the mission plan and the functional capabilities of the aircraft (Geddes, 1985). The concept of incorporating neurophysiological data were discussed as a part of the associate system concept, with the general concurrence that they would provide a valuable channel for ascertaining pilot state and, perhaps, pilot intent. In fact, some contemporary work was focused on using neurophysiological data to adapt cockpit displays or automation behavior (refs—e.g., Hadley, et al., 1997; Prinzell, et al., 1995; Pope, et al., 1995). Neurophysiological methods were, for the most part, not implemented as a part of associate system development due, in part, to the state of the supporting technology available at those times. An early exception to this general rule was the U.K.'s Cognitive Cockpit effort (Taylor, 2001) which made physiological and neurophysiological state assessment a core part of its design. In contrast to the majority of associate system development efforts, the AugCog community has made the ascertaining of operator neurophysiological state and using it to adapt displays and automation a primary focus.

- *Implicit personification*—the notion of an "associate" drove much of the associate systems effort. While most of the associate systems efforts explicitly avoided overt personification of the "associate" system in the cockpit—generally for user acceptance reasons—there are nevertheless powerful ways in which the "associate concept" or metaphor drove a viewing of the system as an integrated whole and as an intentional agent. This, in turn, informed its design and use by pilots. This emphasis on holism and human-machine relationship (not merely interaction) seems to be largely absent from the AugCog effort.
- *Strong Automation, High criticality and User Role*—Although there have been many different target applications for associate systems, and for AugCog systems, both have emphasized at least some "higher criticality" applications. By "high criticality" here, we mean a domain in which the consequences of error can have larger and more immediate consequences to the operator making decisions and taking actions. Thus, the pilot of an aircraft who makes an error in maneuvering or firing a weapon can very immediately kill himself or terminate his career. But the approaches may be said to differ with regards to the "strength" of the automation they permit. While AugCog approaches have focused almost exclusively on display manipulations, associate systems were able to (and if permitted by the operator, did) take specific actions with regards to the mechanical system including communications, sensors, flight and even weapons subsystems. Perhaps due to this difference, or due to a potentially stronger focus on near-term applications in the associate development efforts, these differences in focus may have had significant consequences for the respective development efforts. Among these are an increased tolerance for risk and for more nearly autonomous technology solutions on the part of AugCog technologies and applications. By contrast, most associate systems efforts wrestled with conservative, mistrusting and risk-adverse pilots—and made operational design decisions to accommodate this fact.
- *Interactivity*—Perhaps as a consequence of the above factor, we have noted a general absence in the AugCog efforts for a consideration that became paramount to many associate systems efforts—explicit interactions between the operator and the system to constrain or instruct the system's behavior. In the associate system efforts, this interaction typically took the form of some form of pilot authorization (generally, but not always, on the ground, pre-mission) of specific behaviors the system was permitted to exhibit or the "level of autonomy" it could exercise. In RPA (Miller & Hannen, 1999), however, and in subsequent efforts such as the Cognitive Cockpit (Taylor, 2001), this took a more dynamic, in-flight form whereby the pilot could communicate at a meta-level about plans and intents (e.g., saying, in effect, "I don't intent to attack at this point, please quit trying to help me do so") and could thereby influence the associate's behavior in a fashion more nearly like s/he would influence the behavior of a human co-pilot. Again, we find this type of explicit interaction and operator control over the behaviors of an AugCog system largely lacking in the research we have seen reported. AugCog has rarely concerned itself, in reports we have seen, with what is the right type of control (by permission, by exception, and so on). Again this may be because the focus has been more squarely on real-time assessment of cognitive state, and not the automation behaviors that are to be driven by that assessment.
- *Human-Automation Roles and their Consequences*—Adaptive decision-support and automation assistance triggered by real time classification of cognitive state offers many advantages over traditional approaches to automation. These systems offer the promise of leveraging the strengths of humans and automation - augmenting human performance with automation specifically when human abilities fall short in demanding task environments. However, by delegating critical aspects of complex tasks to autonomous automation components, these systems risk introducing many of the problems observed in traditional human-automation interaction contexts. The pros and cons of automating complex systems have been widely discussed in the literature (e.g. Sarter, Woods, Billings, 1997; Miller and Parasuraman, in press). However, as widely noted, poorly designed automation can have serious negative effects. Automation can relegate the operator to the status of a passive observer –limiting situational awareness, and inducing cognitive overload when a user may be forced to inherit control from an automated system. Both associate systems and AugCog technologies are seeking to apply an even-higher level of automation support than has yet been widely accepted in human-machine interactions, and there may well be inevitable temptations for both to "show off" their technological capabilities in circumstances where less automation might well produce a better overall human + machine response. Fortunately, this problem has been extensively studied in the academic literature and some concrete advice is available (cf. Parasuraman, et al., 1992, 1996; Scerbo, 1996; Layton, Smith and McCoy, 1994; etc.)

5 LESSONS LEARNED FROM ASSOCIATE SYSTEMS EFFORTS

The following are, in our opinions, some of the lessons learned from the associate systems development, fielding and evaluation efforts:

- *Importance of user acceptance and, therefore, importance of keeping human "in charge"*. While user acceptance is an important consideration for any new technology development, it is perhaps extremely so in the sorts of high criticality domains involving highly trained operators that both the associate systems and AugCog technology developers are seeking to aid. By removing direct control over some functions of the work station in a high criticality environment, we are almost inevitably provoking feelings of being "out of control" at times and in contexts when such operators are least willing to lose control. Miller has argued elsewhere (Miller, et al, 2005) that this "loss of control" is inevitable if there is to be some savings in workload, but it can be handled in better and worse ways. The associate systems development efforts developed a variety of methods to leave pilots "in charge" even when they weren't explicitly controlling every action of their display suite or, in some cases, their aircrafts. This was done both from a sense of moral requirement (if the pilot is to be responsible for the actions of his/her aircraft, then s/he must be the final authority over the actions it takes), and from necessity in that operators were frequently unwilling to make use of associate systems in realistic settings unless they had the opportunity to control or at least override them. The modern era of unmanned vehicles illustrates a more important, related reason to leave the operator in charge: the human is, by the laws of war, required to make final authorization decisions about the use of force. Insofar as any automated system usurps that authority from the human, or minimizes his/her control over the information with which to exercise that authority, it may impinge on legal requirements for military actions.
- *Importance of co-development and progressive testing*—The overall behavior of an associate is dependent on each of it's component parts. Planning and decision aiding recommendations cannot be valid if the sensing and information fusion technologies do not perform appropriately—and plan recommendations do little good if they are presented to the user at a time or in a way that s/he cannot adequately process them and act on them. All components are co-dependent and all contribute to final performance. Thus, they must be developed and evaluated in concert. Since associate system development efforts frequently involved the efforts and talents of multiple team members from different geographic locations and different companies, there was generally a temptation to allow each component to be developed in isolation pending a grand integration effort scheduled for the end of the program. This approach rarely proved effective.
- *Benefits of an explicit, integrative framework (task model)*—The majority of associate system development efforts made use of an explicit task (or, in some cases, context) model around which to integrate the behaviors of their multiple reasoning and aiding components. This integrative framework proved to have many benefits, some of which extended beyond the associate system itself. Among these were that it served as a powerful *lingua franca* for engineers, designers, domain experts, pilots, etc. to coordinate during development. Having a task-based framework proved to be an effective means of coordinating multiple, diverse sets of subsystems and provided a convenient means to minimize the costs of revising or extending those systems when new technologies were available, or new tactics created.
- *Pros and Cons of personification*—Personification of the user interface per se seems comparatively out of place in the high criticality domains inhabited by fighter pilots and infantry soldiers. Furthermore, animated and explicitly anthropomorphized "faces" on software systems can lead to assumptions of capability and expectations of performance that the system cannot deliver. In a high criticality domain, this mismatch between assumed and real capabilities can lead to disaster (cf. Parasuraman and Miller, 2004). Nevertheless, viewing the associate system as a combined entity with understanding, knowledge, behavior and even needs and intentions led perhaps to a tighter coupling in the design effort and a better understanding of the performance of the overall system on the part of both its developers and its users.
- *Importance of interface and interaction design*—How and when the user interactions with the associate system proved to be critical to both user acceptance and to overall human + machine performance. This is important because although user interface design efforts typically involved 5% or less of the overall effort in developing an associate system, they represent the "pointy end of the spear". Anything that is wrong with any module, will manifest itself to the user via the user interface, and errors in the design of the UI will make all other aspects of the associate less effective. In addition, users' initial ideas about how they would like to interact with an associate have frequently proven not to hold over even fairly

short term interaction with an actual system. The user interface and, more generally, the overall design of user interactions must be customized to the capabilities and limitations of the associate—which means they must be customized to the strengths and weaknesses of the other components of the associate system (e.g., state assessors, planners, intent inferencing capabilities, etc.)

- *Importance of learning, especially individuation*—most of the associate system efforts at one time or another have speculated about the value of incorporating learning capabilities to extend or customize the capabilities of the associate system. Few, however, have had the available funding to actually implement a learning approach. (One notable exception is the Learning System for Pilot Aiding project designed to acquire novel plans and the information management data structures to support them from instances of pilot behavior—Levi, et al., 1992). Generally, one of the higher payoff areas for such learning is thought to be adaptation to individual differences and user expectations—though whether this actually holds true in practice is yet to be tested.

6 IMPLICATIONS FOR AUGCOG DEVELOPMENT EFFORTS

In this section, we draw on the lessons learned articulated above to provide specific recommendations for the development of AugCog technologies and applications. As stated above, the authors' insights into the AugCog development efforts is limited and so it is quite possible that some of these recommendations may be wide of the mark, or may in fact already be in use by the AugCog teams.

- *Importance of user acceptance and, therefore, importance of keeping human "in charge"*--Beware relying too heavily on inferred operator state or intent. This leads to the operator feeling, and perhaps being, "out of control" of the system. True, in some cases, the operator needs to release some aspects of control due to workload or superior performance ability on the part of the automation. But it is extremely rare that automation is so trustworthy (especially in highly complex, high criticality domains such as military operations) that we should remove the human from the control loop. If nothing else, highly trained operators in life threatening situations resent, and will resist, this loss of control. Instead, solutions which allow human and system to share control, or which allow the human to vary the amount and level of automation used (effectively migrating control to a supervisory level) should be sought. Ultimately, the goals of adaptive automation are similar to those of automation in general; improve overall performance while avoiding "operator out of the loop" conflicts or mistrust in the automation.
- *Importance of co-development and progressive testing*—The development of neurophysiological sensors or "meters" and other means of assessing operator state and the development of methods for "augmenting" cognition through information display technologies can proceed reasonably well independent of an emphasis on the specific application or user interface through which these technologies will be applied—but only at the level of basic science. This level of research is certainly needed, but when it comes to developing specific applications of AugCog technologies to solve specific problems for specific classes of users, it will be necessary to integrate development efforts and individual technologies into holistic systems that deliver superior performance as an integrated whole.
- *Benefits of an explicit, integrative framework (task model)*—One means of achieving such integration that proved useful in the associate systems work was a shared task model. The associate systems efforts have demonstrated the ability to improve human performance and reduce workload by means of a task-inferred reasoning system (e.g., Miller and Hannen, 1999). The addition of AugCog's neurophysiological assessment techniques and advanced display management should only enhance this capability, while the explicit task models of associate systems may improve the user acceptance and understanding of AugCog technologies. It is important to note that the task context itself holds implications for operator state and for the information to be absorbed. Adaptive assistance can alter the task demand that the controller is subject to. As a consequence, neurophysiological measures may not effectively reflect the overall task demand imposed by the task environment. Unless the task context is assessed and considered using non-physiological sensors, a neurophysiologically triggered adaptive system could potentially return control to the user under circumstances that may be beyond the capability of a user to handle. Despite the fact that systems developed under the Augmented Cognition program display high degree of sensitivity to a user's cognitive state, as automated systems they stand to inherit many of the problems commonly observed with highly automated human-in-the-loop systems (Mathan, Dorneich, and Whitlow, 2005). A certain amount of operator agitation and heavy cognitive processing

are to be expected for some tasks and maintaining an even cognitive load may not be desirable under conditions where abnormally large or small amounts of data need to be attended to—but knowledge of the task context and its associated information needs will inform the overall system of these effects.

- *Pros and Cons of personification*—The ultimate goals and applications of the AugCog projects seem to us to be more "backgrounded" than the associate systems applications were. While information and display management techniques are centrally a part of AugCog, plan recommendation and automation management are less so—this is the lack (or under-emphasis of) "strong automation" as discussed above. These claims, if true, imply a somewhat less robust and holistic role for AugCog systems. This probably results in an even stronger argument *against* explicit personification of the AugCog system to the operator than was true in associate system efforts. An AugCog "agent" or "manager," if personified via an animated actor, would quite probably get in the way of AugCog's goals by distracting operator attention and thereby hindering information throughput rather than increasing it. By contrast, thinking of AugCog systems holistically as intentional agents which perceive, think, and then decide and act might serve to enhance the integration among component technologies. Similarly, thinking of an AugCog system as a personified agent whose goal is to aid the user and for whom the user might have feelings or attitudes might serve to focus attention on the nature of effective AugCog interactions. For example, Miller (2005) has written elsewhere skeptically about an agent who always presents the right information at the right time—but does so without any explicit interaction with the user.
- *Importance of interface and interaction design*—It is critically important that any technology which seeks to manipulate a user interface in a high criticality domain be designed for conditions in which the technology fails to behave accurately. Giving the user the ability to override and turn off the technology is one way to accomplish this—but it is a particularly coarse-grained one. Other methods include allowing the user to explicitly authorize a display modification, to be notified of pending changes, to be notified of executed changes, and to rapidly return to a previous display state. Other interface design attributes may be appropriate for various forms of interface manipulation—for example, hysteresis effects, picture in picture to convey map movements or previous and current screens, etc. AugCog is clearly pioneering some new display manipulations and technologies for which lessons from the associate systems efforts may need to be generalized or rethought, but this is not universally the case.
- *Importance of learning, especially individuation*—AugCog efforts, especially those making heavy use of neurophysiological techniques, are perhaps in a much better position to exploit learning, especially learning about individual differences in perception, cognition and behavior, than the associate systems work has been. This is because such systems must already be instrumented for and tuned to the individual who is operating them. Extending this tuning to recording individual performance effects—even at the level of simple acceptance or rejection of AugCog-initiated display modifications (see previous bullet)—could serve to provide a powerful means of adapting system behavior to the individual.

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