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Augmented Cognition for Warfighters; a Beta Test for Future Applications

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Abstract

For close to thirty-five years, Department of Defense (DoD) Military Platform Program Managers (PMs), Combat Developers and Operators have recognized the need for improved situational awareness, off bore sight targeting, multi-spectral sensor fusion and indirect viewing through integrated information management systems. These systems had historically been focused on fixed wing and rotorcraft applications. Because of revolutionary advancements in miniature displays, sensors, optics, electronics, processor power reduction, weight, and size; man portable systems are being evaluated for dismounted warfighter applications and soldier integration.

Integrating communication and sensor fused, multi-modality information systems on soldiers is the mandate for the Transformational Future Force Warrior (FFW). Based on past integrated soldier system developments with DARPA, Natick Soldier System human factors specialists and Training and Doctrine Command (TRADOC) combat developer representatives have acknowledged that overloading warfighters with information through technology is easily accomplished. Together they have sought solutions through task and sub-task analysis, as well as minimizing and filtering the information that flows to the warfighter. Examples of these systems relate to combat vehicles, rotorcraft, maintenance, medical, law enforcement and Special Forces. Each user community has their own unique tasks and informational needs. System interfaces and the manner in which information is distributed will be of critical importance to assimilate the users with the transformational information management systems in development.

Overloading the Future Force Warfighter is a major problem and understanding the means by which the information will be disseminated and displayed from the integrated Command, Control, Communications Computers, (C4) systems under development in Future Force Warrior and other transformational warfighter systems requires an intelligent solution. This paper will discuss the soldier of the future who will carry a wide variety of battlefield networked sensors and displays embedded into his equipment, which will data-link to his weapon and to displays on his helmet to information streaming in from the battlefield.

This paper will focus on Augmented Cognition as a new paradigm that assists the information inundated 21st century warfighter with an operational capability that employs an "interactive/intelligent" system "human machine interface", that is correspondingly "normal" and making the "computer–human" interactions fundamentally like "human-human" interactions. The discussion will include descriptions of success stories in the integration and operational evaluation of Augmented Cognition and potential new areas for research that could address other Military Mission Occupational Specialties. This paper will address the importance of working with end users in exploratory research such as experienced warfighters, subject matter experts and the Combat Equipment Developers from TRADOC Schools in support of the Transformational Army's Future Force Warrior (FFW) Advanced Technology Demonstration.

The net-centric Future Force Warrior will operate in squads or sub-squad teams, requiring dedicated wireless communications networks for operation. Each warrior will be equipped with a sensor set, comprised of a helmet integrating day and night cameras and weapon-mounted sight cameras. The images will be displayed on a helmet integrated see-through monocular display, or on a hand held PDA like terminal. Images will also be relayed to other team members for coordination. Future Force Warrior (personal) digital assistants will display navigation and situational awareness pictures, and images received from team members. The radio will be transmitting wideband data communications in addition to the current voice radio. Soldiers will be able to talk naturally with each other, whisper, or chat with text messages during missions. As a novel interface the feasibility and usefulness of a

wearable vibrotactile feedback system is also being explored. The Future Force Warrior system has the ability for tying each soldier into tactical local and wide-area networks by an onboard computer that sits at the base of the soldier's back. Troops will also be able to share data with vehicles, aircraft and other individuals.

The Augmented Cognition system supports the Future Force Warrior development by creating a prototype environment with operational utility that employs an "interactive/intelligent" system "human machine interface", mixed-initiative interactions, dialogue and gesturing methodologies. The system is developed to ensure that prioritized information being delivered to the warfighter is in a mode that has utility for human consumption.

The Augmented Cognition program, which involves military agencies, academic institutions, and industry, has generated significant interest from many system and product developers. The development, integration, experimentation and evaluation of Augmented Cognition in Future Force Warrior operational scenarios should lead to many Future Applications of Augmented Cognition such as Homeland Defense, other defense platform integration, law enforcement, security, automotive industry, mass production manufacturing, health care, and professional and industrial occupations where they are all involved in multi-tasking environments and require performance improvement, education or rehabilitation.

1 The Need for Improved Battlefield Situational Awareness

In 1991 under the auspices of the Defense Advanced Research Projects Agency (DARPA) High Definition Systems (HDS) program, miniature displays were being developed as devices that would be integrated into rotorcraft visors to provide sensory information and flight symbology.

This resulted in new programs to develop miniature sensors, optics, and electronics that would be compatible with this new low power, light weight and high resolution display technology. Following these successful developments and evaluations in combat weapon platforms such as combat vehicles and rotorcraft where power was not an issue, new programs commenced where these display and system components would soon be integrated into Head-Mounted Displays (HMD) for dismounted warfighters such as infantry and special operations warfighters, who were evaluating HMDs for hands-free capability when viewing alphanumeric and graphical data.

Man portable system developments using head mounted displays coupled with sensors and cameras required the development of new man portable processors. Components needed to consider space on the body, weight and consume very little power if these man-portable systems were to be objectively evaluated for dismounted warfighter soldier integration and expecting to provide warfighter performance enhancement.

The majority of these systems were developed under the auspices of the DARPA High Definition Systems, Smart Module, and Warfighter Visualization Programs. These systems were developed for the following tactical/operational applications: Combat Vehicles, Rotorcraft, Dismounted, Medical, Maintenance, Special Operations, Reconnaissance Scouts, and Military Police/Law Enforcement applications. Integrating communication and sensor fused multi-modality information management systems on soldiers with HMD systems as the interface called for new graphical User Interfaces (GUI) to the system because a Windows Operating System would not work as a GUI in a mobile environment. Throughout the period from 1991-2001 many variations of systems for the aforementioned warfighter tactical/operational applications were developed. (See Figure 1)

Many operational field experiments were conducted by experts in human factors and research psychologists. Military users were always in the development loop to over see the design through iterations of these experiments so that the Non Recurring Engineering (NRE) design enhancements would capture the feedback of the users. The lessons learned through the years of experiments, operational tests and iterative system enhancements identified critical bottlenecks that pertained specifically to the limitations of the human (warfighter). Human system integration limitations were associated with information dissemination in a multimodality situation especially when the warfighter is mobile; walking, running, climbing and possibly coupled with exertion from the 80 and 120 Lb. load carried by the soldiers. Other stressors to be considered affecting diminished cognition are heat, cold, hunger, fear sleep deprivation etc.

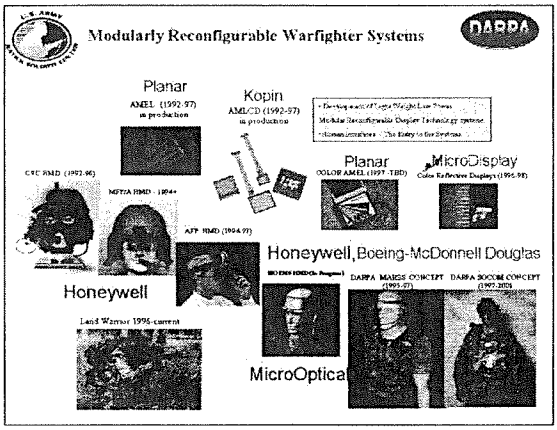

Figure 1: 1991-2001 DARPA –Army Information Management Systems and Component Developments

1.1 The Need for Augmented Cognition

The DARPA Augmented Cognition program, which began in 2001, was viewed by the Army as a means to understand the information management capacity of the human-computer warfighting system by co-developing and demonstrating quantifiable enhancements to human cognitive ability in diverse, stressful, operational environments through experiments that would mitigate information bottlenecks. This could enable validation of human performance enhancement by understanding the cognitive capacity of a soldier to multitask and process multimodal information.

Future Force Warrior notional concepts seek to create a lightweight, overwhelmingly lethal, fully integrated individual combat system, including weapon, head-to-toe individual protection, netted communications, soldier worn power sources, and enhanced human performance. The program is aimed at providing unsurpassed individual and squad lethality, survivability, communications, and responsiveness. The Human Performance portion of the Future Force Warrior Advanced Technology Demonstration (FFW ATD) was viewed as the ultimate cognitive challenge because the integrated system of systems would be relaying enormous quantities of data and information to soldiers without a full comprehension of a dismounted soldiers capacity for information processing.

The FFW ATD information management system and component subsystems centered on warfighting doctrinal changes that brings about new tactics, techniques and procedures for conducting warfighting operations. The system of systems will consist of Sensors & Communications (C4ISR) Vision: Netted Future Force Warrior small unit/teams with robust team communications, state-of-the-art distributed and fused sensors, organic tactical intelligence collection assets, enhanced situational understanding, embedded training, on-the-move planning, and linkage to other force assets where words like "180-degree, multispectral sensor-fused; see through augmented reality Head-mounted vision system" will allow the warfighter to be one with the environment having 360-degree optimized, intuitive system control. 1.

General Kevin P. Byrnes, Commanding General, TRADOC stated in a recent interview "We talk about a networked force and empowering the force with knowledge—it worked well in Operation Iraqi Freedom at the higher echelons. The picture was much clearer; their ability to communicate data, voice and video was there. At the lower levels, where the fighting was conducted, we're not there yet. We have an awful lot of work to do to push information and intelligence and connectivity to those lower levels, and that's absolutely key to our force. If we're to fight effectively and trade mass for knowledge, we've got to work the lower end, where the fighting occurs." [2]

Future Force Warrior is expected to provide information management capabilities and the expectations being placed on the ability for human information consumption and understanding is significant. The DARPA-Army information management systems and technologies developed during the 1991-2001 period were designed to enhance warfighter performance and augment their situation awareness but none of these systems were developed with the expectations of the Future Force Warrior system where the cognitive capability of the human may be exceeded. Understanding the capacity of the specific warfighters using the system will be as huge as the Future Force Warrior information management system development itself.

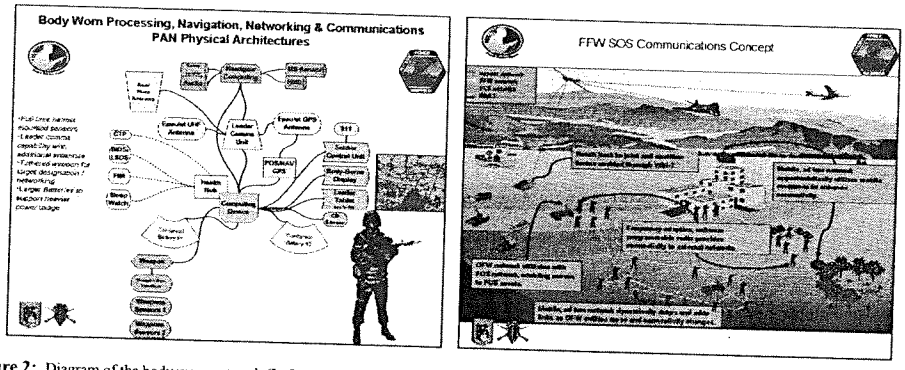

Figure 2: Diagram of the body worn network (Left) connecting the Warfighter (Right) to all echelons space-based and below system of systems (SOS)

1.2 The Relevance of Augmented Cognition

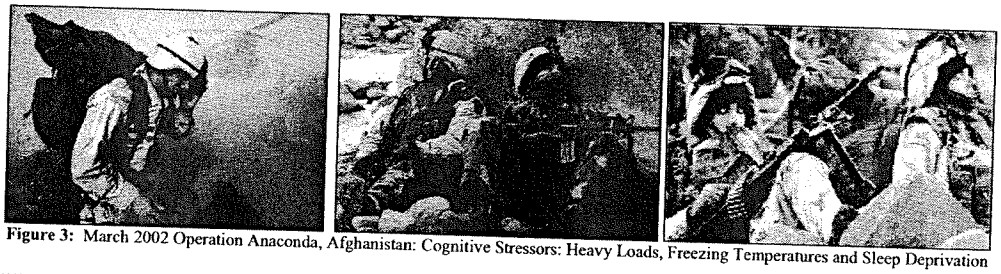

Figure 3: March 2002 Operation Anaconda, Afghanistan: Cognitive Stressors: Heavy Loads, Freezing Temperatures and Sleep Deprivation

Military medical researchers at U.S. Army Research Institute for Environmental Medicine study the effects of sleep deprivation, exertion and the effects of freezing temperatures because these stressors can diminish cognitive functionality in warfighters and can lead to accidents and poor decision making. [3] When the soldiers deployed to Afghanistan in the inaugural battles in the War on Terror, the organic weapon assets were minimal to do the job that was needed to reach the enemy peering out of the cave openings in the mountains. The maps and data used was based on Russian maps from the Russia-Afghanistan war era. The indigenous language turned out to be Russian and the special operations soldiers first to "hit the ground" quickly learned that all their lethality depended on their ability to communicate with support from US Air Force Bombers and AC-130 gunships who's primary missions were close air support, air interdiction and force protection and communications from higher headquarters to provide them with ammunition, food, water, batteries etc. [4] Their cognitive capacities had to be acute because they were on the move in search of Taliban and Al Qaeda. Their combat loads were in excess of 100 Lbs, the cold at night was well below freezing and almost all fire support to eliminate the enemy had to be called in from USAF weapon platforms. The Special Forces would designate the targets with their laser designators and batteries essential for their mission essential electronics had to be air dropped into the theatre of conflict. Many times, they would leave behind clothing and individual equipment articles because of space, weight and power considerations.

In an interview with the U.S. Army 82nd Airborne in October 2002, factors that affected their operations were weight and bulk of mission equipment, electronics and the many different types of batteries that were needed for

them. [5] Although certain items were considered mission essential, if they were not critical they were left behind because of weight, power, bulk and in some instances, performance. They did without precision Position-Navigation equipment and used commercial-consumer grade products. They field-stripped their meal rations and took higher fat content components for endurance. They left behind some warm clothing articles and using their saying which is "travel light-freeze at night" meant that they were huddling with each other to use body warmth as a means to survive. Leaving behind critical mission equipment, food and clothing articles, compromised, their survivability, situational awareness and because they were susceptible to extreme cold, hunger, exertion, and lacked precision navigation, their cognitive performance might have been compromised as well. The degree to which extreme cold effects have on human cognition are the subject of a study being completed by the U.S. Army Natick Soldier Systems Center and the U.S. Army Research Institute for Environmental Medicine (USARIEM).

1.3 Augmented Cognition: a Beta Test

The Augmented Cognition program is expected to benefit the warfighter in a digital information abundance environment through synergistic development between DARPA and the Army. The integration of the Augmented Cognition technology into the Future Force Warrior, both programs simultaneously in development, is a parallel approach where, with the Future Force Warrior Program, Augmented Cognition technology has an optimal platform on which to develop a system that will mitigate informational bottlenecks and maximize the warfighter potential.

The Augmented Cognition system is expected to enhance and maximize the Future Force Warrior's capability to successfully accomplish the functions currently carried out by three or more individuals. A key objective of the Augmented Cognition program is to foster development of novel and state-of-the-art technologies, in order to experiment with, and understand, the means by which they may be integrated into existing operational systems. Where Future Force Warrior and Augmented Cognition were beginning simultaneously, there was a preconceived opinion by research psychologists and human factors experts that the Future Force Warrior's networked collaborative situational awareness, providing 360° information to 21st century warfighters would severely tax the cognitive capacity of soldiers. Based on the information management system developments mentioned earlier in this paper, limits of information to assist the warfighter, as opposed to overloading the warfighter were understood fairly well based on experiments executed in controlled environments. The Future Force Warrior development is a system of systems primarily aimed at netted communications and collaborative situational awareness objectives that, in a tactical environment, could prove to cause cognitive overloaded situations.

The Augmented Cognition program will accomplish evaluations of cognitive overload and examine mitigation strategies by experimenting with innovative technologies and design principles for human-computer symbiosis. This involves some revolutionary concepts of biomedical and behavioral monitoring interacting with intelligent digital information and control systems. (i.e. gauges consist of arousal (attention) meter, stress gauge, engagement index, executive load gauge, and P300-driven novelty detector and biosensors including: EEG (Electroencephalogram), pupil diameter, eye movements, ECG (Electrocardiogram), and EDR (Electro-Dermal Response)).

Correlating both Augmented Cognition and Future Force Warrior Advanced Technology Demonstration allows for concurrent system design. In using the same processor, bus architecture for carrying the information to the soldiers "human sensors" (eyes, ears, smell, touch etc) the Future Force Warrior development provides the Augmented Cognition team with the opportunity to explore the interaction of cognitive, perceptual, neurological, and digital domains to develop improved performance application concepts for the Future Force Warrior system. The advanced applications will be tailored to operational scenarios and task development in order to experiment and qualify mitigation strategies and demonstrate potential pay-off for first Future Force warrior system operational users. Success will be the improvement in the way the 21st Century warriors interact with computer based systems, advance systems design methodologies, and provide the ability to fundamentally re-engineer military decision making.

1.4 Understanding Stress: Augmenting - Augmented Cognition

There are additional considerations that factor into mitigating information bottlenecks in the Augmented Cognition Program. In the DARPA baseline program, the research is predominantly focused on information understanding and performance. However, there are several additional stressors that can play a role in human cognition. Some of these

stressors that decrease cognitive state are mobility, exertion, fatigue, cold, heat, hunger, fear and isolation. The Augmented Cognition team is working on a solution to understand the cognitive capacity of the dismounted soldier. Research conducted with the Medical Research and Material Command and U.S. Army Research Institute for Environmental Medicine (USARIEM) to understand the Warfighter Physiological Status of the soldiers in battlefield situations are part of the Future Force Warrior system development and will provide the capability for assessing the cognitive health of the individual soldiers. The Warfighter Physiological Status Monitor (WPSM) will first determine level of consciousness, and secondly, the level of cognitive workload. Understanding cognitive workload is especially important in environments where there is an abundance of collaborative netted communications and basically too much information going to the soldier through radios, displays, sensors and other information disseminating devices that will inundate the warfighter. The adverse effects of stressors and information overload will be associated to the division of attentional resources among the various components of the task to be performed. Understanding the implications of the overload conditions will be necessary to prioritize relevant tasks through mechanisms such as a message scheduler, a mechanism to filter and disseminate in a proper modality prioritized information to the warfighter. [6] How will the warfighter handle all the information that is supposed to make them more survivable, lethal and sustainable with the aforementioned stressors factored in to a battlefield situation?

These questions are being addressed under the auspices of new research protocols:

1) "The Effect of Walking Over Irregular Terrain on Soldier Ability to Process Information from the Environment and Communication Displays"
2) "The Effect of Walking with a Load on Soldier Vigilance Performance"

The first new research protocol will investigate to what degree ground soldiers are able to allocate cognitive resources to digital information sources while moving over varied terrain and at the same time remain alert to situations in their immediate environment. Additional objectives are to understand the level of cognitive complexity required to produce a drop off in performance while a soldier is moving over ground with loads, and which presentation modalities might be best suited for information processing while mobile. A choice reaction time task will be used to measure changing capacity to process information from the environment. In addition, a communications task involving two modalities, visual and auditory, will be used to measure ability to monitor and process information from communication channels during mobility. The mobility conditions will be standing, walking, and walking while avoiding obstacles.

The Second new research protocol will investigate whether physical exertion affects concurrent cognitive performance. Participants will perform a vigilance task under a variety of mobility conditions. They will be instructed to detect and respond appropriately to brief signals that are presented at the rate of approximately one per minute. Independent test groups will be exposed to test stimuli (visual, auditory or tactile) from a small, portable device that must be responded to as quickly as possible Each group of test subjects will navigate a walking course of approximately 2.4 km with or without a load. They will be asked to cover this distance as quickly as possible, but at a pace they are comfortable with. The load will be factorially combined with three mobility conditions: standing, walking, and walking while avoiding small obstructions. This experimental design allows us to assess whether walking with a load affects performance on an elemental information processing task, examine potential mechanisms that may underlie any effects, compare potential differences when the critical signal is presented in different sensory modalities and examine whether imposing small obstructions affects performance differentially across sensory modality.

There is much more detail to these protocols but due to the page limitations of this paper, only a cursory summary has been provided. In addition to the two protocols mentioned above, there are three more protocols being prepared for execution within the next year. These are:

3) "Cognitive-Attentional Workload of Soldiers Performing Simulated Combat Tasks While Moving Over Irregular Terrain."
4) "Cognitive Workload Analyses of Infantry Leaders Executing Complex Tactical Missions (field interviews)."
5) "The Effects of Exertion on Soldier Ability to Process Information from the Environment."

The Augmented Cognition team and the Future Force Warrior teams are working together to ensure relevance of Augmented Cognition to Future Force Warrior. In addition to MRMC and USARIEM we have been working with the Human Research Engineering Directorate of the Army Research Labs in at Aberdeen, MD to team and matrix

our approach with their research on Motion Artifacts from neurophysiological and physiological sensors to better understand how to deal with motion artifacts.

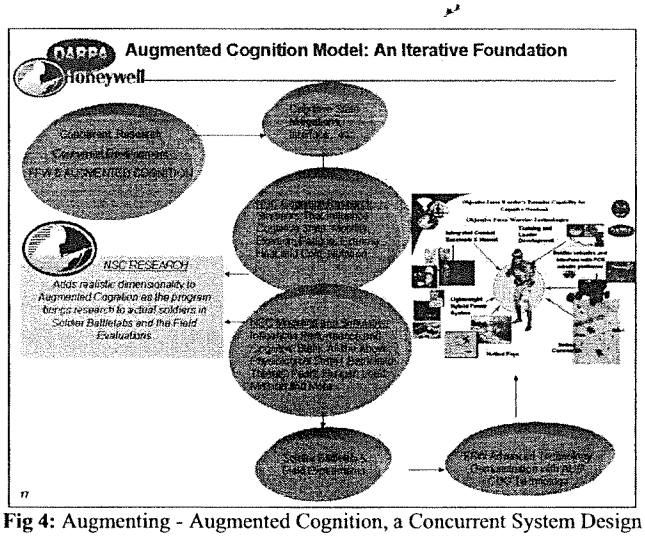

Fig 4: Augmenting - Augmented Cognition, a Concurrent System Design

Performance may be assessed through a number of different experiments to include target acquisition and weapon performance. Army researchers augmenting the program through additional research will look at cognitive processes and complex task performance based on operational scenarios provided by Future Force Warrior. There is also the possibility of designing experiments with both contractor teams in the Joint Rotational Training Center environment. This "real life-like" situation using man-portable communication and information management equipment in this type of experiment might be useful to evaluate how to increase our military's ability to think asymmetrically.

1.5 Conclusion

The Augmented Cognition program experiments thus far show promise for developing a conceptual solution that mitigates informational bottlenecks by classifying cognitive state. Using knowledge of an individual's cognitive state and the development of a communications scheduler protocol to disseminate prioritized communication and information through various modalities to the Warfighter in a hostile environment appears to be an approach that may prove successful in improving overall warfighter performance. With transformational developments expecting more from the individual warfighters, they will continue to be provided with more information technologies that add to their cognitive burden. Throughout the remainder of both Augmented Cognition and Future Force Warrior programs, research and experiments pertaining to the use of physiological, neurophysiological and environmental stress information will continue. The findings of the experiments and evaluation of warfighter performance will advantageously guide developments of information systems to provide future operational capabilities that will maximize the warfighter potential.

1.6 Acknowledgements

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The Natick Soldier Systems Center would like to acknowledge CDR (Sel.) Dylan Schmorrow, DARPA Program Manager of Augmented Cognition Program for recognizing the limitations on warfighter performance based on an overloaded human's cognitive state and developing a conceptual solution that mitigates informational bottlenecks. Augmented Cognition technology integrated into the Future Force Warrior system, as an optimal platform, is expected to maximize the warfighter potential.

Dr. Jim Sampson, Natick Soldier Systems Center, Research Psychologist is acknowledged for his guidance, oversight and research in the program and for linking the experimental designs and technology developments directly to user based on tasks analysis and evolving transformational concepts of operation.

Ms. Cynthia Blackwell, Future Force Warrior Human Factors and Training Lead, is acknowledged for ensuring Augmented Cognition is connected to FFW and that the Augmented Cognition team has access to all scenario developments.

The Honeywell Labs extended team, led by Dr. Trish Ververs, Augmented Cognition Principal Investigator, is acknowledged for the high quality teaming approach to successful developments that have the potential to change the manner in which warfighters manage high volumes of information and simultaneously enhance performance.

Any opinions, findings, conclusions or recommendations expressed herein are those of the author's and do not necessarily reflect the views of DARPA or the U.S. Army.

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FOUNDATIONS OF AUGMENTED COGNITION

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Foreword

With the rapid introduction of highly sophisticated computers, (tele) communication, service, and manufacturing systems, a major shift has occurred in the way people use technology and work with it. The objective of this book series on Human Factors and Ergonomics is to provide researchers and practitioners a platform where important issues related to these changes can be discussed, and methods and recommendations can be presented for ensuring that emerging technologies provide increased productivity, quality, satisfaction, safety, and health in the new workplace and the Information Society.

The present volume is published at a very opportune time, when the Information Society Technologies are emerging as a dominant force, both in the workplace, and in everyday life activities. In order for these new technologies to be truly effective, they must provide communication modes and interaction modalities across different languages and cultures, and should accommodate the diversity of requirements of the user population at large, including disabled and elderly people, thus making the Information Society universally accessible, to the benefit of mankind.

Augmented Cognition is a rapidly evolving disciple being the brain child of Dylan D. Schmorrow, a Program Manager at DARPA and ONR, and Commander in the U.S. Navy. This book is the proceedings of the 1st International Conference on Augmented Cognition jointly held with HCI International 2005 Conference in Las Vegas, July 22–27, 2005. The 2nd International Conference on Augmented Cognition will be held in conjunction with the Human Factors and Ergonomics Society 50th Annual Meeting, October 15–16, 2006 at the San Francisco Hilton in San Francisco, CA. The 3rd International Conference on Augmented Cognition will be held jointly with HCI International 2007 in July 22–27, 2007 in Beijing, P.R. China (http://www.hcii2007.org/).

The book's five sections and 24 chapters present the theoretical foundation and operational models for the understanding, design and operation of engineering systems requiring increased interaction with humans. The effectiveness of the operation of such systems is significantly unchanged through augmented cognition integration into the human information processing utilized for decisions and actions.

The book would be of special value to individuals working in human-computer interaction, human factors and ergonomics and cognitive science who are interested to learn today where the future of the discipline will lead.

—Gavriel Salvendy
Purdue University, USA
Tshighua University, P.R. China