Ubiquitous Augmented Cognition

Anna Skinner[1], Clementina Russo[1], Lisa Baraniecki[1], and Molly Maloof[2]

[1] AnthroTronix. Silver Spring, MD, Unites States of America
[2] 3Scan. San Francisco, CA, United States of America
{anna.skinner,clementina.russo,lisa.baraniecki}@atinc.com,
mmaloof@gmail.com

Abstract. The paradigm shift in pervasive computing drives human-computer interaction (HCI) toward complex domains, where novel approaches to support human cognition in mobile and dynamic environments are necessary. The field of Augmented Cognition (AugCog) provides a scientifically-grounded approach toward intrinsic human information processing and challenges associated with data-intensive systems, leveraging empirically-based HCI solutions that account for human cognitive limitations. Applying this to ubiquitous computing demands unobtrusive technologies capable of time-dependant user assessment in various environments. Technological advances and utilization of personal activity reporting at a consumer level have made ubiquitous AugCog a necessary implementation. Such technologies (i.e., head-mounted displays) produce a deluge of data, generating a need for experimentally-based metrics, algorithms, and adaptive interfaces for closed-loop, synergistic human-technology performance systems. A Ubiquitous AugCog framework is proposed along with an essential use case to guide the design of multi-modal human performance assessment and optimization tools beyond laboratory settings.

Keywords: HCI, Augmented Cognition, Ubiquitous Computing, Pervasive Computing.

1 Introduction

With a growing trend toward the use of embedded computing technologies to support the human cognitive system within mobile and dynamic environments, ubiquitous computing has emerged as a prevalent paradigm in which human-computer interaction (HCI) is not limited to computer terminals and traditional work or learning environments. As the pervasive computing paradigm shift drives HCI toward increasingly diverse and complex domains and contexts, novel approaches are needed to support the human cognitive system, particularly within mobile and dynamic environments. Microprocessors are being embedded in wearable, portable, and even in vivo devices, and the ubiquity of the smartphone and real time access to the world's knowledge repositories has been altering the manner in which humans access and process information. This paradigm shift in computer use contexts has resulted in a parallel shift in current HCI, and specifically interface modality, paradigms. Keyboards and mice,

D.D. Schmorrow and C.M. Fidopiastis (Eds.): AC 2014, LNAI 8534, pp. 67–77, 2014.

as well as large visual displays, are increasingly replaced by respective input and output modalities that are better suited for mobile technologies and dynamic environments. Wearable computing technologies are driving the integration of HCI into an increasingly broad spectrum of occupational and everyday activities. The recent release of Google Glass is beginning to drastically alter the cognitive computing landscape. While head-mounted display (HMD), heads-up display (HUD), and augmented reality (AR) technologies have been available for decades, the Google brand and price point are projected to bring the Glass wearable computer and optical head-mounted display (OHMD) to unprecedented numbers of consumers. The use case scenarios and users themselves will vary vastly from traditional HMD, HUD, and AR users and applications. The initial functionality and applications will be limited; however, Google is already promoting sales to developers and researchers in anticipation of Glass-specific app development, as well as implementation and exploration within cutting edge research and development (R&D) efforts. Undoubtedly at the forefront of such efforts will be novel approaches to capitalize on the embedded eye-gaze tracking capability.

Simultaneously, a tipping point has been reached within personal physiology and activity tracking and reporting, including DNA sequencing at a consumer level. Not only are consumers increasingly demonstrating interest in understanding their own physiology and willingness to wear computing devices capable of tracking physiological and physical activities, but also a compulsion to share such information via social media. While tracking of social media status updates alone can provide a detailed picture of an individual's nutrition, exercise, and sleep routines; users are increasingly using technology devices to track and report increasingly high fidelity activity, nutrition, and sleep data. This phenomenon has also contributed to widespread use of biofeedback such as heart rate variability to monitor and modulate stress and mood throughout the day. Finally, the emergence of consumer market-priced products, to include consumer electroencephalography (EEG) devices, has led to the delivery of high fidelity/sensitivity measures of real-time and over time human cognitive and emotional function into the hands of lay users.

2 Pervasive Computing

As microprocessors are being incorporated into devices as a standard, there is an emergence of the accessibility of ubiquitous computing. Objects that were primarily considered to transmit unidirectional information to the end-user, now have embedded sensors to allow for pervasive computing. This allows for the utilization of enhanced contextual information by the end-user. Augmented context-awareness could also operate as a guide for interactive user interfaces [2]. This prevalence of pervasive computing capabilities therefore lends itself to a paradigm shift in computer interface modalities and, further, a concurrent shift in human computer interaction.

Within the field of human computer interaction, pervasive computing has facilitated the paradigm shift from an explicit to an implicit interaction [12]. Typically, with human-human interaction, there is a higher availability of contextual information. Human-computer communication, however, does not contain as large of a contextual bandwidth [2]. With the emergence of novel ubiquitous computational metrics, new interaction methods are being established. Such an increase in the quality of awareness on the computational end will facilitate a motion towards more effective human-computer interaction. These new interaction methods also allow for pervasive computing to perform particular functions autonomously.

Future applications of ubiquitous computing would include its integration with augmented cognition. Such an intersection would provide a constructive outlet towards which the processed information can be applied. This has been outlined as a fundamental requirement for implicit interaction, with two other requirements identified as the ability to collect information and the ability to process information [12]. Ubiquitous computing provides a platform on which a theoretical framework for the enhancement of human performance can be initiated.

3 Augmented Cognition

The field of Augmented Cognition (AugCog) provides a scientifically-grounded approach to addressing the intrinsic human information processing and manipulation challenges associated with complex and data-intensive digital systems, leveraging empirically-based HCI solutions that assess and account for human cognitive limitations. The application of AugCog principles to ubiquitous computing highlights a need for unobtrusive technologies capable of supporting real-time and over time user assessment in operational and everyday environments.

AugCog provides an innovative approach to HCI challenges, centering on the ability of technology to measure human information processing and a user's cognitive state with the goal of supporting the design of closed-loop systems to modulate information flow with respect to the user's cognitive capacity in real time. Research within the domain of AugCog has demonstrated the technical feasibility of utilizing psychophysiological measures to support real-time cognitive state assessment and HCI reconfiguration to mitigate cognitive bottlenecks within a wide variety of operational domains.

Research within the field of AugCog requires the monitoring of the individual's real-time cognitive state. This information can be used to determine the information processing needs such that the human-system interaction can adapt to the individual. The goal of such a system seeks to mitigate informational bottlenecks that might occur given an excess of cognitive workload. The understanding of such a system and the bridge it provides for the interactions between humans and computers could provide substantial groundwork for an enriched HRI experience. Including AugCog principles in design considerations for HRI systems could also result in lower cost systems that operate at higher efficiency than those currently available [9].

At the core of all AugCog research lies the necessary ability to obtain the "operator functional state" in order to provide a basis for real-time adaption of the system [10]. This "closed loop state" is a vital principle for most, if not all, AugCog applications. Placed in a laboratory setting, AugCog practices resulted in a 150% improvement in performance on a working memory task. When later in an operational environment, an AugCog implemented system was shown to have the capability to detect high workload state and employ mitigation measures, thus continuing to exhibit improved task performance for the individual [19].

Initial technical demonstrations conducted under the Defense Advanced Research Projects Agency (DARPA)-funded research program explored the potential for developing cognitive state gauges to drive real-time HCI adaptations within the context of simulated flight, driving, ship-based, and dismounted warfighter task scenarios [7]. However, demonstration within real world task environments presents significant science and technology challenges.

Recent technological advances, combined with unprecedented adoption of personal physiology/activity tracking and reporting at a consumer level, has resulted in a tipping point in which ubiquitous AugCog is becoming both a reality and a necessity. Increasingly prevalent data-rich environments across domains such as medicine, education, and information analysis necessitate novel and intelligent approaches to overcome inherent human information processing limitations in both human-technology and human-human interactions [16]. Similarly, the prevalence of portable and wearable computing technologies such as consumer head-mounted displays and physiological assessment technologies is producing a paralyzing deluge of data, which users are unequipped to process or utilize effectively.

4 Wearable Physiological Monitoring Devices

Wearable technology has emerged as one of the most exciting frontiers in technology of the 21st century. Consumer health tracking has largely relegated itself into a few categories including physical activity, nutrition, sleep, weight control, posture, emotion, brainwave, pregnancy, fertility, and child monitoring. There are a variety of companies breaking into the consumer health diagnostic space, some of which involve remote sensing capabilities for vital signs, sensors, and home laboratory test devices. Many individuals have complained that there is limited access to raw data and the algorithms layered upon the information that companies use to analyze the information.

The desire for better health through better metrics spurred the movement entitled, “the Quantified Self”. Modern healthcare largely ignores wellness aside from vague recommendations for patients to “eat right” and “exercise more.” This is due to the absence of wellness education in modern medical student curriculums. But, we have learned that it is not just information about behaviors that can lead to improved health, there must be actionable insights gleaned from trends in the data. Many individuals have complained that there is limited access to raw data and the algorithms layered upon the information used analysis. Open data would help us better understand how sleep, nutrition, and activity tracking impact health outcomes. Integration across platforms through uniform units of measure would improve research into data sets. We are beginning to see intelligent ways of viewing the data from the various devices through companies such as TicTrac, RevUp, and Bioniq Health. Whether or not consumers and companies extract meaning and value from these entities has yet to be determined. The medical community has complained that there is a lack of scientific validity in the wearable monitoring space and have demanded more information on the measurements behind these popular devices. For example, most home "sleep monitors" that claim to discern between REM and NREM sleep have little relevance to clinical polysomnography and are generally considered to be extremely poor indicators of sleep quality by the medical community. However, recent partnerships between leading academic institutions and technology companies aim to tackle this exact problem. The landscape of personal activity tracking involves active engagement on the part of the consumer either with the device or the attached application. There is anticipation into the future that these devices will monitor behavior passively, will become more invisible, and will blend more into daily life. It is hoped that through better research and through establishing clinical validity in rigorous scientific research studies and clinical trials that the back-end equations used to interpret information will be accurate, reliable, and will translate to improved user outcomes.

5 Research Gaps

A primary challenge presented by current wearable/portable physiological monitoring technologies is the development of scientifically-grounded methods for use and interpretation of resulting data by consumers, as well as health and research professionals. The research community has yet to fully decode and effectively utilize individual psychophysiological measures, let alone combined measures having varied latencies and time courses in response to complex internal and external stimuli.

First and foremost, the quality of data acquired and the fidelity of algorithms employed for data analytics and interpretation are critical to identifying meaningful correlations across physiological, environmental, subjective, and performance-based measures. The extension of AugCog principles to pervasive contexts necessitates effective artifact removal and robust algorithms to differentiate signal from noise within unstructured and unpredictable environments. Environmental considerations must include any factors capable of impacting user performance such as ambient light, noise, and distracters. Ambient conditions may dictate the optimal modality for interaction with the system (i.e., natural language processing, haptic feedback, etc.), and may assist in the diagnosis and prediction of contextually-driven cognitive stress. Girolamo (2005) [4] identified a range of cognitive state stressors relevant to dismount soldiers, including mobility, exertion, fatigue, cold, heat, hunger, fear, and isolation. Contextual considerations must also include not only the primary task, but also any secondary tasks and peripheral, non-task stimuli that may interfere with task performance. Artifact removal often relies on robust determinations of critical versus non-critical information, as well as the determination of task-relevant and irrelevant data. An example within HCI is real-time assessment of attention allocation. In order to determine what a user is attending to, eyetracking alone may not be sufficient as the user may be attending to auditory information while looking at visual stimuli. A novel approach is described by Hale, Fuchs, and Berka (2008) that combines

EEG-based event-related potentials (ERPs) with eyegaze fixations to provide time-locked cognitive state assessment that correlates to realtime environmental stimuli. Fusion of metrics represents a primary challenge to be addressed and validated within the research community. While past and ongoing research efforts within the fields of AugCog and Operational Neuroscience have begun to address metric fusion issues, significant gaps exist, particularly with relation to time synchronization and fusion of metrics having variable sampling rates, latency responses, and time courses. For example, when examining such metrics, a simple "snapshot" will not suffice to highlight meaningful cross-metric correlations. Dynamic visualization and analytic capabilities are needed to identify dependant and mediating variables over time, as well as in real-time. Additionally, the fusion of subjective metrics with objective measures presents a challenge in terms of both data acquisition and analysis.

An additional consideration, which has yet to be addressed within the operational neuroscience literature, is the detection of triggering events and stimuli that are generated internally by the user, such as thinking about something stressful, and therefore unobservable using traditional or individual assessment metrics. Finally, individual differences must be taken into account, and in many cases may necessitate individual baseline assessments in order to generate accurate diagnostic and predictive indicies relevant to HCI within and across users.

6 Ubiquitous AugCog Framework

Ubiquitous Augmented Cognition is a conceived paradigm in which heterogenous metrics of user, task, and environmental state drive computing device interactions across dynamic contexts with the goal of enhancing human performance and interaction experience. Ubiquitous AugCog devices are completely connected and constantly available. Ubiquitous AugCog relies on the convergence of wireless technologies, advanced electronics and the Internet. The goal of Ubiquitous AugCog is to create products that seamlessly scaffold the full range of cognitive processes. The products are connected to the Internet allowing for real-time processing and cloud computing for complex problem solving and decision-making.

While the traditional AugCog paradigm provides a framework for physiological data fusion to generate gauges of user cognitive state capable of driving HCI adaptations in a variety of semi-structured task environments, the ubiquitous AugCog paradigm seeks to extend this capability to less structured environments, requiring environmental constraints to be assessed and factored into real-time interface adaptations.

We propose a research methodology to support instantiation of Ubiquitous AugCog to provide intelligent real-time measurement, fusion, analytics, and interpretation of heterogeneous metrics to enhance human cognitive performance within the context of human-computer interaction across domains and contexts. Specifically, this framework is designed to address the following:

1. Meaningful interpretation of combined objective and subjective measures of physiological data in real-time and over time as these measures relate to resulting cognitive performance (mood, attention, memory, etc)

2. Intelligent use of resulting real-time and over time assessments to predict cognitive performance breakdowns and drive effective adaptations to a user's HCI experience
3. Determine how and when to reduce cognitive load and assist in contextually adapting the delegation of taskwork functions to suit the dynamics of a team member's cognitive/physiological state and environmental conditions outside of traditional laboratory and workspace settings.

The goal of such a methodology is to extend human cognitive capabilities such that functional operations can be carried out efficiently and completely.

6.1 Fusion of Heterogeneous Metrics

A primary challenge to be addressed within this framework is the synchronization and fusion of heterogeneous metrics. To make sense of a compendium of heterogeneous information, researchers must have a prepared key with which to decode it. Namely, it is foremost important that data is collected under thoughtful intentions, set with foresight about the type of information that can be rendered from it. In the research context, it is often the case that more information is better as it is usually beneficial to be in a position to have to exclude excess information than to come to find that whatever was collected was insufficient to draw any meaningful conclusions. Essentially, if there is more information to mine then there is a greater potential that desirable outcomes will present themselves in it.

Nonetheless, if a large portion of the measurements made are unintentionally redundant (literally or proximally), ambiguous or corrupted, then the data will not realistically produce meaningful results let alone be elucidating of the interactive dynamics in question which drove the collection effort in the first place. Hence, it's imperative that set guidelines are consistent with the given boundary conditions of the experiment as the capacity to answer the study questions is dependent upon this adherence: a plethora of methods to measure any one particular event may exist, but not all of them are universally applicable to any given situation. Ultimately, the volume of raw, heterogeneous data that results from the collection effort should be "camera-ready" for meaningful curation; namely, the measurements made should provide answers to the specific queries posed to them.

6.2 Real-Time Adaptive HCI

A primary objective of AugCog paradigms is to drive real-time interaction adaptations based on user cognitive state assessments. The proposed Ubiquitous AugCog paradigm seeks to extend this to pervasive computing within a wide variety of task domains, applications, and computing interface platforms, as well as across a diverse user population. High-level design guidelines and instantiation of closed-loop adaptive interaction techniques applicable to warfighters in hazardous environments may also bare relevance to consumer computing products such as commercial head-worm displays to support increased cognitive throughput and reduced errors within a multi-tasking context. Envisioned HCI adaptations include automated adaptive augmented reality display content, intelligent alerting, intelligent modality selection, and physiological entrainment to optimize performance.

6.3 Team Taskwork Delegation

We propose that heterogeneous metrics taken on a team member's physiological and cognitive states, coupled with measures of environmental and human-computer network interaction factors should together support the ultimate interpretation, analysis, prediction, and enhancement or mitigation of human performance factors within a ubiquitous HCI paradigm.

The complexity of sociotechnical systems requires continuous adaptation from team members and team managers to efficiently run an operation; specifically, the design of a resilient system to support adaptive behavior is key for operational efficiency [8]. The design of a resilient system is founded in how team members actually perform rather than how they are expected to perform, with a focus on the system's capability to operationally succeed in both expected and unexpected conditions [6]. The ability to effectively allocate taskwork functions is a primary component to a resilient design, and the process of function allocation is dependent upon the moment-to-moment capabilities of each team member in the loop [3], i.e., in terms of proper allocation and dissemination of taskwork functions, the time-sensitive cognitive, physiological, mental and emotional status of any team member affects the overall efficiency and progress of the system's assigned tasks.

For maximum efficiency, the right tasks need to be precisely delegated to the right team members at the right time, and to do this feasibly, a system of checks must be enacted to assess the time-sensitive performance of each individual team member. The performance metrics of each member may also plausibly serve to demonstrate either the similarity indicators of the team's collective performance or the unique links that sufficiently uphold or effectively denigrate the work process [18].

7 Use Case Instantiation

With regard to the human-computer interaction design, a host of inherent boundary conditions to be considered lie therein, namely those determined by the cognitive and information processing limitations of the human team members as affected by the physical, physiological and environmental burdens that each member may experience. For example, motion sickness can result from teleoperation tasks, particularly in instances when the team member teleoperates a robotic asset while in some kind of moving vehicle. The perceived motion of the unmanned asset and the motion experienced directly by the operator within his or her own environment generates a perceptive mismatch that induces motion sickness. An AugCog-based system can be used to gauge and correct the physiological effects of the physical and virtual motion experienced by the operator, thus mitigating the effects of inefficient or incomplete taskwork flow.

A current effort is being undertaken to design, develop, and validate an intentionally packaged suite of sensors arranged to procure unobtrusive, real-time capture, synchronization, and analysis of environmental, physiological, physical, and subjective measures associated with motion-induced performance degradation within sea-based task environments. This multi-dimensional assessment technology called, Portable Automated Sensor Suite (PASS) Motion-induced User Symptomotology Toolkit for Evaluating Readiness (MUSTER) will provide a valuable tool for researchers investigating the time-sensitive effects of motion-induced mishaps, fatigue, and sickness, and it will also provide a deployable tool for operational use in determining "fitness for duty".

With a suite of sensors measuring a multitude of parameters, it is important to maintain the integrity of the experimental hypothesis - with greater information accessibility is greater potential to both anticipate a desired outcome and thus succumb to confirmation bias, as well as to lose sight of the intended design altogether. The path to avoiding either of those results is paved in properly curating the information at hand. From a first-principles data science perspective, the primary order of business is to temporally arrange the data and look for time-sensitive patterns across all of the information gathered. If the construct is valid and the measurements made are the ones that the design purports, then observable correlations between measured parameters can be taken through another layer of analysis. Specifically, if many parameters seem to first-order correlate well with one parameter in time, then second-order physiological and cognitive signatures may be observed when all affected parameters are normalized for the effects of the driving parameter: e.g., heart rate variability may temporally increase with increases in every other measured physiological and cognitive parameter and thus to remove the effects on other parameters driven by heart rate variability, we normalize the measures by heart rate variability. We perform this type of analysis to understand the interactive dynamics of the test case, that is essentially, to best clarify the interplay between the human-computer interaction, environmental factors, and team member responses such that characteristic markers for events such as motion-induced sickness can be verifiably identified and corrected.

Ideally, a combination of objective and subjective measures could be used to develop validated, multi-dimensional algorithms and constructs to enable effective assessment, prediction, and prevention of motion-induced human performance degradation within a multitude of training and operational environments, including both apparent motion, such as that associated with simulation-based training and teleoperation of remote unmanned vehicles; and actual motion within ground, sea, air, and spaceflight vehicles.

8 Future Directions

Future directions will seek to extend this paradigm to research targeting optimization of human performance across data-rich task environments such as the medical and information analysis domains. For example, DARPA has identified a need for science and technology to support a novel paradigm of domain-specific indexing and search capabilities, including configurable interfaces for search and analysis to defeat human trafficking enterprises. A primary shortcoming of current search interfaces is the inability to interact with the majority of web content in an efficient manner that supports parallel processing, information sharing across sessions and investigators, and dynamic manipulation of content. Instantiation of the Ubiquitous AugCog paradigm within such task domains may support enhanced capabilities of teams of human investigators to more effectively interact with complex, multimodal data sets. This paradigm also has inherent implications for future R&D within both the military and civilian health and wellness domains, which will be further explored.

References

1. Besnard, D., Hollnagel, E.: Some myths about industrial safety. CRC technical report (2013)
2. Abowd, G.D., Dey, A.K.: Towards a better understanding of context and context-awareness. In: Gellersen, H.-W. (ed.) HUC 1999. LNCS, vol. 1707, p. 304. Springer, Heidelberg (1999)
3. Feigh, K.M., Pritchett, A.R.: Requirements for Effective Function Allocation: A Critical Review. J. Cog. Engineering & Decision Making (2013)
4. Girolamo, H.J.: Augmented cognition for warfighter: A beta test for future applications. In: 11th Annual HCI Human Computer Interaction International Conference, Las Vegas, NV (2005)
5. Hale, K.S., Fuchs, S., Berka, C.: Driving EEG cognitive assessment using eye fixations. In: Applied Human Factors and Ergonomics 2nd International Conference, Las Vegas, NV (July 2008)
6. Hollnagel, E.: Resilience engineering and the systemic view of safety at work: Why work-as-done is not the same as work-as-imagined. Bericht Zum (2012)
7. Morrison, J.G., Kobus, D.A., Brown, C.M.: DARPA Improving Warfighter Information Intake Under Stress. Augmented Cognition (2006)
8. Rankin, A., Lundberg, J., Woltjer, R., Rollenhagen, C., Hollnagel, E.: Resilience in Evveryday Operations: A Framework for Analyzing Adaptations in High-Risk Work. J. Cog. Engineering and Decision Making (2013)
9. Reeves, L.M., Schmorrow, D.D.: Augmented Cognition Foundations and Future Directions—Enabling “Anyone, Anytime, Anywhere” Applications. In: Stephanidis, C. (ed.) HCI 2007. LNCS, vol. 4554, pp. 263–272. Springer, Heidelberg (2007)
10. Reeves, L.M., Schmorrow, D.D., Stanney, K.M.: Augmented Cognition and Cognitive State Assessment Technology – Near-Term, Mid-Term, and Long-Term Research Objectives. In: Schmorrow, D.D., Reeves, L.M. (eds.) HCII 2007 and FAC 2007. LNCS (LNAI), vol. 4565, pp. 220–228. Springer, Heidelberg (2007)
11. Satyanarayanan, M.: Pervasive Computing: Vision and Challenges. IEEE Personal Communications (2001)
12. Schmidt, A.: Implicit Human Computer Interaction Through Context. Personal Technologies (2000)
13. Schmorrow, D.D., Kruse, A.A.: Augmented Cognition. In: Bainbridge, W.S. (ed.) Berkshire Encyclopedia of Human-Computer Interaction, pp. 54–59. Berkshire Publishing Group, Great Barrington (2004)

14. Schmorrow, D., Stanney, K., Wilson, G., Young, P.: Augmented Cognition in Human-System Interaction. In: Salvendy, G. (ed.) Handbook of Human Factors & Ergonomics, 3rd edn., pp. 1364–1384. Wiley, Hoboken (2006)
15. Sharp, H., Rogers, Y., Preece, J.: Interaction Design: Beyond Human-Computer Interaction, 2nd edn. John Wiley & Sons, Ltd, West Sussex (2007)
16. Skinner, A., Long, L., Vice, J., Blitch, J., Fidopiastis, C.M., Berka, C.: Augmented interaction: Applying the principles of augmented cognition to human-technology and human-human interactions. In: Schmorrow, D.D., Fidopiastis, C.M. (eds.) AC 2013. LNCS, vol. 8027, pp. 764–773. Springer, Heidelberg (2013)
17. St. John, M., Kobus, D.A., Morrison, J.G.: DARPA Augmented Cognition Technical Integration Experiment (TIE). SPAWAR Systems Center Technical Report, San Diego, CA (December 2003)
18. Sætrevik, B., Eid, J.: The "Similarity Index" as an Indicator of Shared Mental Models and Situation Awareness in Field Studies. Journal of Cognitive Engineering and Decision Making (2013)
19. Ververs, P.M., Whitlow, S.D., Doneich, M.C., Mathan, S.: Building Honeywell's Adaptive System for the Augmented Cognition Program. In: Schmorrow, D.D. (ed.) Foundations of Augmented Cognition, pp. 460–468. Lawrence Erlbaum Associates, Mahawah (2005)