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CSERIAC GATEWAY

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In this issue:

CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Ft. Belvoir, VA, technically managed by the Armstrong Laboratory Human Engineering Division, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

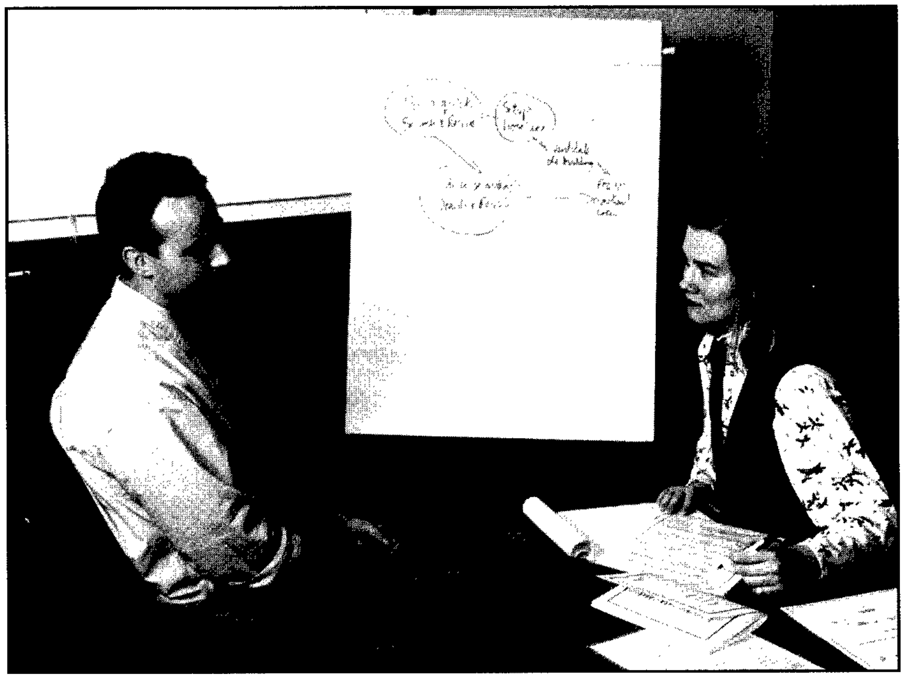

Figure 1. CTA techniques typically include interviewing subject-matter experts. Photograph by Robert Hock.

Cognitive Task Analysis: Bringing a Powerful Tool into Wide Use

Laura G. Militello
Gary Klein

Task analytic techniques have played a critical role in the development of training and system design for the past 50 years. Only recently, however, have researchers begun to develop methods focused specifically on capturing the cognitive elements of a task. The use of Cognitive Task Analysis (CTA) techniques to augment behavioral task requirements has become increasingly critical as the nature of the workplace has changed. The transition from the industrial age to the information age has increased, rather than lowered, cognitive demands on humans.

The great success of traditional behavioral task analysis approaches has been to show that tasks can be decomposed into behavioral elements, focusing on elements that can be seen. These elements can then be targets for training or system design issues. Behavioral task analysis has provided a significant step forward in achieving reliable and effective courses of instruction, and usable systems.

Continued on page 2

Definition and Examples

CTA propels us further, providing a means to examine the cognition that underlies the behaviors identified using traditional task analysis techniques. The focus of CTA is on difficult decisions, judgments, and perceptual skills, elements that cannot be seen as overt behaviors, but play an important role in many tasks. Cognitive Task Analysis is the description of the cognitive skills needed to perform a task proficiently. This definition encompasses both knowledge elicitation methods, usually in the form of interviews with subject-matter experts (see Fig. 1), and knowledge representation methods or means to depict and communicate the cognitive information. It is not enough to elicit cognitive information; the information must also be structured in a usable format if the analysis is to be applied in a meaningful way.

Many powerful techniques fall within this definition (for a comprehensive review of current CTA methods, see Cooke [1994]). CTA has been successful across a variety of domains, including system design, training design, interface design, accident investigation, and consumer research. Because CTA techniques have been developed independently in research throughout the world, there is considerable variety in approach, emphasis, and resource requirements.

For example, Hall, Gott, and Pokorny (1995) used the Precursor, Action, Result, and Interpretation (PARI) method to develop an avionics troubleshooting tutor. This technique involves the use of subject-matter experts to identify issues to probe, and to aid in the elicitation of cognitive information from other subject-matter experts. They are asked to generate lists of potential equipment malfunctions and then engage in group discussions to reach agreement regarding a set of categories of malfunctions. Experts then design representative scenarios illustrating each category of malfunctions. These scenarios elicit information from an independent set of subject-matter experts regarding how they would approach the situation in each scenario. Focused questions are asked of the subject-matter expert to identify actions or solution steps and the precursors or reasons for the expert's actions. The expert is then asked to interpret the system's response to his/her actions. The knowledge gathered is represented using flowcharts, annotated equipment schematics, and tree structures. The PARI technique is also being applied to other difficult problems such as weather forecasting and command-and-control teams. Clearly this is a very thorough, comprehensive technique. It is relatively labor intensive for both the researchers and the subject-matter experts with considerable emphasis on knowledge elicitation.

In contrast, Gordon and Gill's (1992) Conceptual Graph Analysis (CGA) technique for CTA emphasizes knowledge representation. This technique can be used exhaustively or in a more focused manner, depending on the researcher's goals. The CGA technique was built around conceptual graph structures (see Fig. 2) adapted from representation techniques used in artificial intelligence research. This technique emphasizes knowledge representation, in that the goal is a conceptual graph structure which can be transitioned to expert system and artificial intelligence applications. The knowledge elicitation portion of this CTA consists of asking the subject-matter expert to respond to specific questions and then representing the information in a conceptual graph structure. This is central to the interview as it provides a shorthand representation to which the interviewer and the expert can refer.

Klein, Calderwood, and Clinton-Cirocco (1986; see also Klein, Calderwood, & MacGregor, 1989) developed the Critical Decision method, which emphasizes knowledge elicitation and requires skilled interviewers to carry out the method. The Critical Decision method involves in-depth interviews in which a subject-matter expert is asked to recount a challenging or critical incident in which his/her skills were needed. The incident is then probed for decision points, shifts in situation assessment, critical cues leading to a specific assessment, cognitive strategies, and potential errors. The Critical Decision method lends itself to several knowledge representations. Often narrative accounts are used. In other projects, knowledge representation is organized in the form of a Cognitive Requirements Table which lists the specific cognitive demands of the task, as well as contextual information needed in developing relevant training and/or system design recommendations.

Applications of Cognitive Task Analysis

The following paragraphs describe how we have applied the Critical Decision method and other CTA techniques to both system design and training development across a variety of domains.

Armstrong Laboratory at Wright-Patterson AFB sponsored a CTA of experienced researchers, so that this information could be fed back into the organization (Hutton & Klein, 1996). The loss of corporate memory that occurs as experienced people leave an organization is a key problem for many established organizations. In recognition of this potential problem, particularly as it applies to successful scientists, a CTA involving a group of scientists and engineers was initiated. The Critical Decision method was used to interview 11 experienced researchers, focusing on a project in which the researcher had played a significant role and which had provided concrete benefit to the Air Force. Several attributes identified characterized successful research projects. For example, successful scientists select projects that are newly solvable due to advanced technology, and tend to avoid problems not yet ready for progress. In addition to identifying common

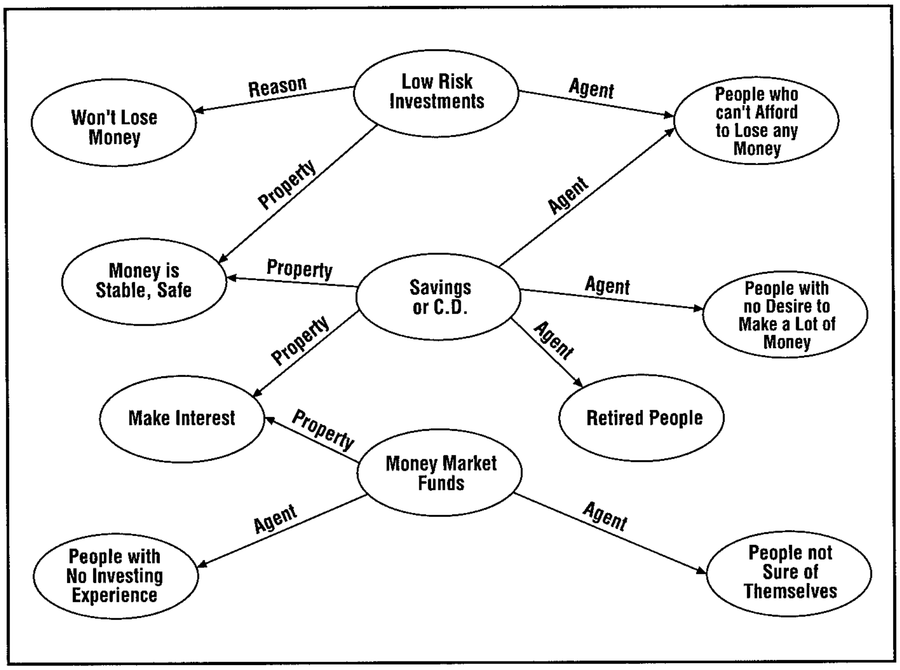

Figure 2. Moore and Gordon's (1988) conceptual graph for investment knowledge. Reprinted with permission from Proceedings of the Human Factors Society 32nd Annual Meeting, 1988. Copyright 1988 by the Human Factors and Ergonomics Society. All rights reserved.

features of successful projects, recommendations were made to encourage the initiative of laboratory personnel and increase opportunities for success. Plans are in place to publish and disseminate these findings and recommendations throughout the organization, so that scientists at all levels of the Armstrong Laboratory have access to them.

In a study funded by the Federal Aviation Administration (FAA), CTA methods were used to better understand the job of airport baggage screeners (Kaempf, Klinger, & Wolf, 1994), who have, at most, five seconds to judge whether a passenger is carrying dangerous items. Thousands of these assessments are made every day, making it difficult for the subject-matter experts to remember a critical incident. In this case, researchers observed baggage screeners at work and used their observations to identify interesting incidents. Critical Decision method probes were then used to probe real-life incidents shortly after they occurred. Current training teaches screeners to recognize the X-ray images of various threat items only. This CTA revealed that baggage screeners build large mental libraries of image patterns, particularly of non-threat items. These image libraries enable screeners to quickly examine the contents of a bag and weed out innocuous items, leaving only those images that are large and dense, or that they don't recognize. These findings have important implications for the way baggage screeners are trained.

A CTA was conducted consisting of Critical Decision method interviews with 13 weapons directors who work on the Airborne Warning and Control Systems (AWACS) aircraft. One goal of this project, sponsored by the Armstrong Laboratory Crew Systems Directorate, was to redesign the weapons director CRT interface to better meet the needs of the changing battlespace, which includes an increasingly cluttered and dynamic airspace. The results of this CTA were interface recommendations to reduce the workload and increase situation awareness of weapons directors (Klinger, Andriole, Militello, Adelman, Klein, & Gomes, 1993). These included the use of color to more easily differentiate land from sea; the use of colored circles to highlight high-threat tracks and high-value assets; the transfer of side-panel functions to an on-screen menu to reduce the need to look away from the scope during intense situations; and the introduction of a quasi-automated nomination feature which would provide suggestions for matching specific friendly aircraft to threats. An evaluation study, using the simulation facility at the Aircrew Evaluation Sustained Operations Performance (AESOP) Center at Brooks AFB, indicated that the redesigned interface markedly improved performance. In simulated exercises, weapons directors showed a significant improvement in reducing the distance enemy aircraft were allowed to approach friendly assets, increasing the number of enemy aircraft shot down, and reducing the number of missiles fired that missed their targets.

CTA was used to develop a better understanding of the knowledge and skills underlying expert weather forecasting in a project funded by the Armstrong Laboratory at Brooks AFB (Pliske, Klinger, Hutton, Crandall, Knight, & Klein, 1997). The Air Weather Service is critical to all Air Force and Army operations. Access to timely and accurate weather information is a key factor in nearly all combat and peacekeeping operations. The task of the weather forecaster is quite complex and poorly understood. To better understand the job and provide recommendations as to how to support this critical function, Pliske et al. conducted observations and in-depth interviews with over 42 forecasters, which revealed that the skill level and experiential background among forecasters is widely varied, and that there is a mismatch between current technology provided and the demands of the forecasting task. These findings suggested improving forecasting performance via improved training, including relevant feedback for job

Continued on page 4

performance and on-the job training; and adaptations of new technologies to accommodate forecasters of different skill levels.

Streamlined CTA

The above examples illustrate the power of CTA for gaining access to difficult cognitive elements across many tasks and domains. However, all these projects have been part of research efforts, conducted by researchers with a background in cognitive science. If CTA methods are to have the same impact as behavioral task analysis techniques, they must be made accessible to practitioners.

To make CTA tools available to a wider community, we have developed streamlined methods. The Navy Personnel Research and Development Center funded a three-year project which resulted in three techniques termed Applied Cognitive Task Analysis (ACTA). The ACTA techniques were designed for Navy Instructional System Specialists and other instructional designers to be used in course design and revision, so that more cognitive information can be included in courses.

These techniques include the *Task Diagram*, aimed at gaining a broad overview of the task; the *Knowledge Audit*, which elicits specific examples of situations requiring expertise and the expert's approach to these situations; and the *Simulation Interview*, which uses a simulation to aid the expert in unpacking rich contextual information about the decision making/problem solving in a specific task. Although the ACTA techniques are less powerful than the other techniques described here, they are easier to learn and apply. An evaluation study has provided data indicating that graduate students trained to use the ACTA techniques obtain accurate, important, cognitive information (Militello & Hutton, in preparation). In addition, multimedia software (Militello, Hutton, & Miller, 1996) designed to train people to use the ACTA techniques is undergoing beta testing. The development and availability of streamlined tools are likely to expand the use and effectiveness of CTA. ●

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Fax: (937) 873-8258

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Calendar

June 16-19, 1997
New Orleans, LA, USA
36th Amercian Society of Safety Engineers Professional Development Conference. Contact ASSE, 1800 Oakton Street, Des Plaines, IL 60018-2187, USA. Tel: 847-699-2929, Fax: 847-699-2929, Email: 73244.562@compuserve.com

June 17-20, 1997
Cincinnati, OH, USA
4th Annual Managing Ergonomics in the 1990's: A Discussion of the Science and Policy Issues. Contact Managing Ergonomics Conference Secretariat, The Pearson Group, 1150 S Washington Street, Suite 210, Alexandria, VA 22314. Tel: 703-683-6334, Fax: 703-683-6407, Email: pgplanners@aol.com

June 29-July 4, 1997
Tampere, Finland
13th Triennial Congress of the International Ergonomics Association, "From Experience to Innovation." Contact Prof. Markku Mattila, Tampere University of Technology, Occupational Safety Engineering, PO Box 589, FIN-33101 Tampere, Finland. Tel: +358-31-3162-621, Fax +358-31-3162-671, Email: mattila@cc.tut.fi

July 14-18, 1997
Cambridge, MA, USA
Fundamentals of Flight Simulation short course, MIT Summer Session. Contact MIT Professional Institute, 77 Massachusetts Avenue, Room 8-201, Cambridge, MA 02139-4307. Tel: 617-253-2101, Fax: 617-253-8042, Email: professional-institute@mit.edu, WWW: http://web.mit.edu/summer-programs/

July 14-18, 1997
Sydney, Australia
INTERACT97. 6th IFIP TC13 Conference on Human-Computer Interaction. Contact INTERACT97 Conference Office, Australian Convention and Travel Services, Unit 4, 24-26 Mort Street, Braddon, GPO Box 2200, Canberra ACT2601, Australia. Tel: +61-6-257-3299, Fax: +61-6-257-3256, Email: interact97@acs.org.au, WWW: http://www.acs.org.au/interact97

July 31-August 3, 1997
Breckenridge, CO, USA
5th International Symposium on Organizational Design and Management (ODAM'96). Contact Ted Brown, 2 Belle Aire Road, Colorado Springs, CO 80906-4204, USA. Tel & Fax: 791-635-8881, Email: jbrown@databahn.net

August 24-29, 1997
San Francisco, CA, USA
HCI International '97. 7th International Conference on Human-Computer Interaction jointly with 13th Symposium on Human Interface (Japan). Contact Dr. Gavriel Salvendy, General Chair, or Kim Gilbert, Conference Administrator, School of Industrial Engineering, Purdue University, 1287 Grissom Hall, West Lafayette, IN 47907-1287. Tel: 317-494-5426, Fax: 317-494-0874, Email: salvendy@ecn.purdue.edu, WWW: http://palette.ecn.purdue.edu/~salvendy/hci97/

September 8-10, 1997
York, United Kingdom
16th Annual Conference on Computer Safety, Reliability, and Security. Contact Ginny Wilson, SAFECOMP'97, Department of Computer Science, The University of York, York Y01 5DD, United Kingdom. Tel: +44-1904-432782, Fax: +44-1904-432708, Email: safecomp-97@minister.york.ac.uk, WWW: http://www.cs.york.ac.uk/safecomp-97

September 14-17, 1997
Marseilles, France
Seventh International Conference on Vision in Vehicles. Contact VIV7, Applied Vision Research Unit,University of Derby,Mickleover, Derby DE3 5GX, United Kingdom. Tel & Fax: +44-1332-622287, Email: avru@derby.ac.uk, WWW: http://www-hcs.derby.ac.uk/avru/

September 15-20, 1997
Stockholm, Sweden
25th International Congress on Occupational Health (ICOH). Contact ICOH-Congress, National Institute of Occupational Health, S-171 84 Solna, Sweden. Fax: +46-882-05-56.

September 22-26, 1997
Albuquerque, NM, USA
41st Annual Meeting of the Human Factors and Ergonomics Society, "Ancient Wisdom–Future Technology." Contact the Human Factors and Ergonomics Society, PO Box 1369, Santa Monica, CA 90406-1369, USA. Tel: 310-394-1811, Fax: 310-394-2410, Email: hfeshq@aol.com, WWW: http://hfes.org

October 1-3, 1997
Galway, Ireland
International Conference on Revisiting the "Allocation of Function" Issue: New Perspectives. Under the auspices of the Irish Ergonomics Society, International Ergonomics Society (IEA), and the Institute of Industrial Engineers of Ireland. Contact: Edna F. Fallon, Centre for Occupational Health and Safety Studies, Department of Industrial Engineering, University College, Galway, Ireland. Tel: +353-91-52524411, Ext 2770 or 2754; Fax: +353-91-750524; Email: enda.fallon@ucg.ie; WWW: http://indeng.ucg.ie/allfn97

October 7-9, 1997
Yellow Springs, OH, USA
A short course in Anthropometry emphasizing hands-on training in anthropometric measurement and providing background lecture material. Contact Anthropometry Research Project, Inc., PO Box 307, Yellow Springs, OH 45387. Tel: 937-767-7226, Fax: 937-767-9350, Email: bbradt@aol.com

November 6-8, 1997
Kuala Lumpur, Malya
Association of Southeast Asian Nations (ASEAN) Ergonomics 1997 - 5th Southeast Asian Ergonomics Society (SEAES) Conference. A joint SEAES and International Ergonomics Association (IEA) conference in cooperation with the Universiti of Malaysia Sarawak. Contact Dr. Halimahtun Mohd Khalid, Centre for Applied Learning and Multimedia, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Tel: +6082-672311, Fax: +6082-672312, Email: hali@calm.unimas.my, WWW: http://www.unimas.my

May 17-20, 1998
Amsterdam, The Netherlands
4th World Conference on Injury Prevention and Control: Building Partnerships for Safety Promotion and Accident Prevention. Contact Conference Secretariat, Injury Prevention & Control, PO Box 1558, 6501 BN Nijmegen, The Netherlands. Tel: +31-24-323-44-71, Fax: +31-24-360-11-59, WWW: hhttp://www.consafe.nl/conference/

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022

The CSERIAC Interface

Human Factors Tools: What Art Thou? And How Do We Find (and Select) Thee?

Aaron "Ron" Schopper

A variety of efforts have been made over the years to compile lists or catalogs of human factors (HF) tools. The Human Factors and Ergonomics Society (HFES) has formed a task force to learn more about these efforts and CSERIAC has agreed to act as an initial information collection agency and repository. Announcements of this effort are being made jointly in both the HFES' *Bulletin* and in the present issue of *Gateway.*

Survey

In this preliminary effort, we are simply attempting to identify currently existing catalogs or lists of HF tools. Toward this end, we've assembled a brief questionnaire that appears in this issue of *Gateway* (it also appears in inter-active form on CSERIAC's web site, identified below). If you are aware of currently available HF tool catalogs or lists, we would appreciate your completion of either the hard-copy version of the questionnaire that appears herein, or the interactive questionnaire found at our Web site: http://www.dtic.dla.mil/iac/cseriac/survey

If you elect to complete the hard copy, you can return it to CSERIAC either via mail (the address is on the form) or fax (937-255-4823); for DoD respondents, the DSN prefix is 785. (If you can provide information about more than one such source, please photocopy the form and submit one for each—or provide the requested information in a single email.) The results will be consolidated and reported in future articles.

Simple Concept, But . . . *"It depends."*

In preparing to respond to this solicitation, a question that is apt to surface quickly is "What are considered to be *human factors tools?"* As human factors and ergonomics professionals, you already know the answer; it is one which we often provide (with justification—but not without criticism—the subject of another, future column). It is, "*It depends.*"

It depends on your particular niche within the profession (researcher, practitioner, academician...). The common thread that is apt to underlie all answers, however, is that it (an HF tool) is something that assists you in performing your work—a position that is clearly consistent with Webster's second-ranked definition, "Something (as an instrument or apparatus) used in performing an operation or necessary in the practice of a vocation or profession."[1] But the tremendous diversity of tasks addressed within the domain of "human factors" yields a large and diverse set of candidate tools, e.g., subjective measures of mental workload or situation awareness, goniometers, and computer models to assist in the assessment of biomechanical risks associated with lifting activities and repetitive exertions.

It is unlikely that there would be disagreement as to the status of these examples as viable candidates. However, if one assumes a broader perspective, the list could grow substantially. For instance, what about the inclusion of laboratory or field instrumentation? The HF researchers or practitioners who design or evaluate visual or auditory displays might like to have information about spectrophotometers, oscilloscopes, and/or data acquisition hardware and software. And both the researcher and the industrial ergonomist may have need for information regarding portable instruments used to assess light or sound characteristics in the field environment.

It is, perhaps, easier to deal with another potential category of items that might be of interest, i.e., HF-related handbooks and standards. Whereas the information they contain is critical to many applications, the Websterian perspective cited above suggests that they are not tools, per se (unless one argues that they are "instruments of knowledge"). However, given their importance, they might be accommodated in the present (or future) endeavor by including them within a separate section or chapter.

What Do We Want to Know About HF Tools?

Let's pretend that we have successfully dealt with the issue of defining and bounding the HF tool domain, and focus instead on what it is we would like to know about them i.e., what should appear within the eventual catalog for each of the tools included? To simplify matters, let us assume that, regardless of the type of tool, there is agreement regarding the need to provide sufficient information to allow the reader to obtain the tool, i.e., to provide information regarding where it can be acquired and how much it costs. Stopping at this level would greatly simplify the project; however, the result would not be a catalog, it would be a directory much like the "Yellow Pages" of a US telephone book. It would inform one where to obtain a product, but it would provide little assistance in deciding which among the tools listed would best meet the needs of the task to be performed. More information is needed to provide a catalog. But what information? Consider subjective assessment tools and electronic instruments.

What would be useful to an individual wanting to make a decision as to which of several potential subjective workload assessment tools to use? Beyond the "how-to-get-it" information discussed above, one would probably appreciate the inclusion of a brief overview (e.g., not-to-exceed 150 words) of (a) its principal assessment dimension(s) and (b) the ancillary equipment, if any, required (e.g., is a computer for participant data entry?). Beyond this, potential users might wish to know something of the procedures involved (to enable them to assess how resource-intensive it is to apply it and generate results). And some might want to know how others have used it and to learn something of its status and credibility within the HF community. Such needs point to the potential desirability of including a bibliographic listing of pertinent past research and providing an independently written assessment of its merits (e.g., an assessment of its developmental rigor and the extent to which it has been empirically validated).

And (assuming they were to be included) what should be provided for laboratory and field instrumentation? Specifications? Service policies? Warranties? All would be clearly desirable. While surfacely a simple endeavor, the acquisition of such information could be as demanding and fraught with potential pot holes as efforts to provide information about subjective measures. Consider only "specifications." Which ones? (What is important to know will vary with the domain being measured.) Do we publish only the information available in the manufacturer's or supplier's marketing literature (thereby accepting voids wherever they may exist)? The alternative (seeking the opinions of subject-matter experts in each area, asking them to come up with a list of desired information and specifications, and then engaging in individual follow-up with each supplier in an effort to generate that missing from their sales catalogs) could be very resource-demanding. And what of the seemingly simple matter of soliciting and/or deciding which manufacturer or supplier's information to be included. Do we again rely on voluntary submissions received in response to our newsletter requests-for-input or do we engage in direct mail solicitations? What if they do not respond? And what of the half-life of the accuracy of such information?

The Media: Traditional vs. Avant-Garde Approaches

And last (for this column, at least), there is the matter of the media to be used in "publishing" such a catalog. The traditional approach is to publish a hard-copy document. An alternative that would be less costly (and save trees) would be to make it available as a CD ROM. Or it could be made available to all via the Internet. The publishing expenses and updating difficulties become smaller for each of these options in the order listed. However, other *avant-garde* approaches also exist. For instance, it may be reasonable to consider the development of a "virtual catalog." Indeed, were the decision to be to attempt to adopt the broadest interpretation of what constitutes a HF tool, the development of an Internet-based virtual catalog—consisting of a central web site with links to the originators and/or vendors of each of the tools identified—may represent a viable and powerful option. However, different issues crop up here (e.g., the headaches and hassles of managing such a site, prodding contributors to keep their materials updated, attempting to get similar types of content from each originator/vendor identified).

Where Do We Go From Here?

Clearly, the effort appears worthwhile. Yet it is also clear that even for this seemingly simple undertaking, there are a myriad of potential issues and options that could be considered. Some may be easy to dismiss due to resource constraints; others may warrant substantially greater consideration. But as many as can be should be surfaced before embarking—unbounded projects tend to be difficult to manage and frustrating to all involved.

Each of these issues (and others not cited) could be pursued in greater depth. But the intent, at this time, is merely to surface the idea in sufficient detail to generate some thought and reaction from you, the reader. We recognize that the overall project could be a very substantial undertaking (that's why we're approaching it with this initial solicitation-for-feedback and presenting the survey cited at the outset). To provide the greatest benefit for those in the HF community, what would you recommend? What should an HF Tool Catalog include? In what medium and format would you like it to appear?

Let me hear your comments or questions. I can be reached via e-mail (schopper@cpo.al.wpafb.af.mil), fax (937-255-4823), or telephone (937-255-5215, voice-mail equipped). **And don't forget the survey!** ●

Aaron "Ron" Schopper, Ph.D., is the Chief Scientific and Technical Advisor for the CSERIAC Program Office.

[1] *Merriam Webster's Collegiate Dictionary*, Tenth Edition (1993). Springfield, MA: Merriam-Webster.

CSERIAC Techology Teams

CSERIAC has organized Technology Teams chartered with developing and maintaining a corporate knowledge base of their respective technologies. This will provide a single authoritative DoD point-of-contact for human factors information and assistance in these high-interest areas. Technology Teams were established to address current science and technology (S&T) challenges. If you have information in one of these areas you wish to share, please contact the following Technology Team Managers:

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Dear CSERIAC...

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts. These questions were compiled by David F. Wourms, Senior Technical Analyst.If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway.*

■ A representative from the Training Battle Lab, Ft. Dix, NJ contacted CSERIAC and requested information regarding the safety of lasers and eye protection used during military training exercises.

■ A consultant from Rockford, IL contacted CSERIAC regarding human factors considerations for direction of motion expectancies relating to the use of joystick controls in a manufacturing environment.

■ A researcher from the Naval Undersea Warfare Center asked for information on the response characteristics of displacement (isotonic) joysticks for controlling submarines.

■ A representative from the NAVAIR Human Systems Integration Office requested a quick search on the topic of crew endurance as it relates to continuous operation scenarios for the next generation carrier.

■ A flight engineer from Wright-Patterson AFB, OH contacted CSERIAC and requested any and all information available on the topic of cockpit resource management.

■ A researcher from a federally funded R&D center requested information and points of contact for researchers studying intelligent tutoring system effectiveness.

■ The manager of manufacturing from a pharmaceuticals corporation was interested in information documenting the benefits (e.g., reduced on-the-job injuries) of starting a before-work flexibility program.

■ A representative from the Naval Air Station, Jacksonville, FL inquired about the use of cognitive task analysis methods in training development.

Armstrong Laboratory Human Engineering Division Colloquium Series

Cognitive Compatibility and Aircrew System Design

Robert Taylor

Editor's note: Following is a synopsis of a presentation by Mr. Robert Taylor (see Fig. 1), Defence Research Agency, Farnborough, United Kingdom, as the first speaker in the 1996 Armstrong Laboratory Human Engineering Division Colloquium Series: Human-Technology Integration. This synopsis was prepared by Dr. Michael Vidulich of the Human Interface Technology Branch, Paul M. Fitts Human Engineering Division, Armstrong Laboratory. JAL

Mr. Taylor's objectives for this lecture included reviewing the background for the development of his ideas regarding cognitive compatibility and his hopes for the application of the cognitive compatibility concept in the future. His interest in cognitive compatibility grew out of his research in situation awareness and his belief that situation awareness provided an underlying theme for cognitive compatibility.

The interest in situation awareness was a major operational problem of the late 1980s and early 1990s. Through his research of this time period, Mr. Taylor reached several conclusions regarding situation awareness: situation awareness is the basis for effective planning and action; overloading and underloading reduce situation awareness; enhancing situation awareness is a key design-driver and training issue; and human factors practitioners need to predict and evaluate what situation awareness aiding works best.

Responding to the perceived need for situation awareness metrics, much of Mr. Taylor's early work in this field focused on metric development. One notable product of his research was the Situation Awareness Rating Technique (SART). The SART is a set of rating scales designed to assess three main categories of experience that aircrews reported were central to situation awareness: demand on attentional resources, supply of attentional resources, and understanding. The overall situation awareness score generated from the SART is the level of rated understanding modified by any discrepancy between the attentional resources that are demanded and supplied.

Figure 1. Mr. Robert Taylor, Defence Research Agency, Farnborough.

During the development and validation of SART, Mr. Taylor noticed that the moment-to-moment situation awareness experienced by a person was strongly influenced by the interaction of that person's understanding of the task domain and the current information presented to that person. This led to the belief that the basic strategy for creating human-centered interfaces would be to exploit human-centered design and knowledge engineering to elicit schema-based design solutions.

In this sense, design can be considered the management of knowledge, and cognitive compatibility becomes a key design driver to ensure good situation awareness and performance. Cognitive compatibility is the matching of interface design to user expectations. As cognitive compatibility is improved in an interface design, the user's experience of "intuitiveness" in using the interface should increase as well.

Having identified cognitive compatibility as an important issue related to, yet distinct from, situation awareness, Mr. Taylor set about developing a metric for cognitive compatibility using a research program very similar to that used to develop SART. The first step was to conduct a laboratory experiment with a set of simple displays designed to inflict different levels of compatibility in commanding left/right responses. After using these different displays, subjects described their experiences and impressions. Analyzing these descriptions, some 32 unique constructs were identified that appeared to be related to the general concept of cognitive compatibility. Through logical analysis and further experimentation using factor analysis, the original list was cut down to a total of ten dimensions sorted into three main concepts related to cognitive compatibility. The three main categories identified were (1) depth of processing, (2) ease of reasoning, and

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Naval Air Warfare Center Training System Division: Science and Technology Division

Elizabeth J. Muniz
Eduardo Salas

The Naval Air Warfare Center Training Systems Division (NAWCTSD) is the Navy's principal center for research, development, and product support of simulation and training systems. Through cooperative arrangements with other services, federal agencies, academia, and industry, NAWCTSD strives to share its expertise for the benefit of all. For over 50 years, NAWCTSD has pioneered the use of training and simulation to enhance force readiness, and save lives and dollars.

The roots of NAWCTSD reach back to 1941 when then-Commander Luis de Florez became head of the new Special Devices Desk in the Engineering Division of the Navy's Bureau of Aeronautics. De Florez championed the use of "synthetic training devices" and urged the Navy to undertake development of such devices to increase readiness.

Throughout World War II, the Special Devices Section developed numerous innovative training systems that included devices that used motion pictures to train aircraft gunners, a device to train precision bombing, and a kit with which to build model terrains to facilitate operational planning in the field.

In the mid-1960's, the Special Devices Section was commissioned the Special Device Center and was moved from Long Island, New York to Orlando, Florida.

Today, this center has become NAWCTSD, and its headquarters are located in the de Florez building in Central Florida Research Park. NAWCTSD's mission is to plan and conduct a full range of directed research and development (R&D) in support of Navy and Marine Corps training systems for all warfare areas and platforms, to maintain an expanding technology base, and to transition research results to the fleet.

Science and Technology Division

A key contributor to helping NAWCTSD accomplish its mission is the Science and Technology Division (S&T Division). The on-site staff includes research psychologists, computer scientists, electronic engineers, electrical engineer technicians, and research assistants (students from the University of Central Florida). As a result of teaming with academia and industry, a multidisciplinary environment has developed that allows integration of training methodology with technology systems and has enabled the conduct of numerous successful research projects. The accomplishments of the S&T Division scientists and engineers have been recognized nationally and internationally for a wide range of subjects related to training systems. Areas of expertise include:

- Individual and Team Performance and Training Methodologies
- Tactical Decision Making Under Stress
- Team Situation Awareness
- Shipboard Embedded Training
- Sensor Simulation
- Optics
- Weapons Simulation
- Virtual Environment Technology for Training

The work undertaken by the S&T Division varies in the level of complexity and directness of transition, in application to the various warfare areas (air, surface, ground, undersea, and joint services), and level of technology demonstration. The basic research emphasizes research in simulation and training technologies. For example, eye movement is being examined to design performance metrics for aviation situation awareness.

At the applied research level, innovative technologies and methodologies are being developed. For example, for the past six years NAWCTSD researchers have worked in collaboration with the Naval Command, Control, and Ocean Surveillance Center's Research and Development Division to apply recent developments in decision-making theory, individual and team training, and information display to the problem of enhancing shipboard combat information center tactical decision making under stress (TADMUS).

In addition to the TADMUS program, research is being conducted which involves developing, demonstrating, and evaluating the use of virtual environment technology for significant Navy training applications. The use of virtual environments in training applications can enhance training through increased availability of training systems, decreased cost of training systems, and, most important, improved ability to train in areas where it is difficult to train (e.g., dangerous settings).

One other applied project entails designing, demonstrating, and evaluating a low-cost vision device. This includes examining how diverse nighttime environments affect night-vision goggles use during missions. Furthermore, research is being conducted for the application of advanced weapon simulation technology to be used in small- and medium-caliber weapon simulation systems. NAWCTSD engineers have 32 patent awards for weapons simulation technology.

Lastly, the advanced technology development research is where proof-of-concept is established. For example, an advanced embedded training concepts technology demonstration program is underway which will develop a prototype automated training system to improve the capability for ships to independently conduct comprehensive, consistent, timely, and effective team training in port and at sea.

A submarine research program is developing, demonstrating, and evaluating the training potential of a stand-alone virtual-reality-based system for submarine officer-of-the-deck training, and integrating this system with existing submarine piloting and training simulators.

Although the resulting products of this research have emphasis in different warfare areas, many of the products from these efforts have been applied in a variety of settings. Specifically, aircrew coordination principles were developed and applied in commercial airlines, coast guard fleets, and navy platforms. In addition, the S&T research team developed guidelines for scenario design for civil aviation, surface training, and the Navy helicopter community. Finally, performance measurement concepts and tools were developed and have been used by the Federal Aviation Administration (FAA) and multiple Navy communities. Under TADMUS, the Team Dimensional Training (TDT) program has been tested at both shorebased and shipboard surface warfare training. This strategy is currently being applied to the aviation and submarine communities. Specifically, TDT develops team skills by enabling instructors to systematically debrief teams through the use of performance measurement tools combined with a two-way (instructor-to-team, team-to-instructor) communication process. Finally, the submarine research program has identified adverse side effects and solutions for the use of haptic interfaces and head-mounted visual displays; developed haptic interfaces for virtual environments; developed principles for virtual environment training applications; and created a virtual environment training effectiveness testbed.

On-Site Research Facilities

The S&T Division maintains several laboratory facilities equipped with state-of-the-art simulator systems to support research across all warfare areas.

Moving Weapons Simulator. The Moving Weapons Simulator (see Fig. 1) is used to address training for the widely used M-2 .50-caliber machine gun. This system can be used by all military services to train gunners in weapon handling, burst rate and target recognition, acquisition, and tracking. A key training tool is instructor-controlled scenario replay with feedback on weapon aim point, round impact and target destruction.

Weapons Team Engagement Trainer. The Weapons Team Engagement Trainer (WTET) (see Fig. 2) allows for up to eight team members to participate in realistic trainee movement through a multiple-room and/or screen environment that requires the trainee to make use of cover to avoid the threat of the shoot-back capability. Multiple branching scenarios include hostage rescue, room clearing, and judgmental use of force situations. An elaborate instructor feedback component provides continuous aimpoint tracking and sector-to-fire analysis for both individual and team performance. WTET is currently being commercialized through a cooperative agreement with industry.

Organic Combat Systems Training Technology. The Organic Combat Systems Training Technology (see Fig. 3) was developed to reduce the costs associated with shipboard embedded training systems. Systems components include a shipboard electronic warfare training capability that uses distributed interactive simulation (DIS) protocol; a voice communication capability which uses digitized voice and DIS protocol; and a device called

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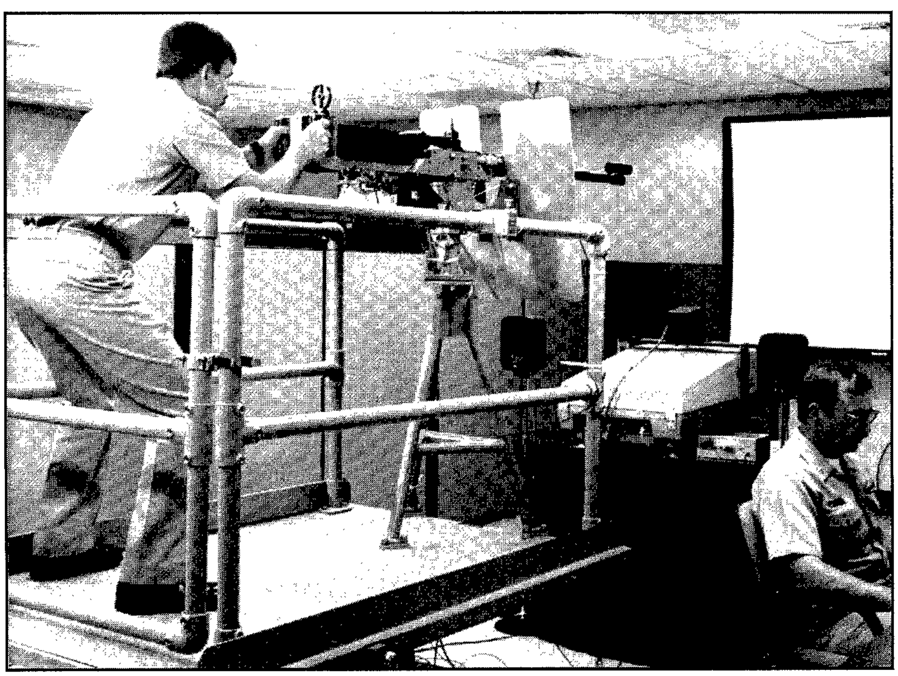

Figure 1. Moving weapons simulator.

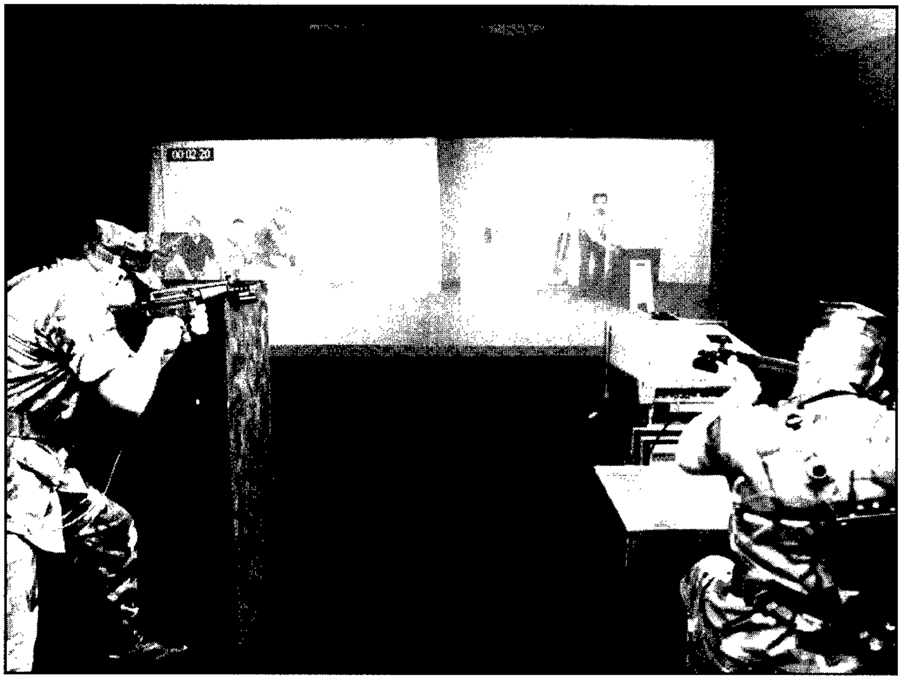

Figure 2. Weapons team engagement trainer.

"Magic Carpet" which allows one to view synthetically a battlefield from any vantage point, and which is also implemented using DIS.

Virtual Environment for Submarine Ship Handling Training. The Virtual Environment for Submarine Ship Handling Training (see Fig. 4) is used to demonstrate virtual environment technology for the officer of the deck. Systems components include an image generator (SGI Onyx IR®); a helmet-mounted display (n-Vision High Res®) with head tracker (Polhemus Fast Track®); a speech synthesis/recognition system; an instructor station; and a bridge mock-up.

Future

The armed forces are faced with changing force size, roles, and missions. At the same time, they must be prepared to handle diverse threat potentials. All of these uncertainties will require innovative approaches to training to ensure preparedness. The unique integration of our S&T Division research teams will help solve these complicated problems as we head into the 21st century. Future research efforts are expected to focus on enhancing the capabilities of technology and training, and determining their effects on our combat teams. For example, continued investigations will focus on developing a single design user-simulation interface, based on the human sensory system, and thereby reduce the cost associated with unique hardware fabrication.

In addition, current technology will allow us to exploit the potential of distributed exercises to reduce the cost of training and improve combat readiness across multiple warfare areas and forces. The capabilities of training will also be enhanced as research focuses more on the modeling and training of complex cognitive processes to improve performance in complex and knowledge-rich environments.

Finally, future investigations will address issues related to new combat ship designs. For example, the next generation ship (e.g., 21st Century Combatant-SC-21) will require a reduction in manning and changes in job design and training of crews. As a result, training research will focus on creating versatile crews, preparing crews for jobs that will be much broader in scope, and migrating training aboard the ship.

To accomplish these projects, the S&T Division must continue to evolve. Currently, this division is experiencing a rapid growth period. Within the next year, the S&T Division is expecting a function transfer and will need to fill 41 additional positions. In addition, the S&T Division is also working to conduct increased collaborative efforts with the Armstrong Laboratory and Army Research Institute. This will allow sharing of

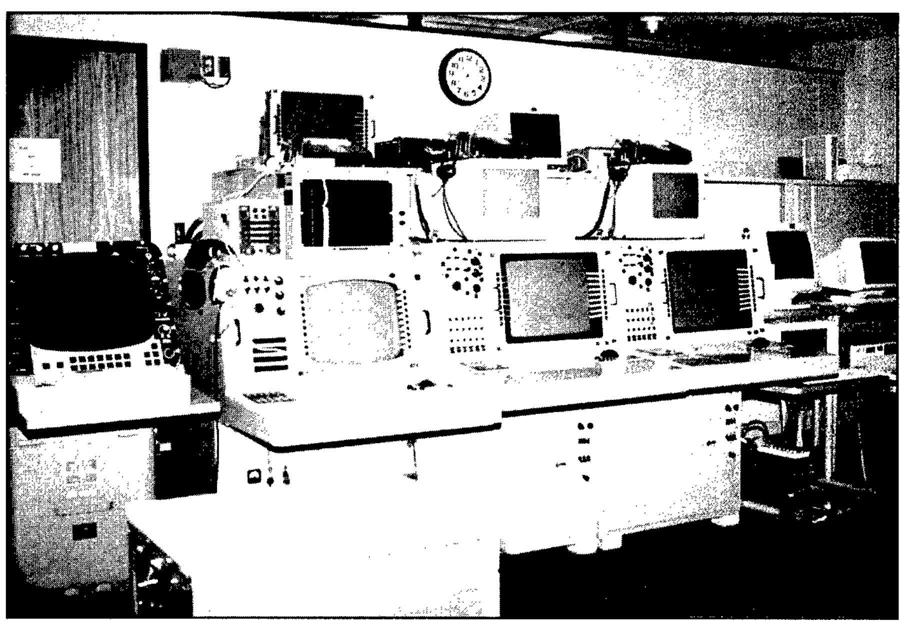

Figure 3. Organic combat system training technology.

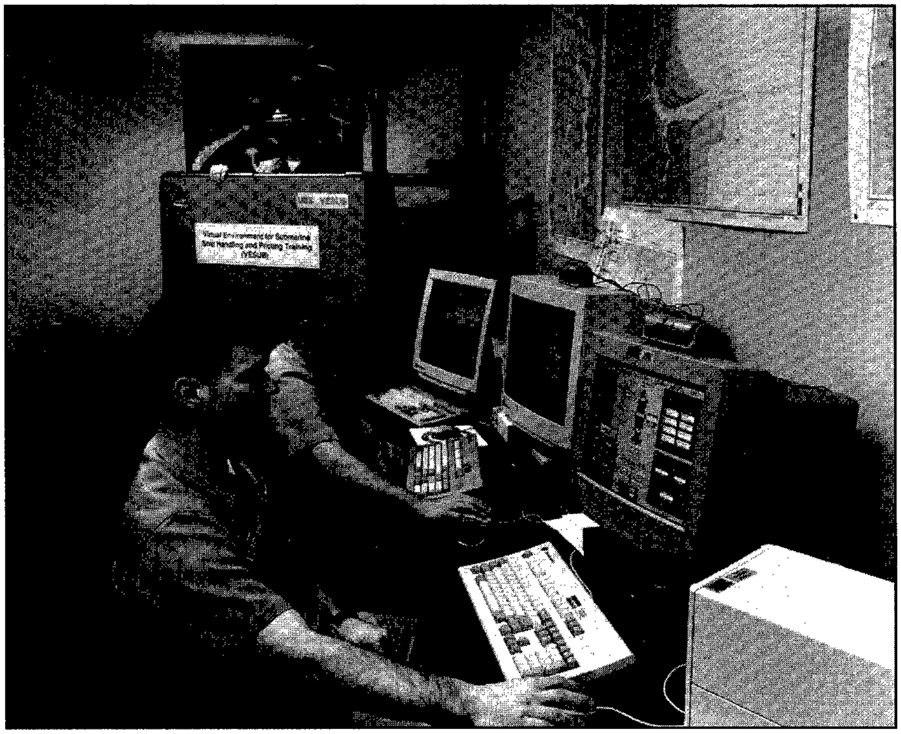

Figure 4. Virtual environment ship-handling training.

expertise and products for the benefit of all services.

Overall, the S&T Division is committed to pursue NAWCTSD's mission of being the Navy's principal center for research and development of training and simulation systems. Our vision is to be the leaders in training research and development, and we are dedicated to the continuous performance improvement of our nation's forces. ●

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(3) knowledge activation. These dimensions have been combined to create the Cognitive Compatibility-Situation Awareness Rating Technique (CC-SART).

At the time of the colloquium, the effort to validate the CC-SART as a metric of interface design had just started and the preliminary results were encouraging. Mr. Taylor has been working with Armstrong Laboratory researchers to implement a more thorough validation in an international cockpit design evaluation to be conducted in the Synthesized Immersion Research Environment (SIRE) facility at Wright-Patterson Air Force Base. He expressed hope that the general concept of cognitive compatibility and the CC-SART measurement tool would result in improved interface design methodologies for the future.

A Preview of HCI International '97

Gavriel Salvendy
Michael J. Smith

With increased emphasis on the design and use of computer-integrated business, the role of computers and the effectiveness of human interactions with computers are significant contributions to customer satisfaction, product quality, the quantity of output, and international competitiveness. HCI International '97 is the 7th International Conference on Human-Computer Interaction held jointly with the 13th Symposium on Human Interface Conference (Japan) in San Francisco, August 24-29, 1997. HCI International '97 will be the most comprehensive conference of its type ever held, with over 1,500 expected participants from more than 40 countries, representing the leading industrial corporations, research laboratories, and universities worldwide. At the end of the Conference, participants will have better understanding about how to design and operate computerized products and systems for effective human use. For further information about the Conference, and to receive the Advanced Program, refer to the end of this article.

Workplace-related cumulative trauma disorders such as carpal tunnel syndrome cost the American economy over 100 billion dollars annually. Table 1 lists some of the risk factors for such disorders. Employers, manufacturers, and users can apply knowledge gained at HCI International '97 to address the problems of cumulative trauma disorders.

Another issue is software design. There are principles to help design software so it can be more user-friendly (Table 2). By using these principles at the design stage, users will be able to learn to operate computer systems

Table 1. Risk Factors for Work-Related Cumulative Trauma Disorders

- Repetitive motions of prolonged duration
- Non-neutral postures of joints or spine
- Excessive loading of tissues or exerted force
- Psychosocial stress
- Gender
- Body mass index and weight
- Physical condition
- Disease status
- Personality
- Personal behavior
- Prior CTD injury or damage to susceptible tissues
- Work regimen, work pace, workload
- Intrinsic characteristics of job and organizational design
- Workstation design
- Environmental conditions

Table 2. Same Interface Design Guidelines

- Ensure consistency in content and structure
- Adapt interface to accommodate individual differences
- Left-justify columns of alphabetic data for rapid scanning
- Use similar colors to convey similar meanings
- Only present information needed for decision making
- Allow easy reversal of actions
- Ensure design matches user's mental model
- Speak user's language
- Minimize short-term memory load
- Provide feedback
- Provide error messages (as needed)
- Chunk similar information in groups

Table 3. Effectively Designing Human-Computer Interaction: Knowledge to be Gained at HCI International '97

- How to increase usability of web site design
- How to design virtual reality systems
- How to design multi-media
- How to design visual information search strategies of support browsing, searching, and data mining the Web
- How to evaluate usability
- How to prevent muscular disorders when working with computers
- How to design computer interfaces
- Collaboration technologies
- How to design and use telecooperative systems
- How to design interfaces for all users
- How to design using ISO software ergonomics standards

Table 4. What You Will Learn at HCI International '97

- 18 full- and half-day tutorials (short courses) which will teach you how to design computerized systems for effective human use
- 579 lectures covering the whole spectrum of HCI from ergonomics and health considerations to cognitive and social aspects of computer design
- 181 late-breaking professional news items presented in interactive poster presentations
- Over 40 exhibits providing the latest information on HCI-related products and services

faster, with fewer errors and greater job satisfaction.

However, to bring your knowledge into the 21st century with regard to effective design and use of computerized systems, it is essential for you to participate in HCI International '97, which will provide a comprehensive coverage of all aspects of HCI (Tables 3 & 4), from software and technology design to the design of cognitive, social, ergonomic, and health aspects of working with computers, as well as networking, browsing, and posting at the World Wide Web. ●

For more information about HCI International '97, please contact:

Conference Administrator
HCI International '97
School of Industrial Engineering
Purdue University
1287 Grissom Hall
West Lafayette, IN 47907-1287

Tel: 317 (or 765) 494-0874
Fax: 317 (or 765) 494-5426
Email: kgilbert@ecn.purdue.edu
WWW: http://palette.ecn.purdue.edu/~salvendy/hci97/

Gavriel Salvendy, Ph.D., is the NEC Professor of Industrial Engineering, Purdue University, West Lafayette, IN, and General Chair, HCI International '97. Michael J. Smith, Ph.D., is Professor & Chair, Department of Industrial Engineering, University of Wisconsin-Madison, Madison, WI, and Program Chair, HCI International '97.

Request for Topics For State-of-the-Art Reports (SOARS)

CSERIAC makes every effort to be sensitive to the needs of its users. Therefore, we are asking you to suggest possible topics for future SOARS that would be of value to the Human Factors/Ergonomics community. Previous SOARs have included *Hypertext: Prospects and Problems for Crew System Design* by Robert J. Glushko, and *Three Dimensional Displays: Perception, Implication, Applications* by Christopher D. Wickens, Steven Todd, & Karen Seidler. Your input would be greatly appreciated.

Send your suggestions and other replies to:

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Wright-Patterson AFB OH USA
45433-7022

The Human Factors and Ergonomics Society:
Test and Evaluation Technical Group

Valerie Gawron

Organization History

The Test and Evaluation Technical Group (TETG) of the Human Factors and Ergonomics Society (HFES) consists of a diverse range of about 300 specialists who share a common interest in human factors and ergonomic test and evaluation. These specialists determine if the human/system interface (1) meets the design specifications, (2) fits the operational need, and (3) is usable by the intended population of users. The goals of the TETG are to develop tools to support these determinations. To achieve these goals, the TETG sponsored two sessions at the last annual meeting of the HFES as well as a colloquium to document test and evaluation needs across all the technical groups within the HFES. Both of these efforts are summarized below.

TETG Sessions

First Session

The first session consisted of four lectures describing data collection methods and measures.

Everything I Ever Wanted to Know About Driving. Richard Carter, Philip Spelt, and Frank Barickman (Oak Ridge National Laboratory) designed an integrated data acquisition, power supply, and sensor suite to measure driver, vehicle, and environment status. The system was developed under contract to the National Highway Traffic Safety Administration.

In the Eye of the Beholder. David Clarke and Barry Beith (Monterey Technologies) applied an interobserver method to evaluate a commercially available VCR designed to automatically fast forward through commercials during playback (yeah!). The method requires that at least two trained observers rate if the commercials were fast forwarded or not on the same videotapes. The method greatly reduces observer bias and as enhances the reliability of the data.

Tracing Your Ancestry. Rebecca Unger (CSERIAC), Bradley Purvis, Joe McDaniel (Armstrong Laboratory), and Carl Orr (CSERIAC) developed a method for creating detailed three-dimensional computer-aided design (CAD) drawings of an existing cockpit. An electromechanical coordinate measurement machine is used to trace controls and displays in the cockpit. The tracings are captured in a lap-top computer and transferred to a CAD package for subsequent analysis.

So How Much Do You Know? Laura Miller and Kay Stanney (University of Central Florida) validated a Windows Computer Experience Questionnaire, which takes five minutes to administer and reliably (i.e., high test-retest correlation) measures computer experience. Such measurement is critical in conducting human-computer interaction research.

Second Session

The second session was composed of four lectures detailing enhanced measurement techniques.

Splitting Hairs Helps. Doug Harris (Anacapa Sciences) increased the reliability of pipe weld inspections by subdividing the pipe inspection areas into smaller areas to be graded. The increase was dramatic from 0.28 to 0.92 reliability; the decreases in standard error in measurement were from 13.81 to 1.35 or even more.

Sitting On the Job. Cindy Lu and Gang Lin (BCAM International) empirically developed guidelines for enhancing the accuracy of a seat pressure measurement system. The guidelines include limiting the calibration and measurement periods to two minutes (sit patiently!), controlling the contact area (sit straight!), and applying the force equally (sit still!).

Model Sales Person. Beth Meyer and Richard Catrambone (Georgia Institute of Technology) developed models of the keystrokes that sales clerks use to complete transactions. These models predict performance times for both novice and experienced clerks.

Weighty Decisions. Helmut Zwahlen, Torm Pracharktam, and Thomas Schnell (Ohio University) developed PC-based software for designers to weigh the importance of design requirements. This software helps these users perform design tradeoffs, for example, is a 3% increase in reliability worth a 10% increase in power consumption?

TETG Colloquium

Last year representatives from 18 HFES technical groups identified "Human Factors Test and Evaluation Needs" in a full-day colloquium. This year, the same participants, plus representatives from two new technical groups, developed a plan for documenting and meeting these needs. The document will be placed on the HFES Web Home Page and maintained by the TETG. The document has four sections:

1. Definition of Human Factors Test and Evaluation. This section

defines need as a technology the technical group must have to advance its discipline. All needs identified must be achievable within reasonable time and funding.

2. Overview of Common Needs. This section will describe those test and evaluation needs shared by many if not all the technical groups.

3. Human Factors Test and Evaluation Needs by Technical Group. This section includes a separate subsection for each technical group. Each subsection (1) begins with an overview of that technical group's goals and objectives, (2) is followed by a description of needs of that technical group to meet its goals and objectives, and (3) provides a description of what test and evaluation tools are currently being used by that technical group or *may be* added later as part of a separate effort being led by Brian Peacock (GM Corporation).

4. Recommendations for the Next Step. The primary recommendation is to develop a roadmap for meeting the test and evaluation needs and thus advancing human factors. This roadmap may be used by the HFES Research Institute to guide future development. ●

Valerie J. Gawron, Ph.D., is Principal Human Factors Engineer at Calspan SRL Corporation, Buffalo, NY. She is a Fellow of the HFES and was Program Chair for the TETG for 1995, 1996, and 1997, and is the current Technical Chair of the TETG.

Questions? Comments? Address Change?

Please contact the Editor, Jeff Landis, at:

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CSERIAC PRODUCTS AND SERVICES

CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

- technical advice and assistance;
- customized responses to bibliographic inquiries;
- written reviews and analyses in the form of state-of-the-art reports and technology assessments;
- reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

- organizes and conducts workshops, conferences, symposia, and short courses;
- manages the transfer of technological products between developers and users;
- performs special studies or tasks.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Government Technical Manager.

To obtain further information or request services, contact:

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