Dedication

In memory of:

Ryszard Karwowski
Eugenia Kaczmarek
Edward Kaczmarek

W&BK

Edited by: Waldemar Karwowski, University of Louisville, USA

Distinguished Scientific Advisory Board:

Colin Drury, SUNY at Buffalo, USA
Jan Dul, Erasmus University Rotterdam, The Netherlands
Peter Hancock, University of Central Florida, USA
Martin Helander, Nanyang Technological University, Singapore
Krystyna Gielo-Perczak, The Liberty Mutual Research Institute for Safety, USA
Julie A. Jacko, Georgia Tech, USA
David B. Kaber, North Carolina State University, USA
Holger Luczak, Aachen University, Germany
Tadeusz Marek, Jagiellonian University, Poland
Neville Stanton, Brunel University, United Kingdom
Eduardo Salas, University of Central Florida, USA
Gavriel Salvendy, Purdue University, USA

Assistant Technical Editor: Bohdana Sherehiy, University of Louisville, USA
Preface to 2nd Edition
Fifty Years of Human Factors and Ergonomics and Counting...

In 2007, we will celebrate the 50th birthday of both the International Ergonomics Association and the Human Factors and Ergonomic Society. We will also cherish the wisdom of Wojciech Jastrzebowski of Poland who 150 years prior to this date coined the term “ergonomics,” and published the first treatise on ergonomics, which provided the foundations for the science and practice of the contemporary human factors and ergonomics (HFE) discipline. Over the last 50 years HFE has been evolving as a unique and independent discipline that focuses on the nature of human–artifact interactions, viewed from the unified perspective of science, engineering, design, technology, and management of human-compatible systems, including a variety of natural and artificial products, processes, and living environments (Karwowski 2005).

Today, human factors and ergonomics professionals worldwide contribute to the design and evaluation of tasks, jobs, products, environments, and systems in order to make them compatible with the needs, abilities, and limitations of people (IEA 2000). These professionals, who are often certified by the professional certification bodies (e.g. Board of Certification in Professional Ergonomics in the United States, or the Centre for Registration of European Ergonomists — CREE in the European Union), promote the human-centered approach to work systems design, testing, and evaluation, which considers the broad set of physical, cognitive, social, organizational, environmental, and other relevant human factors. Such actions should help in the socio-economic development of the world society at large. As noted by the National Academy of Engineering in the USA, in the near future “engineering will expand toward tighter connections between technology and the human experience..., and ergonomic design of engineered products” (NAE 2004). For example, the International Ergonomics Association works to enhance the public understanding of the meaning of ergonomics, and facilitates making informed decisions about the promotional claims of “ergonomically designed” systems. The IEA Certification for Ergonomics Quality in Design (EQUID) Program promotes adoption of the human-centered process approach through the application of relevant human factors knowledge and methods during product design and development.

Design of interactions with technological artifacts and work systems require involvement of ergonomically competent people. One of the critical issues in this context is the ability of users to understand the utility and limitations of technological artifacts. Ergonomics literacy prepares individuals to perform their roles in the workplace and outside the working environment (Karwowski 2005). The basic dimensions for ergonomics literacy include ergonomics knowledge and skills, ways of thinking and acting, and practical ergonomics capabilities. An ergonomically literate person can learn enough about how technological systems operate to protect her/himself by making informed choices and making use of beneficial affordances of the artifacts and environment.

Publication of the first edition of the International Encyclopedia of Ergonomics and Human Factors (2001) illustrates the rapid growth in the demands for ergonomics knowledge and expertise, as well as developing needs for ergonomics literacy of citizens around the world. The encyclopedia aims to provide the most comprehensive coverage of the HFE discipline and profession, and develop the authoritative archival resource of theoretical and practical knowledge, design data, and other human-centered information that can be universally studied and applied by all people inside and outside of the HFE field.

This extended second edition of the encyclopedia includes a total of 695 articles divided into 13 main parts. Part I includes 52 articles related to general ergonomics issues, and the history of ergonomics and human factors. Articles describing the scope and activity of national ergonomics societies of several countries are also included in this part. Part II consists of 66 articles related to the most important anthropometric, biomechanical, and cognitive human characteristics. Part III includes 87 articles focused on factors related to human performance. Part IV consists of 77 articles concerned with human factors issues related to information presentation and communication. Display and control design are discussed in Part V, which consists of 23 articles. Issues related to design of workplace and equipment is presented in Part VI with 43 articles. In Part VII, 22 articles discuss the environmental factors important for ergonomics design. Part VIII consists of...
28 articles that describe systems characteristics. Work design and organization are discussed in Part IX with 89 articles. Health and safety related articles are gathered in Part X, which consists of 64 articles. Social and economic impact of the system is analyzed by 27 articles in Part XI. Methods and techniques applied in human factor and ergonomics are presented in Part XII with 76 articles. Finally, Part XIII contains 38 biographies of outstanding human factor and ergonomics professionals.

My sincere thanks go to all the authors for their scientific contributions and diligence with the editing process. I would like to express my appreciation to Bohdana Sherehiy from the Department of Industrial Engineering, University of Louisville, who served as Assistant Technical Editor for this challenging project. I would also like to acknowledge the cooperation and support of many people at CRC Press/Taylor Francis, including Cindy Carelli and Jessica Vakili who inspired me to keep going, as well as Katharine Godfrey Smith, Project Manager at Alden Pre-Press Services. Finally, my sincere appreciation goes to my family: my wife Bela who always supported my scientific endeavors, and my children Mateusz and Jessica, who remind me every day why the HFE discipline is important for the future of humankind.

REFERENCES


Waldemar Karwowski
Louisville, Kentucky
The Editor

Waldemar Karwowski, Sc.D., Ph.D., P.E., is Professor of Industrial Engineering and Director of the Center for Industrial Ergonomics at the University of Louisville, Louisville, Kentucky. He holds an M.S. (1978) in Production Engineering and Management from the Technical University of Wroclaw, Poland, and a Ph.D. (1982) in Industrial Engineering from Texas Tech University, Lubbock, Texas. Recently, he was awarded the Sc.D. (dr hab.) degree in Management Science by the Institute for Organization and Management in Industry (ORGMASZ), Warsaw, Poland (June 2004). He also received Doctor of Science Honoris Causa from the South Ukrainian State K.D. Ushynsky Pedagogical University of Odessa, Ukraine (2004). Dr. Karwowski is a Board Certified Professional Ergonomist (BCPE). His research, teaching, and consulting activities focus on human system integration and safety aspects of advanced manufacturing enterprises, human–computer interaction, prevention of work-related musculoskeletal disorders, workplace and equipment design, and theoretical aspects of ergonomics science.

Dr. Karwowski is the author or co-author of over 300 scientific publications (including over 100 peer-reviewed archival journal papers) in the areas of work system design, human factors in organization and management; human–system integration and safety of advanced manufacturing; industrial ergonomics; neuro-fuzzy modeling and fuzzy systems; and forensics. He has edited or co-edited 40 books, including the International Encyclopedia of Ergonomics and Human Factors, Taylor & Francis, London (2001). He was a winner of the Best Reference Award 2002 from the Engineering Libraries Division, American Society of Engineering Education Ltd, USA, and the Outstanding Academic Title 2002 from Choice magazine.


Dr. Karwowski served as Secretary-General (1997–2000) and President (2000–2003) of the International Ergonomics Association (IEA). He was elected an Honorary Academician of the International Academy of Human Problems in Aviation and Astronautics (Moscow, Russia, 2003), and was named the Alumni Scholar for Research (2004–2006) by the J. B. Speed School of Engineering of the University of Louisville. He also received the University of Louisville Presidential Award for Outstanding Scholarship, Research and Creative Activity in the Category of Basic and Applied Science (1995), Presidential Award for Outstanding International Service (2000), and the W. Jastrzebowski Medal for Lifetime Achievements from the Polish Ergonomics Society (1995). Dr. Karwowski is a Fellow of the International Ergonomics Association (IEA), the Human Factors and Ergonomics Society (HFES, USA), the Institute of Industrial Engineers (IIE, USA), and the Ergonomics Society (UK). He is a recipient of the highest recognition in occupational safety and health in Poland, Pro Labore Securo (2000). He is past President of the International Foundation for Industrial Ergonomics and Safety Research, as well as past Chair of the US TAG to the ISO TC159: Ergonomics/SC3 Anthropometry and Biomechanics. He served as Fulbright Scholar and Visiting Professor at Tampere University of Technology, Finland (1990–1991), and was named an Outstanding Young Engineer of the Year by the Institute of Industrial Engineers (1989). He can be reached via e-mail at karwowski@louisville.edu.
Foreword to First Edition

Y. Ian Noy

Ergonomics is the discipline concerned with interactions among humans and other elements of a system (the term “system” is intentionally vague and ranges from simple tools to complex sociotechnical structures). As a science, ergonomics is relatively young; however, the underlying ideal, human-centred technology, has played a pivotal role in the evolution of human society from its very start. The use of stone tools by *Homo habilis*, over two million years ago, represents the dawn of ergonomics as an art-form. Throughout the history of civilization, technological innovations were motivated by fundamental human aspirations for security, prevalence, and self worth, and by problems arising from human-system interactions. In the 20th century, ergonomics emerged as a formal science in its own right, though it continues to be taught as part of other faculties such as engineering or psychology. Although it has been referred to as the science of work, ergonomics, in its broadest sense, is concerned with all forms of human activity. The application of the scientific method to the development of theory, principles, and data relevant to design has had enormous impact on the reduction of user error, improved performance, reduction of occupational injuries and worker discomfort, increased usability, and safety of computer systems and consumer products.

Today, profound changes are taking place that touch all aspects of our society: changes in the nature of work and play; changes in global commerce and communication; changes in science and technology; and changes in population migration and world demographics. These changes cannot but influence the future course of ergonomics since they relate to how people interact with technology in an increasingly dynamic and complex world. More importantly, they beckon ergonomics to play a more direct and vital role in shaping the society of the future.

An encyclopedia of ergonomics and human factors is crucial to the further development of the science and its applications. It serves to inform practitioners, educators, students, and researchers in the field. As well, it is a useful resource for those not directly involved with ergonomics, but who want to understand one or more aspects of human-system interactions. It is a foundation of knowledge that serves all who have an interest in the field.

Preparing an encyclopedia in any discipline is a daunting task; preparing one in ergonomics and human factors is heroic. Part of the reason is that ergonomics is a very broad field, the scope of which includes physical, cognitive, and organizational topics. Moreover, although the science of ergonomics is differentiated from other disciplines by the fact that it is concerned exclusively with the design of human-system interactions, it relies heavily on knowledge from related fields such as psychology, physiology, engineering, medicine, sociology, anthropology, and kinesiology. That is, in addition to knowledge content unique to ergonomics, researchers and practitioners routinely apply knowledge from the relevant biological, behavioral, and engineering sciences. It is clearly not possible for an encyclopedia of ergonomics to cover all of the related disciplines which theories and data it borrows, adapts, and extends. Yet, it is similarly not practicable to exclude content from related sciences that is central to an understanding of human interactions with technology. The editors, therefore, had to make difficult decisions about what to include and what to exclude in their effort to make the encyclopedia as comprehensive and informative as possible. They have clearly attained this goal in this unprecedented volume.

Another challenge that faced the editors was the fact that ergonomics is continually evolving. As an applied science, ergonomics evolves with technology and economic diversification. By necessity, an encyclopedia such as this reflects current directions and state-of-knowledge. Brian Shackole has identified the major thrusts of ergonomics applications in the 20th century as: military ergonomics, industrial ergonomics, consumer product ergonomics, human-computer interaction and software ergonomics, and cognitive ergonomics and organizational ergonomics. To this, Martin Helander has suggested adding eco-ergonomics as the main thrust of the first decade of the 21st century. The editors of this encyclopedia have, therefore, had to strike a balance between covering the theoretical and methodological underpinnings of the field and elaborating topics closely aligned with major applications. Again, the balance achieved provides a rich scientific and technical resource yet one that retains strong relevance to practitioners.
Producing the first edition of an encyclopedia is unquestionably the most challenging for obvious reasons. Future editions will undoubtedly build on this work, update it, and add significant new knowledge. However, the first edition represents a landmark, signifying the true coming of age of ergonomics. It is thus a timely and notable contribution to the field.

The authors, editors, and the publisher are to be commended for undertaking the arduous task of producing such a fine resource. It will serve the discipline and profession well into the future.
Acknowledgments


Figure in “Air Traffic Management,” reprinted with permission from *Occupational Ergonomics Handbook*. Copyright Lewis Publishers 1998, an imprint of CRC Press, Boca Raton, Florida.

MTM printed tables of performance times in article by the late James R. Buck. Source: MTM Association for Standards and Research. Reprinted with permission from the MTM Association.


“Professional Certification in Ergonomics in the USA,” © Board of Certification in Professional Ergonomics and reproduced by kind permission of the Board of Certification in Professional Ergonomics.

Figures 1 and 2 in “Rating Scales for Perceived Physical Effort and Exertion” by Gunnar Borg © Gunnar Borg.

“Performance Effects of High G Environments” by Russell Burton is a US Government sponsored publication and not copyrighted to Taylor & Francis.

“Medical Equipment Usability Testing” by Valerie J. Rice is a US Government sponsored publication and not copyrighted to Taylor & Francis.


“Ergonomics Considerations for Reducing Cumulative Trauma Exposure in Underground Mining” by K.M. Cornelius and F.C. Turin is a US Government publication and not copyrighted.


Figure 1 in “Brain and Muscle Signal-based Control” by Grant McMillan reproduced by kind permission of Otto Bock Orthopedic Industry Inc.
# Table of Contents

## PART I  General Ergonomics

An Annotated Review of Selected Military and Government Sources of Human Factors  
Design Related Criteria .................................................................................................................. 3  
Australia: Ergonomics Society of Australia ............................................................................. 10  
Ergonomics in Brazil and the Brazilian Ergonomics Society (Abergo) ........................................ 13  
Cognitive Engineering .................................................................................................................. 15  
Core Competencies in Ergonomics ............................................................................................ 19  
Cultural Ergonomics ................................................................................................................... 27  
Defining Ergonomics/Human Factors ....................................................................................... 32  
Design ........................................................................................................................................ 36  
Ecological Approach .................................................................................................................. 38  
Epistemological Issues About Ergonomics and Human Factors ............................................... 43  
Ergonomic Society of Sweden (ESS) ........................................................................................ 48  
Ergonomics in the Nordic Countries .......................................................................................... 49  
The European Union’s Policy in the Occupational Safety and Health Sector ............................. 50  
Finnish Ergonomics Society ....................................................................................................... 72  
The French Language Ergonomics Society (SELF) ................................................................... 73  
Fundamental Concepts of Human Factors ................................................................................ 76  
Germany: Gesellschaft für Arbeitswissenschaft ......................................................................... 80
Greece: Hellenic Ergonomics Society (HES) ...................................................................................................................82
History of Human Factors/Ergonomics in Power Systems........................................................................................................84
History of Human Factors in the United States .....................................................................................................................98
Czech Republic: Ergonomics Society of the Czech Republic ...............................................................................................102
History of the Gesellschaft für Arbeitswissenschaft (GfA) ........................................................................................................104
History of Work-Related Musculoskeletal Disorders ..............................................................................................................107
Human Factors, Politics and Power ........................................................................................................................................112
Human–Machine Systems: Written and Symbolic Communication ............................................................................................115
Iceland: Icelandic Ergonomics Society ........................................................................................................................................119
IEA Definitions of Ergonomics .................................................................................................................................................121
The International Ergonomics Association (IEA) ......................................................................................................................122
International Ergonomics Standards: ISO/TC 159 ...................................................................................................................126
Iranian Ergonomics Society .........................................................................................................................................................130
Ireland: Irish Ergonomics Society ..............................................................................................................................................133
ISO and CEN Standardization Committee for Ergonomics (1999): Organizational Structure ...........................................134
Israel: Israel Ergonomics Society ................................................................................................................................................147
Italian Society of Ergonomics (Società Italiana di Ergonomia, SIE) .........................................................................................149
Japan: Japan Ergonomics Society .............................................................................................................................................151
Macroergonomics .......................................................................................................................................................................154
Ontology ....................................................................................................................................................................................157
An Outline of Ergonomics, or the Science of Work Based upon the Truths Drawn from the Science of Nature ...................161
Person-Centered Ergonomics .....................................................................................................................................................176
Poland: Polish Ergonomics Society ..........................................................................................................................................180
PART II   Human Characteristics

Age-Related Vision and Daily Activities of Elderly Adults ........................................................................... 233
Alternative Controls ........................................................................................................................................ 237
Anaerobic Threshold ..................................................................................................................................... 241
Anthropometry ............................................................................................................................................... 242
Anthropometric Databases .......................................................................................................................... 243
Anthropometry of Children .......................................................................................................................... 246
Anthropometric Terms .................................................................................................................................. 257
Anthropometry for the Needs of the Elderly ................................................................................................. 258
Anthropometric Topography ........................................................................................................................ 266
Assessment of Team Cognition ..................................................................................................................... 271
Auditory Ergonomics ...................................................................................................................................... 277
Strength Testing ............................................................................................................................................................... 515
Transient Effects in Vision .............................................................................................................................................. 520
Torque Data ..................................................................................................................................................................... 534
Trunk Muscle Force Models ........................................................................................................................................... 545
Quantifying How We See the World: Visual Acuity, Contrast Sensitivity, and Visual Fields........................................ 551
Visual Perception, Age, and Driving ............................................................................................................................... 558
Workload and Electro-Encephalography Dynamics ....................................................................................................... 561

PART III Performance Related Factors

Activity ............................................................................................................................................................................ 567
Activity Theory ............................................................................................................................................................... 571
Age-Related Cognitive and Perceptual Factors that Influence Computer Usage................................................................. 577
Allocation of Functions: Past, Present, and Future Perspectives .......................................................................................... 581
Arousal States and Human Performance ........................................................................................................................ 590
Attention and Human Performance: A Cognitive Neuroscience Approach ......................................................................... 594
Body Postures.................................................................................................................................................................. 600
Brain and Muscle Signal-Based Control.......................................................................................................................... 601
Burnout ........................................................................................................................................................................... 605
Cognitive Modeling in Human–Computer Interaction ...................................................................................................... 609
Cognitive Psychophysiology in Ergonomics and Human Factors ........................................................................................ 615
Combination Manual Handling Tasks.................................................................................................................................. 619
Comfort–Discomfort Phase Change .................................................................................................................................. 623
Constraints in Design Decision-Making ........................................................................................................................ 627
Critical Reappraisal of Activity Theory .......................................................................................................................... 631
Cross-Cultural Comparison of Computer Anxiety: Concept, Measures, and Related Variables..........................636

Cue-Based Processing and Human Performance.............................................................................................................641

Cybersickness in Virtual Reality .....................................................................................................................................646

Databases for Psychophysically Acceptable Maximum Weights and Forces in Manual Handling Tasks Developed by Liberty Mutual........................................................................................................649

Databases for Psychophysically Acceptable Maximum Wrist Torques in Manual Tasks for Females Developed by Liberty Mutual........................................................................................................668

Design Cognition.............................................................................................................................................................673

Designing for Body Strength ..........................................................................................................................................679

Driver Perception–Response Time ..................................................................................................................................682

Dynamic Situations .........................................................................................................................................................687

Emotions and Design....................................................................................................................................................691

Ergotoxicology: Toward an Operational Prevention of Chemical Risk in the Working Environment ...........................................................................................................................................698

Error Taxonomies ........................................................................................................................................................706

Execution of Ballistic Movements: Intervention of Subcortical Mechanisms ...............................................................710

Fatigue and Driving........................................................................................................................................................716

Fire-Fighting and Rescue Work in Emergency Situations and Ergonomics.................................................................720

Human Control of the Behavioral Environment..............................................................................................................725

Human Error................................................................................................................................................................735

Human Real-Time Processing.........................................................................................................................................739

The Probability and Statistics of Human Error................................................................................................................742

Human Reliability Analysis .............................................................................................................................................753

The Role of Individual Differences in Human Computer Interaction: The Case of Navigation.................................758

The Knee at Work .........................................................................................................................................................763
Learning and Forgetting.................................................................................................................................767
Lifting Techniques..................................................................................................................................................775
Loads on the Lumbar Spine During Dynamic Work ..........................................................................................779
Manual Materials Handling in Unusual Postures ...............................................................................................785
Manual Materials Handling in Multiple Person Teams ......................................................................................786
Manual Work and Back Stress in Industrially Developing Countries .............................................................790
Memory Failures in the Workplace and in Everyday Life: Causes and Consequences ........................................794
Mental Fatigue and Related Phenomena...............................................................................................................798
Mental Models.......................................................................................................................................................800
Mental Workability and an Increasing Life Span ...............................................................................................805
Mental Workload ..................................................................................................................................................809
Mental Workload Measurement ..........................................................................................................................814
Mental Workload: Theory, Measurement, and Application ................................................................................818
Models of Human Performance for Application to Military Simulation ..........................................................822
Monitoring an Operator’s Psychophysiological Fitness for Work .....................................................................826
Monitoring of Operators’ Professional Aging ....................................................................................................829
Work Motivation — State of the Art ....................................................................................................................833
NASA’s Contribution to Aviation Human Factors ..............................................................................................838
Noise: Measuring, Evaluation, and Rating in Ergonomics ..............................................................................844
Occupational Stress Mechanisms ......................................................................................................................852
Physical Demands of Work .................................................................................................................................854
Psychophysical Risk Assessment in Manual Handling ....................................................................................867
Rating Scales for Perceived Physical Effort and Exertion ................................................................................870
Signal Detection Theory..................................................................................................................................................875
Signal Detection Theory — Alternatives ..........................................................................................................................880
Situation Awareness.........................................................................................................................................................886
Situation(al) Awareness: Alternative Theories ..................................................................................................................891
Situation Awareness and Decision-Making..........................................................................................................................897
Situation Awareness in Teams ..............................................................................................................................................903
Skill Learning: Augmented Feedback.................................................................................................................................907
Skill Learning: Conditions of Training ...............................................................................................................................912
Sleeping Systems...............................................................................................................................................................916
Sleeping Systems: Design Requirements...........................................................................................................................923
Standing Work ..................................................................................................................................................................929
Static Load......................................................................................................................................................................933
Static Work Capacity.........................................................................................................................................................937
Stimulus–Response Compatibility .....................................................................................................................................941
Subjective Mental Workload Assessment ..........................................................................................................................946
The Substance of Cognitive Modeling................................................................................................................................948
Systemic Situation(al) Awareness ..................................................................................................................................952
Tolerance to Shiftwork .......................................................................................................................................................956
Cathode-Ray Tube Monitors Versus Paper: A Review of Performance Differences..........................................................961
Vigilance.............................................................................................................................................................................965
Visual Display Terminals: Age and Psychophysiology ....................................................................................................969
Visual Measurement: Modern Methods.............................................................................................................................972
Visual Perception Under Night Driving Conditions ...........................................................................................................976
Work Ability.......................................................................................................................................................................979
PART IV  Information Presentation and Communication

Accessible Web Page Design ..................................................................................................................997

Adaptive User Interfaces and Personalization ..........................................................................................1004

Alarm Initiated Activities .........................................................................................................................1008

Assistance for Users of Interactive Devices ...........................................................................................1011

Auditory Alerts in Avionics .........................................................................................................................1018

Auditory Displays, Alarms, and Auditory Interfaces .................................................................................1021

Auditory Warnings ....................................................................................................................................1026

Augmented Reality .................................................................................................................................1029

Automatic Speech Recognition .................................................................................................................1033

Chinese Keyboard Input ...........................................................................................................................1039

Cognitive Walkthrough for the Web .........................................................................................................1044

Collaborative Interaction in Process Control ............................................................................................1047

Evaluation of Graphical Symbols ..............................................................................................................1053

Convergence of Telephony, Television, and Computing in the Home ......................................................1058

Cross-Cultural Issues in Human–Computer Interaction ............................................................................1063

Cultural Aspects of User Interface Acceptance ........................................................................................1067

Describing and Predicting Human Interaction with Technology ............................................................1071

Design of Menus: Choosing Names, Organizations, and Selection Devices .............................................1076

Dynamic Function Allocation ..................................................................................................................1080
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological Interface Design — Theory</td>
<td>1083</td>
</tr>
<tr>
<td>Ergonomics of CAD Systems</td>
<td>1088</td>
</tr>
<tr>
<td>Evaluation of Warning Effectiveness</td>
<td>1094</td>
</tr>
<tr>
<td>Functional Systems Design Versus Interface Design</td>
<td>1098</td>
</tr>
<tr>
<td>HCI Hypermedia: Usability Issues</td>
<td>1101</td>
</tr>
<tr>
<td>Human Acceptance of Information Technology</td>
<td>1105</td>
</tr>
<tr>
<td>Human Ecology: Developing Ecological Auditory Warnings</td>
<td>1109</td>
</tr>
<tr>
<td>Human Factors and Digital Networks: Intranets, Extranets, and the Internet</td>
<td>1113</td>
</tr>
<tr>
<td>Human Factors Issues in Augmented Reality</td>
<td>1117</td>
</tr>
<tr>
<td>Human Failure Mode and Effects Analysis (H-FMEA)</td>
<td>1121</td>
</tr>
<tr>
<td>Human Information Processing: Implications for Human Factors and Human–Computer Interaction</td>
<td>1130</td>
</tr>
<tr>
<td>Human Speech Digitization and Compression</td>
<td>1135</td>
</tr>
<tr>
<td>Human–Computer Interaction (HCI)</td>
<td>1139</td>
</tr>
<tr>
<td>Human–Computer Interaction (HCI) Standards</td>
<td>1142</td>
</tr>
<tr>
<td>Hypertext and Hypermedia</td>
<td>1147</td>
</tr>
<tr>
<td>Information Design: Warning Signs and Labels</td>
<td>1152</td>
</tr>
<tr>
<td>Information Security</td>
<td>1156</td>
</tr>
<tr>
<td>Interactive Speech Technology</td>
<td>1158</td>
</tr>
<tr>
<td>International Standards of Interface Design</td>
<td>1161</td>
</tr>
<tr>
<td>Internet and the World Wide Web</td>
<td>1165</td>
</tr>
<tr>
<td>Knowledge Management in HCI Design</td>
<td>1170</td>
</tr>
<tr>
<td>Knowledge-Based Man-Modeling: Job Design Procedure (Man-Modeling for Job Design)</td>
<td>1177</td>
</tr>
<tr>
<td>Medical Virtual Reality Simulators</td>
<td>1181</td>
</tr>
</tbody>
</table>
Mobile HCI with Physical Selection

Models of Graphical Perception

Multimedia Production

Multimodal Interaction

Natural Language

Performance Support: Online Help and Advisors

Physical Disabilities in Human Computer Interaction

Product Sensorial Quality

Redesign: Integration of Analytical and Creative Processes for Enhancing Software

The Role of Ontologies in User Interface Design and Evaluation

Search Tools for the Web

Sequential Model of the Visualization Process in the Internet

The Social and Ethical Impact of Decision Support Interface Design

Sonification

Speech-Based Alarm Displays

Structured Integration of Human Factors and Software Engineering Methods

Synthetic Vision Systems

Application of Systemic–Structural Activity Theory to Design of Human–Computer Interaction Tasks

Top Ten Mistakes in Web Design

Universal Design in Human–Computer Interaction

Use of Icons in User Interfaces

Use of Modern Chinese Language

User Requirements in Information Technology
User-Centered Graphic Design .....................................................................................................................................1311
A Gameplay-Centered Design Framework for Human Factors in Games .................................................................1314
Vagueness in the Representation of Cognitive Categories Regarding User Interfaces ...........................................1320
Video Telephony ............................................................................................................................................................1323
Virtual Environments ....................................................................................................................................................1332
Virtual Reality ...............................................................................................................................................................1336
Virtual Reality: Virtual and Synthetic Environments — Technologies and Applications ............................................1341
Visualization Support to Data Mining Modeling ..........................................................................................................1353
Voice-Enhanced Interface ..............................................................................................................................................1357
VR Technology for Ergonomics Design .......................................................................................................................1361
Warnings........................................................................................................................................................................1367
Web Design: Effective Log-in or Sign-in Page ..................................................................................................................1374

**PART V Display and Control Design**

Auditory Warnings and Displays: Issues Relating to Design and Selection .................................................................1379
Calibration and Characterization of Color Displays ..................................................................................................1384
Chinese Characters and Computer Input ...................................................................................................................1388
Computer Mouse Use ..................................................................................................................................................1393
Design and Use of Displays .........................................................................................................................................1398
Design Issues: Action Research in Control Room Operations ..................................................................................1403
Development of a New Taxonomy for Display Selection ........................................................................................1406
Handwheels .................................................................................................................................................................1414
Input Devices and Controls: Manual, Foot, and Computer ........................................................................................1419
Keyboards .....................................................................................................................................................................1440
Legibility of Colored Print ................................................................. 1444
Manual Control Devices ...................................................................... 1457
Multivariate Visual Displays ............................................................... 1463
A New Taxonomy for Display Selection ............................................... 1468
Photometry: An Ergonomic Perspective ............................................... 1478
Pointing Devices ................................................................................ 1487
Predictive Displays ........................................................................... 1490
Systematic Control of Exposure to Machine Hazards .......................... 1493
Visual Display Height ........................................................................ 1497
Visual Display Technology .................................................................. 1500
Visual Displays in HCI ....................................................................... 1508
Visual Fatigue and Stereoscopic Displays ............................................ 1512
Warning Design ................................................................................ 1517

PART VI  Workplace and Equipment Design

Active Safety in Car Design ................................................................. 1523
Analysis of Office Systems ................................................................. 1528
Anthropometry for Design ................................................................. 1536
Anthropometry: Definition, Uses, and Methods of Measurement ........ 1544
Biomechanics of the Wrist in Computer Keyboarding ......................... 1549
Consumer Product Design ................................................................. 1555
Creativity in Product Design .............................................................. 1559
Design for All in the Working Environment ......................................... 1563
Design of Automobile Interiors .......................................................... 1568
Design of Consumer Products: A User-Centered Approach
Design of Visual Displays for Teleoperation
Ergonomic Design of Factory Buildings in Tropical Countries
Ergonomic Product Design
Ergonomic Workstation Design
Ergonomics for Design: Assessing and Designing the Ergonomic Quality of Industrial Products
Ergonomics Knowledge and Intelligent Design System (EKIDES): A Software Tool for Ergonomics Design, Assessment, and Education
Ergonomics of Cockpits in Cars
Evaluation of Work Chairs
Facility and Workspace Layout Problems in Ergonomic Design
Handtools
Human Factors as Applied in Apparel Design
Human–Robot Interaction
Instruments and Design
Laptop Computer Use
Methods of Ergonomic Design of Human–Machine Systems
Performance Prosthetic Hands
Principles of Ergonomic Hand Tool Design
Product Development Approach
Product Usability Evaluation
Safety in Public Offices in Italy
Ships and Maritime Systems: Requirements and Issues
Ships and Maritime Systems: Design Process
Shoe Last Design for Improved Fit and Comfort .................................................................1707
Socially Centered Design .................................................................................................1712
Tactical Cockpit Technology ..........................................................................................1717
Usability of Medical Devices ..........................................................................................1721
Usability of Mobile Phone ...............................................................................................1727
User-Centered Product Concept Development ..............................................................1732
Virtual Workplace Design ..............................................................................................1737
Visual Display Units: Positioning for Human Use ...........................................................1742
Wearable Computers ....................................................................................................1746
Wheelchairs ....................................................................................................................1750
Workstations Organization .............................................................................................1755

**PART VII  Environment**

Active Customized Control of Thermal Comfort .............................................................1761
Definitions of Synthetic Environments .........................................................................1767
Environmental Ergonomics ............................................................................................1770
Relevance of Ergonomics in Domotics and Ambient Intelligence ....................................1776
Flight Motion Effects on Human Performance .................................................................1782
Free Flight .....................................................................................................................1788
Human Aspects of Lighting in Working Interiors .........................................................1793
Human Exposure to Vibration .......................................................................................1800
Illumination: Basic Definitions ......................................................................................1802
Lighting Equipment and Lighting Systems ....................................................................1810
Mental Workload Under Thermal Stress ......................................................................1817
Noise at Work .......................................................................................................................... 1821
Noise: Definitions ........................................................................................................................ 1826
Performance Effects of High G Environments ........................................................................ 1842
Physiological Costs of Noise Exposure: Temporary Threshold Shifts ....................................... 1846
Physiological Fundamentals for Work in Extreme Environments ............................................. 1854
Thermal Comfort ....................................................................................................................... 1859
Tolerance to Sustained $+G_c$ Acceleration ............................................................................... 1863
Toxicology .................................................................................................................................. 1867
Work in Extreme Environments: Current and Future Directions ............................................ 1871
Work in Extreme Environments: Effects on Performance ........................................................ 1874
Working Clothing — Thermal Properties and Comfort Criteria ................................................ 1878

**PART VIII  System Characteristics**

Accident Analysis and "Human Error" ......................................................................................... 1889
Adaptive Automation .................................................................................................................. 1893
Affordances ................................................................................................................................. 1897
Automation in Vehicles ............................................................................................................. 1901
Compatibility .............................................................................................................................. 1903
Computer Systems Design for Psychophysical Safety of Human Operations ......................... 1907
Creating Pleasurable Products .................................................................................................. 1911
Engineering Principles of Ergonomics ...................................................................................... 1915
Ergodynamics ............................................................................................................................ 1917
The Ergonomic Qualities of Products ................................................................................****** 1924
Evaluation of Software Usability ............................................................................................... 1930
Fuzziness, Requisite Compatibility, and System Design .................................................................1934


Human Factors in Land Transportation .............................................................................................1948

Human Factors in Space Flight ...........................................................................................................1956

Human Factors and Ergonomics Testing ............................................................................................1963

Human Factors System Design ...........................................................................................................1967

The Practice of Human Factors Testing and Evaluation ........................................................................1972

Integration of Quality, Ergonomics, and Safety Management Systems ......................................................1976

Integration of Risk Management into Complex Management Systems .....................................................1985

Intelligent Transportation Systems .......................................................................................................1989

Operator Testing and System Inspection Performance ..............................................................................1994

Process Control .......................................................................................................................................1999

Human Factors of Wayfinding in Navigation ..........................................................................................2003

Rail Transport ........................................................................................................................................2009


Usability Evaluation .................................................................................................................................2019

Utility Analysis ........................................................................................................................................2024

**PART IX Work Design and Organization**

Computer-Based Training Systems: Using Technology to Aid Aircraft Inspection Training .................2029

Air Traffic Management .........................................................................................................................2037

Air Traffic Management System Design ..................................................................................................2041

Application of Basic Knowledge to the Human Body: Shiftwork ............................................................2049
Balance Theory of Job Design ................................................................. 2056
Capability Acquisition Processes in Manufacturing ........................................ 2061
Change Management .................................................................................... 2066
Changes in Modern Manufacturing Practices ................................................ 2070
Collaborative Engineering: Spanning Time and Space .................................. 2075
Community Ergonomics: Applications ......................................................... 2080
Cross-Cultural Factors in Macroergonomics ................................................. 2085
Design of Shift Systems for Shiftwork ......................................................... 2091
Distributed Mission Training ........................................................................ 2096
The Ergonomic Buddy System ...................................................................... 2100
Ergonomics in the Design of Organizational Memory in IT ......................... 2105
Ergonomic Process in Small Industry ........................................................... 2109
Ergonomics and Production Philosophies ..................................................... 2114
Ergonomics in a Design Engineering Environment ....................................... 2118
Ergonomics/Human Factors Audits .............................................................. 2123
Error Management Training ......................................................................... 2126
Exposure Assessment of Upper Limb Repetitive Movements: Work Reintegration Criteria ......................................................... 2130
Healthy Work Organization ......................................................................... 2134
Historical Development of Macroergonomics: The Development of Human–Organization Interface Technology and Its Application to Work System Design ..................................................... 2139
Human Factors and Total Quality Management ............................................ 2142
Incentive Systems ......................................................................................... 2146
Inspection ..................................................................................................... 2150
Job Rotation ................................................................................................. 2156
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just-in-Time Support (JITS): A Framework to Enhance Human Performance</td>
<td>2161</td>
</tr>
<tr>
<td>Kansei Engineering and Kansei Evaluation</td>
<td>2166</td>
</tr>
<tr>
<td>Readiness for Knowledge Life Cycle Management in Organizations</td>
<td>2169</td>
</tr>
<tr>
<td>Managing Workloads to Optimize Performance, Health, and Well-Being</td>
<td>2175</td>
</tr>
<tr>
<td>Managing System Disturbances: Human Factors Issues</td>
<td>2180</td>
</tr>
<tr>
<td>Modeling of Work Environment in an Organization</td>
<td>2186</td>
</tr>
<tr>
<td>Organizational Behavior and Ergonomics</td>
<td>2195</td>
</tr>
<tr>
<td>Organizational Change and Supporting Tools</td>
<td>2200</td>
</tr>
<tr>
<td>Organizational Culture and Development</td>
<td>2204</td>
</tr>
<tr>
<td>Participatory Innovation</td>
<td>2208</td>
</tr>
<tr>
<td>Participation and Collaboration in Workplace Design</td>
<td>2215</td>
</tr>
<tr>
<td>Participation of Users in Architectural Design</td>
<td>2221</td>
</tr>
<tr>
<td>Participatory Ergonomics</td>
<td>2226</td>
</tr>
<tr>
<td>Participatory Ergonomics — A Scandinavian Approach</td>
<td>2232</td>
</tr>
<tr>
<td>Participatory Ergonomics at the Shop Floor Level</td>
<td>2236</td>
</tr>
<tr>
<td>Prevention and Compensation of Shift Work Effects</td>
<td>2240</td>
</tr>
<tr>
<td>Principles and Strategies for Team Training</td>
<td>2245</td>
</tr>
<tr>
<td>Psychosocial and Work Organization Risk Factors for Work-Related Musculoskeletal Disorders</td>
<td>2249</td>
</tr>
<tr>
<td>Quality and Ergonomics in Concert</td>
<td>2254</td>
</tr>
<tr>
<td>Quality Inspection Task in Modern Manufacturing</td>
<td>2260</td>
</tr>
<tr>
<td>Quality Management, Continuous Improvement, and Total Quality Management</td>
<td>2264</td>
</tr>
<tr>
<td>Quality of Life and Usability Engineering</td>
<td>2270</td>
</tr>
<tr>
<td>Rapid Macroergonomic Redesign</td>
<td>2276</td>
</tr>
<tr>
<td>Risk Management</td>
<td>2282</td>
</tr>
</tbody>
</table>
Teamwork ......................................................................................................................................................................2415
Technology Transfer ........................................................................................................................................................2419
Time Aspects in Assembly Line Design ...........................................................................................................................2426
Tools to Design and Evaluate New Forms of Work Organization ................................................................................2431
Training Evaluation ..........................................................................................................................................................2441
Training System Development in Ergonomics ...................................................................................................................2447
An Up-Front Engineering “Level of Protection” through Human Factor Design ..............................................................2455
Usability and Product Design ..........................................................................................................................................2466
User-Centered Systems Analysis in Aircraft Maintenance ..............................................................................................2470
User-Centered Design: Needs Analysis .............................................................................................................................2474
Work Design: Barriers Facing the Integration of Ergonomics into System Design ..........................................................2479
Work Organization Interventions ......................................................................................................................................2484
Work Organization, Job Stress, and Occupational Health ..............................................................................................2490
Working Time .................................................................................................................................................................2495

**PART X  Health and Safety**

Agriculture ........................................................................................................................................................................2501
Anthropometry for the Needs of Rehabilitation ...................................................................................................................2506
Applying Activity Theory to Flight Safety ..........................................................................................................................2517
Assessing the Risk of Upper Limb Disorders ....................................................................................................................2525
Assessment of Combined Occupational Low Back Disorder Risk Factors ....................................................................2532
A Checklist for Evaluating Exposure to Repetitive Movements of the Upper Limbs Based on the OCRA Index ..................2535
Back Belts ...........................................................................................................................................................................2542
Building and the Construction Industry ............................................................................................................................2546
Symptom Experience and Symptom Surveys in Musculoskeletal Disease Injury Evaluation ........................................... 2789

System Safety Engineering and Risk Assessment ........................................................................................................ 2794

The Strain Index .................................................................................................................................................................. 2798

Workload, Performance, Health, and Well-Being: A Conceptual Framework ........................................................................ 2802

Work Organizations: Health and Productivity Issues ........................................................................................................ 2808

Work Organization and Psychosocial Work Factors: Definitions ......................................................................................... 2812

Work-Related Joint Injuries and Arthritis ....................................................................................................................... 2817

Work-Related Musculoskeletal Disorders (WMSD): General Issues .................................................................................... 2820

Work-Related Musculoskeletal Disorders in Dental Care Workers ...................................................................................... 2825

Work-Related Musculoskeletal Disorders of Upper Limb and Back: Review of Guidelines for Their Prevention .................. 2833

Work-Related Musculoskeletal Disorders (WMSD): A Brief Overview ................................................................................ 2837

Part XI Social and Economic Impact of the System

Analysis of Worker’s Compensation Data ................................................................................................................... 2851

Collaborative Learning Environment in Higher Education: Implementing Job and Organizational Learning Theories in Academia ................................................................. 2854

Communication Processes in Small Groups ................................................................................................................... 2859

Community Ergonomics Theory: Applications to International Corporations ........................................................................... 2863

Community Ergonomics: Planning and Design Solutions for Urban Poverty ........................................................................... 2868

Economic Models for Ergonomists ................................................................................................................................... 2872

Education: The Teaching of Ergonomics ........................................................................................................................... 2876

Enhancing Industrial Performance ........................................................................................................................................ 2885

Ergonomics and Corporate Governance Avoiding the “Drift to Disaster” in Organizations ..................................................... 2892

Ergonomics and Quality of Life ........................................................................................................................................... 2898
Part XII  Methods and Techniques

Activity and Other Sampling Methods ................................................................. 2989

AET Ergonomic Job Description Questionnaire .................................................. 2997

Basic Ergonomics Checklists ............................................................................. 3003

Biomechanical Modeling of Human Strength ..................................................... 3008
Biomechanics of Low Back: Guidelines for Manual Work ................................................................. 3013
Biovect: A Vector Analysis Method on Photographic Documents Applied to Ergonomic Analysis .............................................................................................................. 3018
Bivariate Anthropometric Design for Work Spaces and Products ......................................................... 3023
Noninvasive Optical Spectroscopy — Determined Cerebral Hemodynamics as Psychophysiological Measures of Physical Work ............................................ 3035
Cognitive Systems Engineering .............................................................................................................. 3042
Cognitive Task Analysis .......................................................................................................................... 3044
Communication Analysis .......................................................................................................................... 3049
Computer Simulation: Applications to Human Factors and Ergonomics ........................................... 3053
Confidence in Self-Report Questionnaires Results: An Issue for the Intervention Researcher .......... 3058
Content Analysis: Hypermedia Design ..................................................................................................... 3063
The Critical Decision Method .................................................................................................................... 3067
The Critical Incident Technique: A Method for Identifying System Strengths and Weaknesses Based on Observational Data ......................................................... 3074
Data Mining in Ergonomics ....................................................................................................................... 3077
Design Methodology ................................................................................................................................. 3082
Determining Usability Test Sample Size .................................................................................................. 3084
DIALOG: Human Reliability Assessment ................................................................................................. 3089
Digital Human Models for Ergonomics ....................................................................................................... 3093
Ecological Ergonomics: Theory in Context ............................................................................................... 3097
Ecological Interface Design: Applications ................................................................................................ 3101
Electromyography: Fundamentals ............................................................................................................ 3107
Electromyography: Methods and Techniques ......................................................................................... 3115
Empirical Methods: Experiments ................................................................................................................ 3119
ERGO_X — The Model of a Fuzzy Expert System for Workstation Ergonomic Analysis ..................... 3122
Applications of Microsimulation in Cognitive Skills Development ................................................................. 3262
Mitigating Cybersickness in Virtual Environments ........................................................................................................ 3268
MUSE-JSD: Structured Integration of Human Factors and Software Engineering Methods ...................................................... 3271
The MUSE Method for Usability Engineering ................................................................................................................... 3275
Noise: Metrics and Equipment ........................................................................................................................................ 3279
Observation ........................................................................................................................................................................... 3285
The OCRA Method: Assessment of Exposure to Occupational Repetitive Actions of the Upper Limbs .......................................................... 3289
OWAS — A Method for Analysis of Working Postures ........................................................................................................ 3298
Prevention of Work Injury ...................................................................................................................................................... 3302
Psychophysiological Methods ................................................................................................................................................. 3308
Quantitative Method for Processing Objective Data from Posture Analysis ........................................................................ 3316
Questionnaires ........................................................................................................................................................................ 3320
Research Design Basics ......................................................................................................................................................... 3324
Response Surface Methodology and Sequential Experimentation .......................................................................................... 3342
Scenario-Based Design of ICT-Supported Work .................................................................................................................... 3348
Scientific Management Influences on Ergonomic Analysis Techniques .................................................................................. 3354
Sources of Error in Ergonomics Research .............................................................................................................................. 3357
Survey Design ............................................................................................................................................................................. 3362
A Survey of Ergonomics Methods ....................................................................................................................................... 3367
Taguchi Method for Ergonomic Design .................................................................................................................................. 3372
Task Analysis for Error Identification ....................................................................................................................................... 3376
Task Analysis in Industry .......................................................................................................................................................... 3379
Technique for the Retrospective and Predictive Analysis of Cognitive Error (TRACEr and TRACEr-lite) ................................................................. 3384

Verbal Protocol Analysis ............................................................................................................................................... 3390

Work Stress Quantification and Evaluation Using ErgoMOST™ ................................................................. 3393

Part XIII Outstanding Human Factors and Ergonomics Professionals

Munehira Akita .............................................................................................................................................................. 3401

Earl A. Alluisi ................................................................................................................................................................ 3404

John Annett ................................................................................................................................................................. 3407

M. M. Ayoub ................................................................................................................................................................ 3410

Frederic Charles Bartlett ............................................................................................................................................... 3412

Corwin Bennett ............................................................................................................................................................. 3414

Paul Branton .................................................................................................................................................................. 3415

Donald Eric Broadbent (1926–1993) .............................................................................................. .............................. 3417

Don B. Chaffin .............................................................................................................................................................. 3420

Alphonse Chapanis (1917–2002) .................................................................................................. ................................ 3422

Marvin J. Dainoff .......................................................................................................................................................... 3425

Harry L. Davis ............................................................................................................................................................... 3427

Otto Gustav Edholm (1909–1985) ................................................................................................. ............................... 3430

Jean-Marie Faverge ....................................................................................................................................................... 3431

Paul Morris Fitts ............................................................................................................................................................ 3432

Etienne Grandjean ......................................................................................................................................................... 3435

Antonio Grieco (1931–2003) .................................................................................................................. .................................................................................. 3438

Kunie Hashimoto ........................................................................................................................................................... 3441

Hal W. Hendrick .......................................................................................................................................................... 3444
<table>
<thead>
<tr>
<th>Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wojciech Bogumil Jastrzebowski</td>
<td>3447</td>
</tr>
<tr>
<td>Karl H. E. Kroemer</td>
<td>3449</td>
</tr>
<tr>
<td>Ross A. McFarland</td>
<td>3451</td>
</tr>
<tr>
<td>Neville Moray</td>
<td>3453</td>
</tr>
<tr>
<td>Koiti Motokawa</td>
<td>3455</td>
</tr>
<tr>
<td>Vladimir M. Munipov</td>
<td>3457</td>
</tr>
<tr>
<td>Mitsuo Nagamachi</td>
<td>3459</td>
</tr>
<tr>
<td>Takao Ohkubo</td>
<td>3461</td>
</tr>
<tr>
<td>Masamitsu Oshima</td>
<td>3463</td>
</tr>
<tr>
<td>Longin Paluszkiewicz (1925–1989)</td>
<td>3465</td>
</tr>
<tr>
<td>Bernardino Ramazzini</td>
<td>3467</td>
</tr>
<tr>
<td>Walter Rohmert</td>
<td>3471</td>
</tr>
<tr>
<td>William B. Rouse</td>
<td>3474</td>
</tr>
<tr>
<td>Gavriel Salvendy</td>
<td>3476</td>
</tr>
<tr>
<td>Heinz Schmidtke</td>
<td>3478</td>
</tr>
<tr>
<td>Thomas B. Sheridan</td>
<td>3479</td>
</tr>
<tr>
<td>Karl U. Smith</td>
<td>3480</td>
</tr>
<tr>
<td>Stover H. Snook</td>
<td>3484</td>
</tr>
<tr>
<td>Sadao Sugiyama</td>
<td>3487</td>
</tr>
<tr>
<td>Wesley (Wes) Woodson</td>
<td>3490</td>
</tr>
</tbody>
</table>

**Back Matter**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published Ergonomics Literature</td>
<td>3491</td>
</tr>
<tr>
<td>Bibliography</td>
<td>3518</td>
</tr>
<tr>
<td>Index</td>
<td>3531</td>
</tr>
</tbody>
</table>
Part I

General Ergonomics
An Annotated Review of Selected Military and Government Sources of Human Factors Design Related Criteria

W. F. Moroney* and J. A. Cameron†
*Human Factors Program, University of Dayton, Dayton, OH 45469-1430, USA
†Crew System Ergonomics/Human Systems Technology Information Analysis Center (CSERIAC), Wright-Patterson AFB, OH 45433-7022, USA

1 INTRODUCTION

The purpose of this chapter is to transfer the human factor design related criteria developed by US government agencies to non-government personnel. While many readers are familiar with ISO (International Standards Organisation), ANSI (American National Standards Institute) and SAE (Society of Automotive Engineers) standards, they are not familiar with design standards developed primarily by military agencies or agencies with a specific focus, such as the FAA (Federal Aviation Administration) and NASA (National Aeronautics and Aerospace Administration). Readers seeking design criteria, principles and practices for use in the design and development of systems, equipment and facilities will find these standards useful. Please note that since we have focused on design-related criteria we did not include guidelines or regulations developed by agencies such as NIOSH (National Institute of Occupational Health and Safety) or OSHA (Occupational Health and Safety Agency).

How are these criteria developed? Essentially, these standards were developed by committee and represent (1) the best of what was known at the time of their development and (2) the consensus arrived at by the committee. In some cases, an arbitrary decision is required. For example, luminance contrast (C) can be defined as either \( \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{min}}} \) or \( \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}}} \). The former formula produces whole numbers, while the latter formula produces values between 0 and 1.0. If luminance contrast is to be specified as design criteria then only one definition is acceptable, and DoD representatives elected to use the former definition.

The five major documents described here are:

- MILSTD 1472: Human Engineering design criteria for military systems, equipment, and facilities.
- Department of Defense (DoD) Human Computer Interface Style Guide.
- Federal Aviation Administration (FAA) Human Factors Design Guide (HFDG) for Acquisition of Commercial-off-the-Shelf-Subsystems, Non-developmental Items and Developmental Systems.

Readers may also wish to consult the excellent British Defence Standard 00-25: Human Factors for Designers of Equipment. Defence Standard 00-25, is comprised of 13 parts and designed to “be viewed as a permissive guideline, rather than a mandatory piece of technological law” (vol. 1, p. 1). The text, written for designers with a variety of technical backgrounds, includes both general background information and human factors data. Most parts include definitions of terms relevant to that specific part, references and/or related documents, and sources for obtaining related documents. The 13 parts of this standard were issued over a period of more than ten years. Interested readers can download BDS STD 00-25 from the WWW site provided in the references.

2 MIL-HDBK 46855: HUMAN ENGINEERING PROGRAM PROCESSES AND PROCEDURES

MIL-HDBK 46855 is a DoD guidance document that describes the analysis, design and development, and test and evaluation considerations expected in a Human Engineering (HE) Program. It describes: (1) the program tasks, (2) the procedures and preferred practices useful in implementing the guidance, and (3) selected HE methods. The handbook of approximately 300 pages consists of eight sections.
Annotated Review of Selected Military and Government Sources

3 MIL-STD-1472 HUMAN ENGINEERING

MIL-STD-1472, provides design criteria, principles, and practices for use in the design and development of military systems, equipment and facilities. It was originally developed in 1968 and has been periodically reviewed and updated since. It is currently undergoing technical revision, and the new version, revision F, should be available some time in 2000.

This standard is supported by two additional documents: MIL-HDBK-1908A, Definitions of Human Factors Terms (MIL-HDBK 1908 is currently undergoing revision) and MIL-HDBK-759C, Human Engineering Design Guidelines. These two documents provide important supplementary information for practitioners using MIL-STD-1472. MIL-HDBK-1908A provides standard definitions for human factors terms to supersede conflicting definitions in the literature and to eliminate unnecessary overlap. MIL-HDBK-759C provides additional guidelines and data that may be useful when designing military systems, equipment, and facilities. It is organized in sections that correspond with the top three levels of headings in MIL-STD-1472.

The body of MIL-STD-1472 is structured in five sections: (1) Scope, (2) Applicable Documents, (3) Definitions, (4) General Requirements, and (5) Detailed Requirements. There is also a detailed index. Most of the substantive content of MIL-STD-1472 occurs in Sections 4 and 5.

- Section 4: provides high-level guidance about a variety of topics including functional allocation, human engineering design, fail safe design, simplicity of design, safety, ruggedness, nuclear/biological/chemical (NBC) survivability, and electromagnetic pulse (EMP) hardening. The 16 subsections of Section 5 in MIL-STD-1472E provide detailed requirements (principles, practices, criteria) concerning the topic areas described below.
- Section 5.1. Control/display integration: provides guidance concerning integration issues such as position and movement relationship, grouping, consistency, and control/display movement ratios.
- Section 5.2. Visual displays: much of the information about displays in MIL-STD-1472E concerns displays that are presented using technologies such as trans-illuminated displays, legend lights, and signal lights. Only limited information is provided about displays that are presented using computer technology. Human factors issues considered in Section 5.2 include display illumination; information content, precision, and format; location and arrangement; coding; scale types and designs; counters; and pointers.
- Section 5.3. Audio displays: includes information about topics including audio warning signals, verbal

1. Scope: describes both the document in general and its applicability and tailoring (using selected portions in developing the HE program for a system under development).
2. Applicable Documents: lists relevant DoD standards, specifications, and handbooks as well as other pertinent government documents.
3. Definitions: defines the acronyms used in this HDBK.
4. Program Tasks: provides general program task guidance that the system developer can incorporate into the HE Program Plan. Issues addressed include, among others, risk management, non-duplication, analyses options, procedure development, and failure and error analysis.
5. Significance of HE for Program Acquisition: describes the role of HE in systems acquisition, including Human System Integration (HSI) and Manpower, Personnel, and Training (MPT) implications. The range of HE activities are described, as well as the value of HE (descriptions of benefits and problems resulting from the lack of HE are provided).
6. HE Procedures for DoD Organizations: describes the HE responsibilities of the DoD organization acquiring the system. Descriptions of implementations unique to each service are provided. Details on program planning, budgeting, and scheduling; preparing the Request for Proposal (RFP); proposal evaluation; and contract monitoring are also provided.
7. HE Procedures for Contractors: describes the HE responsibilities of the contractor developing the system. A listing of HE design standards and guidelines is provided. Descriptions of documentation (e.g. HE Test Plan, HE System Analysis Report) required by the acquiring agency are provided.
8. HE Methods and Tools: being of ~100 pages, provides details and references to a wide variety of time-tested methods. The methods described include mission, timeline, and workload analysis; diagrams (operational sequence, decision/action); and checklists, mockups, and mannequin usage. HE Test and Evaluation methodologies described include: HEDGE (Human Factors Engineering Design Guide for Evaluation), interviewing and questionnaire techniques, physiological instrumentation, and physical measurement.
   - Appendix A, Application and Tailoring.
   - Appendix B, Task Analysis.
   - Appendix C, Data Item Descriptors (DID).
   - Appendix D, a matrix that cross-references sections of this HDBK with relevant DoD documents.
warning signals, speech transmission equipment, speech reception equipment, and speech intelligibility.

- Section 5.4. Controls: includes information about rotary and linear controls, about discrete and continuous controls, and about keyboards, joysticks, trackballs, touch screens, and mice. It also addresses human factors issues including direction of movement; arrangement and grouping; coding; and accidental actuation.

- Section 5.5. Labeling: includes both general information about labeling and specific information about label orientation and location, label content, qualities of the information presented (e.g. brevity, stated using familiar terms etc.), design of label characters and labeling of equipment.

- Section 5.6. Physical accommodation: generally based on criteria that are generally stated in terms of percentiles.

- Section 5.7. Workspace design: provides information about common working postures, about workspace design for seated and standing operators, and about specific workspace feature such as stairs, stair ladders, fixed ladders, ramps, doors, hatches, and surface colors.

- Section 5.8. Environment: provides information about heating, ventilation, air conditioning, illumination, acoustical noise, and vibration.

- Section 5.9. Design for maintainer: includes information about mounting, adjustment controls, accessibility, lubrication, cases, covers, access openings and covers, fasteners, conductors, connectors, test points, test equipment, failure indications, fuse requirements, printed circuit boards, and designing for efficient handling.

- Section 5.10. Design of equipment for remote handling: includes information about the characteristics of the equipment to be handled remotely, feedback, manipulators, viewing equipment, and illumination.

- Section 5.11. Small systems and equipment: provides information about portability and load carrying; tracking; and optical equipment and related equipment (e.g. sights, reticles, binoculars).

- Section 5.12. Operational and maintenance ground/shipboard vehicles: includes basic information about vehicle design including information about seating; controls; operating instructions; visibility; heating and ventilation; trailers, vans, and intervehicular connections; cranes, materials handling and construction; and automotive subsystems.

- Section 5.13. Hazards and safety: includes information about safety labels and placards; pipe, hose, and tube line identification; general workspace hazards (e.g. emergency exits, illumination, thermal contact hazards); general equipment-related hazards; platforms, electrical, mechanical, fluid, toxic, and radiation hazards; trainers; and stealth and covert operations.

- Section 5.14. Aerospace vehicle compartments: contains limited information about the design of the crew station and passenger compartments, personnel entrance and exit, and emergency evacuation.

- Section 5.15. User–computer interface: include information about data entry, data display, interactive control, feedback, prompts, defaults, error management/data protection, data and message transmission, and system response time. It was not updated during the technical review of MIL-STD-1472E. For more current information, readers should consult the Department of Defense Human Computer Interface Style Guide, Volume 8 of the Department of Defense Technical Architecture Framework for Information Management (TAFIM see below).

- Section 5.16. Visual display terminals (VDT): directs the user to ANSI/HFS 100 (Human Factors Society) for information about the use of VDT in office environments. However, VDT use in other environments is governed by requirements in this MIL-STD.

4 DEPARTMENT OF DEFENSE (DOD)
HUMAN COMPUTER INTERFACE
STYLE GUIDE

The DoD Human Computer Interface (HCI) Style Guide is Volume 8 of the DoD Technical Architecture Framework for Information Management (TAFIM). This document, of >300 pages, is an excellent source for HCI guidelines, which can be traced back to references. Volume 8 consists of 14 sections that are described below:

- Section 1. Introduction: the goal of this document is to provide HCI standardization, i.e. a common framework for HCI design and implementation within the DoD. It is intended for use by individuals who determine system requirements, program managers, system managers, software developers, and application HCI designers. The secondary audience includes users, software maintainers, and test and evaluation personnel. The document is applicable in both the operational and the business environments.

- Section 2. Interface Style: written for software developers, this section describes strategies for selecting a user interface style and for re-designing interfaces to improve usability. It also addresses application portability across platforms.
• Section 3. Hardware: focuses on input/output (I/O) devices, displays technologies other than CRT (e.g., liquid crystal, large screen, stereoscopic, etc.), and alternate I/O devices (Braille printers, large keycaps on keyboards, etc.) for individuals with disabilities.

• Section 4. Screen Design: provides guidance concerning screen design, log-on/off procedures, and the use of color.

• Section 5. Windows: provides guidance on basic window design including appearance, message areas, scroll bars, labeling, and navigation.

• Section 6. Menu Design: provides information about advantages and disadvantages of menus, pull-down and pop-up menus, hierarchical menus, menu labeling, and dialog menus.

• Section 7. Direct Manipulation: provides information about screen arrangement by users, and about metaphors and icons (types, use, design, evaluation).

• Section 8. Common Features: provides guidance concerning interface features, functions, and formats that should be used consistently in all DoD applications. It also provides information about on-line Help, user computer dialogs (e.g., interrupts, error management, alarms), and the use of function keys.

• Section 9. Text: addresses the use of text within windows (labeling and updating fields, and the text cursor). It also provides guidelines for form completion (form layout, error management, etc.).

• Section 10. Graphics: provides guidelines for presenting data in graphical formats including tactical graphics (overlays, symbology, and terrain representation), pictographic representations (digitized maps, pictures, etc.), and presentation graphics (graphs, pictures, and diagrams). Guidelines pertaining to graphical characteristics of the user interface (e.g., screen design, windows, icons, buttons, etc.) are also provided.

• Section 11. Decision Aids: describes when to use decision aids and expert systems, and offers guidance concerning requirements definition for decision aids, features of decision aids, decision aid interfaces and displays, and user training.

• Section 12. Query: deals with accessing data from Database Management Systems. This Section describes the types of database queries and database storage methods. It focuses on user-oriented database design and provides specific guidance on query screen designs, user requirements, user-friendliness, search options, and differing design requirements for novice and expert users.

• Section 13. Embedded Training: deals with on-line training that focuses on the learning process, as opposed to on-line help which provides assistance with specific functions, commands, etc. It provides guidance on embedded training including components of embedded training, instructional structure, and presentation. Guidance is also provided on screen design, navigation within embedded training, error feedback, and the ability to modify embedded training.

• Section 14. Emerging Technology: is divided into two sections: (1) personalization of the user interface to meet the skill levels and characteristics of different users (this includes adaptive modeling and workgroup situations) and (2) multimedia (including authoring systems and navigating within multimedia).

• Appendices: an 18-page glossary and 31 pages of references are provided.

5 FEDERAL AVIATION ADMINISTRATION HUMAN FACTORS DESIGN GUIDE FOR ACQUISITION OF COMMERCIAL-OFF-THE-SHELF-SUBSYSTEMS, NON-DEVELOPMENTAL ITEMS AND DEVELOPMENTAL SYSTEMS

The FAA Human Factors Design Guide (HFDG) provides referenced information to assist in the selection, analysis, design, development, and evaluation of new and modified FAA systems, facilities, and equipment. This 1996, 2-inch loose-leaf binder document (also available on CD-ROM) combines guidance from other sources into one “human factored, user friendly” document. The document contains 14 sections, four appendices and an index that are described below:

• Section 1. Introduction: describes the purpose, scope, and format of the document.

• Section 2. Complementary Documents: describes the sources from which data were integrated into this document. The sources cited include 32 Government Specifications, Handbooks and Orders, 10 federal regulations (including OSHA), and 20 non-government documents (ANSI/HFS, ASME (American Society of Mechanical Engineers), etc.).

• Section 3. Definitions: provides ~275 definitions of terms used in the text.

• Section 4. General Design Requirements: provides general principles for designing or selecting systems and equipment, and discusses human performance and human–system interactions at the top level.

• Section 5. Maintenance Automation: primarily tutorial in nature. It provides general principles, as well as guidance, on human-centered automation; process control lessons; command, control, and communications; systems engineering; monitoring;
interfaces; remote maintenance; and maintenance management information.

- Section 6. Designing Equipment For Maintenance: provides criteria and guidelines related to designing equipment for handling; packaging, arrangement and mounting of equipment; access openings; covers and shields; cases; fasteners; connectors; lines and cables; packaging, layout, and mounting of internal components; adjustment controls; failure detection and isolation; fuses and circuit breakers; test points and service points; test equipment; and tools.

- Section 7. Human–Equipment Interfaces: addresses display–control integration. It also provides specific guidance concerning the following topics:
  - Visual displays (principles, trans-illuminated displays, scale indicators, CRT, large screen displays, light emitting diodes, flatpanel displays, liquid crystal displays, plasma, electro-luminescent displays, stereoscopic displays, and touch panels);
  - Audio Displays (warnings and signals, controls, and voice communication);
  - Controls (selection of, movement, arrangement and grouping, coding, compatibility with hardware, accidental activation, foot operated, hand operated, keys, thumbwheels, knobs, cranks, pushbuttons, keyboards, levers, joysticks, ball controls, stylus devices, etc.);
  - Labeling and Marking (general guidance, location and orientation, typographic matters, designing label characteristics, wording, and information); and
  - Accommodating People with Disabilities (controls and displays for people with disabilities, telecommunications, and safety for people with disabilities).

- Section 8. Human–Computer Interfaces: provides guidance concerning user computer interaction, basic screen design and operation, windowing, data entry, data display, user guidance, data communication, input devices, and accommodating people with disabilities.

- Section 9. Workplace Design: describes workplace layout, designing of passageways, common working positions, standard console design, visual display terminals (VDT), and accommodating people with disabilities.

- Section 10. User Documentation: provides guidance on writing user documentation, layout and format, components of documents (cover pages, figures, tables, etc.), specific user document contents (proceduralized instructions, interactive electronic technical manuals), and accommodating people with disabilities.

- Section 11. System Security: describes general design practice, physical security and access control, identification and authentication, auditing, information and data protection, documentation of security safeguards, and security training.

- Section 12. Personnel Security: provides guidance on, workplace safety, safety labels, and placards. It also sets limits/specifies protection for the following types of hazards: liquid and gas, toxic, radiation, special chemicals, temperature, fire, noise, explosion and implosion, radiant energy and lasers.

- Section 13. Environment: provides guidelines on ventilation, temperature and humidity, illumination, and noise.

- Section 14. Anthropometry and Biomechanics: provides information about the application of anthropometric and biomechanical data and about anthropometric variability as well as anthropometric and biomechanical data on reach, human strength, and handling capacity. It concludes with a section on designing for physical comfort.

- Appendix A. References: 13 pages of references are provided.

- Appendix B. Sources: sources of the data contained in each section are specified.

- Appendix C. Standard Actions — Pushbuttons: provides definitions of functions that are performed with pushbuttons in windows (e.g. back, close, clear, cut, compile, etc.).

- Appendix D. Standard Verbs: provides definitions of verbs for use in task analysis and in writing procedural instruction (e.g. accomplish, align, find, clamp, etc.).

- Index: the 81-page index allows the reader to locate information that may be located in several sections.

6 NASA-STD-3000: MAN–SYSTEMS INTEGRATION STANDARDS

The NASA Man–Systems Integration Standards (NASA-STD-3000) is a multi-volume set of documents that specifies generic requirements for space facilities and equipment that interface directly with crewmembers is applicable to all manned space programs. Of primary interest are Volume 1, Man Systems Integration Standards (NASA-STD-3000, Revision B) and Volume 2, Man–System Integration Standards: Appendices.

Volume 1 is divided into 14 sections. In general, each section contains three, and sometimes four, kinds of information: (1) an overview of the section’s content, (2) design considerations (background information that can help a user understand the rational behind specific requirements), (3) design requirements (contractually binding standards), and (4) design examples (sometimes included
to illustrate important information). Although written for application in the space environment, with the exception of microgravity concerns, much of the information contained in the NASA-STD-3000 can be applied to comparable human interface/engineering problems in other environments.

- **Section 1. Introduction:** includes a statement of purpose; an overview of the entire set of Man–System Integration Standards; a statement of scope, precedence, and limitations; and general instructions on how to use the documents.

- **Section 2. General Requirements:** focuses on basic design information related to simplicity and standardization.

- **Section 3. Anthropometry and Biomechanics:** presents quantitative information about human body size, joint motion, reach, neutral body posture, body surface area, body volume, and body mass properties.

- **Section 4. Human Performance Capabilities:** documents the significant ways that the performance capabilities of humans may change when they go into space. It includes information about vision; the auditory system; olfaction and taste; kinesthesia; reaction time; motor skills/coordination; strength; and physical workload.

- **Section 5. Natural and Induced Environments:** indicates the kinds of conditions to which a crewmember will be exposed during space flight including information about the effects of the composition of the atmosphere, microgravity, and acceleration, and specification of acceptable noise, vibrations, radiation, and thermal levels.

- **Section 6. Crew Safety:** deals with general safety concerns such as mechanical hazards; electrical hazards, fire protection and control, and decompression as they relate directly to crewmembers.

- **Section 7. Health Management:** discusses measures that must be taken to maintain crewmember health including both preventive care and medical care.

- **Section 8. Architecture:** provides information about the placement, arrangement and grouping of compartments and crew stations in space modules, including design data for concerning traffic flow, translation paths, location coding, orientation of workstations especially in microgravity, physical body envelopes for essential crew functions, hatches, doors, windows, lighting, and mobility aids and restraints.

- **Section 9. Workstations:** covers basic workstation design, including layout, controls, displays, labeling, coding, and user/computer interaction design.

- **Section 10. Activity Centers:** discusses design and layout requirements for off-duty crew stations in the space module including facilities for personal hygiene, body waste management, trash management, crew quarters, recreation and meeting facilities, exercise and medical facilities, laundry facilities, and storage.

- **Section 11. Hardware and Equipment:** offers general equipment design guidance for tools; drawers and racks; closures and covers; mounting hardware; handles and grasp areas for portable items; restraints; mobility aids; fasteners; connectors; windows; packaging; crew personal equipment including clothing; and cable management.

- **Section 12. Design for Maintainability:** provides general guidance concerning maintainability and specific requirements concerning design; physical access; visual access; removal, replacement, and modularity; fault detection and isolation; test points; and requirements for a maintenance data management system.

- **Section 13. Facility Management:** addresses issues associated with housekeeping, inventory control, and information management.

- **Section 14. Extravehicular Activity (EVA):** establishes guidelines for extravehicular activity.

**Volume 2, Man–Systems Integration Standards: Appendices,** contains the appendices which pertain to the Man–System Integration Standards. These appendices include a bibliography, list of sources used to develop specific paragraphs, glossary, abbreviations and acronyms, units of measure and conversion factors, and index/keywords listing. **Volume 3, Man–Systems Integration Standards: Design Handbook,** provides a condensed version of quantitative data from Volume 1. However, this volume currently reflects contents of Revision A, rather than Revision B, of Volume 1.

### 7 Obtaining These Documents

The Internet has profoundly changed our ways of acquiring technical information — so much so that most of the documents described in this section can be viewed on-line and/or downloaded directly from the web.


The DODSSP URL provided above allows access to the Acquisition Streamlining and Standardization
Information System (ASSIST) which provides electronic access to some military standards and handbooks.

The remaining documents described here can be accessed directly on the Web (either viewed on-line and/or downloaded) using the information the Reference section. In addition, the “NSSN: A National Resource for Global Standards” web site (URL: http://www.nssn.org/) allows one to search for standards documents produced by >600 organizations. Their search engine is an excellent source for locating most international civilian and military standards.

ACKNOWLEDGEMENT

The opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by CSERIAC.

REFERENCES

Dates are not provided because these documents, or sections of the documents, are updated on an irregular basis and readers should consult the most current version. The documents reviewed here are those available in February 1999. Current versions may be obtained from the sources listed.


DoD, MILSTD 1472: Human Engineering [http://www.dodssp.daps.mil/].


NATIONAL RESOURCE FOR GLOBAL STANDARDS [http://www.nssn.org/].
References

Preface to 2nd Edition


An Annotated Review of Selected Military and Government Sources of Human Factors Design Related Criteria

Cognitive Engineering


Cultural Ergonomics


SEN, R.N., 1984, Application of ergonomics to industrially developing countries. Ergonomics, 27, 1021-32.


Defining Ergonomics/Human Factors


HENDRICK, H.W., 1996a, Good ergonomics is good economics. Ergonomics in Design (Santa Monica, CA: Human Factors and Ergonomics Society).

HENDRICK, H.W., 1996b, Road map to the future: revised strategic plan. HFES Bulletin, 35(10), 1, 5.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who</td>
<td>Human Factors/Ergonomics</td>
</tr>
<tr>
<td>What</td>
<td>System Engineering</td>
</tr>
<tr>
<td>How</td>
<td>Environment Safety</td>
</tr>
<tr>
<td>When/Where</td>
<td>People Machine</td>
</tr>
<tr>
<td>Goal</td>
<td>Designing Work Comfort</td>
</tr>
</tbody>
</table>
Design

W. W. Gasparski

Institute of Philosophy and Sociology, Polish Academy of Science, Nowy Swiat 72, 00-330 Warsaw, Poland

Ecological Approach


Epistemological Issues about Ergonomics and Human Factors


LATOUR, B., 1993, We Have Never Been Modern (Harvard University Press).


The European Union’s Policy in the Occupational Safety and Health Sector


http://europa.eu.int/comm/dg05/h&s/index_hs.htm.
Exposure Assessment of Upper Limb Repetitive Movements: A Consensus Document

ANSI (USA) — Draft ANSI Z-365, 1995, Control of Work-Related Cumulative Trauma Disorder.


BYSTROM, S., 1991, Physiological response and acceptability of isometric intermittent handgrip contractions. Arbete ochalsa, NIOSH


APPENDICES

In appendices A and B, some risk assessment examples are shown in order to obtain exposure scores. They represent only a hypothesis of simple methods easily applicable in the field. In appendices C and D, information about the assessment of force, posture, and movement in easily applicable, international consensus standards are presented. The appendices contain examples of practical methods previously used for measuring exposure and assessing risk. The methods presented in appendices A and B have proved useful in field studies and illustrate possible approaches to the analysis of work place risk factors. In addition, force capacity values included in the preliminary CEN standard...
(PrEN 1005-3) and the evaluation procedure for postures and movements used in ISO/DIS 11226 and prEN 1005-4 are presented in appendices C and D.

Note: The proposed methods available for work place risk assessment purposes are numerous and the examples presented in this appendix are not especially endorsed or recommended by the authors of the consensus document, nor by the IEA Technical Committee.

APPENDIX A: AN EXAMPLE FOR CALCULATING POSTURAL EXPOSURE SCORES

(COLOMBINI 1998)

In order to allow the technician to make an easier description and classification of posture effort (type of posture per time),

Table 6 reports a form with an example of all the major items for each one of the four segments of the upper limb under consideration.

There are four operational phases in the form:

(a) A separate description of postures and/or movements by each joint: shoulder, elbow, wrist, hand (type of hold and finger movements), and by type of effort (static, dynamic).

(b) Static postures: observation of static postures close to extreme articular range, during the cycle/task time (A 3, C 3, D 3); observation of static postures in medium leverage angle held for prolonged period (A 4, C 4); observation of grip positions (D 1) during cycle/task time.

(c) Joint movements: presence of articular movements, close to the extreme joint excursions during the cycle/task time (A 1, B 1, C 1); repetitive articular movements, due to presence of same technical actions (independently of...
the articular range) for at least 50% of cycle time and subsequently of task time \((A_2, B_2, C_2, D_2)\). (d) Calculation (for each joint) of the postural involvement score within the cycle/task time summing the scores written in the square boxes, checked during the posture analysis. The posture involvement score is attributed to each joint, taking into account that the presence of a significant effort is given by either of the two minimum scenarios, one for static postures and the other for movements, respectively. For practical purposes, a significant cycle should be analyzed (preferably by a video) for each repetitive task. The video could be reviewed in slow motion to describe and evaluate the effort of each joint segment, making a distinction between right and left side when the effort is asymmetrical. A possible example to obtain a risk score for the lack of recovery periods is shown below. Example With the help of Table 6, analyze the work of an operator who picks up a handful of screws with the right hand, and for two-thirds of the cycle fits the screws into their holes, always using the same hand and holding his arms off the table. Cycle time is 15 s; shift duration is 8 h. Begin by observing the shoulders. The operator first takes the screws from a container (abduction/adduction more than 60°) and then keeps the arm in flexion, in a risk area \((60°)\) for 2/3 of cycle time. In Table 6, under shoulder sign in A1: 1/3 (score 4), in A3: 2/3 (score 8), in A4 the continuously keeping the arm raised (score 4). The posture score for the shoulder is 16: in this way critical movements, critical static postures and continuously arm-raised positions are summed up considering time pattern during the cycle. As for the elbow, the operator carries out pronation movements (and return from pronation) \(60°\) for two-thirds of cycle time. Under the elbow B1, enter two-thirds of cycle time for pronation movement (score 4), and in B2 enter “4” for movement stereotypy. The elbow has an overall score of 8. The wrist joint does light flexion (and return from the flexion) movements, but for gestures of the same type, and for two-thirds of cycle time. Under C2 fill in 4. UPPER LIMB: O RIGHT O LEFT RISK SCORE IN CYCLE TASK INVOLVEMENT ELBOW MOVEMENTS SHOULDER POSITION SAND MOVEMENTS WRIST POSITIONS AND MOVEMENTS TYPE OF GRIP AND FINGER MOVEMENTS IN EXTREME ARTICULAR RANGE: Score 4 Score 4 Score 4 EXTENSION FLEXION RADIAL DEVIATION Ulnar DEVIATION Score 3 Score 2 Score 2 Score 2 RANGE EXCURSION OF AT LEAST 60° INDEPENDENTLY BY A START POINT Score 4 Score 4 Score 0° 0° 0° 0° 0° 0° 20° 20° 60° 60° 60° 45° 45° 0° 15° 20° 0° 60° THEY TAKE: \([A1]\) LACK OF VARIATIONS: performs work gestures of the same type involving the shoulder for

Analysis of Upper Limb Postures as a Function of Time: A Simplified Model with an Example (Example 4)

The overall score for the wrist is 4.

The hand is involved in concurrent precision grip (PINCH).

These gestures are always the same, and last for the whole of the cycle. Under D1 sign 3/3 (score 9); under D3 sign the box 4; the overall score the hand is 13.

When the cycle time is extremely short (e.g. shorter than 6 s), the stereotypy of the technical actions is always
A still empirical but effective way of performing such analysis is by examining individually the hours that make up the shift; for each hour it is necessary to verify whether repetitive tasks are carried out and whether there are adequate recovery periods (Colombini 1998).

According to the presence/absence of adequate recovery periods within each hour of the repetitive work under examination, each hour is considered as being either “risk-free,” or “at risk” if there is a lack of adequate recovery periods.

The overall risk related to lack of recovery periods could be determined by the total number of hours of the shift in which recovery is insufficient.

A possible example to obtain a risk score for lack of recovery periods is shown in example 5 (Figure 4). The risk due to a lack of recovery periods is classified with a score of 4. This expresses the number of hours in the shift in which the recovery is insufficient. In an eight-hour shift, with a lunch break but with no other pauses at all, the score will be 6; in fact, the hour of work followed by the lunch break, just as the last hour before the end of the shift, can be considered as risk-free, because they are followed by adequate recovery periods. APPENDIX C: RECOMMENDED FORCE LIMITS FOR MACHINERY OPERATOR (PREN 1005-3 1996)
standard deviation) of the maximal isometric force for the relevant action in the general adult healthy European population. Decide if the machinery is intended for professional or domestic use. Determine \( F_{15} \), i.e. the 15th force percentile for professional use or the 1st percentile for domestic use. APPENDIX D1: EVALUATION OF WORKING POSTURES (ISO/DIS 11226 1998) The holding time for upper arm elevation is evaluated using Figure 5. In a working situation where a single repetitive task is carried out (task A), and where pauses are distributed as follows: BREAK (10 MIN.) BREAK BREAK LUNCH (10 MIN.) 1°h. 2°h. 3°h. 4°h. 5°h. 6°h. 7°h. 8°h. 9°h. A A A A A A A A the following scheme (protocol) should be adopted: 1st HOUR = 60 min. TASK (no rec.) = RISK 1 6th HOUR = 60 min. TASK (no rec.) 8th HOUR = 50 min. TASK (no rec.) 9th HOUR = 60 min. TASK + RECOVERY END OF SHIFT 3rd HOUR = 60 min. TASK (no rec.) 4th HOUR = 60 min. TASK 5th HOUR = 60 min. REC. 2nd HOUR = 50 min. TASK: 10 REC. 7th HOUR = 50 min. TASK: 10 REC. = RISK 0 = RISK 1 = RISK 1 = RISK 1 = RISK 0 = RISK 0 = RISK 0

FIGURE 4 Protocol for work/rest schedule on repetitive tasks.

It is recommended to provide adequate recovery time following the holding time for a certain upper arm elevation.

APPENDIX D2: EVALUATION OF WORKING POSTURES IN RELATION TO MACHINERY (CEN PREN 1005-4 1997)

Upper arm elevation

Step 1: refer to Figures 5 and 6 below. Step 2: (a) Acceptable if there is full arm support; if there in no full arm support, acceptability depends on duration of the posture and period of recovery. (b) Not acceptable if the machine may be used for long durations. (c) Not acceptable if frequency ≤10/minute and/or if the machine may be used for long durations. UPPER ARM ELEVATION \( \gamma \) (DEGREES VERSUS REFERENCE POSTURE) ACCEPTABLE NOT RECOMMENDED MAXIMUM ACCEPTABLE NOT RECOMMENDED M A X I M U M A C C E P T A B L E HOLDING TIME (\( \text{minutes} \)) 0 10 20 30 40 50 60 4 3 2 1 \( 0^\circ < \gamma < 20^\circ \) = acceptable \( \gamma < 60^\circ \) = not recommended awkward and extreme positions of all upper extremity segment and joints = not recommended
FIGURE 5 Maximum acceptable holding time. Upper arm elevation Evaluation of upper arm elevation I* II III IV Static posture acceptable conditionally acceptable (step 2A) not acceptable not acceptable low frequency (<2/minute) ACCEPTABLE acceptable conditionally acceptable (step 2B) conditionally acceptable (step 2B) Movement high frequency (≥2/minute) acceptable conditionally acceptable (step 2C) not acceptable not acceptable Static posture and high frequency movements (≥2/minute), awkward and extreme positions of all upper extremity segments and joints = not acceptable *It is recommended to strive for working postures with the upper arms hanging down. IV IV II III I I III 0° 0° 20° 20° 60° 60°

FIGURE 6
Fundamental Concepts of Human Factors


History of Human Factors/Ergonomics in Power Systems


ECKENRODE, R., and WEST, G., 1997, Detailed control room design reviews - were they worth the effort? In Global Perspectives of Human Factors in Power Generation: Proceedings of IEEE Sixth Conference on Human Factors and Power Plants, Washington, DC, IEEE.


History of Human Factors in the United States


DEMPSEY, C.A., 1985, Fifty Years Research on Man in Flight (Dayton: Wright-Patterson AFB).


History of Work-Related Musculoskeletal Disorders


CONN, H.R., 1931, Tenosynovitis. The Ohio State Medical Journal, 27, 713-16.

HAMMER, A., 1934, Tenosynovitis. Medical Record, 140, 353-5.


Human Factors, Politics and Power

have their own interests and perspectives (Salzman and Rosenthal 1994).

4 POLITICS AND THE ART OF INFLUENCE

Much of the literature on organizational politics has been influenced by a negative view of politics as a black art, something to be reduced or avoided. This interpretation has been dominant among a number of theoretical traditions that have influenced human factors research, such as organizational design and development and socio-technical theory (Buchanan and Badham 1999). The predominance within human factors research of a harder scientific or engineering approach to research and education has tended to encourage such a view of politics as an unfortunate distraction or disruption of the real scientific work of the day. In contrast to such a view, however, has been a more positive view of organizational politics as the techniques and art of getting things done in organizations. Positive political skills are increasingly important when changes are being proposed that cut across organizational boundaries and involve people in changing their traditional patterns of behavior. As the introduction of technology creates or requires behavioral change, it will inevitably trigger organizational politics. The human factors professional is inevitably part of this process. Badham (1993) argues that human factors
professionals need to improve their understanding and skills in this area if they are to be effective actors in technology implementation. Pettigrew (1974) observes that “Specialists do not merely advise, they persuade, negotiate and exercise the power they can mobilize” (p. 27). In so doing they utilize five power sources: expertise; control over information; political access and sensitivity; assessed stature; and the amount and kind of groups support given to the specialist by his colleagues in his own and related specialist groups. The human factors professional, like other specialists, needs to establish credibility if he or she is to be effective. This inevitably involves anticipating the varying needs, expectations and reference groups of different groups of executives and specialists involved in or affected by a human factors project. Those specialists who work on their own tasks, become preoccupied with the intricacies of their own expertise, and only see clients when task issues are involved is unlikely to be able to anticipate such needs very well. Successful specialists develop multiplex relationships with other significant partners or clients in a project, and succeed in demonstrating competence in areas salient to the other actors. Buchanan and Badham (1999) argue that such “power skills” should be part of the
skills of all professional innovators.
Human–Machine Systems: Written and Symbolic Communication


The International Ergonomics Association (IEA)


METZ, B., 1960, Fitting the Job to the Worker: International Conference of Zurich, 2nd-6th March 1959 (Paris: EPA/OECE).


THE INTERNATIONAL ERGONOMICS ASSOCIATION, 1959, Ergonomics, 2, 400.
Macroergonomics

of the workforce. As many organizations struggle with their turbulent external environments, they have turned to such approaches as total quality management, reengineering and restructuring. Macroergonomics can be the organizing framework for such approaches to organizational change and process improvement. In this context, the macroergonomist has played the role of change agent. In addition, systems, products, and processes continue to become more information-dependent, creating heightened needs for the knowledge worker. Optimizing work systems within the context of this unprecedented level of information content is a daunting task for the ergonomist. Macroergonomics offers the perspective, research-based
Ontology

systems of MT, information extraction and summarization, and other sophisticated NLP applications. It is particularly powerful in limited professional domains, which are precisely what ergonomics usually serves in a specific application.

3 STANDARD OBJECTIONS AND REBUTTALS REGARDING ONTOLOGY

While ontology has been gaining ground in natural language and other research, there has been considerable resistance to it from some quarters on a variety of grounds.

3.1 THE NATURAL LANGUAGE FALLACY

Some computational semanticists insist that ontological concepts are simply words of a natural language. For some of them, this is perfectly acceptable and they proceed with their own methodologies, explaining meanings of natural language in terms of the same natural language. Theoretically, this is how the later Wittgenstein’s notion of meaning is usually seen. Practically, this is how traditional lexicographers wrote their monolingual dictionary entries. For others, a charge of circularity is raised and it is indicated that the connection between natural language and extra-linguistic reality (world grounding mentioned above) is not then addressed. Whether accepted or rejected as a method, ontological terms cannot be confused with words of natural language.
Developed for use by computer, the former are totally devoid of ambiguity, which removes them from natural language. What confuses these critics of ontology is that when a human user reads these terms he or she may know another, unintended meaning(s) of the word in a natural language that is used as a concept label. The computer does not possess this ability and is, therefore, unaffected by the ambiguity, which renders the ontological labels non-natural. Besides resulting in disconnecting natural language from the extralinguistic reality that it expresses, this natural language fallacy leads to confusion between object language and metalanguage. All approaches use metalinguistic terms for the categories that they use in language description or representation. Only the ontological approach introduces these categories explicitly and completely, usually in the PROPERTY branch.

3.2 THE IRREPRODUCIBILITY CHARGE

Other objections to ontology question the scientific method of the approach. A sound scientific research should be reproducible, they say, but it is clear that two different people, let alone groups, will come up with different ontologies for the same conceptual domain. The confusion here is twofold.


Person-Centered Ergonomics


POLYANI, M., 1958, Personal Knowledge (Chicago: Chicago University Press).

Scenario-Based Design


CARROLL, J.M., 2002, Making Use is more than a matter of task analysis. Interacting with Computers, 14(5), 629-637.

Symvatology: The Science of an Artifact–Human Compatibility


Task Analysis


Training and Acquisition of Complex Tasks


The Ergonomics Society

Universal Design for the Aging

resources — personal intervention is often more effective and logical (it would be ridiculous to rely on high-tech devices for everything). Next, we consider the problem of who will pay and who will benefit. Figure 4 shows the relationship between duration of designed products and environments and their characteristics as to whether they are public goods or private ones. To the bottom left are consumer products and to the upward right are durable goods, then housing and public buildings, and to the extreme top right lie infrastructures such as urban environments and civil structures. Those in the bottom left are cheaper products of short duration that give the users relative freedom of choice. In other words, one can select the most preferred from among the alternatives — for example, the choice of a ball-point pen that best fits one’s gripping capacity or a telephone that one can easily dial/push. As one moves towards the top right, opportunities for choice become reduced to the point where it may be that one set of conditions must cover virtually all Man Power Resources Assistive Technology Adaptation Universal Design Design Concepts toward UD Public Goods Infrastructure Dwellings Long lived Durable Goods Private Possession Consumer Products Short lived

FIGURE 3 Design concepts toward UD.

FIGURE 4 The relationships between duration of designed products and environments and their characteristics.
KOSE, S., 1998, From barrier-free to universal design: an international perspective. Assistive Technology, 10, 44-50. (This issue, with Molly Follette Story and Ron Mace as guest editors, is devoted to Universal Design).


Age-Related Vision and Daily Activities of Elderly Adults

to determine the visual factors associated with difficulties in performing certain daily activities. The assessed activities were: the ability to manage financial matters, use the telephone, take medication as recommended, and pick up coins. The relationships between vision and activities were analyzed by using logistic regression analysis. It was found that visual functions were more closely related to picking up coins and managing financial matters than with other activities. In female and older subjects, subjects with distance perception and yellowish vision problems had greater difficulty in picking up coins. Older subjects and those with visual problems involving adaptation to bright or dim lighting, dynamic acuity, distance perception, and yellowish vision tended to have more difficulty managing monthly financial matters. The ability to manipulate and use coins, and to pay bills, depends on visual ability. Elderly people often pay bills by putting their wallet in the clerk’s hand at the supermarket checkout, in an attempt to receive help with handling money appropriately. Occasional difficulties in using the telephone and in taking medicine correctly were associated with distance perception and yellowish vision. Difficulty in using the telephone was also associated with age and adaptation to bright or dim lighting. Age was the dominant factor that
identified independent
subjects ("can do" and "can do with occasional difficulty")
and dependent ones ("can do with someone’s help" and
"cannot do"). Yellowish vision had a significant association
with the ability to manage monthly financial matters, use
the
telephone, and take medicine correctly. Significantly, the
study showed that older subjects (aged 75 years or older)
had more intense yellowish vision. Distance perception was
again associated with difficulty in picking up coins and
using the telephone.

TABLE 2

ADL Scale: The List of Activities

Bathing Bathing (sponge bath, tub bath, or shower) and
receiving either no assistance or assistance in bathing
only one part of the body

Dressing Gets clothes and dresses without assistance,
except for tying shoes

Toilet Goes to toilet, uses toilet, arranges clothes, and
returns without assistance (may use cane or walker for
support and may use bedpan/urinal at night)

Transferring Moves in and out of bed and chair without
assistance (may use cane or walker), completely on their
own (without occasional accidents)

Feeding Feeds self without assistance (except for help with
cutting meat or buttering bread) handrails and experiments
to determine the optimal size of staircase handrails.
Gerontechnology, 1(3), 175-189.

KATZ, S., FORD, A.B., MOSKOWITZ, R.W., JACKSON, B.A. and
JAFFE, M.W., 1963, Studies of illness and the aged: the
index of ADL: standardized measure of biological and
psychosocial function. Journal of American Medical
Association, 185, 914-919.


Alternative Controls


Anaerobic Threshold

J. L. Smith

Department of Industrial Engineering, Texas Tech University, Lubbock, TX 79409-3061, USA 241

140

120

100 80 60 40 20

VE 0 0 20 40 60 80 100 % VO2 Max

FIGURE 1 Graphical determination of anaerobic threshold.
Anthropometric Databases


Anthropometry of Children


BOCHENSKA, Z., 1979, Changes in Man's Ontogeny Against Secular Trends and Social Differences (Cracow: Higher School of Physical Education), Monographic Works, 5 (in Polish).


BUDÁVÁRI, E. and EIBEN, O., 1982, Az iskolai bútorok értékelése a tanulók testméreteinek függvényében (Evaluation of school furniture with regard to Students Body measurements). Ergonomia, 15, 2, 70-77.


of Industrial Design), typescript, unpublished paper (in Polish).


Anthropometry for the Needs of the Elderly


NOWAK, E. and KALKA, E., 2003, Anthropometry for the needs of the elderly and disabled. Data for design. Prace i Materialy IWP, 1, CDROM.

NOWAK, E., LAPACZEWSKA, K. and KALKA, E., 2003, Ergonomic recommendations for clothing design including the needs of elderly men. In Proceedings of the IX International


Anthropometric Topography


Assessment of Team Cognition


Auditory Ergonomics

EBUKURO, R., 1984a, Discussion on the voice input word set estimation method. Proceedings of Academic Meeting of Tohoku Chapter of the Society of Instrument and Control Engineers (SICE), vol. 203.


Automaticity and Skill

Cognitive Flexibility


Conceptualization of Risk


Control of Rapid Actions: Motor Programming


Depth Perception under Monocular and Binocular Viewing Conditions


Dynamic Muscle Strength


Dynamic Properties of Human Limb Segments


LAKIE, M., WALSH, E.G., and WRIGHT, G.W., 1981, Measurement of inertia of the hand and the stiffness of the forearm using resonant frequency methods with added inertia or position feedback. Journal of Physiology, 310, 3P-4P.


Foot Biomechanics

Force Exertion: Pinching Characteristics and Strengths


Force Exertion for (Consumer) Product Design: Information for the Design Process


Force Exertion for (Consumer) Product Design: Problem Definition

Only then do they find out how great a force is applied by most door-closing devices. It is hard to open automatically closing doors while standing on one leg, and it requires some dexterity to keep them open long enough to pass through. Doors with less powerful closing devices are much easier to cope with, and apparently perform equally well in all other respects. Latchkeys can be a problem too. An old woman had to make herself a tool for turning the key to her front door—something she could not do otherwise by hand. Lighting a gas fire or a geyser can be quite tricky. To get the pilot flame going a button must be pushed or turned and held for as long as five minutes, or even more. This is certainly not an easy task with a spring-loaded button that requires much force. Child-resistant closures are another category of products in which the required force is an important factor determining the rate of success. On the one hand, children up to a certain age should not be able to open the closure, while on the other hand the elderly must open it without problems. A complicating factor is that the maximal grip force of most 4-year olds exceeds that of many of the elderly. As the closures should be easy to open by the latter, the resistance to opening by children is often further improved by using a combination of two forces (like push
ing and turning at the same time) to open the closure.

Nevertheless, this still requires too much force of the week

est elderly person who must wrestle regularly to obtain

t heir

daily medicines or to open bottles of household detergents. The examples of man struggling with various types

of packaging, apart from the notorious jam jar, are many, notably with coffee-creamer cups (Kanis 1989), milk cartons (van Putten et al. 1990), complimentary sachets of bath foam in hotels (den Uyl 1979) blister packaging, plastic wrapping, certain juice cartons, shrink-wrapped cucumbers and slices of luncheon meat hermetically sealed in plastic.

In those cases the packaging material is so smooth that the friction between packaging and hand is very small, and in addition the shape is often such that it is hard to get a good grip on it. Consequently, although a subject may exert sufficient force, he or she can not transfer it to the packaging.
Gaze-Based Control

more features that can be optically detected on the eye and (3) employ a special contact lens that facilitates eye position tracking. The latter method is too intrusive for most applications. The first method is probably the least expensive and easiest to implement. However, the drift inherent in electro-oculography (EOG) measurements makes this technology more suitable for measuring eye velocity and acceleration profiles rather than measuring eye point-of-gaze. It is possible that EOG tracking would suffice if the eye-based control operations only required detecting whether the operator is looking generally left, right, up or down. The most practical line-of-sight measurement technique involves illuminating the eye with a near infrared source, capturing an image of the eye with a solid state video camera, and tracking one or more features that can be optically detected on the eye. The most often used features include the limbus (boundary between the iris and sclera), the pupil, movement of the lower eyelid, the reflection of a light source from the cornea (1st Purkinje image or corneal reflex) and the reflection from the rear surface of the eye lens (4th Purkinje image). However, these video-based methods, besides being more complex and costly to implement, are very sensitive to the placement of tracking components. Tracking a single
feature on the eye does not enable one
to discriminate between eye rotation and eye translation
caused by movement of the head. This ambiguity can be
resolved by tracking two features, which are at different
radii from the eye center of rotation. The two sets of
features
most commonly employed are (1) the pupil center and 1st
Purkinje image and (2) the 1st and 4th Purkinje images.
Two-feature eye trackers thus permit a small amount of head
motion, assuming that the user stays within the field of
view
of the video camera observing the eye. Some table-mounted
systems also employ a servo-controlled camera or mirror,
which follows the operator’s eye as the head moves. Such
systems permit head motion within a volume of ~0.03 m 3 .
To permit essentially unlimited head motion, head-mounted
eye tracking is required. The eye tracker data are used to
determine eye position with respect to the head and are
combined with head position data to compute line-of-sight
in the environment. Commercially available systems permit eye-tracking
accuracies of ~1° of visual angle. At the typical 61 cm
viewing distance, this translates into a resolution of ~1 cm
on the surface of a computer monitor. Eye tracking, there
fore, provides much coarser operation than a mouse or
trackball. Unless a head-mounted system is employed, the
range over which eye movements can be tracked is limited
to about the area of a 48-cm monitor. Another important constraint is the temporal resolution of the eye tracker. The feature-tracking systems are video-based and typically operate at 60–120 Hz frame rates. Total throughput delays...


Gesture-Based Control


BUXTON, B., 1998, A Directory of Sources for Input Technologies


Growth Normalization of Biomechanical Factors in Children Aged 6-18 Years

Hand Grip and Pinch Strength


Hand Grip Torque Strength


Hand Grip Characteristics and Strength


Human Muscle

K. H. E. Kroemer

ISE Department, Virginia Tech, Blacksburg, VA 24061-0118, USA


Research Series, vol. 3 (Berlin: Mouton de Gruyter). STOCK,
O., 1996, Password swordfish: verbal humor in the
interface. In Hulstijn, J. and Nijholt, A. (eds) Automatic
Interpretation and Generation of Verbal Humor.
International Workshop on Computational Humor. IMCH '96,
TWLT 12: Twente Workshop on Language Technology (Enschede,
Netherlands: University of Twente), pp. 1-8. STOCK, O.,
STRAPPARAVA, C. and NIJHOLT, A. (eds), 2002, The April
Fools’ Day Workshop on Computational Humor, April 2002,
ITC-irst, Trento. TWLT 20: Twente Workshop on Language
Technology. An Initiative of HAHAcronym, European Project
Compassionate Laughter: Jest for Your Health (Salt Lake
City, UT: Commune-A-Key).
Human Alarm Handling Response Times


HOLLYWELL, P.D. and MARSHALL, E.C., 1993, An experiment to support the design of VDU-based alarm lists for power plant operators. TABLE 1 Summary of Minimum and Maximum Response Times AIA Minimum RT Maximum RT Observation 1 s 2 s Acceptance 1 s 8 s Analysis 2 s 6 s Investigation 6 s 40 s Monitoring Variable Variable Correction 7 s 80 s Total 17 s 136 s
Identification of Human Control Behavior


Information Processing


BROADBENT, D., 1958, Perception and Communications (New York: Pergamon).


An Introduction to Neurophysiology


NOTES

1. Discoveries that glial cells can move dendrites and axons at synapses and can also release neurotransmitter modulators raise the possibility that these cells may play a greater role in information processing and cognition than simply being neuron caretakers. Carried to an extreme, one could posit neurons as simply being the communication system for the benefit of glia — this is quite unlikely. 2. The peripheral parts of these sensory systems are the olfactory neurons whose short axons project some millimeters through the skull to the adjacent olfactory bulb and the photoreceptor cells in the retina. 3. Dendrites and axons can conduct impulses in either direction depending on where the irritation initially takes place. Directionality is usually determined because dendritic synapses are particularly sensitive to certain neurotransmitter irritations, while axon endings are specialized to release neurotransmitter irritants. Backwards antidromic conduction acts as a feed-forward mechanism in pain perception. Its role in the central nervous system remains to be determined. 4. The complete role of gap junctions in the nervous system is still being determined. They may be more common than originally thought. 5. Most molecules probably never reach a suitable or vacant receptor and drift around until they decay, or are taken up for recycling. 6. Ironically these same adaptation effects also play a key role in making learning possible. Addiction can be considered a form of "unnatural learning" since the ingestion of transmitter-like substances by-passes the usual behavioral means and built-in controls by which learning usually occurs.

TABLE 3 Continued
Drug Transmitter Effect Behavior Overdose Withdrawal

Hallucinogens

LSD Serotonin Blocks receptors Hallucinations, Longer, more delusions, distorted intense "trip" perception of time episodes, psychosis, and space possible death

Marijuana Anandamide Mimics Euphoria, relaxed Fatigue, paranoia, Insomnia?, inhibitions, possible psychosis hyperactivity? increased appetite, disoriented behavior

Atropine Acetylcholine Blocks Unpleasant hallucinations, sleeping EEG while awake and alert

Mescaline Norepinepherine Mimics Disorientation

Antipsychotics

Chloro-promazine Dopamine and Blocks receptors Reduces Motor tremors, norepinepherine schizophrenic posture rigidity symptoms
Knowledge Representation


Lifting Biomechanics and Strategies

Maximum Holding Times of Static Standing Postures


MIEDEMA, M.C., 1992, Static working postures. Part 1: classification of static working postures on the basis of


Models of Attention


Multiple Resources


Physical Ability Testing


Physical Strength in the Older Population

Physical Work Capacity (PWC)


Postural Adaptation


ZACHARKOW, D., 1988, Posture: Sitting, Standing, Chair Design and Exercise (Springfield: Thomas).
Principles of Simple Movements


Psychophysiological Fitness for Work

activity, but be sufficient for the possibility of its continu
ation on the right levels. The means and methods of func
tional rehabilitation

must restore the functional abilities which were decreased
as result of professional activity. Such methods can include
diverse exercises and measures on renewal of health,
and also the full arsenal of physio- and psychotherapeutic
means. At present, to realize this approach were developed
and used systems of industrial purpose: 0 for a
psychophysiological initial professional selection; 0 for a
periodical check; and 0 for a daily check.
The systems permit the evaluation of the reliability and
efficiency of the operator’s work, as well as to construct
the prognosis of changes of these parameters during his
professional activity. The results of valuation and prognosis
allow either an unreliable operator not to work or to
increase his reliability and fitness to work and make pre
ventive measures for accident precautions.
Psychophysiological initial professional selection.
The efficiency of an operator’s work depends not only on
his professional knowledge and working conditions, but
also on the conformity of psychophysiological features of
a person to the requirements of his profession. As the
results of preliminary researches have shown, the following
structure of tests for determination of the professional
fitness group of the operator is optimum: structure of personality, structure of intelligence, an individual’s psychodynamic features and his bent for either kinds of mental activity. The most informative parameters of efficiency of tests performance are included in the model of a “standard operator” enabling the psychophysiological prediction of the group of the professional fitness of a candidate. Periodical check. The periodical check is intended for a valuation of changes of PPIQ which vary evaluation of slowly, that permits the moment when the operator needs to do some rehabilitation steps or when it is necessary for him to be prepared to leave his profession, if irreversible age related changes occur. With this purpose the system of valuation of operators’ professional aging rate is used (Burov and Chetvernya 1995a, b). The results of valuation of staff’s professional age are presented as an integrated age value, which is calculated by the chosen model, as well as an “age profile,” which is a vectorial diagram of main parameters determining biological and professional human age. The daily check. This is used by the system of valuation of an operator’s functional state and for the prediction of
Push and Pull Data


Kanis, H., 1989, Bediening & Handicap (Delft: Delft University of Technology, Faculty of Industrial Design Engineering).

Engineering).
Pushing and Pulling Strengths


Recumbents

to the seat, the rider will push himself out of the seat when
cycling. The posture of a recumbent rider is defined (Figure 6)
by: $\beta$, the shoulder angle; $\alpha$, the back angle; $\gamma$, the pedaling angle. The resulting angle between body and upper leg
($\theta$) determines to a large extent the maximal power output.
An angle between 105 and 130º is advised (Reiser and Peterson 1998). The posture also influences the aerodynamics of the recumbent (which influences the speed), the feelings of comfort and the view on the road. Investigation is needed into the relation between posture, power output, aerodynamics and endurance.

4.4 MUSCLE USE

There is some controversy whether the muscles used
for recumbent cycling are the same as those used for

FIGURE 6 Posture of a recumbent rider is defined by: $\beta$, the shoulder angle; $\alpha$, the back angle; $\gamma$, the pedaling angle. The resulting angle between body and upper leg ($\theta$) determines to a large extent the maximal power output (Daams 1999a).
Sleeping Postures

FIGURE 5 Evaluation of spinal deformations on a sleeping system by means of white light raster line triangulation (WLRT).
## Static Muscle Strength

**TABLE 2**

Average Static Strength Values from Chaffin et al. (1977) for Male and Female Industrial Workers (n 443 Males and n 108 Females) Average Static Strength (N)

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arms</td>
<td>381</td>
<td>200</td>
</tr>
<tr>
<td>Legs</td>
<td>941</td>
<td>417</td>
</tr>
<tr>
<td>Torso</td>
<td>544</td>
<td>266</td>
</tr>
</tbody>
</table>
Strength Testing


Torque Data


SCHOORLEMMER, W., 1993, Bediening van Knoppen. Internal Report, Faculty of Industrial Design Engineering (Delft University).


Trunk Muscle Force Models


Quantifying How We See the World: Visual Acuity, Contrast Sensitivity, and Visual Fields


GOULD, J.D., ALFARO, L., BARNES, V., FINN, R., GRISCHKOWSKY, N. and MINUTO, A., 1987, Reading is slower from CRT displays than from paper: attempts to isolate a single variable explanation. Human Factors, 29(3), 269.

Visual Perception, Age, and Driving


Workload and Electro-Encephalography Dynamics


**Activity**


Activity Theory

FIGURE 3 Temporal structure of activity.
Age-Related Cognitive and Perceptual Factors that Influence Computer Usage

Allocation of Functions: Past, Present, and Future Perspectives


Arousal States and Human Performance


endogenous and exogenous orienting: a functional MRI study.

In Baddeley, A. and Weiskrantz, L. (eds) Attention:
Selection, Awareness, and Control. A Tribute to Donald
Broadbent (Oxford: Clarendon), pp. 5-35.

TREISMAN, A. and DAVIES, A., 1973, Dividing attention to
ear and eye. In Kornblum, S. (ed.) Attention and
TREISMAN, A. and GELADE, G., 1980, A feature integration
TREISMAN, A. and GORMICAN, S., 1988, Feature analysis in
early vision: evidence from search asymmetries.
structure of attentional resources. In Nickerson, R. (ed.)
Attention and Performance VIII (Hillsdale: Erlbaum).
Brain and Muscle Signal-Based Control


Burnout


Cognitive Modeling in Human-Computer Interaction


Cognitive Psychophysiology in Ergonomics and Human Factors


Combination Manual Handling Tasks

produced by Asfour et al. 1985, and the modeling of
Kim and Ayoub 1991) are only suitable for lifting.
The tables prepared by Mital et al. (1993) do cover a
range of single tasks, but not CMHT. Mital et al.’s tables
could therefore be used to substitute single-task values
for CMHT values. Checklists such as that of Worksafe
Australia (1990) could be used for combination though
are probably not sensitive enough.

3 RECOMMENDATIONS FOR ASSESSMENT OF COMBINATION MANUAL HANDLING TASKS

Direct measurement, using the psychophysical approach,
is expensive, provides results which are probably not gen
eralizable and is vulnerable to extraneous influences such
as industrial relations issues. However, direct measure
ment of MAW for CMHT does not require the assump
tions that the other methods do. It may therefore be useful
for specialized tasks where unique characteristics make
the extrapolation of other methods precarious. The
estimation of CMHT MAW from single-task tables
or modeled on single-task values, assumes a consistent rela
tionship between single-task MAW and CMHT MAW. This
has been shown to be not the case (Jiang and Smith 1985;
Straker et al. 1997a, b; Taboun and Dutta 1984) with a mean
error of estimation around ±20%. Modeling using linear
models appears to be not sufficiently more accurate than
substitution to warrant the extra complication. Thus, the best option for the assessment of risk in CMHT, when resources are not adequate to do direct measurement, may be to use substitution of MAW for critical component tasks (commonly lift or carry). However, this should only be used with the knowledge of an error margin of ~20%. Physiological direct measurement appears a viable risk assessment option for CMHT. Its main disadvantage is the resource cost if used to evaluate every CMHT. As for MAW, this method is likely to be the most accurate. Estimation from single-task tables appears to be hazardous as there is consistent evidence for CMHT having different physiological costs to component tasks. Estimation from modeling from worker and work characteristics is likely to be less successful than modeling from single-task values. However, these conclusions are drawn from a small number of studies with limitations. Until more definitive research is available, the best option for assessment of CMHT using the physiological approach, when direct measurement is not practicable, may be to use substitution of single-task measures. However, considerable error margins need to be acknowledged if this method is used: ~60% when absolute loads are compared and ~20% when MAW loads are compared. Biomechanical modeling based on kinematic and kinetic data appears the only viable biomechanical method
available for assessing the risk in a CMHT. The literature suggests the most accurate method is by dynamic modeling.


Comfort-Discomfort Phase Change

FIGURE 3 Hypothetical relationship between perceived sensation and contact area.
Constraints in Design Decision-Making

as a classification that may be used to group or separate constraints, based on whether they share significant common values. A profile of each constraint may be created, by assessing the values for all descriptors.

3.3 CONSTRAINT NEGOTIATION BEHAVIORS

Examination of the role that constraints play in design engineering stems from concerns about how constraints impact the behavior of tool users. That behavior impacts valued outcomes, such as work product quality and user productivity.

The need for a taxonomy of constraints was explained in the preceding section. A taxonomy of common user behaviors is also needed. Constraints are a stimulus to users as they operate their tools; user behavior when users encounter constraints is a response to that stimulus. In order to understand the impact of constraints, it is necessary to describe and measure behavioral responses.

A taxonomy of user behaviors in response to constraints has been developed. It includes the following descriptors:

0 Avoidance. The user modifies his task approach pre-emptively because he knows that doing otherwise would trigger a constraint.

0 Compliance. The user modifies his task approach to suit the limitations imposed by a constraint.

0 Subversion. The user modifies his task approach to take advantage of known weaknesses in the tool, overriding the spirit but not the mechanism by which the constraint is implemented. This strategy also is known as ‘workaround.’

0 Path-seeking. The user modifies his task approach to find the least constraining path.
Deferral. The user declines to modify his task approach, with the knowledge that subsequent system or human review may reverse, modify, or accept his decision to override the constraint. O Negation. The user declines to modify his task approach, unconditionally overriding the constraint.

In categorizing any given behavior using this taxonomy, it is key whether the constraint is accepted, whether the attempted task approach is modified, and whether the user’s decision is subject to later review (and possible reversal).

4 MEASURING THE IMPACT OF CONSTRAINTS

Taxonomies of constraint and user behavior can be applied empirically to assess the impact of constraints upon design process. The method has been standardized over many


Human–Computer Interaction (Amsterdam: North-Holland), 701-08.
Critical Reappraisal of Activity Theory

Cross-Cultural Comparison of Computer Anxiety: Concept, Measures, and Related Variables


Cue-Based Processing and Human Performance

Cybersickness in Virtual Reality

with a 2–7-day intersession interval, tolerance should be extended by the fourth to sixth exposure. Unfortunately, repetition may not be an efficient or practical means of adaptation because the time required for re-adaptation to one’s normal environment is proportional to the time spent in adapting to the virtual world (Baltzley et al. 1989). Thus, if an individual must undergo numerous exposures to a VE to achieve adaptation a considerable amount of time may be necessary for re-calibrating to normal functioning once the exposure ceases. In many operational settings this may not be viable. Also, when used for entertainment purposes users may not have the opportunity for repeated exposure to the same virtual environment. The goal, therefore, should be to achieve adaptation in as little time as possible, while attempting to lessen the severity of the initial sickness experienced by users. This may be achieved through easing user interaction. Means of easing VE interaction include streamlining the degrees of freedom through which VE users can move about the virtual world, blanking the visual stimulus and manipulating image abstractness (Stanney et al. 1998). To ease interaction, tasks requiring high rates of linear or rotational acceleration and extraordinary maneuvers (e.g. flying backward) should be avoided during early exposure.
Blanking involves graying-out a head-mounted display above a threshold level of head velocity, which selectively eliminates the effect of visual update delays during head movements. The degree of abstractness of virtual images can be manipulated through the use of polygonal versus texture gradients. In general, the greater the abstractness the more severe the sickness experienced. It is important to note that reducing the information content of a VE, either through blanking, manipulating abstractness, or other means, may compromise task performance such as the ability to detect direction of heading, steer effectively or make precise judgments of impeding arrival or collision in VE settings. Any changes in the information content targeted at reducing cybersickness must thus be balanced against removing the information that users would ordinarily rely upon for accurate judgments. As tolerance is gained through repeated exposures or interaction techniques and exposure duration is extended, after effects may become more prevalent. Thus, before the identification of technological solutions that minimize after effects a means of managing after effects must be identified. The best way to eradicate VE after effects is
Databases for Psychophysically Acceptable Maximum Weights and Forces in Manual Handling Tasks Developed by Liberty Mutual


Design Cognition


Driver Perception–Response Time


Dynamic Situations


Emotions and Design

FIGURE 6 Cute cartoon characters: Kitty, Pikachu, Winnie the Pooh, Tweetie and Snoopy.

FIGURE 7 Cute products: Apple computer, Black & Decker kettle, Philips kettle, Philips memory container, Toyota/Sony Pod car.

FIGURE 8 (a) Ash-tray design with a graphical representation of lung airways; (b) Koziol brush and dustpan; (c) Gratefish storm drain – IDSA Silver winner 97.


GRiffin, T., 1999, Semantic communication through products (http://www.acs.ucalgary.ca/~tgstiffin/index2.htm, [19.2.2001])


Ergotoxicology: Toward an Operational Prevention of Chemical Risk in the Working Environment


<table>
<thead>
<tr>
<th>Activity Level of Exposure *(mg/h)</th>
<th>Preparation with liquid/solid substances in open air</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pulverization with manual equipment</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Application with pulverizer mounted on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>any type of low-vine tractor or high-vine straddler</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Application with pulverizer mounted on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>intervine tractor for high vines</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Application with pulverizer mounted on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>any type of tractor alternating between low and high vines</td>
<td>10</td>
</tr>
</tbody>
</table>

Etc. * Values obtained by extrapolation from documented meta-analyses.


Error Taxonomies*


Execution of Ballistic Movements: Interception of Subcortical Mechanisms


Fatigue and Driving

GEORGE, C., 2001, Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. Thorax, 56, 505.


National Transportation Safety Board, 1995, Safety Study: Factors that Affect Fatigue in Heavy Truck Accidents. NTSB PB95-917001 — SS-95/01.


Developing work content Improving work environment More flexible working hours Changing work tasks Security of work place Possibility to be away from work More salary Developing joint work of personnel Discussions between chief and workers Developing management More education possibilities More chances to advance More debriefing More rehabilitation possibilities Occupational health services Increasing safety at work

FIGURE 3 The most important factors affecting coping at work in fire-fighting and rescue work (percentage of respondents).
Human Control of the Behavioral Environment


MARX, K., 1867, Das Kapital.

MARX, K. and ENGELS, F., 1848, Communist Manifesto.


Human Error


Human Real-Time Processing

development of mental models. There are many different
conceptualizations of what constitutes a mental model and
the idea has been seen as problematic within cognitive
science. However, they are widely used in human factors
work and provide a useful framework for understanding
complex situations. One particular type of mental model can
be characterized as operating in real time (although this is
rarely emphasized it is implicit in such models). Generally,
mental models can be seen as mental constructions that con-
tain an individual’s knowledge of something, perhaps, for
example, how to perform some work task. Such a model
could be just a long-term memory procedure for a given
skill. However, research shows that a rather elaborate men-
tal model can be “run, with trial, exploratory inputs and
observed for it’s resultant behavior” (O’Malley and Draper
1992: 74) and such “runs” make extensive use of visual
imagery. One way in which some operatives report using
mental models is as “thought experiments.” In this case a
process that the “experimenter” understands well is imagi-
ined and then “run” in real time (not the real time of the
process but at the operatives real-time processing rate,
i.e.
the rate at which the imagery unfolds), a problem is intro-
duced and the possible outcomes and solutions are imagined
(although it appears to be a characteristic of mental models
that only a very small number, sometimes zero, alternatives reside in the construction) (Sloutsky and Goldvarg 2004). This allows the operative to develop mental models that are protocols for use when a problem arises. When such protocols are activated to deal with a problem, verbal protocols (a procedure whereby one verbalizes one’s reasoning as it emerges) make explicit the problems and actions needed in response to the status of the system at that moment in time (Bainbridge 1992). Thus the real-time processing rate of the operative will be a limiting factor in the timeliness of interventions. Very experienced operatives may have mental models for many eventualities and if these can be “run” without having to be first created from, say, more basic principles of engineering, then real-time intervention will be more rapid because intermediate decision processes will be reduced.

5 CASCADE FAILURES
When failures become too complex or they occur too quickly, for comprehension of the problem, real-time mental modeling cannot help. Running a visualization of a problem past one’s “mind’s eye” is not a particularly rapid process. Cascade failure, a process whereby a given failure precipitates multiple further failures “downstream” in
the process, and each of these failures instigates multiple
failures, leads to runaway fault proliferation until, usually,
the whole system fails and makes the failure process self
limiting. Such failures are often extremely rapid; the cooling
system failure at Three Mile Island is a classic example of
The Probability and Statistics of Human Error

Human Reliability Analysis


The Role of Individual Differences in Human Computer Interaction: The Case of Navigation


Learning and Forgetting


Lifting Techniques

contemporaneous movement of the lower limb and trunk

joints, that is, the joints flex and extend at the same time

rather than sequentially (as is sometimes modeled).

However, the joints are not perfectly synchronized: a con

sistent pattern of deviation from synchronous coordination

is commonly observed. Knee extension typically occurs

more rapidly earlier in the lifting movement relative to

extension of the hip, and the onset of rapid lumbar

vertebral

extension is delayed substantially after the start of the

lift.

The moderate lumbar flexion observed lengthens the erector

spinae relative to its length in normal standing, and the

delay before rapid lumbar vertebral extension delays rapid

shortening of the erector spinae. Estimation of the length

changes of the biarticular hamstring muscles has revealed

that they are also relatively lengthened at the start of the

extension phase, and that the pattern of coordination

between knee and hip joints also has the consequence of

delaying rapid shortening of the hamstrings. Muscles are

stronger when lengthened, and when not

shortening rapidly, and thus this pattern of coordination

increases the strength of the hamstrings and erector spinae

early in the extension phase when the acceleration of the

load is greatest by both lengthening the muscles, and delay

ing their rapid shortening. Delaying shortening of the
hamstrings has the additional functional consequence of allowing the monoarticular knee extensors, paradoxically, to contribute to hip extension through a tendinous action of the hamstrings. The pattern of coordination observed thus reduces the muscular effort required to perform the task, and the pattern of interjoint coordination is exaggerated with increased load mass. A different pattern of coordination between hip and knee occurs when a stooped posture is adopted at the start of extension. The large range of hip flexion and small range of knee flexion involved results in the hamstrings being lengthened further than if a semi-squat posture were adopted. A stooped posture has the advantage of lowering the center of gravity of the upper body less than a semi-squat posture and thus less work is done in lifting the upper body during each lift. However, during lifting from a stooped posture the hamstrings must immediately shorten rapidly because the knee is unable to extend rapidly. This counteracts to some extent any strength advantage that might accrue as a consequence of the increased hamstring length and prevents the monoarticular quadriceps from contributing to hip extension.

5 RECOMMENDATIONS FOR PREVENTING BACK INJURIES DUE TO LIFTING

Training people to perform lifting in safer ways has been
consistently proposed as a means of reducing the risk of injury; however, research evaluating the effectiveness of lifting training programs involving the uninjured worker


Loads on the Lumbar Spine During Dynamic Work

Manual Materials Handling in Unusual Postures


Manual Materials Handling in Multiple Person Teams

2.4 BIOMECHANICAL DIFFERENCES BETWEEN INDIVIDUAL AND TEAM LIFTING

Differences in lifting technique produce differences in the spinal compression and lateral shear forces for one- vs. two-person lifting. Spinal compression and moments about the sagittal plane are reduced for two-person symmetrical lifts compared with individual symmetrical lifts when the load is equated on a per-person basis. When lifting asymmetrically, however, two-person lifts result in significantly higher lateral shear forces and moments than one-person lifts. These biomechanical differences are probably due to differences in lift kinematics. Changes in pelvis and trunk positioning and limitations in the ability to position one’s body with respect to the load occur during two-person lifting and change the biomechanics of the lift (Marras et al. 1999).

2.5 PREDICTION OF TEAM MANUAL MATERIALS HANDLING PERFORMANCE

There are several reports of regression equations in the literature that can be used to predict team manual materials handling performance using various measures of muscle strength (1RM lifting strength and individual MAWL), anthropometric characteristics (flexed bicep, abdominal, and chest circumference), and gender (all-male, all-female, or mixed-gender teams) (Fox 1982; Karwowski and Mital).
1989; Sharp et al. 1993). These equations were able to account for between 35 and 98% of the variance in team MMH performance, but many reported a relatively large standard error of the estimate, making them of limited practical use.

3 CONCLUSIONS/RECOMMENDATIONS 1. The 1RM for dynamic two-person team lifting is 10 to 20% lower than the sum of individual IRM lifts, but little further decrease is found with the addition of one or two more people. If a recommended load for an individual performing a task has been determined, the % sums from Table 1 can be used to estimate the load for two to four persons lifting as a team. It is essential that there is adequate team coordination, space, handholds, and an equal distribution of the load, when performing infrequent heavy team lifting tasks. 2. Repetitive team lifting and carrying MAWL tends to be equal to or greater than the sum of the individual MAWL for the same task. Therefore, doubling the individual MAWL provides a reasonable estimate of the load two-person teams will find acceptable for a repetitive MMH task. This is most appropriate for tasks that are symmetrical, and the same qualifiers teams. In Proceedings of Human Factors and Ergonomics Society, Santa Monica, CA, 640.

Manual Work and Back Stress in Industrially Developing Countries


Memory Failures in the Workplace and in Everyday Life: Causes and Consequences


Mental Fatigue and Related Phenomena


Mental Models


Mental Workability and an Increasing Life Span


Mental Workload


Mental Workload Measurement


Mental Workload: Theory, Measurement, and Application


Monitoring an Operator’s Psychophysiological Fitness for Work

same way as cognitive tasks performance. According to the performance of all tasks, parameters of rate, dynamics, and biorhythmic structure are calculated. Among these numbers, a subset of parameters that are the most informative ones in relation to human professional durability is chosen. Our research shows that in order to formally describe human work efficiency in conditions of simulating an operator’s activity, the statistical models in classes of multiple regression models of 4–6 degrees with volumes of training samples of 24 supervisions are the most exact and reliable ones.

5 APPLICATION

Despite all the possible measures available to make a professional selection, from 40 to 60% of accidents arise because of personnel problems. It is recommended that the assessment and prediction of operator reliability begin with the identification of the context and the common performance conditions (Hollnagel 1998). However, the question arises as to what should be included in the “context” and what efforts should be made to collect sufficient data. According to our data, natural fluctuations of the human functional state account for failures in cases which do not enable an operator to realize his/her qualifications
completely. The approach discussed is based on using an individual, i.e. inherent in each particular person, tempo
ral organization of mental activity in systems for a preshift (intrashift) check of operators’ fitness for work. Thus, the prediction model is not fixed: instead of a specific model, the algorithm of constructing adaptive models is used. The system to project operators’ efficiency opens up the following opportunities: 0 to collect indirect information on human psychophysiological state; 0 to investigate the dynamics of human psychophysiological state during his or her professional career; 0 to give human information which could be used to make predictions of his/her professional efficiency and improve it in a certain way.
Monitoring of Operators’ Professional Aging

as feedback between AP and contour of a functional reserve of blood circulation. It is necessary to take into account the age-related changes of professionally important psychophysiological qualities in the time of monitoring the professional service ability (for example, during the periodical check) with the purpose of predicting and preventing a natural decrease of operator work efficiency.

4 SYSTEMS FOR MONITORING OF PROFESSIONAL AGING

Complicated and difficult work conditions cause people to change profession a long while before pensionable age. As is known, in 30–40% of professions the 30–40 age range is already a “threshold” of professional aging. The proportion of professions with the “threshold” at 50 years is approximately twice as high. Available system of inter-professional migration is a mechanism of professionally-laboured rehabilitation aimed at safeguarding aging workers from the unfavourable action of work factors. But growth of the death-rate population bears witness to the insufficiency of the protective action of this system. The effectiveness of such rehabilitation could be higher if based on results of operators’ health level and functional possibilities assessment during regular periodical examination. The system for valuation of rates of professional aging
is intended for use during annual routine inspection of company staff. It takes into account age dynamics of profession ally important psychophysiological qualities and leading medical parameters by way of prognostication and prophy laxis of critical health reduction and human fitness for work (Burov 1998). Three variants of biological age determination are pro
vided, which differ in complexity and in work intensiveness.

The results of assessment of staff’s biological age are
Physiological profile of age name Data: 4-3-98 Observation N:1 Printing <Prt Scr>. ZDo ZDi ADp SOZ AP CSS MSp MSI SB PSS M v 1 2 3 4 5 6 7 Exitany key

FIGURE 1 An example of physiological age profile displayed on the screen after observation of the user “name.”


Work Motivation — State of the Art


NASA’s Contribution to Aviation Human Factors


Noise: Measuring, Evaluation, and Rating in Ergonomics


ANON., 1990, Accident Prevention Regulation — Noise, UVV Lärm, Unfallverhütungsvorschrift der gesetzlichen Berufsgenossenschaften, VBG 121 (Cologne: Carl Heymanns) [in German].


STRASSER, H., 1990, Ergonomic considerations with reference to the notion of dose and the equal energy hypothesis in environmental workload. Zentralblatt fur Arbeitsmedizin, 40, 330-54 [in German].

Occupational Stress Mechanisms


Physical Demands of Work


GRANDJEAN, E., 1988, Fitting the Task to the Man (London: Taylor & Francis).


Psychophysical Risk Assessment in Manual Handling


Rating Scales for Perceived Physical Effort and Exertion


Signal Detection Theory


Signal Detection Theory—Alternatives


Situation Awareness


Situation(al) Awareness: Alternative Theories

Situation Awareness and Decision-Making


Situation Awareness in Teams


Skill Learning: Augmented Feedback


Skill Learning: Conditions of Training


Sleeping Systems

TABLE 2

Sleeping System Combinations PU Foam Latex Foam Biconical Spring Pocket Spring

Board base — —
Boxspring
Spiral base
Fixed slats
Canting slats
Adjustable base —

Note: -, impossible; 1, unwise; 2, possible; 3, desirable.
Sleeping Systems: Design Requirements


Standing Work

5.1.1 Sitting

Sitting reduces the load that is exerted on the feet and legs.

Thus, there is less energy consumption and less biomechanical loading on the leg/foot joints. However, the person may become a “couch potato,” giving inadequate nutrition to the spinal discs (which depend on movement for nutrition) and overadequate nutrition to the flesh, yielding a weight gain. As pointed out above, the legs are ~32% of body weight. A stool (i.e. no arm or back support) means only 68% of the body weight must be supported by the human structure. It is difficult to quantify the benefits of a chair back support but common experience indicates they are beneficial. Supporting both hands/arms is ~10% of body weight but the percent decreases as the hands are used (e.g. keyboarding, assembly). Biomechanically, sitting provides a stable support (chair seat) that is closer to the hands than the feet; this reduces sway and tremor. Yet standing permits movement of the legs and feet (not just the torso) so reach distances are improved and ability to twist the torso is improved.

5.1.2 Walking

Some of the problems of standing can be reduced by movement. Occasional walking (say 10 steps) improves
blood flow in the legs, decreasing ankle blood pressure
~60 mmHg. The movement of walking also improves disc
nutrition. Walking also improves reach ability over
standing.

5.2 EXTERNAL AIDS

Two divisions are aids on the body and aids off the body.

5.2.1 Aids on the Body

Body aids are divided into back belts, support hose and
shoes. For such a popular product as back belts, there has
been
relatively little theoretical analysis or experimental study
(Rys and Konz 1995). Back belts come in an amazing vari-
ety of designs with an equally amazing lack of theoretical
support for the design. Back belts generally are tested on
healthy male students doing lifting for short periods (often
1 h); the results are extrapolated to male and female
workers doing a wide variety of tasks for 2000/h year for
multiple years. Much more (and better) research needs to be
done. However, for simple standing tasks (with no material
handling), it is hard to visualize benefits from back
belts. Support hose reduce venous pooling by constricting
leg diameter and, thus, not permitting space for the blood
to pool. Shoes also come in an amazing variety of types and
styles. Athletic shoes are divided into running shoes
(designed for forward movement) and court shoes (designed
for quick side-to-side movement); neither would seem appli
cable to prolonged standing, awkward postures of the legs, 
trunk and neck. International Journal of Industrial 
Ergonomics, 9, 283–301.

aids in the furniture industry. In Buckle, P. (ed.) 
Musculoskeletal Disorders at Work (London: Taylor & 
Francis).

NODELAND, H., INGEMANSEN, R., REED, R. and AUKLAND, K., 
1983, A telemetric technique for studies of venous pressure 
in the human leg during different positions and activities. 
Clinical Physiology, 3, 573–6. POLLACK, A. and WOOD, E., 
1949, Venous pressure in the saphenous vein at the ankle in 
man during exercise and changes in posture. Journal of 
Applied Physiology, 1, 649–62. RYS, M. and KONZ, S., 1994, 
Standing, Ergonomics, 37, 677–87. RYS, M. and KONZ, S., 
Occupational Safety and Ergonomics, 1, 294-303. SWAT, K. 
and KRZYCHOWICZ, G., 1996, ERGONON: computeraided working 
posture analysis system for workplace designers. 
Static Load

BECLARD, J., 1861, De la contraction musculaire dans les rapports avec la température animale. Archives of General Medicine, 17, 157-180.


SIMONSON, E., 1971, Physiology of Work Capacity and Fatigue (Springfield, IL: Charles Thomas).


FURTHER READING


Stimulus–Response Compatibility


Subjective Mental Workload Assessment


The Substance of Cognitive Modeling


Systemic Situation(al) Awareness


Tolerance to Shiftwork


Cathode-Ray Tube Monitors Versus Paper: A Review of Performance Differences


BLANCO, M.J. and LEIRØS, L.I., 2000, Temporal variation in the luminance level of stimuli displayed on a cathode-ray tube monitor: effects on performance on a visual vigilance task. Ergonomics, 43, 239.


GOULD, J.D., ALFARO, L., FINN, R., HAUPM, B. and MINUTO, A., 1987, Reading from CRT displays can be as fast as reading from paper. Human Factors, 29, 497-517.


Vigilance

Visual Display Terminals: Age and Psychophysiology


Visual Measurement: Modern Methods


Visual Perception under Night Driving Conditions

been on the physical variables such as headlights, roadways, signs, road marking and delineators. However, psychological variables such as expectancy can have a tremendous impact on visibility. For example, retroreflective tags can provide an improvement in nighttime visibility of pedestrians when drivers expect to see retroreflective tags on pedestrians (Shinar 1985). Retroreflective tags, as safety devices, can be attached to any piece of clothing, thereby increasing the visibility of pedestrians. It is also more likely that pedestrians will wear tags rather than whole clothing pieces to increase their visibility at night since tags can be easily attached and detached from clothing. However, in order for retroreflective tags to serve as safety devices,
Work Ability


Work Design: Age-Related Policies


Work Hazards and Risk Assessment in Human Performance


NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH), 1997c, Elements of Ergonomics Programs (Cincinnati, OH: US Department of Health and Human


Working with Age: An Ergonomic Approach to Aging on the Job


Adaptive User Interfaces and Personalization


KEEBLE, R.J. and MACREDIE, R.D., 2000, Assistant agents for the world wide web intelligent interface design challenges. Interacting with Computers, 12, 357-81.


Alarm Initiated Activities

Assistance for Users of Interactive Devices


Auditory Alerts in Avionics


Auditory Displays, Alarms, and Auditory Interfaces

Auditory Warnings

of which is ergonomically desirable. The second of the problems is that the more auditory warnings there are in a set, the harder it will be to identify and learn them. A third problem is that if auditory warnings are used ubiquitously as information sounds (such as they might be in a nuclear power plant control room or an intensive care ward) then this will weaken their role as specific attention-getting sounds. Ideally only the highest priority situations should be signaled by unique auditory warnings, that is where there is one-to-one correspondence between warnings and specific hazards and events. Situations of lower priority can be signaled by using a single warning denoting the category of risk only (such as second-or third-priority). On hearing the warning, the operator can then further identify the problem through other means, such as visual scanning. By using such a strategy, the number of auditory warnings can be kept to a minimum without compromising safety.

2.2.2 Relationship between auditory warning design and function

At the time of writing there is no clear consensus as to which category of sounds (abstract, semi-abstract or concrete; see Section 1.2.2) are best suited for use as auditory warnings per se. There is little consensus also as to which
sorts of sounds are best suited to which sorts of function. Traditional warning sounds have the advantage that they are generally recognized, as warnings (although their specific meaning may not be clear) whereas semi-abstract and concrete sounds may be intuitively more easy to identify. A more clearly defined, but more specific type of mapping between auditory warning and referent is that of urgency mapping (Edworthy and Adams 1996). Urgency mapping is a process through which warnings may be mapped on to referents so that the more important, hazardous situations and events are signaled by more urgent sounding warnings. By such a process, some degree of cognitive compatibility can be achieved between warning and referent. Assessments of importance and hazardousness of risks must be generated by experts in the occupational settings in which the warnings are to be used. Sets of warnings can then be generated from existing databases showing the relationship between perceived urgency and acoustic design (e.g. Edworthy et al. 1991; Hellier et al. 1993). One advantage of appropriate urgency mapping is that even when the precise meaning of a warning may not be known, the degree of attention that the hearer should pay to the situation being signaled is conveyed through the warning. The same process can be used for visual warnings.
2.2.3 Believability

A warning’s believability is a strong determinant of its effectiveness. Any warning, no matter how well designed, will be ignored if it continually sounds when there is no
Augmented Reality


Automatic Speech Recognition


Chinese Keyboard Input


Cognitive Walkthrough for the Web

4.1 COGNITIVE MODELS OF USER SEARCH BEHAVIOR

Information foraging theory (Pirolli and Card 1999) incorporates measures of semantic similarity in a model of user search behavior that is closely related to CoLiDeS’s use of LSA. Both models take actions that are perceived as being close to a user’s description of goal. However, information foraging theory has a much broader scope, attempting to characterize users’ cost/benefit perceptions in making decisions, such as terminating the search of one website and searching for another site that contains more information relevant to their goals. However, the critical point is that the two frameworks are complementary, sharing a common model of the search process even though the common models are derived from very different cognitive architectures (ACT-R; see Anderson and Lebiere 1998 for the information foraging theory versus Kintsch’s (1998) construction-integration theory of text comprehension for the CoLiDeS model).

4.2 APPROACHES TO UNDERSTANDING USER BEHAVIOR ON THE WEB

Many research groups are studying user behavior on the Web, since insights are valuable for designing useful web sites as well as efficient web servers. One approach focuses on the global behavior of web users. Byrne et al. (1999) identified user interaction patterns by analyzing verbal pro
tocols collected during browsing sessions. Tauscher and Greenberg (1997) addressed the same issues with usage data. Huberman et al. (1998) derived distributions of numbers of user clicks in a site by applying statistical analysis to user log data. Pitkow and Pirolli (1999) predicted the web pages that users are likely to request by applying a data mining technique to user log data. Chi et al. (2001) applied techniques used in information retrieval research to estimate the likelihood of selecting each link in a given website for given information needs. Except for Chi et al. (2001), the common characteristic of most of these studies was that user behavior was aggregated over the different user goals. These studies used click stream data to uncover properties of typical sequences of page accesses. In most cases, investigators had no information about the content of users’ goals. Thus, these studies did not attempt to show how the content of users’ goals controls navigation behavior, despite widespread agreement that goals control search behavior.

5 CONCLUSIONS

CWW helps designers detect and repair usability problems by simulating user’s web navigation process. CWW is
Collaborative Interaction in Process Control


Evaluation of Graphical Symbols


Convergence of Telephony, Television, and Computing in the Home


Cross-Cultural Issues in Human-Computer Interaction


Cultural Aspects of User Interface Acceptance


Describing and Predicting Human Interaction with Technology


Design of Menus: Choosing Names, Organizations, and Selection Devices


Dynamic Function Allocation

Ecological Interface Design — Theory

CHERY and VICENTE, K.J., 2000 (in this volume)


Ergonomics of CAD Systems


Evaluation of Warning Effectiveness


ROGERS, W.A., LAMSON, N. and ROUSSEAU, G.K., 2000, Warnings research: an integrative perspective. Human Factors, 42(1), 102-139.


Functional Systems Design Versus Interface Design

provided as efficiently (in terms of processing power) as possible. However, the current level of technology is making truly human-centered systems more possible. In the past, the user had to accommodate the system because the system was severely limited. In the future, more capable technology will enable the system to accommodate the user.

6 ROLE OF HUMAN FACTORS IN HUMAN-CENTERED SYSTEMS DEVELOPMENT PROCESS

All of this implies that the role of human factors in systems development processes will change. Since the beginning of operational requirements functional requirements system requirements interface requirements

FIGURE 1 The traditional systems development process begins with engineering requirements; the interface is added after system functions and operational logic have been defined. task requirements interface requirements system requirements functional requirements

FIGURE 2 A more human-centered process begins with the user’s task requirements and interface requirements; these, in turn, drive the engineering requirements.
HCI Hypermedia: Usability Issues


GOULD, J., ALFARO, L., FINN, R., HAUPT, B. and MINUTO, A., 1987, Reading from CRT displays can be as fast as reading from paper. Human Factors, 26(5), 497-517.


NIELSEN, J., 1995, Multimedia and Hypertext: The Internet and Beyond (Boston: AP Professional).

Human Acceptance of Information Technology


Human Ecology: Developing Ecological Auditory Warnings

2.5 RECOGNITION/MATCHING TEST

The matching test requires the participant to assign a sound to one of the referent functions from a list they are given. They may assign more than one sound to a function if they see fit. This information is used for a preliminary modification of the sounds where required. Sounds that are successfully matched to functions at this stage proceed for further testing. In the recognition test, respondents are required to recognize the situations to which the sounds refer. Sounds are presented to respondents who are required to write down the sound reference number and what they think the sound represents until all of the sounds have been presented. Some development of the most pragmatic procedure will be necessary for auditory warnings, as opposed to public information symbols, because of the demands that listening to the complete set of warning will make on the respondent. (It is relatively easy for the respondent to scan a set of symbols in a few seconds – this is not the case for auditory warning sounds.) It is important that the respondent is aware of the nature of all the sounds which are later to be linked to referents before the procedure begins. An iterative procedure, such as response surface methodol
ogy, is envisaged as being appropriate. Respondents should be free to write more than one sound reference number against a particular function if they wish. These responses are then evaluated against the referent function that they were intended to convey. Again, if any function fails to reach an acceptable criterion level (e.g. ISO suggest 66% recognition accuracy as a minimum for visual symbols) then it is modified or referred back to the initial design stage.

2.6 GENERATE STANDARDIZED VERBAL DESCRIPTIONS

The verbal descriptions of the sounds serve as identifiers only and are given to label sounds with referent functions. In a similar way to public information symbols, these verbal descriptions would allow some flexibility in the application of the designs while retaining the essence of the sound.

2.7 OPERATIONAL TEST

An operational test may be carried out in a simulated or real environment. While this sort of testing often lacks the controlled rigor of experimental laboratory studies, it may provide the users with the ecological validity necessary to gain acceptance. At this stage, it is important to carry out an audibility test, especially if the warning set would typically be heard under noisy conditions. The operational test also has the advantage of testing sounds within the envi
ronmental context in which they are to be used. To do this

Human Factors and Digital Networks: Intranets, Extranets, and the Internet


Human Factors Issues in Augmented Reality


Human Failure Mode and Effects Analysis (H-FMEA)

FIGURE 12 Ergonomic redesign measure “color trolley.” 8 6 4 4 1 2 0 0 0 0 0 0 Product Errors Discovered in a Plant after Measure Implementation (Extract Relating to 24 Hour Period)

Color Abrasion Color deviation Color Injector Color not scratch resistant Streaks Lack of motivation

Product Errors

Average Error Frequency

FIGURE 13 Error avoidance through the application of H-FMEA.

FIGURE 11 Error frequency before use of H-FMEA. Product Errors Discovered in a Plant before Measure Implementation (Extract Relating to 24 Hour Period) 8 6 4 2 2 1 1 6 3 3 0

Internal Color Abrasion Color deviation Color Injector Color not scratch resistant Streaks Lack of motivation

Product Errors Average Error Frequency

ALGEBRI, J., FRIELING, E., SCHÄFER, E. und STÖRMER, S., 2002,

FRIELING, E., ALGEDRI, J. und SCHÄFER, E., 2001, Der Beitrag der
H-FMEA zur Vermeidung von Produktfehlern. Arbeitsgestaltung,
Flexibilisierung, Kompetenzentwicklung. GfA. FRIELING, E.,
5 (Kirchberg, Switzerland: Swiss Association for Quality).
Human Information Processing:
Implications for Human Factors and
Human–Computer Interaction


Human Speech Digitization and Compression

a simple excitation model (i.e. a model that does not take into account vocal tract differences among people): an amplitude parameter; a voiced/unvoiced parameter; and, if voiced, a pitch parameter that specifies the fundamental periodicity of the speech signal. Various techniques have been used to simulate the manner in which the human vocal cavity imposes a particular spectral shape on the excitation signal. One of the first techniques developed uses a bank of band-pass filters, similar in many respects to the adjustable multiband “graphic equalizers” found on some high-end stereo systems. The center frequencies of these filters are fixed; an adjustment in the gain of each filter or channel allows the desired spectrum to be approximated, in much the same way that adjusting the tone controls may vary the spectral characteristics of a stereo system. The chief drawback to this approach is the large number of filters required. The number of filters can be reduced if it is possible to control their center frequencies. Specifically, by matching the center frequencies of filters to the desired formant frequencies, one can encode speech with only three or four tuneable band-pass filters. The important point is that even though the center frequencies of the filters must now be encoded along with the gains of the filters, the total number of parameters required for
accurate shaping of the excitation signal is reduced greatly. Although early speech synthesis systems relied on
analogue mechanisms to filter and shape the excitation
signal, modern speech compression systems rely entirely
on digital filtering techniques. With these systems the
decode speech signal heard at the receiving end is the out
put of a digitally controlled filter that has as its input the
appropriate excitation sequence. Digital control of the fil-
ter is accomplished through the use of a mathematical
model — in essence, an equation with constants and vari-
ables in which the desired spectral filtering is specified
by
setting the appropriate values for the variables. Great reductions in the data transmission rate are achievable
with this approach because the same mathematical model
is preloaded into both the encoder and decoder. Therefore,
the only data that must be transmitted am the relatively
small number of variables that control the model. A good example is the technique known as linear
prediction, in which speech samples are generated as a
weighted linear combination of previous output samples
and the present value of the filter input. This yields the fol-
lowing expression for each output sample (S[i]) as a func-
tion of previous samples (S[i 1], S[i 2], ..., S[i n]),
the prediction weights (A[1], A[2], ..., A[n]) and the filter

The filter input in this equation \( U[i] \) is the product of 

the amplitude parameter and the excitation sequence. The


Human–Computer Interaction (HCI)


Hypertext and Hypermedia


VORA, P.R., 1994, Evaluating interface styles and multiple access paths in hypertext. Unpublished PhD Dissertation (Department of Industrial Engineering, State University of New York at Buffalo).
Information Design: Warning Signs and Labels


Interactive Speech Technology

termed “Spanish Inquisition” mode with users having to answer a long string of questions before finding the information they require. It is apparent that, even with questions designed to elicit “yes” or “no,” some users will reply with other words (Baber et al. 1997). Thus, using a restricted vocabulary with apparently unambiguous questions need not eliminate out-task vocabulary. An alternative approach is to develop an exhaustive vocabulary, containing all the words which people are likely to use. However, increasing vocabulary could return us to the problem of perplexity (without a sound syntax to support such a vocabulary). Rather than increase vocabulary size, one could employ a form of “word-spotting,” i.e. the speech recognizer is “tuned” to search for specific words in the incoming speech. The implications of this approach are that appropriate, relatively unambiguous keywords can be defined and that people can be encouraged to limit their extraneous speech. A recent trend in large vocabulary systems has been to move from word spotting to topic spotting, i.e. rather than simply “listen” for particular words, the recognizer is able to detect keywords associated with a given topic and can call upon appropriate subsets of vocabulary pertaining to that topic.

6 WORKLOAD AND STRESS One of the key issues for applications of automatic speech recognition is the effects
that different environments may have on human speech production. As the technology becomes efficient enough to be considered for deployment in situations which were previously considered “adverse,” then it becomes important to consider how workload and stress could influence performance. Baber (1995) reported a series of studies investigating the effects of workload and stress on speech production and proposed the following problems. Given the tendency to revert to well-learned behaviors under stress, people may attempt to structure their utterances without due regard for the syntax. This problem could also manifest itself in speech errors, which involve violation of vocabulary constraints in using speech recognition systems, where users revert to more familiar words and phrases. If the quantity of information in feedback
Internet and the World Wide Web


VORA, P.R., 1998b, Designing for the web: a survey. Interactions, 3, 13-30. WORLD-WIDE WEB CONSORTIUM (W3C) [http://www.w3.org]
Knowledge Management in HCI Design


Knowledge-Based Man-Modeling: Job Design Procedure (Man-Modeling for Job Design)

(source: AnySIM). FIGURE 4 Anthropos as an example of Virtual Ergonomic Prototyping (source: IST).
Medical Virtual Reality Simulators

Mobile HCI with Physical Selection

Models of Graphical Perception


IVES, B., 1982, Graphical user interfaces for business information systems. MIS Quarterly, special issue, 15-47.


VERNON, M.D., 1962, The Psychology of Perception (London:
Multimedia Production


Multimodal Interaction


TABLE 3

Preliminary Multimodal Interaction Design Guidelines

O Coupling information source: Combine visual, auditory, and haptic stimuli to enhance cueing strategies (e.g. for warnings/alerts, vigilance tasks, target detection/discrimination).

O Haptic and visual augmentation: Use visual and haptic cues (i.e. force feedback, vibratory cues) to enhance object recognition and manipulation during spatial tasks (e.g. size, shape, position, location estimation; ETSI, 2002).

O Auditory and haptic augmentation: Use auditory (e.g. earcons, spatial auditory signals) and haptic cues to ensure temporal accuracy (i.e. reaction time; ETSI, 2002).

O Multimodal cues coupling: When tasks include both spatial and temporal accuracy (e.g. navigation task), combine visual presentation with haptic feedback and/or 3D auditory cues to describe task attributes (i.e. heading, location, distance, terrain; Mulgund et al. 2002).

O Temporal and spatial coincidence: When seeking a large amount of perceptual integration of multimodal stimuli and neural coactivation (e.g. for enhanced RT, augmented perception, enhanced memory), ensure different modalities are close temporally and spatially (Stanney et al. 2004).

O Sensory distribution: When attention is required to different presentation modalities, it is easier to divide attention between two concurrent tasks when tasks are presented to multiple modalities (e.g. auditory, tactile, and visual) than to one modality (Samman et al. 2005).

O Working memory capacity enhancement: When seeking WM capacity enhancements, direct sensory stimuli to a multitude of WM modalities, while avoiding extensive cross-encoding among visual and auditory percepts into linguistic terms (Samman et al. 2005).

O Intersensory facilitation effect (IFE): When seeking enhanced target acquisition, introduce a preceding sensory accessory in an alternative modality than the primary percept (Stanney et al. 2004).

O Congruency effectiveness: When seeking enhanced RT via redundant-signals or neural coactivation, employ congruent combinations of cross-modal percepts as opposed to incongruent combinations (Stanney et al. 2004).

O Spatial orientation augmentation: When seeking enhanced spatial orientation, ensure multimodal spatial senses yield
congruent information, such as by coupling head movements with visual scene updating or auditory localization (Stanney et al. 2004). Magnitude or inverse effectiveness: If a system has less than optimal displays (e.g. low resolution CRT), then couple with additional modality displays in order to garner the multiplicative effect of crossmodal integration (Stanney et al. 2004).
Natural Language: The Role of Language in Human–Human and Human–Computer Interaction


Performance Support: Online Help and Advisors


Physical Disabilities in Human Computer Interaction


Product Sensorial Quality


SCHOPENHAUR, A., 1819, Die Welt als Wille and Vorstellung (Lipsia).
Redesign: Integration of Analytical and Creative Processes for Enhancing Software


KAWAKITA, J., 1967, Hassouhou (Tokyo: Chuohkohron) [In Japanese].


The Role of Ontologies in User Interface Design and Evaluation


Search Tools for the Web


Sequential Model of the Visualization Process in the Internet


The Social and Ethical Impact of Decision Support Interface Design


bias. International Journal of Human-Computer Studies, 52, 701.
Sonification

in tandem; and wavelet-based models. Sound spatialization systems have also been integrated into sonification systems.

6 RECOMMENDATIONS

Sonification displays have distinct advantages for certain tasks, environments, and user populations. The design and application of sonification displays requires expertise in sound design, consideration of delivery systems, and knowledge of auditory perception and the task domain. There are many unanswered questions regarding displays that rely entirely upon sonification and regarding the use of sonification in multi-modal displays. Demanding tasks and complex data, and support by increasingly capable and ubiquitous sound-related technologies, are creating a shift in display and interface design. The notion that engagement of the
Speech-Based Alarm Displays

Structured Integration of Human Factors and Software Engineering Methods


SUTCLIFFE, A., 1988, Some experiences in integrating specification of HCI within a structured system development method. In D.M. Jones and R. Winder (eds), Proceedings of BCS HCI'88, People and Computers IV (Cambridge: Cambridge University Press), 145-60


Application of Systemic–Structural Activity Theory to Design of Human–Computer Interaction Tasks


BOBROVA, E.S. and KHOMSKAYA, E.D., 1968, Eye movement during tracking contour of objects under different qualities of visual feedback. In Leont’ev, A.N. and Zinchenko, V.P. (eds) (Moscow: Moscow University Publishers), pp. 95–140.


Universal Design in Human-Computer Interaction

human activities. (The term developmental approach to studying computer-mediated human activities is used to refer to various established theoretical strands within the social sciences and/or psychology that take explicit account of and model development in human behavior and capability. Such developmental approaches have recently started to progressively find their way into HCI. Examples include activity theory (Bødker 1989; 1991; Nardi 1996), situated action plans (Suchman 1987), distributed cognition (Hutchins 1995), language/action theory (Winograd 1988), etc.) In all cases, the tight evaluation-feedback loop advocated by user-centered design should provide the primary channel for timely input into design processes, so as to ensure that deficiencies are corrected at an early stage, while updates are less costly to make.

4.4 ESTABLISH SUITABLE ACCOMPANYING MEASURES

Support measures cover a whole range of multidisciplinary and cross-sector actions needed to facilitate the development of an industrial environment favorable to an Information Society for the broadest possible end-user population. Actions are needed to promote and facilitate the adoption and diffusion of good practice in the areas of accessibility and usability to ensure quality in the use of products and
services. To this end, it is important that accompanying measures are initiated to articulate demand (Kodama 1992) for universal design, support the industry in adopting novel methods and practices, raise awareness, promote knowledge dissemination, and transfer technology in the form of know-how and know-why.

5 DISCUSSION AND CONCLUSION

The above are only some of the goals of international collaboration aiming to promote universal access in the Information Society. They demonstrate the benefits resulting from an international, multidisciplinary effort to advance the concepts and principles of universal design in the context.

FIGURE 3 New virtual spaces for individual and collective experience.


Use of Icons in User Interfaces


ON, H.K., 2000, Modeling icon performance. Masters Thesis (Hong Kong: Hong Kong University of Science and Technology).

4 DISCUSSION

4.1 SOME BASIC RESULTS OF MODERN CHINESE RESEARCH

Statistical studies figured out the outline of Chinese character features which form the basis of designing CKI methods. For example, in 6763 characters defined in GB 2312-80, the average number of stroke components are 10 and 3 respectively. In the ISO 10646 character set, 560 components are used. There are a total of 417 initial-final syllables used as phonological elements in Chinese. Of the characters commonly used in modern Chinese, 18.16% can be read with differing pronunciations.

TABLE 2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Note: Total number of characters in ISO (CJK Unified Chinese Coded Character Set) 10646 is 20902.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3

Correspondent Relationship Between 6 Standards

Issued in Mainland China Simplified Traditional Characters

Characters GB 2312-80 GB 12345-90 (0: 6763) (1: 6866) Standards GB/T 7589-87 GB 13131-91

(Set No.: Character number) (2: 7237) (3: 7237) GB/T
Note: Set number and number of characters was shown in brackets.

There are several situations in GB12345-90 where more than one old characters were simplified so correspondent to 1 character, hence total number of characters (6866) is more than 6763.


INTERNET SOURCES

http://www.cssn.net.cn/cgi-bin (China Standards Service Net) for detailed information about Chinese standards, standards publications, directory of organisation, etc. It offers both Chinese and English versions.

http://ftp.ora.com/pub/txamples/nutshell/ujip/doc/cjk.inf for a brief description of international and domestic standards CJK (China, Japan, Korea) Chinese character set, and a detailed introduction about the technique of the CJK encoding system, together with valuable introduction of relative Internet resources.

http://www.kudpc.kyoto-u.ac.jp/~yasuoka/CJK.html for CJK character tables, Kanji (hanzi) variant tables, Unicode related tables, Domestic ISO646 character tables in gif format files.
User Requirements in Information Technology


User-Centered Graphic Design

Childhood as a distinct cognitive and emotional stage, rather than as an imperfect adulthood, and proposed the need to adapt the educational tasks to the intellectual and psychological characteristics of children. Their learning theories developed as attempts to look at education not as a process of transmission of information but as a process of development of capacities. This was done on the basis of taking cognizance of child development and of strategies believed to be most effective for the fostering of maturation.

6 User-Centered Design as a Conscious Notion

User-centered design began with the application of physical ergonomics to the design of objects. Intuitive at first, as in the medieval shoemaker that measured the clients' feet, and systematic later, as in the production of mass-made clothing, passenger vehicles or workstations. The conscious notion of user-centered design began with the ergonomic studies of Alphonse Chapanis during World War II, and then moved onto the cognitive, the emotive and the cultural, including today ecological and health issues. It could be argued that commercial advertising has for the past 50 years been user-centered, in that, rather than being centered on descriptions of the virtues of the products (as it was at the beginning of the 20th century) it has
been centered on desires and values of people. Unlike edu-
cation and ergonomics, however, the main purpose of adver-
tising is not to benefit the public, but to benefit the
business
that produces the advertised goods. User-centered design
in all its implications not only intends to attend to the
characteristics of the public to be addressed in order to reach
it, but also it attends to the needs and the welfare of that
public. This is the case in urban design that improves the
quality of living, or in computer interface design that
facilitates the tasks of the user (Pradeep 1998). The aim of
user-centered design that takes all dimensions into account is to benefit the user. This concern does
not end with the user’s wishes and capacities but it extends
to the users’ physical and psychological health and well
being. This is the point at which user-centered design
touches on science and culture, becoming contextualized
A Gameplay-Centered Design Framework for Human Factors in Games


Vagueness in the Representation of Cognitive Categories Regarding User Interfaces

Once the mathematical representation of the vague concepts is available, they can be used as part of the implementation of concrete usability analyzers, using standard fuzzy rule frameworks. This requires implementing each guideline as a rule that concludes a partial aspect of the usability of the interface, e.g. “if the page has excessive links, the usability is poor.” Finally, the evaluation might provide additional evidence to refine the concepts selected or to suggest the improvement of the elicitation process for a given concept, resulting in several iterations of the process described. Adaptive (personalized) user interfaces may also use vague categories to tailor the interface based on a model layout (Sicilia 2003). An example of (fuzzy) rule that can be used is “if user likes long content items and current content is c then [c is appropriate],” where c is the name of the content under consideration. The computation will proceed by taking the degree of preference to “long” concepts and combining it with the degree of compatibility of the content under consideration with the vague granularity specified. The fire of the rule will give a concrete belief degree to “appropriateness,” which could be used, for example, to perform “link sorting” of the pointers to
several contents, using the appropriateness degree as criteria. This approach may also be combined with quantified the user. For example, the rule “if most contents read by
Video Telephony


PAHL, G. and BEITZ, W., 1988, Engineering Design – A Systematic Approach (Berlin: Springer).


SHNEIDERMAN, B., 1992, Design the User Interface: Strategies for Effective Human-Computer Interaction (2nd ed.) (Reading: Addison-Wesley).
Virtual Environments

the display and how realistic color should be represented
in the periphery. At present, the full integration of human
sensing and
manipulation capabilities with current display technologies
is impeded by either the lack of knowledge of human capa
bilities or by limitations in technology. With haptic
displays,
this means that there are human movements that cannot be
adequately sensed, or, more importantly, human senses that
are under-utilized. The present disparity between rate of
task
performance in teleoperated or virtual environments, com
pared with real ones, is the net result of such disparity. If we
can completely match the specifications of human sensing
with virtual environment display characteristics, then it
may
reduce this disparity to zero. This will not likely happen in
the near future.

3.2 RELEVANCE OF THE TASK

The optimal coupling of display fidelity with human’s
sensory capacities will also be task-dependent. That is, not
all tasks will require the largest field of view, the most real
istic tactile feedback, or the most realistic spatialized sound
technically possible. In this regard, Barfield et al. (1995a, b)
have discussed the tradeoff between field of view and display resolution in the context of the required application and task. If the task is to navigate through a virtual environment, then a HMD with a wide field of view may be necessary. However, if the task is to control a slave manipulator at a remote site, then a HUD providing a smaller field of view with higher resolution may suffice.

3.3 PROLONGED EXPOSURE, TO VIRTUAL ENVIRONMENTS

Before the use of virtual environments will gain wide spread prevalence, researchers must address the question of the effect of prolonged exposure to virtual environments on the human’s ability to re-adapt spatially and cognitively to the real world. This consideration becomes especially important when the stabilization of the virtual environment is poor. In such cases, exposure may lead to symptoms of simulator sickness, manifested as general discomfort, apathy, drowsiness, headache disorientation, fatigue, pallor, sweating, salivation, stomach awareness, nausea and vomiting after or during a session with a virtual environment. Isolation of these causal factors must occur before prevention techniques can exist.

4 PRESENCE IN VIRTUAL ENVIRONMENTS

Because virtual environment display technology has the capacity to surround the user with three-dimensional stimuli
from multiple sensory modalities, under ideal conditions these components may interact to provide the viewer with a

Advanced Interface Design (New York: Oxford University Press),

pp. 471-513.

CATER, J.P., 1992, The nose have it! Presence: Teleoperators and

Virtual Environments, 1, 493-4.


Virtual Reality


Virtual Reality: Virtual and Synthetic Environments — Technologies and Applications


HARVEY, D., 1987, VCASS: a second look at the super
cockpit. Rotor and Wing International, 21, 32-3, 63.


Visualization Support to Data Mining Modeling


Voice-Enhanced Interface


VR Technology for Ergonomics Design


Warnings


Web Design: Effective Log-in or Sign-in Page


Auditory Warnings and Displays: Issues Relating to Design and Selection


FLETCHER, H., 1940, Auditory patterns. Reviews of Modern Physics, 12, 47-65.C.


MILLER, G.A., 1956, The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological Review, 63, 81-97.

OSHA, 1989, Occupational noise exposure limit, Code of


Calibration and Characterization of Color Displays

BERNS, R.S., GORIZNISKI, M.E. and MOTTA, R.J., 1993a, CRT colorimetry, part II: metrology. Color Research and Application, 18, 315-25.


Editorial Department, 1996/97, People’s Republic of China Year Book, vol. 16 (Beijing: PRC Year Book Ltd, with Hong Kong: NCN Ltd).


Computer Mouse Use


Design and Use of Displays


Design Issues: Action Research in Control Room Operations

retained because the researcher is still apart, but ecological validity is ensured by drawing on the participants’ day-to-day experiences. The key features of the approach are as follows: 1. Ecological validity is approximated. 2. All psychologically significant variables are likely to be identified. 3. Participants and researchers develop a partnership of exploration. 4. Sampling is flexible and by mutual consent. 5. Participants reveal and are able to reflect upon coping strategies developed over time. 6. Research studies emerge naturally. 7. Participants themselves will suggest studies or identify salient variables. 8. Participant loss will be minimal thereby allowing longitudinal studies. 9. Cooperation will affect broader organizational structures, such as new ways of working. The CAFE OF EVE methodology offers an action research approach. There is obviously an element of risk associated with investing in such a long-term project. The researcher is likely to encounter unperfected events and difficulties, but this likely to be outweighed by the quality of the data and the insights gained through research of this nature.
Development of a New Taxonomy for Display Selection


MILLER, G., 1956, The magical number seven, plus or minus two: Some limits on our capacity for processing information, Psychological Review, 63, 81-97.


Handwheels


Input Devices and Controls: Manual, Foot, and Computer


Keyboards


Legibility of Colored Print


Manual Control Devices


Multivariate Visual Displays

FIGURE 3


A New Taxonomy for Display Selection


2. Glare occurs when light from other directions is superimposed on light from the direction of gaze. This can occur when the gloss of a viewed surface acts as a mirror to directionally reflect light from other sources along with light from the surface itself. Glare also occurs when minute opacities in the cornea and lens reflect light from other directions into the direction of gaze and on to the retinal receptors for that direction. Since it adds light from other sources to light from the viewed source, glare alters the viewed source’s appearance and obscures its details.

3. A steradian can be visualized as follows: Hold one arm straight out front; bend your elbow 90°; place the center point between finger tips and elbow in front of one eye. Now rotate the forearm around that center. From your eye’s perspective, the conical viewing angle of the circle swept by the finger tips and elbow is about one steradian. Since the cone’s base is a spherical surface, a small correction for curvature is needed. The correction becomes negligible for solid angles less than 0.008 steradian. A true point source would be infinitely small and emit essentially no light. That is why the candela had to be defined in terms of a finite source area. In practice, a circular source can be treated as “point source” with less than 1% error when its diameter is less than 1/10th its distance from the detector and thus subtends less than 0.008 steradians or a 6° plane angle with respect to the detector. Assume that the arrangement in Figure 6 produces a detector response of “L.” Let a new source have 1/9th the area of the illustrated source. Let the detector response still equal L, and recalculate the emitted luminance. The luminance of the new source is 9L because the response is divided by the smaller source area. Now calculate the incident luminance. The luminance incident from the new source is also 9L because of the division by the smaller solid angle of the source.
Predictive Displays


Systematic Control of Exposure to Machine Hazards

American Society of Agricultural Engineers, 1993, Guarding for Agricultural Equipment. S493 (St Joseph: ASAE).
head and neck are positioned to minimize the flexor torque imposed by gravitational acceleration. Indeed, the necessity for muscle activity to stabilize the cervical spine is likely to be greater when it is relatively extended (Winters and Peles 1990). Another factor that must be included is the recognition that the tension generating capability of a muscle is highly dependent on its length. In general, changes in posture at the atlanto-occipital and cervical joints will alter both the moment arm and the average fiber length of muscles actively providing both the required extensor torque and stiffness. While accurate measurements of moment arm and fiber length changes are unavailable, it is clear that the muscle fibers that produce extensor torque will be shortened to some extent by increased extension of the head and neck. The suboccipital muscles in particular are relatively short and even a small change in average fiber length caused by extension of the atlanto-occipital joint is likely to cause significant decrement in their tension-generating capabilities. Yet it is precisely these muscles which appear to be primarily responsible for vertical movements about axes high in the cervical spine (Winters and Peles 1990). The best available estimates suggest that extension of the atlanto-occipital
joint beyond neutral rapidly leads to a decrement in the force-generating capability of the small suboccipital muscles (Burgess-Limerick et al. 2000). This is also true of muscles which cross both cervical and atlanto-occipital joints (such as the semispinalis capitis), unless the cervical spine is in a markedly flexed posture.

4 CONCLUSION

In a normal erect posture the ear-eye line is typically 15° above horizontal (Jampel and Shi 1992) and this provides the best available definition of the neutral posture of the atlanto-occipital joint. When viewing visual targets from a seated position the head is, on average, held in this erect posture when the visual target was 15° below horizontal eye height. In addition to leading to gaze angles higher than preferred, locating visual displays higher than 15° below horizontal causes extension of the atlanto-occipital joint from neutral. Even a small amount of extension of the atlanto-occipital joint is likely to cause a decrease in the tension-generating capabilities of both the suboccipital muscles and the cervical muscles which insert on the occiput (although the gradient of the relationship for
Visual Display Technology


Visual Displays in Human–Computer Interaction


Visual Fatigue and Stereoscopic Displays

Warning Design

is made up of a significant proportion who can read only some other language. A judge in a court case suggested that in these circumstances a skull and crossbones poison warning symbol (Figure 1b) would have been an appropriate alternative to a multilingual warning. However, in a random sample survey in the UK in 1977 this symbol was shown to 479 respondents. The symbol was shown within the triangle shape commonly used for warnings and was tested together with other symbols. On a very lenient criterion only 48% of the respondents correctly identified the symbol as indicating a poison. Thus the symbol used alone would have communicated successfully with a smaller proportion of the population than the English language warning used alone. When designing a warning symbol there are guidelines that can improve legibility and comprehension. These are embodied in a number of national and international standards dealing with the use of symbols in signs in general, and in warnings in particular. International Standard ISO 9186:1989 (currently under revision) and Australian Standard 2342-1992 give guidelines for designing legible symbols and methods for testing their comprehension. ANSI Z535 from the USA gives extensive guidelines. For common warning symbols, such as “No Smoking,” “No Swimming” and “Danger, electrical hazard,” standardized
symbols exist that have been subject to testing. Designing successful symbols for new concepts, however, has proven more difficult. The standards mentioned above require between 66 and 85% comprehension among a representative sample of users. In general these targets have been difficult to meet for complex concepts such as, “In case of fire do not use lift” or “Danger, freak waves — do not fish off the rocks.” In some circumstances it may be possible to convey a concept by means of several symbols in succession, much like a cartoon strip. This method has been used successfully to produce a warning for use on packets of candles to indicate that lighted candles should not be left unattended. If color is available for a symbol such as this the negating cross should be in red.

3.4 LOCATION OF WARNINGS

Much research has gone into the design details of warnings, but rather less into the question of where a symbol sign should be located to enhance its attention-getting properties. From the small pharmaceutical vial that provides insufficient space, to the house-hold product on which the manufacturer deliberately wishes to minimize the prominence of a warning, each product presents its own challenges. For a warning to be useful it must be appropriately attention getting and it must be present at the time the user needs it. This may be at the time of pur
chase, possibly to alert the user to the fact that certain protective equipment is required, or at the time of use to remind the user to make use of that equipment or to follow certain ANSI Z535, 1997, Standards for Warning Signs, Labels and Symbols.


Active Safety in Car Design

FIGURE 3 Human-machine interface (HMI) in active safety.
Analysis of Office Systems

TABLE 2
Decision Table: Selecting an Alternative Based on Future Conditions

<table>
<thead>
<tr>
<th>Future Conditions Moderate (e.g. funding)</th>
<th>High Level</th>
<th>Low Level</th>
<th>Probability of Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding</td>
<td>0.5</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Redesign job/job content
Ratings 1 4 2 2 Alternative B
Ergonomically redesign workstation and environment
Ratings 1 5 1 3 Alternative C
Redesign job/job content, ergonomically redesign workstation and environment; train managers and distribute office ergonomics manual
Ratings 1 1 6 7 Alternative D
Ergonomically redesign workstation and environment; train managers and distribute office ergonomics manual

Ratings 1 2 4 5

1 The numbers indicate the selection preference rankings based on the weighted criteria and overall rating score from Table 1. Each alternative was subjectively rated on a 0 to 10 scale where a rating indicates a low preference and a 10 rating indicates a high preference.

Psychological Function of Person (Bonn, West Germany: Federal Ministry for Work and Social Order).


ROBERTSON, M.M. and ROBINSON, M., 1995, Enhancing user control of VDT work environments: training as the vehicle.
Anthropometry for Design

FIGURE 3 Hand grip named according to different classifi-
cations: power grip, hammer grip, or clench grip palmar.

FIGURE 4 Functional anthropometric measurements for the
needs of clothes design.

MASALI, M.I., CONIGLIO, E., FUBINI, C., MASIERO, G.,
PIERLORENZI, A., MILLEVOLTE, A. and RICCIO, G., 1992,
Anthropometric characteristics of Italian population from
an ergonomic aimed research (unpublished). In Proceedings
of the International Congress of European Anthropological
Association, Madrid.

McCORMICK, E.J., 1964, Human Factors Engineering (New York:

NOWAK, E., 1978, Determination of the spatial reach area of
the arms for workspace design purposes. Ergonomics, 7, 493.

NOWAK, E., 1993, Anthropometric data for designing a
pupil’s workstand. Prace i Materialy IWP (Warsaw: Institute

NOWAK, E., 2000, Anthropometric Atlas of the Polish
Population — Data for Design (Warsaw: IWP). PEEBLES, L. and
NORRIS, B., 1998, ADULTDATA: The Handbook of Adult
Anthropometric and Strength Measurements — Data for Design
Safety (Nottingham: Institute for Occupational Ergonomics,
University of Nottingham). PHEASANT, S.T., 1996, Bodyspace:
Anthropometry, Ergonomics and Design (London: Taylor &
Francis). REBIFFE, R., GUILLEN, J. and PASQUET, F., 1981,
Enquete anthropometrique sur les conducteurs francais
(Unpublished) (Paris: Laboratoire de Physiologie et de
Biomécanique de l’association Peugeot-Renault). THOREN, M.,
1994, Clothing made to fit the disabled users. In 12th
Triennial Congress of International Ergonomics Association,
Anthropometry: Definition, Uses, and Methods of Measurement

Further details about the above methods can be found in the following publications:


Biomechanics of the Wrist in Computer Keyboarding


Consumer Product Design


Creativity in Product Design

TABLE 2

Strategies for Enhancing Creativity Individual-Based Strategies

- Development of basic skills
- Development of domain-specific skills
- Formation of purpose and intentions
- Development of self-management skills
- Maintaining motivation

Environmental-Based Strategies

- Promoting curiosity
- Allowing for risk-taking
- Rewarding mastery and self-competition
- Supplying opportunities for choice and discovery
Design of Automobile Interiors


Design of Consumer Products: A User-Centered Approach


WENZEL, H., HAUSCHILD, M. ALTING, L., 1997, Environmental

Design of Visual Displays for Teleoperation


Ergonomic Product Design

Ergonomic Workstation Design


Biomechanics (2nd ed.) (New York: Wiley).


PUTZ-ANDERSON, V., 1994, Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs
Ergonomics for Design: Assessing and Designing the Ergonomic Quality of Industrial Products

FIGURE 1 Ergonomics for product design process.


Ergonomics Knowledge and Intelligent Design System (EKIDES): A Software Tool for Ergonomics Design, Assessment, and Education

FIGURE 22 Finding an eye-to-monitor distance with the search function in EKIDES.

FIGURE 23 Illustration of the user feedback.


Ergonomics of Cockpits in Cars


WICKENS, C.D., 1984, Engineering Psychology and Human Performance (Columbus, OH: Merrill).
Evaluation of Work Chairs


Facility and Workspace Layout Problems in Ergonomic Design


Handtools


FIGURE 3 Set of ergonomic designed kitchen knives for professional use. Working side: blade (7 types) Hand side: handle (3 types) Cook knife 200 mm Cook knife 160 mm Meat knife 200 mm Bread knife 200 mm IEEH Paring knife 140 mm Butcher knife 140 mm Allround knife 100 mm Functional direction Functional direction Force direction Force direction Supporting force Handle axis Handle axis

FIGURE 4 Design alternatives of a powered hand drill: suitable and unsuitable motion assignment.
Human Factors as Applied in Apparel Design

the visibility of the wearer. Camouflage print fabrics are designed to blend the wearer with the background and are worn by soldiers and hunters to avoid detection. The shapes of camouflage garments are also manipulated using shredded fabrics or leaf-shaped attachments to the surface of the garments. The fluttering forms simulate the foliage of the environment. Apparel that incorporates high visibility is crucial for activities such as night jogging, firefighting, and highway construction. Retroreflective tapes are often used to enhance the visibility of garments worn for these activities. The wearer is most visible in these situations when the viewer is positioned behind a light directed at the wearer, for example, seated at the steering wheel of an automobile. Retroreflective materials use embedded mirror-like particles that bounce the light source back to the viewer. Fluorescent materials and colors that contrast with the background may be used in well-lighted daylight conditions to enhance visibility. Firefighters' turn out coats are often trimmed with reflective tape placed in patterns, such as geometric shapes or letters to convey meanings that are easily recognized by fellow firefighters trying to locate a comrade in a smoke-filled environment. Auditory perceptions of the wearer can be reduced by headwear. The effects may not be hazardous in everyday
wear situations, for instance wearing a heavy winter hat, but protective clothing that surrounds and protects the head from impact may impede hearing thus affecting safety. Protective headwear is worn by construction and utility workers, amateur and professional athletes, sports enthusiasts, policemen, and soldiers. The impact protective features of materials such as hard-shell and padded helmets may affect a person’s ability to locate direction of sound and may diminish sound intensity. The primary goal when designing protective headwear is impact protection, but diminished hearing due to materials and structure must be considered. Apparel interacts with the wearer and the wearer’s environment to affect thermal balance. The goal of designing apparel for either cold or hot environments is to provide comfort and, in extreme conditions, to maintain the temperature of the body core to preserve life. Apparel can be used to contain the body’s heat, to move excess heat away from the body, or to prevent heat from penetrating the body. The textile’s fiber, structure and finish, along with the garment’s shape and how the garment is worn, affect heat transfer methods of conduction, convection, radiation, and evaporation. When designing apparel to protect the wearer from cold environments, the major consideration is building a layer of still air next to the skin, so textiles are chosen
for maximum insulating value. As an example, textiles
Human–Robot Interaction


Instruments and Design

is not limited to enriching data and ensuring the increased validity of technical choices. The analysis of instrumental geneses shows that while reducing effort and improving efficiency are definite motives, they can also come from the subject’s sense of action (Minguy and Rabardel 1993). Next we look at the post-design process in the designing of instrumentalizable artifacts. It is not only a question of designing artifacts that tolerate a range of uses. While a certain anticipation of uses and outcomes can be grounds for an artifact’s design to an extent, only a small number of uses can be anticipated due to the contingencies that contribute to their appearance. It should also not be imagined that artifacts adapt themselves to the user, even if this perspective seems interesting in certain cases. It is more a question of providing the user with artifacts that facilitate the process of instrumental genesis by bringing appropriate assistance to the elaboration of uses by novices, and by allowing users to act on the behavior and structure characteristics of the artifact. An artifact designed in this way must not only allow instrumentalization. It must also help the user to carry out an action and ensure that a coherent, collective use is maintained by making possible a shared construc
tion between individuals. Shared is used to mean both
“placed at everyone’s disposal” and “true of everyone.”
Laptop Computer Use


Methods of Ergonomic Design of Human-Machine Systems

possible and recommended to use the methods of solving small problems in ergonomic designing, which have been already discussed in the paper. A more radical approach involves restructuring of the designing process according to scientifically justified sequence of solving particular problems arising at the stage of designing human-machine systems (Tytyk 2001). The structure has been made broader by including a set of ergonomic criteria of decision effectiveness, well selected for definite designing steps (Figure 2). Those ergonomic criteria constitute its integral parts. A number of designing criteria are deterministic, which allows the designer to use computer-aided techniques (for example, while designing work places or optimization of physical burdens); however, a significant number of them are indeterministic and are used for heuristic aiding of decision making processes (Table 1). There are serious difficulties to render criteria of this kind into a digital language and that is why no efficient computer-aided method to facilitate heuristic decision-making processes has been worked out yet. An attempt to fill in the gap has been made: a heuristic method to facilitate decision making in ergonomic designing, based on directed questions has been presented in Tytyk and Lasota (2003). The method
can still be developed as far as principles of automatic con-
cluding and creating expert computer systems are concerned.

Popular and widely used neural networks processing data
together with fuzzy sets offer a theoretical possibility to cre-
ate artificial intelligence, which could be used to facili-
tate
the process of ergonomic designing. Owing to the fact that
there are not sufficient data available, which are indispen-
sible to generate correct concluding rules it is still, for
the time
being, a purely theoretical idea.

6 CONCLUSIONS

At the present time it is necessary or perhaps even indis-
pensable to create a new quality approach to the process
of designing in the field of technology. There is an urgent
necessity for designers, constructors and engineers to
acquire ergonomic knowledge so that they can create
human- and environment-friendly technology. That kind
of knowledge, in a specific way, influences evaluation of
solutions to technical problems and generates modification
of designing methods and its practical effects can be
observed on the market of technical products.
Performance Prosthetic Hands

design a prehensor which is functional as a hook and esthetically acceptable. The upper-limb amputee will prefer the functional design

that provides an attractive-looking device. The ability to perform a set of 15 activities common to daily living was also tested. The

scores from this performance analysis indicated that the Standard Hosmer/Dorrance hook, the Gilad design, and the Parker design

were preferred. Of these, the two designs referred to as the Gilad and the Parker meet the challenge for good performance devices.

Although the Gilad design got better scores in both geometrical and ADL tests, it is believed that the Parker design will be more suit
able for users who seek the better esthetic appearance.
Principles of Ergonomic Hand Tool Design


SIVALOGANATHAN, S., EVBUOMWAN, N.F.O. and JEBB, A., 1995,


Product Development Approach

5 TIME FOR A CHANGE IN TEACHING HUMAN FACTORS

Currently, most psychology oriented human factors programs prepare students to become good researchers and average practitioners. For example, students are required to know in details all the theories of information processing and master long and heavy methods of task analysis. Their “theoretical” preparation is excellent. However, after graduating, human factors students know very little about the realities that they have to deal with in the product team: the engineers’ “techno-centered” approach, short product development timelines, management expectations, the importance of innovation and aesthetics etc. It is important to balance theory courses with concrete and realistic examples of the role that a human factors specialist should adopt in the product team. It becomes crucial to “build” students’ character in college in order for them to be able to defend themselves in the tough industrial world. The following points would help students be integrated easier in the product team: 0 the techno-centered approach should be explained with concrete examples of the “appropriate” ways to deal with it (e.g. correlate objective and subjective data); 0 the “business” language (Norman 1998) should be taught with the help of marketing experts; 0 product stylists should be invited to present their approach and the influence human factors has on it; 0 experienced human factors specialists involved in product development should be invited to explain the short and “approximate” evaluation methods that they use to deal efficiently with the design partners; 0 students should be put in situations where they have to propose an innovative
product and defend it using marketing, aesthetics and usability criteria; students should be taught to “sell” their discipline to upper management by preparing clear and attractive slides demonstrating the importance of human factors in the early stages of product development;

ANSELMI, L. and TOSI, F. (eds), 2004, L’usabilità dei Prodotti Industriali (Bergamo: Moretti & Vitali).


Safety in Public Offices in Italy


Ships and Maritime Systems: Requirements and Issues


Ships and Maritime Systems: Design Process


Shoe Last Design for Improved Fit and Comfort

FIGURE 4 Foot and last outlines.
Socially Centered Design


Tactical Cockpit Technology

FIGURE 2 Advances in pilot state measurement and modeling, combined with advanced control and display technology, will revolutionize the tactical cockpit within the next 15 years.
Usability of Medical Devices


SAWYERS, D., 1996, Do It by Design: An Introduction to Human Factors in Medical Devices (Rockville, MD: Centre for Devices and Radiological Health (CDRH), FDA).


WIKLUND, M.E., 1995, Medical Device and Equipment Design: Usability Engineering and Ergonomics (Buffalo Grove, IL:
Interpharm Press).
Usability of Mobile Phone


User-Centered Product Concept Development


Virtual Workplace Design

ANDREDONI, G., RABUFFETTI, M and PEDOTTI, A, 1997,
Biomechanical method for the ergonomic evaluation of the entry-exit
Visual Display Units: Positioning for Human Use


Wheelchairs


TABLE 2 Categories in Three Groups: Components and Meanings Category Adjustment/Feature Category

A is for Chair Frame
A1 foldable frame
A2 footrest
A3 distance between A4 rear wheel width front/rear wheels
A5 caster wheel size
A6 caster wheel fork size
A7 detachable wheel
A8 assistant handle
A9 centre of gravity
A10 wheelchair weight

B is for Chair Seat
B1 backrest height
B2 seat depth
B3 seating angle
B4 armrest height
B5 detachable arm rest
B6 seat cushion

C is for Accessories and Special Aids
C1 foreleg harness
C2 rear safety wheel
C3 tipping lever
C4 support accessories
C5 head and neck
C6 assisting table supports
C7 spasm leg belts
C8 upper body harness
C9 hip supporting belts
C10 seat add-on
C11 hand rim
Workstations Organization


Active Customized Control of Thermal Comfort


Definitions of Synthetic Environments

sion, but you can experience immersion without presence. The sense of immersion and presence is what we have in real-world experience. The psychological and technological challenge for synthetic environments is: to what extent can they make us feel that we are part of their worlds? Aukstakalnis and Blatner (1992) categorized synthetic environments into three basic types: passive, exploratory, and interactive. In a passive synthetic environment, the person is merely an observer of the world. They have no control over it, nor can they move through it of their own volition. It is analogous to being a spectator. In an exploratory synthetic environment, the person is capable of exploring the world. They can move through the world, but they cannot interact with it. In an interactive synthetic environment, the person has a degree of control over it that was not possible with the passive and exploratory environments. They can hold and move objects, change perspectives, and do many of the things that they might do in the real world. From the perspective of these three different kinds of synthetic environments, we might consider the properties of immersion and presence as two orthogonal dimensions. In an alternative view on the immersion-presence debate mentioned previously, immersion could relate to the characteristics of
the sensory experience, whereas presence could relate to the
degree of interactive engagement. These dimensions are
explored in relation to desktop and head-mounted synthetic
environments in Table 3. TABLE 3 Exploring the Dimensions
of Immersion and Presence Immersion Low High Low
Desktop-passive Head-mounted Presence passive High
Desktop-interactive Head-mounted interactive
Environmental Ergonomics

Relevance of Ergonomics in Domotics and Ambient Intelligence


Flight Motion Effects on Human Performance


HENN, V., YOUNG, L.R. and FINLEY, C., 1974, Vestibular nuclei in alert monkeys are also influenced by moving visual fields. Brain Research, 71, 144-9.


Free Flight


Human Aspects of Lighting in Working Interiors


INTERNATIONAL COMMISSION ON ILLUMINATION (CIE) (2001)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) (2002)


Human Exposure to Vibration


Mental Workload under Thermal Stress


4 NOISE ENCLOSURE DESIGN RECOMMENDATIONS

4.1 IN GENERAL
1. Use a calibrated sound meter to obtain overall dB(A) sound levels and overall full or fractional octave data. Then identify the high level emitters and gather the same data at those loci. 2. Rank significant emitter levels from greatest to least dB levels. 3. Focus effort on emitters that are within 10 dB of the overall sound level, and do whatever is practical to quiet each. 4. Select a surface mass density that causes the transmission losses (each minus 6 dB) <0.75 kHz to meet design goals. 5. Initially line the interior enclosure surface with thick absorptive material. 6. Assure that the total area of all unsealed openings through the enclosure does not exceed 1% of the total enclosure surface area. 7. Iterate the design to optimize tradeoffs of weight, noise reduction, and component accessibility.

4.2 RECURRENT DESIGN ELEMENTS

Over several enclosure design efforts (1) sufficient low frequency transmission loss was usually obtained with 1–2 lb/ft² surface material; and (2) an absorptive liner consisting of 1–3 inches of glass fiber usually was needed. On unquieted engine-powered items, noise emitted from the engine fan, crankcase, engine air intake, hydraulic...
Noise: Definitions


FASOLD, W., KRAAK, W. and SCHIRMER, W., 1984, Taschenbuch Akustik. Bd. I, II (Berlin: VEB) [in German].
Performance Effects of High G Environments


Physiological Costs of Noise Exposure: Temporary Threshold Shifts


FIGURE 10 Restitution time courses TTS(t) and IRTTS (in dBmin) as physiological cost associated with preceding noise exposures

(94 dB(A)/1 h in TS I, 94 dB(A)/1 h 9000 113 dB(A)/5 ms)
in TS II, and 94 dB(A)/1 h preceding 70 dB(A)/3 h in TS III).

All test series inherited the same noise energy of legally tolerated 85 dB(A)/8 h (source: Irle et al. 1998).
Physiological Fundamentals for Work in Extreme Environments

Thermal Comfort

AMERICAN SOCIETY OF HEATING RADIATION AND AIRCONDITIONING ENGINEERS (ASHRAE), 1989, Thermal environmental conditions for human occupancy. ANSI/ASHRAE, Atlanta, GA.


FANGER, P.O., 1967, Calculation of thermal comfort: Introduction of a basic comfort equation. ASHRAE Transactions, 73, 4.1-4.18


INTERNATIONAL STANDARDS ORGANIZATION (ISO), 1992, DIS 7730 Moderate thermal environments: Determination of the predicted mean vote (PMV) and predicted percentage
dissatisfied (PPD) indices and specification of the conditions for thermal comfort. Geneva: Switzerland.


Tolerance to Sustained $\pm G$


Work in Extreme Environments: Current and Future Directions

sense that the risk of burns is reduced if the user accidentally touches the appliance). This work is interesting and useful because it leads to the drafting of very clear specifications and guidelines. However, it could be extended to look at novel ways of providing users with feedback about the state of an appliance. For example, should a domestic kettle change color as it heats up to signal that it is full of boiling water? A more general question is, “can feedback provided by appliances about their state be augmented in useful ways to enhance safety?”

6 WORK IN NONTRADITIONAL ENVIRONMENTS

The environments in which humans live and work will become even more extreme as technology advances. Three examples include: the deep sea, outer space and the automotive environment. The deep sea is totally dark, extremely cold and subject to intense pressure, while the outer space environment has no gravity or air and is subject to heavy radiation. An artificial environment will be required for humans to function under these conditions. The automotive environment (in terms of heating, ventilating and air-conditioning systems and seats) is another burgeoning topic (Brooks and Parsons 1999).
The extent of human heat and cold strain depends on the interaction of variables that describe the person, the environment, the activity and the clothing. Clearly, it is impractical to investigate all variables empirically for every human activity, so an alternative method of evaluation is essential: mathematical modeling provides this alternative. As an example, Pilcher et al. (2002) used a meta-analytic technique to provide a comprehensive, quantitative analysis of the effects of temperature exposure on performance. Meta-analytic reviews, because of their mathematical nature, have several statistical advantages over the more common narrative reviews. Their results indicate that hot and cold temperature exposure has a negative impact on performance and that other variables (e.g. length of exposure to the temperature or task duration) may modify this relationship. The question of ethics and morality was briefly addressed in the context of air pollution. Rodahl (1994) recounted how Norway was considering lowering the upper limit for SO₂ concentration of the working atmosphere from 2 p.p.m. to 1 or even 0.5 p.p.m. A study showed that lowering the upper limit of SO₂ concentration would mean that the plant under study would have to close. Ultimately, the upper limit of SO₂ concentration was not lowered. This
may not necessarily have been the best decision for the
Work in Extreme Environments: Effects on Performance


RAMSEY, J., BURFORD, C., BESHIR, M., and JENSEN, R., 1983,
Effects of workplace thermal conditions on safe work behaviour, Journal of Safety Research, 14, 104-114.


Working Clothing — Thermal Properties and Comfort Criteria


CAN2-4.2-M77 (Method-49), 1977, Method for the Test of Resistance of Materials to Water Vapor Diffusion (Control-Dish Method).


DIN-33403, 1986, Klima am Arbeitsplatz und in der Arbeitsumgebung (Berlin).


HOLMER, I., 1995, Protective clothing


MADESEN, T.L., 1976, Thermal manikin for measuring the thermal insulation capacity for human clothing. Thermal Insulation Laboratory (paper no 48) (Technical University of Denmark).


Accident Analysis and “Human Error”


Adaptive Automation

automation, the system might shift among the various levels of automation depending upon the circumstances or operator behavior. One important issue associated with adaptive automation concerns authority and invocation, i.e. who should have control over changes among modes of automation? One could argue that the operator should always have authority over the system because he or she is ultimately responsible for the behavior of the system. In addition, it is possible that operators may be more efficient at managing resources when they can control changes in the state of automation. On the other hand, there may be times when the operator needs to change automation modes at the precise moment he or she is too busy to make that change. Further, the operator may not be the best judge of when and if automation is needed. Finally, there are situations where it would be very beneficial for the system to have authority over automation invocation. If lives were at stake or the system was in jeopardy, allowing the system to intervene and circumvent the threat or minimize the potential damage would be paramount. In fact, Inagaki et al. (1999) have shown that the best decisions to abort a takeoff are made when the pilot and automation share control depending upon critical factors such as airspeed, desired airspeed,
the reliability of warnings, and pilot response time.

7 A TEAM PERSPECTIVE

Scerbo (1996) has discussed some of the unique issues facing users of adaptive technology. For instance, both the operator and the system will have to learn the capabilities and limitations of one another. Efficient performance with the system may require extensive training. Although the user and the system will have unique responsibilities, they may have to collaborate on others. During periods of high work load, the system should be capable of stepping in and assuming some of the user’s responsibilities. In addition, it is critical that the operator and system can exchange information freely and effortlessly. Activities, such as collaboration, backing up one another, and communication suggest that knowledge of team performance may be useful in designing adaptive technology. There are several factors that are important for efficient team performance including: activities associated with the acquisition and distribution of information to team members; the need to distribute work equitably; setting the proper pace of work and coordinating and sequencing activities among members; setting team objectives and monitoring team performance. Many of the same kinds of functions apply to adaptive technology. For instance, the
operator and system need to know the capabilities and limitations of one another, functions must be allocated between the system and operator so as to stabilize workload, and system performance must be continually monitored and


Affordances


Automation in Vehicles


Compatibility

FIGURE 3 Configural displays illustrating the proximity compatibility principle. (a) Display of command and actual values of a system: the emergent feature signaling 0 error is the continuous line across the top of the two bar graphs. (b) Display of rate × time: the emergent feature of amount (rate × time) is signaled by the area (height × width) of the rectangle.
Computer Systems Design for 
Psychophysical Safety of Human Operations


Creating Pleasurable Products


Engineering Principles of Ergonomics

Ergodynamics


The Ergonomic Qualities of Products

evaluating, or judging the ergonomic characteristics of a product.

Ergonomic parameters must make reference to knowledge possessed in relation to various disciplines closely linked to ergonomics, and it will only be necessary to define new parameters in the absence of satisfying parameters.

Ergonomic parameters can derive from: O Methods, instruments, and units of measurement taken from the disciplines closely linked to ergonomics. For example, intensity of sound may be measured in A′ decibels, ease of handling by means of measurements made using the metric system, the equilibrium of the object in relation to the center of gravity and its distance from the center of the object, etc. O Methods, instruments, and units of measurement chosen as the most suitable among those elaborated by disciplines closely linked to ergonomics. For example, to characterize types of noise it will be necessary to make use of the most suitable sonograms, those most representative of the phenomena; to describe forces one will have to choose representative means that place intensity and movement in relation to one another; for a usability analysis it will be necessary to choose one of the many techniques developed for use in this area, etc. O Definitions of methods, instruments, and units of measurement developed specifically for situations in which the representation of ergonomic characteristics cannot rest on support provided by disciplines closely linked to ergonomics. For example, the definition of human body simulators of different
Evaluation of Software Usability

of evaluation methods but few firm conclusions can yet be
drawn. John and Marks (1997) compared multiple evalua-
tion methods and concluded that no one method is best and
all evaluation methods are of limited value. Andre et al.
(1999) attempted a meta-analysis of 17 comparative studies
and remarked that a robust meta-analysis was impossible
due to the failure of many evaluation comparisons to pro-
vide sufficient statistics. Caveats noted, several practical
findings follow: 0 It is generally recognized that
expert-based evaluations employing the heuristic method
locate more problems than other methods, including
user-based tests. This may suggest that heuristic
approaches label as problems many interface attributes that
users do not experience as problems or are able to work
around. 0 The skill-level of the evaluator performing the
expert-based method is important. Nielsen (1992) reports
that novice evaluators identify significantly fewer
problems than experienced evaluators, and both of these
groups identify fewer than evaluators who are both expert
in usability testing and the task domain for which the tool
under review is being designed. 0 Team or multiple expert
evaluations produce better results than single expert
evaluations. 0 Finally, there are good reasons for thinking
that the best approach to evaluating usability is to
combine methods e.g. using the expert-based approach to
identify problems and inform the design of a user-based test
scenario, since the overlap between the outputs of these
methods is only partial, and a user-based test normally
cannot cover as much of the interface as an expert-based
method. Obviously, where usability evaluation occurs
throughout the design process, the deployment of various
methods

<table>
<thead>
<tr>
<th>TABLE 1 Relative Advantages and Disadvantages of Each Usability Evaluation Method</th>
<th>Usability Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>User-based</td>
<td>Most realistic estimate of usability</td>
<td>Time consuming</td>
<td>Can give clear record of important</td>
</tr>
<tr>
<td></td>
<td>Requires prototype to occur</td>
<td>Costly for large sample of users problems</td>
<td></td>
</tr>
<tr>
<td>Expert-based</td>
<td>Expert-variability unduly affects outcome</td>
<td>Fast</td>
<td>May overestimate true number of problems</td>
</tr>
<tr>
<td>Model-based</td>
<td>Provides rigorous estimate of usability</td>
<td>Measures only one component of</td>
<td></td>
</tr>
</tbody>
</table>

LEWIS, J., 1994, Sample sizes for usability studies: additional considerations. Human Factors, 36, 368-78.


Fuzziness, Requisite Compatibility, and System Design


GROBELNY, J. and KARWOWSKI, W., 1992, Quantifying risk estimations of a work-related musculoskeletal disorders according to an expert knowledge: the methodological framework, unpublished report, Technical University of Wroclaw, Wroclaw, Poland.


KARWOWSKI, W., 1991, Complexity, fuzziness and ergonomic incompatibility issues in the control of dynamic work environments, Ergonomics, 34, 671-86.


MILLER, G.A., 1956, The magical number seven plus or minus two: some limits on our capacity for processing information, Psychological Review, 63, 81–97.


WICKENS, C.D., 1984, Engineering Psychology and Human Performance (Columbus, OH: Charles Merrill).
Methodology for Human Error Risk Management in Engineering Systems: Theory and Applications


Human Factors in Land Transportation


Human Factors and Ergonomics Testing

usability of prototype controls and displays and consider
their implications for user performance. Testing at this
stage is conducted to reveal and correct problems through
a process of design-test-redesign. When one or more fully
functional prototypes have
been developed testing can assume a new role, focusing on
full-scale or end-to-end tests with representatives of the
intended user population. The testing performed at this
stage is somewhat independent of development and design activi
ties. Sometimes called operational testing or acceptance
testing, the goal is to determine whether the new prototype
can meet the design specifications and requirements. It is
typically conducted on complete production-representative
articles under realistic conditions and sometimes involves
comparison between competing products or systems. It is
important to note that the degree of fidelity intrin
sic is necessarily different for tests at various stages of
system development. Tests occurring early in develop
ment are typically limited to laboratory-based compo
nents, whereas the production-representative prototypes
needed for full-scale tests will only be available later in
the development process. In this context, it is important to
view testing as a means of minimizing or mitigating the
risk inherent in developing and producing a new product.
As system development progresses towards production,
changes to the design become more difficult and much more expensive to accomplish. The earlier a test can be conducted, the greater the potential savings in terms of costly redesign or engineering changes. Here again, the tester is confronted with a trade-off decision, early test results may save a lot of money, but only if they produce meaningful and representative results.

4 ANALYSIS AND EVALUATION

The final test phase we will consider comes in the analysis and interpretation of the test data. A frequently encountered difficulty with human factors measures used in test and evaluation, particularly those involving cognitive issues such as workload, situation awareness, and decision-making, is that they do not possess definite criteria or “red-line” limits. For these sorts of measures testers will typically report the results in a narrative, without making an explicit “pass-fail” judgment on the human factors measure in question. Alternatively, a tester may try to establish the measure’s impact on user and system performance post hoc, either logically or through quantitative statistical methods such as multiple regression analysis. Another evaluation issue, which may arise, regards the statistical methods used to determine whether a human
factors criterion was in fact met. As mentioned at the outset,
there are many stakeholders in a system's development, each bringing quite different assumptions to the interpretation of test results. For example, application of data analysis methods used in academia would lead the tester to attempt


there are other ways of testing a new design to verify it. Usability testing can be performed in special laboratory facilities (in which case it would be much like OST). In one form of usability testing a new SEP is given over to actual users (companies), and the SEP is used in a routine way (Weimer 1995). There is less control over conditions of performance, but if the specialist imposes controls over the test, very realistic data can be obtained. Although the OST and the usability test are the final situations is SEP design, they have consequences for the design process. If all goes swimmingly, production management can proceed to distribute its products. In many cases, however, the OST and the usability test will point to design features that must be corrected. These final tests are unlikely to lead to complete rejection of the SEP, because it cannot perform its assigned mission; previous tests would have indicated something wrong that had to be fixed, and it would have been fixed. More common, however, is the revelation of a number of detailed design faults that need fixing; and among these faults may be behavioral deficiencies (e.g. inaccuracies in operating procedures, the placement of controls and displays vexatious to test subjects). Fixes for such inadequacies will be made immediately, if they do not involve “bending hardware” or
The Practice of Human Factors Testing and Evaluation


Integration of Quality, Ergonomics, and Safety Management Systems


Integration of Risk Management into Complex Management Systems

Intelligent Transportation Systems


Operator Testing and System Inspection
Performance

0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9 1 0 0.2 0.4 0.6 0.8 1 Testing Performance

FIGURE 3 Relationship between testing performance and field inspection performance, over a range of defect signal strengths (voltages).
Process Control

Several models of attention dynamics are available (Moray 1986). It is important to realize that in a very large system, even optimal distribution of attention cannot guarantee that all abnormal signals will be detected. Efficient and reliable alarms must be provided, and their reliability should be considerably higher than the processes they monitor. The data acquired by the observer serve to allow the latter to identify system state, and hence support diagnosis and the detection of faults. Although much research has concentrated on how operators reason when performing fault diagnosis, direct perception of patterns of displays, in particular patterns of illuminated annunciators, often provide potent diagnostic ability without reasoning (Rasmussen 1986). Hence, the design of displays is extremely important, and recent research has provided new insights into how to design displays for complex systems (Moray 1997; Vicente 1999). Monitoring and pattern perception together provide the basis in process control for system state identification, which in other domains may be called “situation awareness.” A major difference between novices and experts in process control is the extent to which they possess well developed and accurate mental models of the plant. Having a mental model is more than merely having knowledge
about the plant. It implies that the operator has learned how to choose a subset of state information which is practical to monitor and which suffices under normal conditions to deduce causal relations among plant components, and thence to make appropriate diagnoses and take appropriate actions. It also supports predictive behavior. Operator mental models can take many forms, from unconsciously embodied transfer functions in closed- and open-loop control to complex verbal or mental images of how the plant works (Moray 1997b, 1999). Training should aim to provide accurate mental models and support their use.

4 FAULT MANAGEMENT AND ALLOCATION OF FUNCTION

Although allocation of function between human and machine is not restricted to periods of fault management, it is convenient to consider them together because of the way operators decide when to intervene in plant operation. Since modern plants are usually optimized for automated control, operators should not intervene unless they believe that the automation is malfunctioning. It is therefore necessary that they should trust the automation. Characteristically, it is during fault conditions that trust fails, and operators take manual control. While this is desirable, they should be prepared to return control to the automation when conditions
change. One problem is that when reasoning about faults operators tend to show certain characteristics which hin
ders dynamic allocation. When faced with abnormal con
ditions in a complex system, operators tend to choose a hypothesis to explain the fault as rapidly as possible, and


MORAY, N., 1997a, Human factors in process control. In
Human Factors of Wayfinding in Navigation


Rail Transport


GRABAREK, I., 1999b, Zaoztenia metody rangowania czynników kryterialnych ergonomicznej oceny stanowisk pracy w srokach transportu (Method assumptions to value ergonomic factors in means of transports) (in Polish). Prace Wydziai Transportu Politechniki Warszawskiej


UIC 651 OR, 1994, Layout of Driver’s Cabs in Locomotives, Railcars, Multiple Unit Trains and Driving Trailers.
Systems Modeling.
Physical-Control-Information Approach to
Decompose Systems for Modeling: A
Warehouse Analysis Case Study

BARTHOLDI, J.J. and HACKMAN, S.T., 2003, Warehouse &
Distribution Science, release 0.30 (Atlanta, GA: School of
Industrial and Systems Engineering, Georgia Institute of
Technology) http://www.isye.gatech.edu/~jjb/wh/wh-sci.html,
March 24.

CHEN, P.P., 1983, ER — historical perspective and future
directions. In Proceedings of 3rd International Conference
on Entity-Relationship Approach (Amsterdam: Elsevier

NARAYANAN, S., BODNER, D.A., SREEKANTH, U., GOVINDARAJ, T.,
McGINNIS, L.F. and MITCHELL, C.M., 1998, Research in
object-oriented manufacturing simulations: an assessment of
the state of the art. IIE Transactions, 30(9), 795.

NARAYANAN, S., SCHNEIDER, N.L., PATEL, C., REDDY, N.,
architecture for developing interactive simulations using

PRATT, D.B.S., FARRINGTON, P.A., BASNET, C.B., BHUSKUTE,
H.C., KAMATH, M. and MIZE, J.H., 1994, Separation of
physical, information, and control elements for
facilitating reusability in simulation modeling.
Usability Evaluation

testing to collect more detailed data. Typically, an interface log will contain statistics about how frequently each user has used each feature in the program and how frequently various events of interest occurs; for example, how frequently error messages are called. This method is especially useful in evaluating Web site usability. Together, observational methods of usability evaluation have the major advantage of investigating the performance of the real system and, therefore, ought to reflect the performance more accurately than the other methods. Disadvantages of these methods are that they tend to be slow to conduct, use many resources, and require expertise in experimental design and interface issues.

6 CONCLUSION

There are many usability evaluation methods available, and each has its own advantages and disadvantages. Some scientists argue that there is no single “best” evaluation
Utility Analysis

Task Analysis (0.226 0.591 $114,746) $21,920 ($6,594) Checklists (0.307 0.589 $88,668) $16,800 ($767) Observation (0.89 0.729 $224,278) $43,540 $101,974

Questionnaires (0.578 0.615 $31,394) $6,000 $5,160

Therefore, the overall net benefit is more likely to be in the region of $100,182 (the sum of the credits and debits for the five methods above), which is less than 25% of the estimated benefit before the reliability and validity of the methods was taken into account. The utility analysis shows that some methods are likely to have greater payback than others. The take-home message of this analysis is that ergonomists need to be realistic in showing the value of their approach, and make credible claims about the payoffs. The analysis can also be used to assess the relative merits of using one method over another.

ENHANCING ARTIFACT DESIGN In conclusion, we have begun to show that it is possible to collect evidence to strengthen, or weaken, the confidence that may be placed in ergonomics methods in the design of devices. The picture painted in our studies might represent a worst-case scenario, and further studies could lead to a more optimistic picture. However, in the absence of substantive
Computer-Based Training Systems: Using Technology to Aid Aircraft Inspection Training

FIGURE 7 O Inspect is a collaborative virtual environment (CVE) which allows the co-immersion of the trainer and the trainee in the virtual replica of the aircraft inspection environment. Avatars (Figure 7) are used in the CVE to represent the participants.

6.4 Research Studies

Some of the studies conducted at Clemson University using the virtual reality simulator are briefly described below.

1. Presence and performance measurement study. In this study, participants were taken to the hangar and shown the real aft cargo bay of a wide-bodied aircraft. Then, they were taken to the VR laboratory and immersed in the virtual cargo bay scenario. The results of this study point to a high level of presence experienced by the subjects. Participants indicated that the experiences with the VR environment were consistent with those in the real world.

2. Evaluating the effectiveness of alternate feedback strategies on visual search performance. Here participants were asked to perform an inspection task in the virtual environment. Performance measures and process measures were recorded and then provided as feedback training followed by an inspection task. The results indicate that the training enhanced speed and accuracy, thereby improving overall inspection performance.

3. Evaluating the use of prior information, feedforward training. Prior information about defect characteristics such as type, severity/criticality, location, and the probability was provided to participants as feedforward training, and they were asked to perform inspection tasks to study the effect of this training on their inspection performance. The results indicate that this type of training is effective in improving inspection performance.


EMBREY, D.E., 1979, Approaches to training for industrial inspection. Applied Ergonomics, 10, 139-144.

FEDERAL AVIATION ADMINISTRATION (FAA), 1991, Human Factors in Aviation Maintenance Phase One Progress Report,

Air Traffic Management


Air Traffic Management System Design


Application of Basic Knowledge to the Human Body: Shiftwork


AKERSTEDT, T., TORSVALL, L. and GILLBERG, M., 1982, Sleepiness and shift work: field studies. Sleep, 5(Suppl. 2), S95-S106.


EASTMAN, C.I., STEWART, K.T., MAHONEY, M.P., LIU, L. and FOGG, L.F., 1994, Dark goggles and bright light improve circadian rhythm adaptation to night-shift work. Sleep, 17,


Balance Theory of Job Design


LEVI, L., 1972, Stress and Distress in Response to Psychosocial Stimuli (New York: Pergamon).


Change Management

around Dunphy and Stace’s argument that organizational development approaches may be more appropriate to incremental changes where there is little opposition and time is available, whereas in conditions of high conflict and time pressure and a need for radical change, a more coercive style of change may be required. The central argument of contingency theories that change management strategies should be tailored to different circumstances is a valid and important one. Contingency models may, however, degenerate into mechanistic prescriptions providing over-simplified and deterministic views of the environment and over-generalized and unhelpful views of change strategies.

2.4 POLITICAL–PROCESSUAL APPROACH

Political approaches to change management have their roots in views of organizations as sets of competing individuals and coalitions making choices in conditions of uncertainty in line with their own interests, perceptions and bounded rationality. Drawing on “strategic choice” models of organizations, change strategies are seen as being influenced by dominant coalitions of senior managers, and mediated by middle management and other groups pursuing their own goals and interests. In contrast to simplistic recipes for orga
nizational change, a “processual” model has been developed by Pettigrew (1985) and others viewing change as an “untidy cocktail” of rational plans, managerial visions and numerous power plays in different and changing internal and external contexts. As Buchanan and Badham (1999) argue, this view informs an approach to change management in which politics needs to be understood in all its complexity, and “managed” by change agents who recognize that it cannot be “managed away.” While the processual approach has traditionally only offered limited prescriptions for planned change, Buchanan and Badham (1999) have further developed the implications of this approach for the self-understanding and training of change agents as political entrepreneurs. They detail the political skills and knowledge required by the change agent, the behavioral repertoire needed by change drivers that attempt to address the political dimension of change, and the manner in which effective change agents adopt a reflexive practitioner’s perspective toward learning and improving on their ability to diagnose and act politically.

3 REFLECTIVE APPROACHES TO ORGANIZATIONAL CHANGE

In contrast to managerial models of planned organizational change, more reflective analysts of organizational change are highly critical of what they view as the simplistic
change recipes of “snake oil salesmen” (Czarniawska and Sevon 1996). Influenced by ethnographic and post-modernist research traditions, many of these analyses adopt what


Changes in Modern Manufacturing Practices


the use and effectiveness of modern manufacturing practices. Human Factors and Ergonomics in Manufacturing, 14, 415-432.
Collaborative Engineering: Spanning Time and Space


Goals of distributed conferencing telepresence teledata General Application Engineering Individual Subjects Group word processing spreadsheets e-mail e-mail calendar presentation etc. etc. etc. groupware meeting support bulletin board systems video conferencing application sharing sketching/CAD finite element simulation process planning facility layout scheduling

FIGURE 2 Engineering collaboration tools.
Community Ergonomics: Applications


NEWMAN, L., 1997, Quality Improvement/Assessment of Educational System for Students of Color in the University of Wisconsin College of Engineering, Department of Industrial Engineering, University of Wisconsin-Madison.


Cross-Cultural Factors in Macroergonomics


Design of Shift Systems for Shiftwork


Distributed Mission Training


The Ergonomic Buddy System

NUM

FIGURE 4 Recordable injuries.

NUM
TABLE 1
Implementation Steps for the Ergonomic Buddy System Element

Description

Workout the Logistics of the Program The logistics that need to be worked out are: 1) How will an employee notify a buddy that he/she needs an assessment, 2) How will the buddy schedule the assessment, 3) Once performed, how will the data be collected in a central location, 4) Who will maintain the database.

Seek Employee Volunteers Employees are asked to volunteer to participate in the program. The employees should have expressed interest in the process and are willing to do what it takes to implement it. These employees will be called Ergo-Buddies.

Training Employees are given training on the basics of ergonomics and how to perform an ergonomic assessment. The training program used at the INEEL comprises two days and includes the principles of ergonomics, anthropometry, what are cumulative trauma disorders, workplace design and how to perform a practical ergonomic assessment.

Develop the Database A database is developed that will contain: 1) The results from assessments, 2) Keep track of who has/haven't been assessed 3) Keep track of those who still need solutions, and 4) Keep track of workstation...
measurements and generate a “move-card.” A “move-card” shows a diagram of an employee at a workstation with the measurements for the specific employee. Figure 1 shows the diagram for the move card.

Perform Awareness Training Awareness training is performed for all employees. This training consists of: 1) What are CTDs, 2) Elements of workstation design, 3) How to report a problem, and 4) How to request an assessment.
Ergonomics in the Design of Organizational Memory in IT


FIGURE 2 Research topics in the short, medium, and long term.
Ergonomic Process in Small Industry

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH), 1997, Elements of Ergonomics Programs: A Primer Based on Workplace Evaluations of Musculoskeletal Disorders. DHHS (NIOSH) Publication no. 97-117 (Cincinnati: NIOSH).

Ergonomics and Production Philosophies


Ergonomics in a Design Engineering Environment


Ergonomics/Human Factors Audits

ergonomic criteria. We can then count the fractions of workplaces where specific criteria are met (e.g. 47% meet visual standards), and overall fractions of workplaces meeting all ergonomic criteria (e.g. overall, 17% of workplaces were free from ergonomic problems). To do this we have to assume that all failures to meet ergonomic criteria are equally bad, or provide some weighting scheme. Any choice of weights would be difficult to justify, so the assumption of equality is usually the most practical one. A useful technique is to provide an overall index of ergonomic effectiveness with some qualifier about its constituents. For example, “38% of the workplaces in this division were ergonomically acceptable. The most frequent cause of non-acceptable workplace was poor posture caused by ill-designed conveyors.” This gives the decision-maker an assessment of the gravity of the situation, and an idea of what might be required (e.g. redesigned conveyors) to make improvements. Percentage of ergonomically acceptable workplaces (or jobs) is a useful measure of overall ergonomic effectiveness, but it does presuppose ergonomics standards. We can collect data on jobs and workplaces, but eventually we must compare what is measured with what is appropriate for human use. Audit tools must do this either in the data collection or the data analysis: At times, the standard is built
into the tool, for example by asking whether illuminance is
greater than 500 lux for moderately difficult visual tasks.
But measurements can be difficult to make reliably, espe-
cially when a standard of acceptability is implied. At many
workplaces, careful placement of the light meter can be
used to miss or achieve the 500 lux standard. It is usually
preferable to write specific instructions for data
collection,
e.g. “record illuminance in horizontal plane at four points
within the central 10° field of view.” Data can later be com-
pared with standards during analysis, particularly computer
analysis. Having decided what data to present, the report
(or other presentation) should use human factors good
practice to format graphs and figures for user comprehen
sion. Suitable guidelines are given in Gillan et al. (1998).
The most effective case is made when the report is written
to address the user’s issues rather than the writer’s
issues.
An example is the ERNAP output (Koli et al. 1998) which
is in the form of a memo to a Quality Assurance Manager
listing overall findings for each aspect measured, and
specific requirements for those places where ergonomic
criteria were not met.

6 BEYOND THE AUDIT
Use of an audit tool and sampling plan can address the
specific objectives used audit design. But the same data are
Error Management Training


Exposure Assessment of Upper Limb
Repetitive Movements: Work Reintegration
Criteria

0 For the program to be successful, it is vital to ensure active participation and excellent communications between all those involved (technical staff, plant medical staff, workers).


Historical Development of Macroergonomics: The Development of Human–Organization Interface Technology and Its Application to Work System Design

(1990) of major system disasters (e.g. Three Mile island and Chernobyl nuclear power plants, and the Bhopal chemical plant), have all led to similar conclusions. Based on the above observations, Hendrick concluded in his 1980 report that, for the human factors/ergonomics profession to truly be effective and responsive to the foreseeable requirements of the next two decades and beyond, there is a strong need to integrate organizational design and management (ODAM) factors into our research and practice. It is interesting to note that all of these predictions from 1980 have come to pass, and are continuing. These needs would appear to account for the rapid growth and development of macroergonomics that since has occurred.

3 INTEGRATING ODAM WITH ERGONOMICS

As a direct response to Hendrick’s report, an ODAM technical group was formed within the Human Factors Society in 1984, and similar groups were formed that year in both the Japan Ergonomics Research Society and the Hungarian society. Less formal interest groups were formed in other ergonomics societies internationally. In 1985, the International Ergonomics Association formed a Science and Technology Committee comprised of eight technical groups. The first eight groups formed were based on the input from
the various federated societies as to what areas could most benefit from an international level technical group. One of those first eight was an ODAM Technical Group (TG).

This TG has consistently been one of the IEA’s most active groups. For example, the IEA ODAM TG has helped to organize six highly successful IEA international symposia on Human Factors in ODAM, with the proceedings of each being commercially published by North-Holland (Elsevier), and it is planned to continue this activity indefinitely on a biennial basis. In 1988, in recognition of its importance to the discipline, ODAM was made one of the five major themes of the 10th IEA Triennial Congress in Sidney, Australia. In recognition of both its importance and rapid growth, it was one of twelve themes for the 11th Triennial Congress in Paris, France in 1990. At the 12th Triennial Congress in Toronto, Canada in 1994, and again at the 13th Congress in Tempare, Finland in 1997, a major multi-session symposium on Human Factors in ODAM was organized. For both of these congresses, more papers were received on macroergonomics and ODAM than on any other topic. A similar symposium is being planned for the 14th Triennial Congress in the year 2000.
Human Factors and Total Quality Management


Incentive Systems


TABLE 3

Factors Affecting Screener and System Performance

Function Task Operator Machine Environment

Set-up Calibration procedures Ability to follow procedures
Operator interface for Management support to accurately
calibration and maintenance Maintenance
procedures Training (quality and recency) Operator
interface for Location of equipment for maintenance
calibration and maintenance Availability of procedures, job
aids

Present Baggage selection Training (?) Physical layout of
Management control over procedure equipment baggage
selected Perceived and actual passenger pressure

Search Defined wand search Training (quality and recency)
Human interface, e.g. wand, Management support to pattern
for search pattern alarm indicator ensure procedures are
Operator dexterity followed Perceived and actual passenger
pressure

Decision p (true threat) Knowledge of threats Operator
interface to Management support for p (false alarm)
Knowledge of potential false display design following
correct decision Time available alarm items Operator
interface to acquire procedures Experience, overall and
recent additional information Perceived and actual Decision
ability passenger pressure Resistance to passenger pressure

Response Alarm resolution Knowledge of alarm resolution
Interface to other systems Management support for
procedures procedures (LEO, management, security) alarm
resolution procedures Management provision Resistance to
passenger pressure Perceived and actual of adequate
feedback passenger pressure

GRAMOPADHYE, A.K., DRURY, C.G. and PRABHU, P., 1997,
Training for aircraft visual inspection. Human Factors and
Ergonomics in Manufacturing, 3, 171-96.

study of hybrid inspection systems and allocation of
inspection function. International Journal of Human Factors
in Manufacturing, 3, 351-67.

Job Rotation

TABLE 1

Critical Dimensions of Job Rotation Dimension Potential Values

Class of work White-collar, blue-collar, pink-collar

Type of industry Manufacturing, service

Purpose of rotation To prevent cumulative trauma disorders, to broaden knowledge, to train for a future managerial role, etc.

Repetition Former jobs revisited, former jobs not revisited

Frequency of rotation Hourly, daily, weekly, annually, etc.

Who rotates Whole work group, selected individuals, etc.


Just-in-Time Support (JITS): A Framework to Enhance Human Performance


BOOHER, H., 1975, Relative comprehensibility of pictorial information and printed words in proceduralized instructions. Human Factors, 17, 266.


Kansei Engineering and Kansei Evaluation

model. In this system, the mathematical model works as if it is a kind of logic like the rule-base. Sanyo Electric Co. attempted to implement Kansei Fuzzy Logic as a machine intelligence in a new color printer and it was successful in a sophisticated color printer which can produce more beautiful color print than the original picture. Nagamachi has developed a computerized naming system for a new product based on Kansei Fuzzy Integral and Measure Logic.

VIRTUAL KANSEI ENGINEERING SYSTEM
Virtual Reality Technology is now very popular technology in which people can walk through virtually a graphic design created by the computer and displayed by means of HMD (head-mounted display) and data gloves. We tried to combine Kansei Engineering System with Virtual Reality Technology regarding kitchen design in which a candidate of kitchen is determined by the Kansei Engineering System with a specific kansei and the customer can have a virtual experience by walking through a displayed kitchen. Nagamachi extended this system to a whole house design that is called “HousMall.”

COLLABORATIVE KANSEI DESIGNING SYSTEM
We have many kansei databases. Then, we decided to implement these databases in the Website which has an intelligent 3D computer graphic system. The designers in
Readiness for Knowledge Life Cycle Management in Organizations

5 CONCLUSION

The term readiness in our heading incorporates a twofold view of preparing organizational settings for KLM. First and foremost an organization has to establish a stable and workable basis for knowledge management and knowledge access (knowledge stored in people’s heads, data bases, etc.) in order to effectively execute KLM. Our paper tried to sensitize organizations for the fundamental structural, intrinsic issues which have to be addressed to implement KLM successfully. The second, by companies often overrated view, namely the acquisition of technical resources (tools) to run KLM must not be on top of the
Managing Workloads to Optimize Performance, Health, and Well-Being

Managing System Disturbances: Human Factors Issues


Modeling of Work Environment in an Organization


Organizational Behavior and Ergonomics


Organizational Change and Supporting Tools


VERBAND DER AUTOMOBILINDUSTRIE E.V., 1986, Sicherung der Qualität vor Serieneinsatz (2nd ed.), vol. 4, Qualitätskontrolle in der Automobilindustrie (Frankfurt
Organizational Culture and Development


Participatory Innovation


MOORE, J.S. and GARG, A., 1996, Use of participatory ergonomic teams to address musculoskeletal hazards in the red meat packaging industry. American Journal of Industrial Medicine, 29, 402-408.

process: tips, tricks and traps, commentary from focus
groups and case-studies. In Proceedings of the 34th Annual
congress of the Nordic Ergonomics Society, Linköping
University Sweden, 597–602.

NORO, K. and IMADA, A., 1991, Participatory Ergonomics
(London: Taylor & Francis).

VINK, P. and KOMPIER, M.A.J., 1997, Improving office work:
a participatory experiment in a naturalistic setting.
Ergonomics, 40(4), 435-449.

WILSON, J.R., 1995, Solution ownership in participative
work redesign: the case of a crane control room.
International Journal of Industrial Ergonomics, 15,
329-344.
Participation and Collaboration in Workplace Design


Participatory Ergonomics


Factors in Organizational Design and Management (Amsterdam: Elsevier), pp. 155-60.
Participatory Ergonomics — A Scandinavian Approach


Participatory Ergonomics at the Shop Floor Level


Principles and Strategies for Team Training


SMITH-JENTSCH, K.A., SALAS, E. and BAKER, D.R., 1996,
Psychosocial and Work Organization Risk Factors for Work-Related Musculoskeletal Disorders


KARASEK, R.A., PIEPER, C.F. and SCHWARTZ, J.E., 1985, Job content questionnaire and user’s guide, revision 1.1. Developed at Columbia University; information from Dr Karasek, Department of Work Environment, University of Massachusetts, Lowell MA.


SIEGRIST, J., 1996, Adverse health effects of
Quality and Ergonomics in Concert

TABLE 2

Examples of Component Design Aspects for Improved Quality in Assembly Design Features

Visibility Sequence Weight Friction Hardness

Position Size Color Fragility Fittings

Layout Shape Texture Heat Force conductivity
is a lack of support for the left-hand branch (assertion that
the task performance level can be improved by increasing
the load). McGrath (1965) conducted one of the first exper-
iments that supported the left-hand side in a vigilance
task.
After comparing easy and hard visual monitoring tasks con-
ducted concurrently he concluded that the presence of the
hard task facilitated performance on the easy one. Wiener
et al. (1984) conducted an experiment in which a control
group performed a vigilance task (the signal was the
decrease
in distance between two dots presented on a computer
screen), and a second group performed a one-dimensional
compensatory tracking task in addition to the vigilance
task. They found that the performance of the second group
(vigilance and tracking tasks) in terms of signal detection
exceeded the performance of the control group (vigilance
task only). They concluded that these research results pro-
vided support for the facilitating effect of increasing the
task load (left side of the inverted-U). Some researchers
describe the quality inspection
task as being intrinsically boring. According to them, this
explains why it is often the case that mild stress will
increase
the performance in terms of detection and response time.
However, Wickens (1992) has indicated that vigilance tasks with working memory loads are susceptible to interference from concurrent tasks. The results of a recent study on the effects of multitasking on the decision-making component of the quality inspection task were consistent with the information presented herein (Pesante-Santana 1997). The performance of the operator in the quality inspection task while multitasking in an AMS will be determined not only by the number of different types of defects that can be presented at a time in the inspected parts, but also by the mental processing resources required to meet the demand imposed by the multiple independent tasks and the memorized quality criterion. The best performance will be obtained when the additional tasks’ load minimizes the monotony of the quality inspection task without interfering with the processing resources needed for the memorized quality criterion.

7 RECOMMENDATIONS

Whenever human operators perform the quality inspection a certain degree of error should be expected. However, some ideas oriented to minimize the quality inspection errors are:

1. Identify the inspector with the best performance and understand his/her inspection strategy.
Quality of Life and Usability Engineering

factors professionals and related investments in corporate
usability engineering programs. First, using expensive
usability labs, performing for
mal usability tests or heuristic evaluations, etc. without
being able under the given time and cost constraints sys
tematically to consider obtained test results in system’s
redesign, does not contribute to better usability and
quality
of life. Second, low cost usability testing methods often do
not provide reliable enough basis for making right user
centered design decisions. Third, many companies especially
who are working in
the same area perform similar low-cost usability tests
instead of cooperative performing explicit and informa
tive tests for typical interaction tasks. Hence main
research efforts have to be focused on
turning quality of life and usability studies into relevant
engineering approaches and computer-aided engineering
platforms.

5.2 FUTURE TRENDS
Systematic approach and notations for multi-view task
oriented architecting of flexible information systems are
proposed by Levis (1999). Further enhancement of this
Rapid Macroergonomic Redesign

Risk Management

efforts in prevention and control should be placed and to make decisions on the adequacy of control measures. It is generally not necessary to make precise numerical calculations of risk. Complex methods for quantified risk assessment are normally only required where the consequences of failure could be catastrophic. Risk assessments in major hazard industries, for example, in the chemical or nuclear industry, may be required by legal standards and guidance. Hazard and operability studies (HAZOPS) and hazard analysis systems such as event or fault tree analysis may be applied when planning a new system or major changes of an existing system.

5 RISK MANAGEMENT CHALLENGES

The past two decades have witnessed a significant transformation in how firms are structured. Tall organizations with many management levels have become flatter, competitors that have adopted a modular organizational structure have gained market shares. Organizational de-layering and the rise of smaller, often entrepreneur-based firms gives self management new meaning covering personal self-management, self-leading teams and semi-autonomous units. Companies and public services adopt cooperative forms of work at a very fast pace. Teleworks provides flexibility in both working hours and the location of work and allows...
employees to cultivate tailored life-styles while working a
full-time job. These “boundaryless” organizations, e.g.
organizations whose membership, departmental identity
and job responsibility are flexible create new challenges
for
risk management particularly for people management. The
traditional approach to managing people focuses on
selection, training, performance appraisal and compensation
for individuals in specific jobs. It also presumes a
hierarchy
of control rather than horizontal workflow sequences. When
organizations are restructured around teamwork instead of
individual performance, different forms of team autonomy
and HSE responsibilities are emerging. Risk management
systems in small, medium and mod
ular organizations must rely on the participation of mem-
bers, on self-management, personal and team responsibility.
Selection, performance appraisal and reward policies are
the most likely candidates for change. Contingent pay and
peer pressure generated by teams are emerging as substi-
tutes for both managerial influence and internalized
The Role of Ergonomist in a Design Engineering Environment

5 CONDUCTING DETAILED STUDIES

For the project manager, the aim of this fourth stage is to come up with precise plans that will render possible the realization of the installation. In most engineering environments, it is at this stage that the need for an ergonomist is striking: information on conveyor heights, control panel design, seat types, all of these issues need urgent answers. There are, of course, textbooks, reference manuals and software products that can help designers. But most of these data need interpretation and this can only be done by an ergonomist as long as s/he can anticipate what the work activities will be. This is where it pays to have the ergonomist in the project from the very start: s/he can provide better advice and help the design team in working out the details of the installation with the different suppliers. One way of helping designers in the completion of plans is to simulate with different supports (plans, mock-ups, software products, prototypes) the anticipated workers activities. Scenarios can be constructed from data collected in the existing situations taking into account the future user characteristics, the regular production and maintenance task as well as the related critical tasks. The main goal of simulation is to make fore
casts on the future work activities: are the working conditions acceptable for most of the population and from an operations point of view, are the objectives met. Modifications can still be made at this stage without adding undue expenses to the initial cost. This is also the stage where the word “iteration” takes all of its meaning; if the forecast on the workers future activities is poor, designers will modify their proposal which can again be tested and so on until the design is deemed acceptable. Discussions on the acceptability of the proposals will often oppose different professional fields: production, health, safety, maintenance may not necessarily point towards the same solution. The final word always results from compromise. These discussions are important for the remainder of the design process. For example, in a discussion about a joystick, the engineer in charge of the project may suggest to choose one with a high resistance to guarantee that it will not be activated accidently, while the ergonomist may suggest the force to be as low as possible to prevent musculoskeletal strain. On the other hand, maintenance people will be preoccupied by frequently replacing the joystick’s springs. The final decision may reflect all of these considerations; however, every actor
involved in the discussion then knows what to expect from
the selected design in terms of consequences for the work
activities and for the function s/he represents in the plant.

6 CONSTRUCTION

The ergonomist is usually not involved at the construction
stage. But from experience, many changes are made on
Safety Culture


for any reason, particularly in high-hazard plants, this needs to be under a strict change control management system, which recapitulates the design process and its risk assessment, otherwise new hazards can be introduced. This need has long been recognized in industries such as chemicals. A similar approach to organizational change is much more recent, and often not yet applied. Yet organizational change can have profound effects on allocation of responsibilities, manpower availability and competence, as well as communication and coordination channels. A threshold has to be defined as to what will be considered a change great enough to trigger a certain level of reassessment in both cases.

3.7 SYNTHESIS

Putting all of these elements together within one life-cycle phase gives Figure 4. This shows that safety management is a complex activity involving virtually everybody in the company in a wide range of tasks. The models presented here all deal with management functions. They have to be carried out no matter how large and complex, or small and simple the organization. Large organizations have the manpower and expertise to cope with this complexity using their own resources, or by hiring in and supervising contractors. The complexity of the SMS presents very different problems
to the small company. All of the functions have to be per
Safety, Ergonomics, and Total Quality Management

FIGURE 1 Operations model for implementing occupational safety oriented TQM system.
Self-Managed Work Teams

Across the literature, conditions and management strategies for changes to teamworking have been defined, propositions laid down for types of team, content for different levels of autonomy specified, suggestions about team leadership, size of teams and payment systems given, and decision aiding tools and decision support systems proposed. Analytical frameworks do exist which may be used in selection and training of team members, for instance Belbin’s (1981, 1993) team roles. However, a detailed program covering all implementation issues likely to be faced by a company introducing group work is hard to find. Published advice is more at the level of desirable concepts (such as shared vision, values and conviction, management faith, common knowledge base), rather than the direct operational guidance needed for implementing work teams while managing all the other direct and tangential issues involved. One must face the fact that such guidance may not exist because it is impossible to generalize from specific cases, and that content of any change must be set in the light of prevailing circumstances. This would make the mechanisms used to support change to teamwork even more crucial (Wilson and Grey Taylor 1995). On team evaluation also there is a relatively inadequate literature to give guidance. As well as assessing technical
performance, organizational infrastructure (e.g. absenteeism) and work attitude outcomes, we need to evaluate the very group structure and its workings, in terms of how well the team is operating as a group. Measures are beginning to emerge but some of the better initiatives in this area may possibly do well to learn from related work with the armed forces or other such teams (e.g. Brannick et al. 1997).
Service Quality and Ergonomics


Shift Work


TABLE 6
Examples of Support for Shift Workers

Better work schedules Consultation about shift schedules, increasing flexibility

Keeping capacity at work Ergonomic work design, fail-safe operations

Securing restful conditions Flexible schedules, resting facilities, housing

Support for family care Child care facilities, child care leave, social services

Facilitating coping measures Group work, training on coping

Support for health Health counselling, health check, access to daywork


Shift Work and Sleep

Figure 2 shows the response of these three groups to two sleep quality questions: “Do you often have difficulty falling asleep?” and “Do you often have difficulty staying asleep?” The results obtained for the two questions are quite similar in each case. Workers in the N/D group most often reported that they had sleep problems. These data suggest that complaints by night shiftworkers about the quality of their sleep than to working the night shift per se. When chronic exposure to a work schedule system is to be assessed, sleep length data are often a benchmark which can be used to assess the merits of a specific system. Sleep data provide the ergonomic investigator of work shift systems with a valuable tool. However, this does not mean that ergonomic analysis need only focus on estimates of physiological systems or chronobiology. Chronic reductions in sleep are associated with health and safety hazards, but the usability of a given work schedule system depends on many variables. The state and interaction of multiple physiological, social and cultural variables must be considered. In most cases, if not all, intervention efforts call for a macroergonomic approach to work schedule system design.

3 ERGONOMIC DESIGN CONSIDERATIONS
Given the conclusion that multiple interacting variables determine the impact of a given shift schedule, it should not be surprising that work schedule systems take many forms. In fact, thousands of different work schedule systems are being used. In practice, managers often behave as if they think work schedule systems take only a few forms. They assume that one or two of these forms can be labeled by the expert as the best schedule available. However, the contemporary consensus among work schedule experts is quite different. Research data leads work schedule experts to assume that there are no universal work schedule solutions for shiftwork which can be applied to most workplaces or all workers. Some dimensions which should be considered in designing a system are: worker age and gender; job and experience; current employment conditions; and, assessments of stress, fatigue, health and safety data. Just as it is reasonable to conclude that there is no single variable which determines shiftworker maladjustment or adjustment, it is also reasonable to expect that multiple work schedule solutions may all be acceptable for a given workplace. Most ergonomic design efforts consider and evaluate alternative designs, and this is also true when one evaluates work schedules. A good work schedule systems design or evaluation effort includes a consideration and evaluation of
alternative work schedule forms. Some of the options which should be considered are: whether the hours of work should be permanent or rotating; the direction of rotation, if there TEPAS, D.I., WALSH, J.K., MOSS, P.D. and ARMSTRONG, D., 1991, Polysomnographic correlates of shiftworker performance in the laboratory. In Reinberg, Vieux and Andlauer (eds) Night and Shift Work: Biological and Social Aspects (Oxford: Pergamon), pp. 179–86.


Shift Work Health Consequences

influence of several risk factors related to genetic and family heritage, psychological characteristics, life styles, social conditions, and intervening illnesses. Moreover, their chronic-degenerative trend makes their manifestation more likely to occur after long-term exposure and with increasing age; both factors are often closely connected, but their interactions are not always clearly interpretable. In this context, shift work can act as a further stress factor or trigger, as it matches conflicts between endogenous rhythms and social synchronizers with demanding working conditions and interference in family and social life. Therefore, the process of maladaptation or intolerance to shiftwork can manifest at different times of life, with different degrees of severity and duration, and sometimes in an alternating or fluctuating way; this further increases the interindividual and intraindividual variability. Although it is still not clear to what extent maladjustments of biological rhythms have an influence on long-term tolerance, it is presumable that difficulties in short-term adjustment of circadian rhythms, including sleep, are the main causes of intolerance to night work in the first years of shift work, whereas long-term intolerance seems more related to other personal, working, and social circumstances. Both factors influence the process of self-selection.
which occurs among these workers (healthy worker effect),
that sometimes masks the results of epidemiological
inquiries and intervention studies. However, the scarcity of
longitudinal studies on this perspective does not allow any
conclusion at present. Consequently, it seems rather
arbitrary and unjustified
to focus the problem of tolerance only on specific aspects, in
particular as concerning individual characteristics as
predictors for selection of “more tolerant” shift workers. On the
contrary, the most appropriate way to address the question
appears to be a systemic approach, able to match as many
variables as possible, with the aim of defining which
factors
are the most relevant for those individuals, among those
groups, and in those specific work and social contexts. It
must be stressed that any attempt for “selection” of
potentially more tolerant shift workers should not have a
Shift Work Stress


Situational Awareness Issues at Work


Sociotechnical Systems Analysis


KLEINER, B.M., 1998, Macroergonomic directions in function. In Vink and Koningsveld (eds), Human Factors in Organizational Design and Management VI (Amsterdam: Elsevier).


Sociotechnical Theory


DAVIS, L.E. and TAYLOR, J.C. (eds), 1979, Design of Jobs (Santa Monica: Goodyear).


ULICH, E. and WEBER, W.G., 1996, Dimensions, criteria and
evaluation of work group autonomy. In West, M.A. (ed.)
Handbook of Work Group Psychology (Chichester: Wiley).

VON BERTALANFFY, L., 1950, The theory of open systems in
Stress: Degenerative Changes in the Brain

induced by stress is the hippocampus. It results mainly from regulatory functions which the amygdala and the hippocampus have in response to stress. While the amygdala is activated by the hypothalamic-pituitary-adrenal axis stimulating the reaction to stress, the hippocampus by means of negative feedback inhibits the production of cortisol alleviating the activity of the axis under discussion (Davis 1992). We do not intend to discuss the particular mechanism at work by which the amygdala and the hippocampus control the activity of the axis responding to stress (the hypothalamic-pituitary-adrenal axis). For the purpose of the present study, the significant issue is that under chronic stress conditions the alleviating influence of the hippocampus may become ineffective. In such a case the level of produced glutamate becomes excessive and as a result excitotoxicity occurs leading to the degeneration of neurons. Tests on both animals and humans confirmed the degenerative effect of chronic stress and high intensity stress on the hippocampal cells. Experiments on baboons revealed that intense and chronic stress provoked adrenal degeneration and alimentary tract ulcers, as well as significant degeneration of neurons in the hippocampus area (Sapolsky 1994). Tests carried out by means of brain-imaging tech
niques revealed degenerative changes in the hippocampus area observed in individuals who experienced intense or chronic stress (Watanabe et al. 1992). The degenerative effect of cortisol on hippocampal cells is treated by many researchers as a result of the brain’s aging (e.g. Kerr et al. 1989).

4 BRAIN PLASTICITY AND HIPPOCAMPUS DEGENERATION

Many scientists point to the activation of NMDA receptors as the agent responsible for the plasticity of the brain (Larkman and Jack 1995). In other words, it conditions the effectiveness of learning and memory processes. It is no coincidence that hippocampus is inextricably connected with these processes. Paradoxically however, the excessive activation of NMDA receptors leads to excitotoxicity and, in consequence, to the degeneration of neurons, which determine plasticity of the brain, mainly in the area of the hippocampus. That is to say, they condition the reaction and functioning of what in psychology is referred to as the mind.

Thus, stress by destroying hippocampal neurons simultaneously destroys brain plasticity and destroys the mind. For years, brain plasticity has been linked closely to the phenomenon of long-term potentiation (LTP). The LTP phenomenon was discovered in 1970s by the British neurophysiologist, Timothy Bliss, and the Norwegian, at the time a psychology student, Terje Lomo, when study
ing the rabbit’s hippocampus (Bliss and Gardner-Medvin 1973; Bliss and Lomo 1973; Bliss and Collingridge 1993).


Sustainable Development and Human Factors


Systems Approach to Training


Task Analytic Methodology for the Design of an Aircraft Inspection Training Program


Team-Building


Team Effectiveness and Competencies

equately, in the team process box, it is recommended that
the team’s degree of shared task models, understanding of
cue/strategy associations and collective efficacy is
assessed.

In the individual process box (still referring to teamwork
processes, but those held at the individual level), it is rec
ommended that assertiveness, mutual performance monitor
ing and task procedures be measured. Taking this a step
further, Cannon-Bowers and Salas (1997) offered sugges
tions about what type of measurement strategy would be
most appropriate for each category. Beginning with the
upper left quadrant (team process measures), they recom
mend that observational scales targeting teamwork
processes are an effective means in assessing this aspect of
performance. Such scales can be developed using subject
matter experts (SME) to guide delineation of critical behav
iors that must occur in team members. SME can also be
employed as experts as expert raters when the task is partic
ularly complex. Another technique for assessing team
process is content analysis. By reviewing what happened
over the course of team performance – what decisions were
made and by whom – an assessment of the team’s process TEAM
INDIVIDUAL Shared Task Models Cue/Strategy Associations
Task Organization Compensatory Behavior Collective Efficacy
Dynamic Reallocation of Function Task Interaction
Mission/Goal Accomplishment Aggregate Latency Aggregate
Accuracy Error Propagation Assertiveness Task-Specific Role
Responsibilities Procedures for Task Accomplishment
Cue/Strategy Associations Mutual Performance Monitoring
Flexibility Information Exchange Accuracy Latency Errors
Safety Timeliness Decision Biases

FIGURE 3 Framework for developing TPM in training.
Team Effectiveness in Organizations: 
Current Research and Practice

BETTENHAUSEN, K.L., 1991, Five years of group research: 
What we have learned and what needs to be addressed. 
Journal of Management, 17, 345.

CAMPBELL, J.P., 1990, The role of theory in industrial and 
organizational psychology. In Dunnette, M.D. and Hough, 
L.M. (eds) Handbook of Industrial and Organizational 
Psychology (Palo Alto, CA: Consulting Psychologists Press), 
p. 39.

COHEN, S.G. and BAILEY, D.E., 1997, What makes teams work: 
group effectiveness research from the shop floor to the 

DAY, D., ZACCARO, S.J. and HALPIN, S.M., 2004, Leader 
Development for Transforming Organizations (Mahwah, NJ: 
Erlbaum and Associates).

DRISKELL, J.E., HOGAN, R. and SALAS, E., 1987, Personality 
and group performance. In Hendrick, C. (ed.) Group 
Processes and Intergroup Relations (Beverly Hills, CA: Sage 
Publications), p. 91.

HACKMAN, J.R., 2002, Leading Teams: Setting the Stage for 
Great Performances (Boston, MA: HBS Press).

KOZLOWSKI, S.W.J. and BELL, B.S., 2002, Work groups and 
teams in organizations. In Borman, W.C., Ilgen, D.R. and 
Klimoski, J. (eds) Comprehensive Handbook of Psychology: 
Industrial and Organizational Psychology (New York: Wiley).


MARKS, M.A., MATHIEU, J.E., and ZACCARO, S.J., 2001, A 
temporally based framework and taxonomy of team process. 
Academy of Management Review, 26, 356. MORGESON, F.P., 
work teams: recommendations from organizational behavior 
and development theories. In Beyerlein, M.M., Johnson, D.A. 
and Beyerlein, S.T. (eds) Advances in Interdisciplinary 
Studies of Work Teams (Greenwich, CT: JAI Press). ORASANU, 
J. and SALAS, E., 1993, Team decision making in complex 
environment. In Klein, G., Orasanu, J., Calderwood, R. and 
Zsambok, C.E. (eds) Decision Making in Action: Models and 
Methods (Norwood, NJ: Ablex), p. 327. SALAS, E., STAGL, 
in organizations: research themes and emerging needs. In 
Cooper, C.L. and Robertson, I.T. (eds) International Review
Team Performance

Team Training


Team Training for Aircraft Maintenance


Team-in-the-Loop Simulations: Advances in the Study of Collaboration and Conflict

Teamwork

team interaction, whereas socio-technical system theory focuses on the relation between the social and the technical system. For these reasons, both models can be easily combined to deduce recommendations for implementing and improving teamwork.

4 RECOMMENDATIONS

Socio-technical system theory has shown that effective teamwork can only be achieved if both social and technical factors are considered. To analyze them, proven methods for socio-technical system analysis exist that focus on employee needs, technical, social and environmental system variances. These analyses and consequent system design should be done participatively, joining managers, employees and consultants in a project to implement teamwork. Participative implementation strategies have cognitive and motivational effects. They ensure that relevant information is gathered and shared. The development and implementation of specific team models can be based on this information. During the implementation process employees and managers learn about one another. They also start learning teamwork on the job as they participate in project teams doing the analyses, team model development and implementation. Furthermore, their motivation to engage in this process as well as their acceptance of process results is likely
to rise, if they are informed and experience influence, and
control. Team effort, knowledge and task strategies as
crucial
variables for team effectiveness can be influenced by the
way
teams and their organizational context are designed. Teams
need interdependent tasks. Otherwise common team goals
cannot be set, and teamwork cannot develop. Task require
ments have to be matched with employee skills and abilities.
In a constant process of dynamic task design, task require
ments can be increased with growing employee qualification.
When teams are composed of members who have hetero
geneous skills they can easily qualify each other on the
job.
Management has to ensure that sufficient resources in man
power are provided to handle daily business and on the job
training. In addition, management can support team
effectiveness
by designing the organizational context (Antoni et al.
1994).
For example, pay systems considering employee qualifica
tion will reward team members efforts to qualify for new
tasks. Team oriented pay systems can strengthen team
resources as well as customer orientation. Customer focus
Technology Transfer


MESHKATI, N., 1986, Major human factors consideration in technology transfer to industrially developing countries: an analysis and proposed model. In Human Factors in Organizational Design and Management Conference, ODAM-II (North Holland), 351-63.


Technology Atlas Team (TAT), 1987, Components of technology for resource transformation. Technological Forecasting and Social Change, 32, 19-35.
Time Aspects in Assembly Line Design


LECLERC, A., FRANCHI, P., CRISTOFARI, M.F., DELEMOTTE, B., MEREAU, P., TEYSSIER-COTTE, C. and TOURANCHET, A., and
Tools to Design and Evaluate New Forms of Work Organization

Related to this are employee acceptance and the need for greater consideration (greater than occurred here) of preventive planning within or after the scenarios workshop. This planning might be for greater involvement of the unions in the initiative, or forums for educating and fine-tuning the responsibilities matrix involving employees and union staff at the relevant sites. The findings from using the tools also reveal the slow and evolutionary nature of work organization implementation. The scenarios tool enabled the organization to devise small steps and helped to provide structure and coherence to a cycle of planning, change, evaluation, and back to planning. The evaluation tools enabled the organization to observe the extent to which the goals were being met and identified small shifts in attitude towards the new scenario. The scenarios tool raises awareness that there is not necessarily one best option. This is of theoretical and practical interest and was initially highlighted for the organization during the workshops when several possible scenarios were developed. And subsequently, at the individual sites, the preference for one best method has not yet worked in practice. Variations in local needs and requirements contribute to this, as well as employee adjustment towards a less specialized and leaner way of working.
This suggests it may require some local control and flexibility in translating principle into practice at the different sites. Indeed, the work organization literature advocates the empowering of sites or individuals to have some control over the way they work, within certain boundaries (e.g. broadly within a particular organizational scenario in which methods are minimally critically specified) (Cherns 1976, 1987; Hackman 1989). Moreover, local involvement and adjustments to the new ways of working would help to enhance ownership of them. These variations suggest that particular forms of work organization should not be considered as fully generalizable (i.e. slotted into place anywhere). We need to know more about the contingencies, circumstances, or boundaries under which these principles will be successful (Parker and Wall 1998). Other issues relate to the local tailoring of the tool itself. The stakeholder group suggested some changes to the headings within the scenarios tool to make it more organization friendly. They suggested that the heading “logic” should be replaced by “reason for vision”; the heading “roles” should be expanded to “roles – who does what?” Alternative and additional headings have also been suggested elsewhere (Nadin 1996; Hesse 1998). We think the scenarios tool can easily be modified to particular organ
izations or problems in this way, as it is a guide to thinking through various issues, rather than a rigid, inflexible dogma.

And we feel this is one of its strengths. Ongoing research has updated the interview evaluation tool. Useful additions have come to light as TPM negotiations have progressed, as employees have gained more


PHSMORE, W.A., 1988, Designing Effective Organizations: The
Training Evaluation

evaluating training effectiveness. However, the benefit of the reduced cost of the proxy criterion measure is countered by a need to increase the size of the participant sample in order to achieve a given level of statistical power. Essentially, these authors point out that there are tradeoffs between power and cost when planning an evaluation of training. Arvey and colleagues (1992) examined how the posttest-only design might be the preferred design under many different conditions (e.g. when there are significant cost constraints owing to a fixed training budget). They conclude that when administrative costs are high, posttest designs tend to be more powerful. In contrast, when item development costs are high the pretest–posttest designs appear to be more powerful (Arvey et al. 1992). An evaluation design that utilizes pre- and posttraining measures, without a control group, is likely to be less expensive than a control-group design, which requires the collection and analysis of additional data.

For Level 4 evaluations, an assessment of the relative costs and benefits is necessary. Essentially, the utility of a training program is the translation of validity information into cost figures that permit comparisons between different types of programs. These utility analyses help organizations demonstrate that training dollars are a wise
business investment and are being well spent. Finally, practitioners in work organizations are particularly concerned about the need to link training activities to the return on investment (ROI) for training costs. Thus, if the cost of formal training is very high, the expected production return is low, and there is high employee turnover, a formal training program may not be the best investment (Goldstein and Ford 2002). As organizations continue to ascertain the value added by HR activities such as training, it is critical that training professionals rely on the science of training and sound principles, guidelines and lessons learned for determining whether training has been effective in reaching organizational goals. Because trainers may intuitively feel that there is a low probability of finding significant training effects, they may be more reluctant to take the chance of not finding significant results, and may choose not to
Training System Development in Ergonomics


An Up-Front Engineering “Level of Protection” through Human Factor Design

Front-end ergonomic evaluation matrix (FEEEM).
Usability and Product Design

the first design idea will be evaluated in terms of how well it meets the users’ needs. The strengths and weaknesses will be assessed and a further design developed on the basis of this. This in turn is evaluated and so on until a product is created that conforms to pre-specified levels of usability. There are different prototyping options of differing degrees of realism and sophistication that can be used in the design/evaluation cycle. Some examples are given below.

6.1.1 Product specification

Perhaps the most basic form of prototyping is simply to give a verbal or written description of the form and functionality of the proposed product.

6.1.2 Visual prototypes

These are simply visual representations of a product. They could be paper-based sketches or drawings or on-screen representations created using drawing or computer-aided design packages. They may be supplemented with written or verbal descriptions of a product’s functionality or procedures for operation.

6.1.3 Models

Sometimes physical representations or models of the product are created. Typically, these will be made of wood or of polystyrene foam. Sometimes they will include addi
tional materials to weight the model so that its weight is representative of the proposed product.

6.1.4 Screen-based interactive prototypes

These are software-based representations of products. They offer simulated interactions – for example, by clicking the mouse on a representation of one of the product’s controls.

The screen-based representation will then change state to represent how the product would react to a particular interaction.
User-Centered Systems Analysis in Aircraft Maintenance

function — the range of BPI coverage by that function’s respective support requirements. In other words, one can assess the frequencies with which BPI are addressed by the set of support requirements, as well as the proportion of matrix cells containing an entry. This proportion is referred to as the extent to which support requirements contribute to the BPI set. Note that the extent to which support requirements contribute to BPI is provided in the summary information of Table 1.

5 IMPLICATIONS

The primary objective was to identify PDM functions that would receive the greatest benefit from ITI-ALC technologies. This type of identification required a ranking of the PDM functions according to a given set of criteria. In this effort, a single criterion was proposed: the extent to which each function’s respective set of support requirements addresses the BPI set. One means of measuring this extent of coverage is to calculate the proportion of matrix cells that reflect a support requirement-to-BPI mapping. As this proportion increases (i.e. as the density of the matrix representing a given function increases), greater benefit will be obtained through the insertion of ITI-ALC technologies into that particular function. In other words, satisfying the function’s support requirements through the
application of ITI-ALC technologies will effect greater improvement to the PDM process. Table 2 ranks PDM functions according to the extent-of-coverage measure. According to this measure, the REMOVALS function receives the greatest benefit, followed by BUILDUPS. The proportions offered in Table 2 indicate that CHECKS, INSTALLATIONS, FACILITATIONS and INSPECTIONS benefit to a lesser extent. One means of readily identifying the BPI addressed most (and least) often by the support requirements defined for a given PDM function is to examine the frequency with which each BPI is addressed by the support requirements defined for that function. By examining such a frequency.

<table>
<thead>
<tr>
<th>Function</th>
<th>Extent of BPI Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>REMOVALS</td>
<td>0.42</td>
</tr>
<tr>
<td>BUILDUPS</td>
<td>0.33</td>
</tr>
<tr>
<td>CHECKS</td>
<td>0.31</td>
</tr>
<tr>
<td>INSTALLATIONS</td>
<td>0.30</td>
</tr>
<tr>
<td>FACILITATIONS</td>
<td>0.30</td>
</tr>
<tr>
<td>INSPECTIONS</td>
<td>0.30</td>
</tr>
</tbody>
</table>
User-Centered Design: Needs Analysis


Work Design: Barriers Facing the Integration of Ergonomics into System Design

Work Organization Interventions


WAHLSTEDT, K., BJORKSTEN, M.G. and EDLING, C., 1997, Psycho-social


Work Organization, Job Stress, and Occupational Health


Agriculture


Anthropometry for the Needs of Rehabilitation

FIGURE 8 Example of ankle joint rehabilitation.


MALINA, R.M., 1980, The influence of physical training on some tissues, dimensions and functions of organism during individual development. Wychowanie Fizyczne i Sport, 1, 3-35 (in Polish).


NOWAK, E., 1980, Minimum Pressing Force of the Foot for the


Applying Activity Theory to Flight Safety


Assessing the Risk of Upper Limb Disorders


Assessment of Combined Occupational Low Back Disorder Risk Factors


A Checklist for Evaluating Exposure to Repetitive Movements of the Upper Limbs Based on the OCRA Index

Regarding Additional factors of physical-mechanical type (e.g. inadequate gloves, vibrations, compressions, repeated impacts, etc.), their presence for a relevant part (50% or more) of the task time must be described and scored. The description must also include specifications as to whether the working pace is either partially or totally imposed by the machine. For each block, or group of questions, a single answer is allowed: the sum of the partial scores thereby obtained gives the additional factor score (\[ \text{ADDITIONAL} \]).

2.4 FORM 4 (CALCULATING THE FINAL SCORE)

2.4.1 Calculating the checklist score for the workplace

To obtain the final score for the workplace, it is sufficient to add the partial scores obtained for each of the risk factors:

lack of recovery, frequency, force, posture and movements, and additional.

2.4.2 Calculating the checklist score considering the operators exposure (one or more repetitive task)

In order to estimate the exposure level of the workers, the following procedures must be adopted: 0 if the operators work exclusively at the workplace described in the analysis (monotask job), then the checklist score given to the workplace is the same as that given to the operators 0 if the operators work in more than one workplace, implying
repetitive tasks (multitask job), it is necessary to use the following formula to obtain the specific exposure score:

Checklist score \[ (\text{score A} \times \%PA) \text{ (score B} \times \%PB) \ldots (\text{score Z} \times \%PZ) \]

where “score A,” “score B,” etc. are the checklist scores obtained for the various workplaces (tasks) on which the same operators work, and \%PA, \%PB, etc. represent the percentage time duration of the corresponding repetitive tasks with respect to the overall duration of all repetitive tasks considered during one shift.

2.4.3 Calculating the checklist score considering a reduced daily duration of repetitive task(s)

If the repetitive task(s) lasts less than 6 h within one shift (i.e. part-time work), it is possible to correct the checklist scores previously obtained considering actual duration.

If the repetitive work (part-time) only lasts 2 h, the final score obtained with the checklist must be multiplied by 0.5; if it lasts 3-5 h, then the final result must be multiplied by 0.75. Annex 1: OCRA CHECKLIST A SHORTENED PROCEDURE FOR IDENTIFICATION AND ASSESSMENT OF MAIN RISK FACTORS FOR UPPER LIMB IN REPETITIVE TASKS COMPILED BY………………………………………………………… Date……………..…………. NAME AND SHORT DESCRIPTION OF WORKPLACE

…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
…………………………………………………………………………………………………………………………………………
NO. OF WORKPLACE • • TYPE OF WORK INTERRUPTIONS (BREAKS OR OTHER VISUAL CONTROL TASKS) CHOOSE ONE ANSWER. IT IS POSSIBLE TO CHOOSE INTERMEDIATE VALUES. 0 - THERE IS AN INTERRUPTION OF AT LEAST 8 MINUTES EVERY HOUR IN THE REPEETITIVE WORK (ALSO COUNT THE LUNCH BREAK); 1 - THERE ARE 2 INTERRUPTIONS IN THE MORNING AND 2 IN THE AFTERNOON (PLUS THE LUNCH BREAK), LASTING AT LEAST 8-10 MINUTES ON THE 7-8 HOUR SHIFT, OR AT LEAST 4 INTERRUPTIONS PER SHIFT (PLUS THE LUNCH BREAK), OR FOUR 8-10 MINUTE INTERRUPTIONS IN THE 6-HOUR SHIFT. 3 - THERE ARE 2 BREAKS, LASTING AT LEAST 8-10 MINUTES EACH IN THE 6-HOUR SHIFT (WITHOUT LUNCH BREAK), OR, 3 BREAKS, PLUS THE LUNCH BREAK, IN A 7-8-HOUR SHIFT. 4 - THERE ARE 2 BREAKS, PLUS THE LUNCH BREAK, LASTING AT LEAST 8-10 MINUTES EACH OVER A 7-8 HOUR SHIFT (OR 3 BREAKS WITH THE LUNCH BREAK), OR 1 BREAK OF AT LEAST 8-10 MINUTES OVER A 6-HOUR SHIFT; 6 - THERE IS A SINGLE BREAK, LASTING AT LEAST 10 MINUTES, IN A 7-HOUR SHIFT WITHOUT LUNCH BREAK; OR, IN AN 8-HOUR SHIFT THERE IS ONLY A LUNCH BREAK (THE LUNCH BREAK IS NOT COUNTED AMONG THE WORKING HOURS). 10 - THERE ARE NO REAL BREAKS EXPECT FOR A FEW MINUTES (LESS THAN 5) IN A 7 TO 8-HOUR SHIFT.

RECOVERY NOTES: FORM 1

APPENDIX 1 ARM ACTIVITY AND FREQUENCY OF ACTIONS WHEN PERFORMING THE TASK (IF NECESSARY, INTERMEDIATE SCORES CAN BE CHOSEN) 0 ARM MOVEMENTS ARE SLOW, AND FREQUENT SHORT INTERRUPTIONS ARE POSSIBLE (20 ACTIONS PER MINUTE). 1 - ARM MOVEMENTS ARE NOT TOO FAST, ARE CONSTANT AND REGULAR. SHORT INTERRUPTIONS ARE POSSIBLE (30 ACTIONS PER MINUTE). 3 - ARM MOVEMENTS ARE QUITE FAST, AND REGULAR (ABOUT 40 ACTIONS PER MINUTE), BUT SHORT INTERRUPTIONS ARE POSSIBLE. 4 - ARM MOVEMENTS ARE QUITE FAST AND REGULAR, ONLY OCCASIONAL AND IRREGULAR SHORT PAUSES ARE POSSIBLE (ABOUT 40 ACTIONS PER MINUTE). 6 - ARM MOVEMENTS ARE FAST, ONLY OCCASIONAL AND IRREGULAR SHORT PAUSES ARE POSSIBLE (ABOUT 50 ACTIONS PER MINUTE). 8 - ARM MOVEMENTS ARE VERY FAST. THE LACK OF INTERRUPTIONS MAKES IT DIFFICULT TO HOLD THE PACE, WHICH IS ABOUT 60 ACTIONS PER MINUTE. 10 - VERY HIGH FREQUENCIES (70 ACTIONS PER MINUTE OR MORE). ABSOLUTELY NO INTERRUPTION ARE POSSIBLE FREQUENCY PRESENCE OF WORKING ACTIVITIES
INVOLVING THE REPEATED USE OF FORCE IN THE HANDS-ARMS (AT LEAST ONCE EVERY FEW CYCLES DURING ALL THE TASK ANALYSED): More than one answer can be ticked: add up the partial scores obtained. If necessary, choose intermediate scores, and then add them together. THE WORKING ACTIVITY IMPLIES: THE HANDLING OF OBJECTS WEIGHING OVER 3 KG GRIPPING BETWEEN FOREFINGER AND THUMB, AND LIFTING, OBJECTS WEIGHING OVER 1 KG (IN PINCH) USING THE WEIGHT OF THE BODY TO OBTAIN THE NECESSARY FORCE TO CARRY OUT A WORKING ACTION THE HANDS ARE USED AS TOOLS TO HIT OR STRIKE SOMETHING 1 - ONCE EVERY 5 MINUTES 2 - ONCE EVERY 1 MINUTE 4 - ABOUT HALF OF THE CYCLE (*) 8 - FOR OVER HALF OF THE CYCLE (*) THE WORKING ACTIVITY REQUIRES THE USE OF INTENSE FORCE FOR: PULLING OR PUSHING LEVERS PUSHING BUTTONS CLOSING OR OPENING PRESSING OR HANDLING COMPONENTS USING TOOLS 4 - 1/3 OF THE TIME 6 - ABOUT HALF OF THE TIME 8 - OVER HALF OF THE TIME (*) THE WORKING ACTIVITY REQUIRES THE USE OF MODERATE FORCE FOR: PULLING OR PUSHING LEVERS PUSHING BUTTONS CLOSING OR OPENING PRESSING OR HANDLING COMPONENTS USING TOOLS 2 - 1/3 OF THE TIME 4 - ABOUT HALF THE TIME 6 - OVER HALF THE TIME 8 - NEARLY ALL THE TIME (*) PLEASE NOTE: The conditions evidenced are absolutely unacceptable. FORCE FORM 2 0 0 0 0 0 0 PRESENCE OF AWKWARD POSITIONS OF THE ARMS DURING THE REPETITIVE TASK RIGHT LEFT BOTH (mark the limb with greater involvement) 1 - THE ARM/ARMS ARE NOT LEANING ON THE WORKBENCH BUT ARE A LITTLE UPLIFTED FOR HALF (OR MORE) THE TIME 2 2 2 - THE ARMS HAVE NOTHING TO LEAN ON AND ARE KEPT NEARLY AT SHOULDER HEIGHT FOR ABOUT 1/3 OF THE TIME 4 4 8 - THE ARMS ARE KEPT AT ABOUT SHOULDER HEIGHT, WITHOUT SUPPORT, FOR OVER HALF THE TIME 8 8 - THE ARMS ARE KEPT AT ABOUT SHOULDER HEIGHT, WITHOUT SUPPORT, NEARLY ALL THE TIME 1 1 1 1 - THE WRIST MUST BEND IN AN EXTREME POSITION, OR MUST KEEP AWKWARD POSTURES (SUCH AS WIDE FLEXIONS OR EXTENSIONS, OR WIDE LATERAL DEVIATIONS) FOR AT LEAST 1/3 OF THE TIME 4 4 8 - THE WRIST MUST BEND IN AN EXTREME POSITION, OR MUST KEEP AWKWARD POSTURES (SUCH AS WIDE FLEXIONS OR EXTENSIONS, OR WIDE LATERAL DEVIATIONS) FOR OVER HALF OF THE TIME 8 8 - THE WRIST MUST BEND IN AN EXTREME POSITION, NEARLY ALL THE TIME 1 1 1 1 - THE ELBOW EXECUTES WIDE MOVEMENTS (WIDE FLEXION-EXTENSION OR PRONO-SUPINATION) OR SUDDEN MOVEMENTS (JERKING MOVEMENTS, STRIKING MOVEMENTS) FOR ABOUT 1/3 OF THE TIME 4 4 8 - THE ELBOW EXECUTES WIDE MOVEMENTS (WIDE FLEXION-EXTENSION OR PRONO-SUPINATION) OR SUDDEN MOVEMENTS (JERKING MOVEMENTS, STRIKING MOVEMENTS) FOR OVER HALF THE TIME 8 8 - THE ELBOW EXECUTES WIDE MOVEMENTS (WIDE
FLEXION-EXTENSION OR PRONO-SUPINATION) OR SUDDEN MOVEMENTS
(JERKING MOVEMENTS, STRIKING MOVEMENTS) NEARLY ALL THE
TIME C GRIP OBJECTS, PARTS OR TOOLS WITH
FINGERTIPS WITH CONSTRICTED FINGERS (PINCH)
WITH THE HAND NEARLY OPEN (PALMAR GRIP)
KEEPING FINGERS HOOKED 2 FOR ABOUT 1/3
OF THE TIME 4 FOR OVER HALF THE TIME 8
NEARLY ALL THE TIME D PRESENCE OF IDENTICAL
MOVEMENTS OF SHOULDER AND/OR ELBOW, AND/OR WRIST, AND/OR
HANDS, REPEATED FOR MORE THAN 50% OF THE TIME (please cross
3 also if the cycle is shorter than 15 seconds)
E Use the highest value obtained among the four
groups of questions (A,B,C,D) only once, and add to that of
the last question E POSTURE PRESENCE OF
ADDITIONAL FACTORS (only choose one answer per group of
questions). 2 2 2 2 3 1 2 - GLOVES INADEQUATE TO THE
TASK ARE USED FOR OVER HALF THE TIME (UNCOMFORTABLE, TOO
THICK, WRONG SIZE, ETC.) - VIBRATING TOOLS ARE USED FOR
OVER HALF THE TIME - THE TOOLS EMPLOYED CAUSE
COMPRESSIONS OF THE SKIN - THE TASK IMPLIES REPEATED
IMPACTS BY THE HAND (THE HAND IS USED AS A TOOL) -
OTHER ADDITIONAL FACTOR ARE PRESENT (ONE OR MORE)
(SPECIFY:………………………………………………………………………..) AND, OVERALL,
THEY OCCUPY OVER HALF THE TIME - ONE OR MORE
ADDITIONAL FACTORS ARE PRESENT, AND THEY OCCUPY THE WHOLE
OF THE TIME (SPECIFY:………………………….) - WORKING PACE IS SET
BY THE MACHINE, BUT THERE ARE "BUFFERS" BY WHICH THE
WORKING PACE CAN EITHER BE SLOWED DOWN OR ACCELERATED.
- WORKING PACE IS COMPLETELY DETERMINED BY THE MACHINE
ADDITIONAL FORM 3 CALCULATING THE CHECKLIST SCORE FOR
ONE TASK/WORKPLACE To calculate the task CHECKLIST SCORE, add the values in the 5 boxes: Recovery + Frequency + Force
+ Posture + Additional. CHECKLIST SCORE EXPOSURE SCORE FOR
MORE THAN ONE REPETITIVE TASK If there is more than one
repetitive task carried out during the shift, use the
following procedure to obtain the overall score for
repetitive work during the shift ( % P Z = percentage of
time spent in task 2 with respect to total daily time
spent in repetitive tasks) EXPOSURE SCORE = (score A x %
PA ) + ( score B x % PB) +………+ ( score Z x % PZ) TASKS
CARRIED OUT DURING THE SHIFT: TASK/WORKPLACE DURATION
(min) PREVALENCE IN TIME (P) A………………………………………………
B……………………………………………… C……………………………………………… D………………………………………………
(PA) (PB) (PC)
(PD) EXPOSURE SCORE SCORE CONSIDERING TOTAL DAILY
DURATION OF REPETITIVE TASKS FOR REPETITIVE TASKS (OR
PART-TIME JOBS) LASTING ONLY 2 HOURS IN SHIFT, MULTIPLY
THE FINAL VALUE OF THE CHECK-LIST BY 0.50 FOR REPETITIVE
TASKS (OR PART-TIME JOBS) LASTING 3-5 HOURS IN THE SHIFT,
MULTIPLY THE FINAL CHECK-LIST VALUE BY 0.75
CORRESPONDENCE BETWEEN OCRA INDEX AND CHECKLIST SCORES
CHECK LIST OCRA UP TO A 7.5 7.6 - 11.0 11.1 - 14.0
14.1 - 22.5 > 22.6 2.2 2.3 - 3.5 3.6 - 4.5 4.6 - 9.0
> 9.1 GREEN = NO RISK (acceptable) YELLOW =
BORDERLINE OR VERYLOW RISK RED LIGHT = LIGHT RISK RED
MEDIUM = MEDIUM RISK RED HIGH = HIGH RISK FORM 4 • •
Back Belts

3.2.3.1 Redesign measures: a practical example

As part of its work on redesign measures a construction company in the south of the Netherlands has been using autonomous construction teams on a renovation project.

This team was made up of carpenters, bricklayers, a painter, a tiler and a plasterer. The plumber and electrician of the specialized contractor were permanently assigned to the team.

Without the workers ever really practicing a different trade,

there were three things which differed from the “normal manner of working”. First, a helping hand was given to the other specialist disciplines. This can be seen as job enlargement in several disciplines. Second, job enrichment was created by allowing the teams to also carry out preparatory and organizational tasks. The workers organized the work themselves. For example, arrangements were made with the occupants: “We’ll come to you tomorrow to do this or that”.

They also were responsible for accepting and ordering materials and equipment. The organization, moreover, was under the control of the foreman. Third, there was the matter of learning. Workers in an autonomous construction team learn as a result of the control tasks and by organizing the work. The results show that working with autonomous construction teams has delivered both social and economic benefits.
The following are some figures based on (scientific)
research in practice: O A study at a Swedish construction
company, which was organized on the principles of
team-oriented

BROERSEN, J.P.L., BLOEMHOFF, A., VAN DUIVENBODEN, J.C.,
WEEL, A.N.H. and VAN DIJK, F.J.H., 1992, Figures of the
Atlas of Health and Work Perception in the Construction
Industry (in Dutch) (Amsterdam: Arbouw).

HEDÉN, K., ANDERSEN, V., KEMMLERT, K., SAMDAHL-HIDEN, L.,
SEPPÄNEN, H. and WICKSTRÖM, G., 1993, Model for assessment
of repetitive, monotonous work: RMW. In Marras, W.S.,
Karwowski, W., Smith, J.L. and Pacholski, L. (eds) The
Francis), pp. 315-7.

HOONAKKER, P.L.T., SCHREURS, P.J.G., VAN DER MOLEN, H.F.
and KUMMER, R., 1992, Conclusions and Evaluation of the
Research Projects Concerning the Psychosocial Workload of
Six Professions in the Construction Industry (in Dutch)
(Amsterdam: Arbouw).

Postures (ISO/TC159/SC3 — JISC, Osaka).

KILBOM, Å., 1994a, Repetitive work of the upper extremity:
Part I — Guidelines for the practitioner. International

KILBOM, Å., 1994b, Repetitive work of the upper extremity:
Part II — The scientific basis (knowledge base) for the
guide. International Journal of Industrial Ergonomics, 14,
59-86.

Francis).

NF X 35-106, 1985, Ergonomie: Limites d’efforts
recommandées pour le travail et la manutention au poste de
travail (Paris: AFNOR).

Technical Report No. 81-122 (Cincinnati, OH: US Department
of Health and Human Services, National Institute for
of Machinery — Human Physical Performance — Part 4:
Evaluation of Working Postures in Relation to Machinery
Computer Systems for the Psychophysiological Safety of Operators’ Work


BUROV, A., 2000, Psychophysiological aspects of macroergonomic approach to design of complex technological systems (an example of power industry). In Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual meeting of the Human Factors and Ergonomics Society, San Diego, CA, USA.


Construction

December, Table 2. Number of nonfatal occupational injuries
and illnesses by selected industries and case type.

HOLMSTRÖM, E., ULRICH, M. and ENGHOLM, E., 1995,
Muscloskeletal disorders in construction workers. In
Ringen, Englund, Welch, Weeks and Seegal (eds) Occupational
Medicine: State of the Art Reviews V., Construction Safety
and Health, vol. 10(#2) (Philadelphia: Hanley & Belfus),
pp. 295-312.

LUTTMANN, A., JAGER, M. and LAURIG, W., 1991, Task analysis
and electromyography for bricklaying at different wall
heights. International Journal of Industrial Ergonomics, 8,
247-60.

SCHNEIDER, S., 1995, Implement ergonomic interventions in
construction. Applied Occupational and Environmental
Hygiene, 10, 822-4.

SCHNEIDER, S., in press, Ergonomics in the construction
industry. In W. Karwowski and W.S. Marras (eds)

SCHNEIDER, S. and SUSI, P., 1994, Ergonomics and
construction: a review of potential hazards in new
construction. American Industrial Hygiene Association
Journal, V, 55, 635-49.
The Current Hiatus in Fall Safety Measures


Evaluation, 24(6), 377-85.
The Development of a Human Factors Engineering Strategy in Petrochemical Engineering and Projects

Diagnosis of Work-Related Musculoskeletal Disorders


Ergonomic Diagnosis and Therapy
Components in Rehabilitation


Ergonomics Considerations for Reducing Cumulative Trauma Exposure in Underground Mining


of the method (only one arm, more than one operator) are based on highly empirical data and not on experiments carried out following strictly scientific procedures. But without them, many problems would remain unsolved.

2.2 MULTIPLE TASKS NEED MORE COMPLEX ANALYSIS

In many working situations, the same group of workers have to carry out different load tasks often in the same workshift.

The difference is the result of many different factors (nature of the object, different areas of loading and unloading, work organization procedures). Moreover, the different lifting tasks may be irregular in a given period of time in the workshift (e.g. in a warehouse with picking activities) or according to established time sequences (e.g. when an operator works every 1-2 hours on an assembly line, first loads the line, then unloads the finished products, and then packs them). In such cases the analytical procedure for each task is not suitable to summarize the overall exposure of the worker to load lifting. Therefore these cases require an analytical procedure for multiple tasks, which is obviously more complex. NIOSH has made a proposal for analyzing mixed
multiple tasks, founded on the idea of calculating a synthetic lifting index for multiple tasks based on the index for the more overloading task, increased by values derived from the other tasks considered.

2.3 NONINDUSTRIAL TASKS ARE NOT WELL MODELED

The NIOSH assessment procedure is not well suited to application in various working sectors (typically nonindustrial sectors), sometimes on account of the characteristic of the lifted load, the great variability of lifting tasks, their frequent association with other manual handling tasks (trolley pulling or pushing), and finally the presence of other risk factors for the lumbar spine (e.g. whole body vibrations).

Agriculture, transport and delivery of goods, and assistance to individuals who are not self-sufficient are typical examples. In these situations, though the NIOSH lifting index is useful, validated procedures for integrated exposure assessment are not yet available, hence the need for further research and proposals on specific simplified exposure assessment procedures aimed at managing risk factors.
Exposure Assessment of Low Back Disorders: Criteria for Health Surveillance


Exposure Assessment of Low Back Disorders: Manual Material Handling Limits


Exposure Assessment of Patient Handling Tasks: A MAPO Risk Index


MENONI, O., RICCI, M.G., PANCIERA, D., BATTEVI, N., COLOMINI, D., OCCHIPINTI, E. and GRIECO, A., 1999, Manual handling of patients in hospital and one particular kind of consequent disease: acute and/or chronic spine alteration. La Medicina del Lavoro (Special issue) 90, 2.


YASSI, A., KHOKHAR, J., TATE, R., COOPER, J., SNOW, C. and
Exposure Assessment of Upper Limb Repetitive Movements: Criteria for Health Surveillance


Exposure Assessment of Upper Limb Repetitive Movements: Epidemiology

Exposure Assessment of Upper Limb Repetitive Movements: Ergonomic Principles for Prevention


Fall Accidents Among the Elderly


TINETTI, M., WILLIAMS, T. and MAYEWSKI, R., 1986, Fall risk index for elderly patients based on the number of chronic disabilities. American Journal of Medicine, 80, 429-434.
A Framework for Assessment of Work-Related Musculoskeletal Hazards


WOOTEN, W., 1993, Using knowledge, skill and ability (KSA) data to identify career pathing opportunities: an application of job analysis to internal manpower planning. Public Personnel Management, 22(4), 551–63.
Health and Safety Ergonomics


Health Provisions and Social Policy for the Disabled (Orthoses, Prostheses, and Assistive Technologies)


same industrial category, certain companies, departments, or operations may have unusually high CTS prevalence which contributes to the overall higher prevalence for that industry. Based on equation 4, it is likely that such work places may include tasks performed with high intensity for many h.

4.5 PROTECTION OF WORKERS

For protection of workers against H/W-MSD, the constant C and k can be set to represent an acceptable level of musculoskeletal morbidity among the worker population, e.g. annual incidence rate of MSD at 0.05, 0.01%, etc. In industrial situations, T can be allowed to vary between 2 to perhaps 10 h per day depending on job demands and work schedule. However, T is not to be allowed to become too small. If T is too small, the inverse relationship of I and T will make I excessively large and unsafe. Therefore, any fraction of work duration ≤2 h may have to be treated as 2 h at the minimum (T ≥2) in the equation. The proposed equation is compatible with a general empirical notion that for prevention of H/W-MSD, high intensity manual work (high force, high repetition and/or strong posture deviation) should not be performed for an extended period of time, while a low intensity work may
be performed for a longer period of time. The relationship
between the daily duration of repetitive manual work and 2
H R S 4 H R S 8 H R S A WORKER WITHOUT MSD SYMPTOMS. A
WORKER WITH MSD SYMPTOMS.

A HAZARD ZONE SAFE ZONE REPEITION FORCE
WRIST ANGLE

(DEVIAITION)

FIGURE 2 Conceptual threshold planes as in Figure 1 with var-
iouis daily length of exposure. As h of the exposure
increase,
other risk factors must be reduced to keep exposure points
below
the threshold plane to prevent H/W-MSD.
Human Factors and Prevention of Falls from Height at Construction Sites


COMMISSION OF THE EUROPEAN COMMUNITIES, 1993, Europe for Safety and Health at Work, Safety and Health in the Construction Sector (Luxembourg: Commission of the European Communities).


Integrating Health and Safety Issues to Continuous Improvement Initiatives


INTERNATIONAL LABOUR ORGANIZATION (ILO), 2003, ILO standards-related activities in the area of occupational safety and health: an in-depth study for discussion with a view to the elaboration of a plan of action for such activities. In International Labour Conference, 91st session, Report VI, Sixth Item on the agenda (Geneva: ILO).


Maximum Loads and Manual Materials Handling

ANPAT, 1994, Manutention manuelle de charges. Legislation en pratique 2 (Brussels: Association Nationale pour la Prevention des Accidents du Travail, (ANPAT)).


KUORINKA, I., JONSSON, N., KILBOM, A., et al., 1987,


SJOGGAARD, G., 1990, Exercise-induced muscle fatigue: the
Micro- and Macroergonomic Interventions in Industrially Developing Countries


HENDRICK, H., 1996, Good Ergonomics is Good Economics (Santa Monica, USA: Human Factors and Ergonomics Society).


FIGURE 4 The interdependence of both micro- and macro ergonomics.
therefore be investigated together in order to obtain a better understanding of their interdependency.

3.3 EFFECTS OF AUXILIARY TASKS ON DRIVING

A review of the literature relevant to the problem of time sharing while driving was performed to identify methodological concerns and practices common to dual task studies of driving as well as to consolidate research findings that can be generalized to auxiliary display applications. The studies reviewed shared a common general research methodology, yet they represented a diversity of approaches to a variety of research problems. Because of lack of consistency in experimental protocols and the choice of dependent and independent variables, it was not possible to consolidate the findings to form a clear understanding of the mechanisms underlying driving performance under dual task conditions. Moreover, upon further review, it became apparent that more fundamental issues existed than simply incommensurate data. Issues relating to the nature and measurement of cognitive mechanisms and time-shared performance had not been satisfactorily settled, and they persist to the present day. Theoretical issues such as whether time-sharing occurs as parallel or serial processes bear heavily on the design of experiments and the interpretation of results. The studies
examined drew from a diversity of theoretical models, often mutually incompatible, of human information processing with apparently little regard for the limitations of the underlying theory. Nonetheless, secondary tasks can have adverse effects on at least some aspects of driving when they are performed concurrently with driving. Research directed at the effects on driving performance of the use of electronic in-vehicle displays is sparse indeed.

In a recent field study, Snyder and Monty (1986) tested four prototype automobile touch-screen displays. They reported that lane keeping, speed control and braking frequency were significantly affected by concurrent performance of CRT-related tasks (which required visual feedback). The experimenters also observed significant age and sex effects. However, methodological constraints did not permit generalizing the findings beyond the specific conditions of the experiment. In particular, display/vehicle confounding and lack of systematic manipulation of experimental variables did not permit detailed analyses of the effects of specific task parameters or even separation of the effects of perceptual and response loads. A study directly related to the use of auxiliary displays in automobiles investigated the effect of reading text while driving. Zwahlen and DeBald found that when reading text
from an in-car display, the standard deviation of lane position increased monotonically as a function of time and distance. The results were interpreted as indicating that the use of sophisticated displays and/or touch panels produce significant


Nonoccupational Tasks that Contribute to Musculoskeletal Disorders


Obstacles to Recovery from Work-Related Musculoskeletal Disorders

BRINCKMANN, P., FROBIN, W., BIGGEMANN, M., TILLOTSON, M. and BURTON, K., 1998, Quantification of overload injuries to thoracolumbar vertebrae and discs in persons exposed to heavy physical exertions or vibration at the workplace. Part II. Occurrence and magnitude of overload injuries in exposed cohorts. Clinical Biomechanics, 13, S(2), 1-36.


NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH, 1997, Musculoskeletal Disorders and Workplace Factors (Cincinnati: DHHS (NIOSH)).

FIGURE 18 A window that presents the upper limb position defined with q1 - q7 angles.


KE©DZIOR, K. and ZAGRAJEK, T., 1997, A biomechanical model of the human musculoskeletal system. In Morecki, A. and


Occupational Epidemiology with Special Focus on Ergonomics and Musculoskeletal Disorders

HERNBERG, S., 1992, Introduction to Occupational Epidemiology (Lewis).


XU, Y., BACH, E. and ØRHEDE, E., 1996, Occupation and risk for the occurrence of low-back pain (LBP) in Danish employees. Occupational Medicine, 46, 131-6.
Occupational Health and Ergonomics


Object-Oriented Modeling and 3D-Visualization of Occupational Health and Safety Data


89/391/EWG, 1989, EC guideline on the execution of measures to improve safety and health of employees at the workplace.
Occupational Injuries and Medication Use


Occupational Injury


P5 -P 95 Syndrome

B. J. Daams

Delft University of Technology, Department of Industrial Design Engineering, Jaffalaan 9,
2628 BX Delft, The Netherlands

Presently: Daams Ergonomie, Mauvezand 17, 1251 JC Laren, The Netherlands
A Paradigm for Characterizing the Property of Slip Resistance

Proactivity: A Necessary Ingredient for an Effective Prevention Policy in Safety


Rehabilitation of Musculoskeletal Disorders


Risk Factors for Musculoskeletal Disorders in the Nursing Profession


Risk Factors for Nonspecific Musculoskeletal Disorders


Risk Factors of Musculoskeletal Disorders: Demographic, Social, and Work Change Aspects in France

Slaughterhouses

rubber gloves for their waterproof qualities and steel mesh
gloves to protect against injuries. There is a real need to
develop gloves better suited to
the conditions in slaughterhouses that comply with hygiene
requirements and are not too expensive.

4.4 TIME-RELATED CONSTRAINTS

The time-related constraints inherent in this type of work
(the pace imposed by the production line or conveyor
belt) influence WMSD risks in a number of ways (Toulouse
1995): O lack of breaks; O effort required in awkward
postures determined by the need to begin operations
upstream and continue them downstream when the product is
not in the best position for the worker. Increased
travelling speeds and recovery of incidents exacerbate this
problem; O some related actions that are not considered in
the task (sharpening the knife, cleaning and sometimes
sterilizing the knife, cleaning the gloves) increase the
cycle time, extending the postural range or causing the
task to be performed more quickly.

Many of these problems can be reduced by planning the
task so as to take into account the possibility of
incidents, product variability, and related activities. When designing
tasks, it is also important to leave enough space between

4.5 WORKER TRAINING

The impact of vocational training on WMSD occurrence
has not been studied directly, but nevertheless appears to be
an important factor. Training in slaughterhouses, often car
ried out "on the job," may be deficient and may not enable
the workers to develop methods that minimize the risk of
WMSD. Vocational training programs should be based on
data obtained from surveillance of symptoms and injuries,
and on the results of ergonomic analysis.

4.6 JOB ROTATION

Job rotation is often proposed as a way of reducing repeti-
tion or exposure to risk factors. However, although research
in this area is by no means extensive, it appears to show
that

job rotation does not always achieve the anticipated
results.

Effective job rotation is subject to a number of
difficulties,
such as training deficiencies, workstations designed with
out taking worker body size variability into account, work
places that limit the ability of operators to move from one
workstation to another, as well as variations in production
management and human resource management.

LOPPINET, M. and APTEL, M., 1997, Les TMS dans la Filière
Viande — revue de littérature, Rapport n ISSN 0397-4529,
Institut National de la Recherche Scientifique.

MERGLER, D., BRABANT, C., VÉZINA, N. and MESSING, K., 1987,
The weaker sex? Men in women’s working conditions report
similar health symptoms. Journal of Occupational Medicine,
outils requis pour accroître l’efficacité des stratégies de
prévention des lésions attribuables au travail répétitif
dans les abattoirs et usines de transformation. Rapport
IRSST, A-158. TOULOUSE, G., 1995, Étude descriptive des
déterminants des facteurs de risque de LATR aux postes
d’Éviscération de deux abattoirs de porcs. Rapport IRSST-
études et recherches, R-105.
Slip, Trip, and Fall Accidents


Health & Safety Executive, 1996, Slips and Trips (Sudbury: HSE Books).


Slips and Falls


Surveillance for Work-Related Musculoskeletal Disorders


Symptom Experience and Symptom Surveys in Musculoskeletal Disease Injury Evaluation


System Safety Engineering and Risk Assessment


FIGURE 2 Risk expectation profile. Scen. 4 Scen. 4 Scen. 3 Scen. 3 Scen. 2 Scen. 2 Scen. 1 Scen. 1 >$25 >$50 >$75 >$100 0.00E+00

S c e n a r i o M e a n F r e q.
3.50E-04 3.00E-04 2.50E-04 2.00E-04 1.50E-04 1.00E-04 5.00E-05
The Strain Index

in a project that involved the analysis of several problem
jobs in a red meat packing plant by two ergonomics teams
(Moore and Garg 1997). More recently, 30 jobs from two
manufacturing facilities and 29 jobs from a turkey process-
ing plant have been evaluated with the job analysts blinded
to health outcomes (Moore 1999, personal communica-
tion). In the manufacturing facilities, there were six “pos-
itive” jobs and 24 “negative” jobs. Of the six “positive”
jobs, all were predicted to be a “problem.” Of the 24 “neg-
avative” jobs, 21 were predicted to be “safe” and three pre-
dicted to be a “problem.” These values correspond to a
sensitivity of 1.00; specificity of 0.90; positive
predictive
value of 0.62; and negative predictive value of 1.00. In the
turkey processing facility, there were 22 “positive” jobs
and seven “negative” jobs. Of the 22 “positive” jobs, 20
were predicted to be a “problem” and two were predicted
to be “safe.” Of the seven “negative” jobs, all seven were
predicted to be “safe.” These values correspond to a sensi-
tivity of 0.91; specificity of 1.00; positive predictive
value
of 1.00; and negative predictive value of 0.78. When all
84 jobs are combined into one 2 x 2 table, sensitivity was
0.93; specificity was 0.93; positive predictive value was
0.93; and negative predictive value was 0.93. Based on this
validation strategy, the SI is an effective
method for identifying jobs likely to have workers with reported distal upper extremity disorders.

6 FUTURE WORK

Other aspects of validation, such as inter-rater variability and test-re-test repeatability, are subjects of current
Workload, Performance, Health, and Well-Being: A Conceptual Framework


COX, T., 1978, Stress (Basingstoke, UK: Macmillan).


KASL, S.V., 1998, Measuring job stressors and strains: where we have been, where we are, and where we need to go. Journal of Occupational Health Psychology, 3, 390-409.

MORAY, N., 1988, Mental workload since 1979. International
Reviews of Ergonomics, 2, 123-150.

National Research Council (Nrc) and Institute of Medicine, 2001, Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities. Panel on Musculoskeletal Disorders and the Workplace, Commission on Behavioral and Social Sciences and Education, National Research Council and Institute of Medicine (Washington, DC: National Academy Press).


Work Organizations: Health and Productivity Issues


Work Organization and Psychosocial Work Factors: Definitions

reported a lack of control over their job tended to have a higher risk of back WRMD, and perceived workload variability was associated with neck WRMD. Some studies have examined the effect of both psychosocial and ergonomic risk factors on WRMD. Kerr et al. (1997) show that psychosocial work factors, such as decision latitude and co-worker support, are important predictors of low back pain, even when adjusting for biomechanical factors. Similar results are reported by Skov et al. (1996) in a group of salespeople and by Wahlstedt et al. (1997) in a group of 655 postal workers. Wahlstedt et al. (1997) found that high psychological work demands was associated with symptoms in the lumbar region and that low social support at work was associated with symptoms in the neck-shoulders-thoracic region. Another study of computer users shows that occupational stress can even have a determinent effect on WRMD that outweighs the effect of workstation design (Patterson 1997). Work organization can define or influence ergonomic risk factors of WRMD, such as repetition, force and posture (for a review of ergonomic risk factors of WRMD; Putz Anderson 1988). Work organization can define the nature of, strength of and exposure time to these ergonomic risk factors
by specifying how a job is to be carried out, establishing product levels and defining pay structure. Work organization may define, for instance, the degree of repetitiveness of the job. In a highly fractionalized job, the worker tends to do the same tasks over and over, which produces repetition and boredom. The work organization also establishes cycle times, through the design of tasks. Short-cycle times and task repetitiveness define the repetition of motions. In this example, the work organization defines that the worker will be exposed to high repetition, which is an ergonomic risk factor for WRMD (Silverstein et al. 1987). Work organization also defines the strength of the ergonomic risk factors. A work organization that designs job tasks that do not encourage movement, and do not allow workers to take mini-breaks when needed, may induce static awkward postures. For instance, machine-paced work is a work organization system where workers have little freedom for influencing the pace or standard operation of their work. Such a work system does not allow for any variation in work, and usually does not give workers time to take mini-breaks when needed (Smith 1987). Work organization can also define the exposure time to ergonomic risk factors. By setting work standards and pay
schemes, management sets the pace at which a worker is supposed to work. This will then define the exposure time to certain risk factors. For example, if the worker is supposed to produce a certain number of products per time period, then this work standard will in turn define the duration of exposure to certain forces and postures. In addition, management defines the number of hours of work. Overtime, for instance, is a work organization factor that increases the duration of exposure to ergonomic risk factors. Such exposure may be particularly risky, due to increased worker fatigue.


musculoskeletal complaints. Ergonomics, 34, 265-76.
Work-Related Joint Injuries and Arthritis


NEUMANN, D.A., 1999, Joint deformity and dysfunction: a basic review of underlying mechanisms. Arthritis Care and Research, 12, 139.
Work-Related Musculoskeletal Disorders (WMSD): General Issues


Work-Related Musculoskeletal Disorders in Dental Care Workers


US Department of Labor, 1970, Occupational Safety and Health Act, Public Law No. 91-596.

Work-Related Musculoskeletal Disorders of Upper Limb and Back: Review of Guidelines for Their Prevention


Work-Related Musculoskeletal Disorders (WMSD): A Brief Overview


BLS, 1995, Total nonfatal occupational injuries and illnesses involving days away from work — 1995 (http://www.bls.gov/iif/oshcndnew.htm#95m).


Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back (Cincinnati, OH: DHHS NIOSH Publication No. 97-141).


Analysis of Worker’s Compensation Data


Wisconsin Worker’s Compensation Form WKC-12. Revised 02/98.
Collaborative Learning Environment in Higher Education: Implementing Job and Organizational Learning Theories in Academia


Communication Processes in Small Groups


Community Ergonomics: Planning and Design Solutions for Urban Poverty


NADLER, G. and HIBINO, S., 1994, Breakthrough Thinking: The Seven Principles of Creative Problem Solving (2nd ed.) (Rocklin: Prima).


Economic Models for Ergonomists

OXENBURGH, M.S. and MATCHBOX SOFTWARE LTD., UK, 2004, ProductAbility, the Complete Software for the Productivity Assessment Tool, 2004. See www.productAbility.co.uk or e-mail maurice_oxenburgh@compuserve.com


Education: The Teaching of Ergonomics


Enhancing Industrial Performance

the sum of squares (Section 4.3) has been introduced and successfully applied in the current and other cases. The consensus matrix (Table 3) indicates on which aspects there is consensus, and on which aspects discussion is still required. The discussions finally contribute to an accepted idea of the ergonomics of the work place and create stronger support for possible improvements. In practice, the feedback on the shop-floor organization also appears to work well. Profiles, as given in Table 2, must be made visible on the production floor next to other performance indicators to continuously stimulate the improvement (glass wall management). This also facilitates communication about possible improvements between the people in the factory and, if possible, with experts. From the practical study, it appeared that ergonomic analyses and solutions must fit in the strategy of the enterprise. Subsequent to “The Philips Way,” which includes “The motivation of our people is decisive for the success of the enterprise,” the following of a participative approach must be regarded as almost obvious. In the execution of the case in the Philips factory, attention must also be paid to the exemplary function that the relevant factory has with regard to its sister factory in Asia. In this framework, the knowledge gained of the ergonomic research must be
transferred, so that one can learn from each other. Determining the profitability of ergonomic solutions contributes to its acceptation by management. In the first instance, the economic consequences of ergonomic redesign can be qualitatively mapped. However, it is not always a case of “earning money on ergonomics”; there can be a case of reducing running expenses. Here, it is recommended to look at the ergonomic solutions from a different viewpoint: “Not participating in ergonomics costs money.” The Organization must be “ready” for ergonomic research. This is achieved at Philips by such actions as the education of the management with the aid of three courses: Shop-floor Management, Middle Management and Top Management. In this way, everyone within the enterprise will speak the same language.
Ergonomics and Corporate Governance
Avoiding the “Drift to Disaster” in Organizations


FERRY, T.S., 1988, Modern Accident Investigation and Analysis (2nd ed.) (Chichester, UK: John Wiley & Sons).


Ergonomics and Quality of Life

The Evolute System: A Co-Evolutionary Human Resource Development Methodology


Forensic Human Factors/Ergonomics


Legal Considerations for the Human Factors Specialist


Low-Cost Ergonomics Improvements


Management Perspectives for Workplace Ergonomics

American National Standards Institute, 2002, Control of Work Related Cumulative Trauma Disorders (Draft for ANSI Z-365) (New York: ANSI).


Organizational Culture and Safety


Production Standards and Performance Feedback: A Strategy for Improving Worker Productivity and Satisfaction


Psychosocial Work Factors and Work Organization


KASL, S.V. and COOPER, C.L. (eds), 1987, Stress and Health: Issues in Research and Methodology (Chichester: John Wiley & Sons).

LINDSTROM, K. and LEINO, T., 1989, Assessment of mental load and stress related to information technology change in
Socially Centered Design

Sociotechnical Analysis of Work System Structure: Applying Empirical Models of Sociotechnical System Elements


Sociotechnical Systems Theory: The Sociotechnical Systems Model of Work Systems


SYMLOG in Ergonomics


SUNDSTROM, E., KOENIGS, R.J. and HUET-COX, G.D., 1996, Personality and perceived values: Myers-Briggs type indicator and coworker ratings on SYMLOG. In Hare, S.E. and I Hare, A.P. (eds) SYMLOG Field Theory.

Telework


Trade Union Approaches to Workplace Improvements


Types of Organizational Designs


Activity and Other Sampling Methods


RAIFFA, H. and SCHLAIFER, R., 1961, Applied Statistical Decision Theory (Boston: Division of Research, Graduate School of Business Administration, Harvard University).

AET Ergonomic Job Description
Questionnaire


Basic Ergonomics Checklists


Biomechanical Modeling of Human Strength

FIGURE 4 Static strength prediction program (courtesy of TMD Software, University of Michigan).
Biomechanics of Low Back: Guidelines for Manual Work


Biovect: A Vector Analysis Method on Photographic Documents Applied to Ergonomic Analysis


KAPITANIAK, B., PENINOU, G. and ZANA, J.P., 2000, Ergonomic study in a mass marketing company concerning preventive action against MSD due to repetitive manual handling. XIV IEA Congress, San Diego, CA.


PENINOU, G., MONOD, H. and KAPITANIAK, B., 1994, Prévention et Ergonomie (Paris: Masson), p. 120.

FIGURE 2 Left: Operator pushing the cart with flexed elbows. Middle: The analysis of the barycenters on the entire subject. Right:

The result of the vector analysis with estimation of the pushing force. P mass of the subject; F1 component of the force exerted as support; F2 component of the force exerted to push.
Noninvasive Optical Spectroscopy — Determined Cerebral Hemodynamics as Psychophysiological Measures of Physical Work


Cognitive Task Analysis


Communication Analysis


Computer Simulation: Applications to Human Factors and Ergonomics


http://www.radata.demon.co.uk/ipme.html.


Confidence in Self-report Questionnaires
Results: An Issue for the Intervention Researcher

ARMENAKIS, A.A. and ZMUD, R.W., 1979, Interpreting the measurement of change in organizational research. Personnel Psychology, 32, 709-723.


Content Analysis: Hypermedia Design


The Critical Decision Method


The Critical Incident Technique: A Method for Identifying System Strengths and Weaknesses Based on Observational Data


Data Mining in Ergonomics


Design Methodology


KOTARBIÓSKI, T., 1986, Thoughts About Humans and Human Affairs (Wroclaw: Ossolineum).


Determining Usability Test Sample Size

Subject 1 3 4 Count p

1 1 1 0 2 0.667
2 1 1 1 3 1.000
3 1 0 0 1 0.333
4 0 0 0 0 0.000

Count 3 2 1 P 0.750 0.500 0.250 0.500
Digital Human Models for Ergonomics


Ecological Ergonomics: Theory in Context


Ecological Interface Design: Applications


Electromyography: Fundamentals


Electromyography: Methods and Techniques


ZIPP, P., 1982, Recommendations for the standardization of lead positions in surface electromyography. European
Journal of Applied Physiology, 50, 41-54.
Empirical Methods: Experiments


ERGO_X — The Model of a Fuzzy Expert System for Workstation Ergonomic Analysis


Ergonomic Data for the Design and Evaluation of Technical Systems

six types of work place contained in the consulting module (Figure 1). For each type of work place, a series of areas for analysis have been defined (e.g. environmental impact, tools, controls, physiological strain, etc.). The user then has to decide, which section is important for the test or is insignificant. By clicking onto the relevant buttons, he opens a list of questions. An example using the environmental factor “illumination” may be: “Is the illumination of the work place or room sufficient for all visual tasks?” The user can then answer this question with “yes,” “no” or “not applicable” using his own experience or questioning the staff concerned (Figure 5). When all questions have been answered, the user receives an information that he now can proceed to the test result. For this purpose, he can choose between several depictions. They can print a list of all questions posed sorted according to fields or criteria (e.g. health, performance, comfort, etc.) or only those questions answered with “no” during the test, i.e. where ergonomic requirements have not been accomplished. Here again a sorting according to fields or criteria is possible. Finally, the entire test result can be printed as a
test report containing a graphical depiction of the evaluation. The checklist for product analysis is build up in the same manner and contains up to now the following types of products: O Motor car. O Omnibus. O Truck. O Earth-moving machinery.

2.5.6 Literary search and definitions of ergonomic terminology

As already mentioned in Section 1 the EDS is completed by a literature compilation, which can be called according
Ergonomic Methods: Selection Criteria

At which stage of the design cycle are you? In what form does the product exist? Do you need access to end users? How tight are time pressures? yes no relaxed very tight concept middle late early prototype finished product

requirement’s capture; user needs analysis; analysis of existing products checklists; heuristic checklists; heuristic checklists; heuristic checklists; heuristic checklists; heuristic checklists; heuristic evaluation; link analysis; layout analysis; evaluation; structured survey; evaluation; focus groups; performance evaluation; survey evaluation; structured survey; evaluation; structured survey; evaluation; error performance evaluation performance evaluation performance evaluation identification identification identification error focus groups; error survey; focus groups; performance evaluation survey; focus groups; performance evaluation

FIGURE 2
The Human Factors Case: A Framework for Human Factors Integration

workload, etc. although such issues will normally be addressed at some level in a safety case, other important HF issues are often not addressed in a safety case. These can include workstation ergonomics, human-machine interaction issues, role changes, trust in and acceptance of the system, longer-term manpower planning, skill changes, aging, motivation, and so on. These issues, if not properly addressed, can lead to the failure (e.g. nonacceptance) of a system, which may be demonstrated to be safe in a safety case. There are several cases where HF issues, such as HMI legibility and staffing, have hindered implementation of large-scale ATM projects, after approval of a safety case. The human factors case has some similarities with quality management and risk-based project management approaches. Project risk management enables the management of risk as an integrated part of project management through all project phases. Many insights have been learned from such approaches, better to enable the human factors case to predict and manage threats and opportunities relating to human-system performance.

5 CONCLUSIONS

The human factors case guidance proposes a standard and straightforward process to enable project managers to make
Functional Magnetic Resonance Imaging (fMRI) and Workload Assessment


General and Systemic-Structural Theory of Activity

Goals Operators Methods and Selection
Rules (GOMS)


# Heart Rate as Strain Index

**TABLE 1**

Grid for Assessing the General Dynamic Workload from the Heart Rate for Continuous Tasks (Performed during 8 h of Work) and Punctual Tasks (Performed for Less than 30 min out of 8 h of Work) Classification of Cardiac Strain

<table>
<thead>
<tr>
<th>Continuous (8 h) Occasional (30 min)</th>
<th>Class</th>
<th>CC</th>
<th>CC</th>
<th>r</th>
<th>HR</th>
<th>CC</th>
<th>CC</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slight</td>
<td>100</td>
<td>20</td>
<td>20%</td>
<td>110</td>
<td>30</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>115</td>
<td>35</td>
<td>30%</td>
<td>130</td>
<td>50</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>130</td>
<td>50</td>
<td>45%</td>
<td>150</td>
<td>70</td>
<td>65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>150</td>
<td>70</td>
<td>60%</td>
<td>170</td>
<td>90</td>
<td>75%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2** Limit Values of Cardiac Costs not to Be Exceeded According to the Principal Work Constraint, either in Average Values, or in Peak Values Limit Values Continuous Peak Principal Constraint

<table>
<thead>
<tr>
<th>CC</th>
<th>CC</th>
<th>r</th>
<th>CC</th>
<th>CC</th>
<th>r</th>
<th>Dynamic</th>
<th>Continuous</th>
<th>Peak</th>
<th>Principal Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>30</td>
<td>50 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>20</td>
<td>15 40</td>
</tr>
</tbody>
</table>
Heuristic Evaluation


Hierarchical Task Analysis


STAMMERS, R.B., 1996, Hierarchical task analysis: an

Human Body Positioning Analysis

FIGURE 3 Electrical goniometers used to quantify postures and motions of the wrist (a) when performing a keyboarding task (photo courtesy of Richard Marklin) and on the spine (b) when performing a beverage delivery job.


Human Factors and Ergonomics Methods


FIGURE 4 Use of a mock-up in the scenario design tool.
Human Factors: Reliability and Risk Assessment


Human Sensory Measurement Application Technology (HSMAT)

and evaluate products and environment comfort in real-life settings. A database containing various types of human data obtained through the HSMAT project, and a handbook providing information on advanced technologies for gauging biological, behavioral and subjective measures will be produced after refining the indices and other resulting technologies. In the near future, comprehensive guidelines indicating proper application of human sensory indices will be constructed by integrating and systematizing the results of the HSMAT project.

3.2.2 Evaluation simulators

3.2.2.1 Thermal sweating manikin

This thermal sweating manikin simulates human skin temperatures and perspiration. Unlike conventional thermal manikins, it can simulate skin temperature and perspiration changes over time, and can also be made to perspire profusely. Micro-climates (humidity) within clothing can also be simulated. The manikin can make different poses including, standing, sitting and lying down, and can be used to design and evaluate products such as bedclothes, chairs, and comfortable clothing.

3.2.2.2 Human comfort meter

This is a small manikin with movable joints and adjustable height that is equipped with 12 thermal comfort sensors.
The manikin allows accurate evaluation of the adaptability
Human Systems Engineering Process and Methods

5 CONCLUSIONS

Incorporating the human element of the total system into the design effort provides a thorough understanding of total system performance requirements. In that the design team has an understanding of what the person is good/not so good at: functions are optimally allocated between people and automation (and decision aids). Hence: 0 There is a better understanding of the implications of automation allocations on people. 0 There is an upfront accounting for what people need for supervisory control. 0 There is an accounting for the workload associated with the human tasks/decisions.

Using this process function allocation to people is explicitly determined and people’s responsibilities are known.

Therefore: 0 The system and the human interaction can be developed with a task design through decision analysis. 0 People can be better trained on their tasks and responsibilities (not just buttonology). 0 The number of people can be determined based on task workload. 0 Concurrently, the type of people needed, the knowledge, skills, and abilities required are identified during the task design and decision analysis – and can be compared to the types of people currently available. This can result in overall system performance increases (likely at reduced life cycle costs) due to the improved and better focused training, identifying the right person for the right job, and the optimization of the human interaction design for people. The rapid and continual advancement of technology makes the human more likely to be the limiting factor in system design and performance, making it increasingly impor
tant that the human factors and ergonomics communities work together with systems engineers. Communication and integration are central to successful design development and there are many mechanisms which facilitate both across systems design teams. Involvement in the professional groups and societies of the designers and specialty engineers with which we interact is an excellent mechanism for understanding
Interviews

6 DATA

No matter what type of data is collected, it is of little use unless it can be shown to be valid and reliable. To be valid, data must measure what they are supposed to measure, whereas to be reliable, the measurement must be consistent. Demographic and use type questions are unlikely to show a lack of validity or reliability, due to their structure and the metrics used. However, where opinions or attitudes are derived from responses to a number of questions (e.g. a scale), then the resulting overall measures need to be shown to be both valid and reliable. There are a number of statistical techniques that can be used to demonstrate the reliability of scales by examining the stability of the measure over time and its internal consistency. Threats to validity in interview research can be greater than other forms of survey research due to the interpersonal nature of the technique, which can induce a high level of variability in responses. More specifically, validity can be threatened by incomprehensible or ambiguous questions, and by interviewer effects leading to a difference between what people do or think and the responses they give. In addition, faulty sampling can reduce the
ability
to generalize from the findings. Analysis of demographic and use/experience data is relatively “clear-cut” as it is most likely to be collected in the form of interval data and, therefore, can be analyzed using either parametric or nonparametric statistical techniques. Preference should be given to the former, as these tests are more powerful, that is, significant findings are more readily obtained. Data obtained from scales should be treated as ordinal data and should be analyzed using nonparametric tests, although some scales are commonly treated as interval data (e.g. the NASA-TLX workload measure: Hart and
Job Analysis and Ergonomic Assessment
After Injury


BLAZ, J., 1998, Fit for duty, how OT-managed health and fitness programs can prevent work-site injuries and reinjuries. OT Week, 12, 12-3.


Job Load and Hazard Analysis


Measurement of Human Movement


Medical Equipment Usability Testing: An Introduction


LEWIS, J.R., 1994, Human Factors, 36(2), 368-78.


Methods of Software Evaluation


Metrics and Measurement of Usability


Applications of Microsimulation in Cognitive Skills Development

of the introduction of this type of simulation-based training.

In an operational context, these costs include lost productivity as a result of learner participation in a training initiative, the maintenance and replacement of equipment, and the involvement of an instructional designer and facilitator. Similar to any investment, these costs must be weighed against the potential gains arising from the opportunity for training and development.

Consistent with other approaches to education and training, the outcomes of microsimulation-based training can be difficult to determine. While a learner may demonstrate competence within the simulated environment, the extent to which these skills are transferred to the operational environment will remain difficult to determine in the absence of a reliable assessment within the actual environment. For example, in the case of safety-related training, outcomes are often assessed using relatively less reliable measures of achievement, such as the frequency of incidents or accidents.

Where it is possible to assess human performance in both the simulated environment and the operational environment, it is possible to employ the cost-effectiveness ratio.
to determine the relative value of simulation-based training (Farmer et al. 1999). The cost-effectiveness ratio (CER) is defined as:

The training effectiveness ratio (TER) is determined by:

where \( Y_c \) time or trials to reach criterion performance in absence of simulation experience, \( Y_x \) time or trials to reach criterion performance with simulation experience, and \( X \) total time or trials in the simulator.

The training cost ratio (TCR) is determined by:

As an example, consider that a learner takes five trials in a simulator to reach criterion performance on a particular task. The same task in the operational environment requires ten trials to reach criterion. Substituting for the TER:

The TCR for the decision-making task can be calculated as:

Substituting for the CER: 1

\[
0.5 \times 2 \times 5 = 0.5
\]

\[
0.50 \times 100 \times 0.5
\]

\[10 \times 5 \times 5 - £1.0 \text{ Cost of Simulator Operation}
\]

Cost of Operating the Equipment

\[Y \times x \times \text{xc -}
\]


SCHIFLETT, S.G., ELLIOTT, L.R., SALAS, E. and COOVERT, M.D.,
2004, Scaled Worlds: Development, Validation and Applications

(Aldershot, UK: Ashgate).
Mitigating Cybersickness in Virtual Environments


LIN, J.J.W., DUH, H.B.L., PARKER, D.E., ABI-RACHED, H. and


MUSE–JSD: Structured Integration of Human Factors and Software Engineering Methods


The MUSE Method for Usability Engineering


Noise: Metrics and Equipment


Observation


The OCRA Method: Assessment of Exposure to Occupational Repetitive Actions of the Upper Limbs


OCCHIPINTI, E. and COLOMBINI, D., 2004, Metodo OCRA: aggiornamento dei valori di riferimento e dei modelli di previsione dell’occorrenza di UL-WMSDs nelle popolazioni lavorative esposte a movimenti e sforzi ripetuti degli arti superiori. La Medicina del Lavoro, 95(4), 305-319.

OWAS – A Method for Analysis of Working Postures

vi. The OWAS documentation provides practical training material for new employees and for retraining experienced workers. This training material is considered especially effective as it is based on a company’s own production technique.

vii. The OWAS documentation, accompanied where possible by videotapes, supports the participative approach in occupational health and safety for the development and introduction of preventive measures and improvements.

viii. Worker involvement is crucial in order that everyone’s work interests are recognized and the aims and principles of the analysis are understood.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>The OWAS Action Categories for Evaluation of Working Postures</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OWAS Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action category I</td>
<td>Work postures are considered usually with no particular harmful effect on musculoskeletal system. No actions are needed to change work postures</td>
</tr>
<tr>
<td>Action category II</td>
<td>Work postures have some harmful effect on the musculoskeletal system. Light stress, no immediate action is necessary, but changes should be considered in future planning</td>
</tr>
<tr>
<td>Action category III</td>
<td>Work postures have a distinctly harmful effect on the musculoskeletal system. The working methods involved should be changed as soon as possible</td>
</tr>
<tr>
<td>Action category IV</td>
<td>Work postures with an extremely harmful effect on the musculoskeletal system. Immediate solutions should be found to change these postures</td>
</tr>
</tbody>
</table>
Prevention of Work Injury


Kouabenan, D.R., 1998, Beliefs and the perception of risks and accident. Risk Analysing, 18(3).


GUNDEL, A., DRESCHER, J. and TUROWSKI, J., 1999, Alertness in airline pilots during night flights: assessment of alertness using EEG
Quantitative Method for Processing Objective Data from Posture Analysis


Questionnaires
groups), there are a number of techniques that can be of particular value. As previously mentioned, Cronbach’s alpha coefficient can be obtained to indicate the level of internal consistency of a scale. This measure indicates how well the individual items hang together to reflect a single underlying construct. Ideally, a scale should have an alpha value of 0.7 or more. If all the items are measuring the same underlying construct, then you should expect respondents to respond in a consistent way to the items. Those items that are not so reliable are ones where responses varied in their relationship to other items. This suggests that the item is not measuring the same underlying construct, and this is probably due to ambiguity in the wording, or may be that the statement is not quite right/relevant to determine the particular attitude you are trying to measure. Less reliable items are ones that if removed from the scale will improve the overall alpha value. Most statistical packages will provide output that will show an “alpha if item deleted” value. This information can then be used to refine the scale, either by removing the item or by revising the wording. Another statistical tool that can be applied to questionnaire research is factor analysis. This is a term that is
used for a number of data reduction techniques, including principal components analysis, which identify underlying groupings of scale items (factors or components). Examination of these groupings can identify themes within a construct, and items that may reduce scale validity.

Regression and, in particular, multiple-regression techniques are able to examine the predictive validity of scales and can identify variables that may influence attitudes toward a system being investigated.
Research Design Basics

<table>
<thead>
<tr>
<th>TABLE 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Schedule for Testing Four Brands of Seats (Bummer, ErgFlex, HiLo, Seato) at Five Worksites during Mornings and Afternoons over a Three-Day Period Work Site Time Tuesday Wednesday Thursday</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Components AM</th>
<th>Bummer</th>
<th>Seato</th>
<th>ErgFlex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>ErgFlex</td>
<td>HiLo</td>
<td></td>
</tr>
<tr>
<td>Sub Assem</td>
<td>HiLo</td>
<td>Bummer</td>
<td>Seato</td>
</tr>
<tr>
<td>F Assembly</td>
<td>Seato</td>
<td>ErgFlex</td>
<td></td>
</tr>
<tr>
<td>Test &amp; Calib</td>
<td>HiLo</td>
<td>Bummer</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component PM</th>
<th>HiLo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>Bummer</td>
</tr>
<tr>
<td>Sub Assem</td>
<td>ErgFlex</td>
</tr>
<tr>
<td>F Assembly</td>
<td>HiLo</td>
</tr>
<tr>
<td>Test &amp; Calib</td>
<td>Seato</td>
</tr>
</tbody>
</table>

Note: No testing was done on Thursday afternoon.
Response Surface Methodology and Sequential Experimentation


Scenario-Based Design of ICT-Supported Work

Further methodological challenges are the integration of the scenario approach for user-centered system design with the strategic management scenario approach, and the integration of scenario methods with more formal methods of systems development.

4.3 EMPIRICAL RESEARCH ON THE EFFECTS AND EFFECTIVENESS OF DIFFERENT SCENARIOS

Although scenarios are, in general, assumed to be useful, their effectiveness has hardly been subject to empirical investigation. Little is known about the effects of varying the different facets of form and content, taking into account the different purposes and stages in the system development cycle. In the above, the position was taken that in the earliest stage of development, rich, contextual scenarios are needed to support a wide-based reflection on technology, work, cooperation, and organization. Human-computer interaction scenarios would narrow the design space in an early stage down too much to user interface issues. Yet, how detailed should the different elements of such contextual scenarios (e.g. the system and personal communication) be represented? Of course, scenarios offer the user great flexibility, e.g. to develop more abstract scenarios when the time and resources for developing high-detail scenarios are
lacking. However, what are the related costs and benefits of}
gathering extra information to be able to work out detailed
scenarios? Moreover, could it be that keeping the scenario
lean, i.e. more abstract, has clear advantages at the first
stage of (participatory) evaluation? The lack of empirical
results concerning the effectiveness of different scenario characteristics also
applies to the form dimension. How do different media influence the content of scenarios i.e. the level of detail in
the representation of action and interaction as well as the
representation of context. What is more, what effects do
different media for scenario representation have on related
processes, e.g. participatory evaluation? At this point, there
is a need for detailed case studies on the use of scenarios and
their influence on design as well as evaluation, as well as
for
Scientific Management Influences on Ergonomic Analysis Techniques

The task description contains the task requirements whereas the task analysis is the actual analysis of the behavioral implications of the task identified in the description (Stammers and Shepherd 1995). The analysis used in scientific management tended to focus on efficiency of activities (e.g. reduction of wasteful motion) and elimination of fatigue. Today, the analysis phase may focus on a broad range of measures that influence human performance, depending on the task and its context. The origins of task analysis often include mention of the landmark report by Miller (1953). The purpose of the methodology reported was to provide a framework for specifying training requirements. The examples provided by Miller (1953) show the focus on breaking work into small units, just as was done by Taylor and the Gilbreths. Miller’s (1953) methodology was more involved and far more advanced from the standpoint of comparing human capacity to task demands, but the general approach to describing work tasks is similar. The notion of performing a task analysis for delineating training requirements is functionally identical to Taylor’s instruction cards for industrial tasks. In some regards, the task description methods form the core commonalties across time, and the analysis progressed and evolved as the knowledge of the human...
responses to work evolved.

4 DISCUSSION

Today, many ergonomic tools incorporate the division of manual work into tasks or task elements. This division provides a structured means of determining which tasks or task elements may result in task demands exceeding human capabilities. The control of work-related musculoskeletal disorders of the upper extremity and low back is currently a priority in many industrial organizations. Numerous analysis techniques used are indeed task analytic approaches, many of which are founded in fundamental time study and motion study techniques. During the Scientific Management era, the task analytic approach was widely used as a means of enhancing productivity through the redesign of the workplace or the elimination of “wasteful” elements. The reduction of fatigue was a primary goal, with the assumption that fatigue was a detriment to productivity. The analysis was focused on
Sources of Error in Ergonomics Research


Survey Design


A Survey of Ergonomics Methods


COOK, M., 1988, Personnel Selection and Productivity (Chichester: Wiley).


Taguchi Method for Ergonomic Design

comparable to more stringent traditional statistic procedures,

it is a good method to be applied in the early stage of the ergonomic designs. The limitation of the Taguchi method, on the other hand,

comes from its dealing with interactions of the design factors.

Some orthogonal arrays used in the Taguchi method involve partial aliasing of the two-factor interactions with the main design factors. If these interactions are large, then the result from the Taguchi analysis can be misleading. So, cautions should be exercised to consider the interactions among the design factors carefully before proceeding to apply the Taguchi method.

5 CONCLUSION

Ergonomic design is a complex procedure concerning human, machine and the environment where human and machine interact. Applying the Taguchi method properly in this area can improve the quality and efficiency of the ergonomic designs and also save time and costs. Currently, the Taguchi method is not very widely used in ergonomic designs, but it will prove to be a promising practical tool here with all its merits.
Task Analysis for Error Identification


Task Analysis in Industry

FIGURE 1 Task analysis framework.
Technique for the Retrospective and Predictive Analysis of Cognitive Error (TRACER and TRACER-lite)

TABLE 4

Information Taxonomy Structure and Example

Keywords ATC/Pilot Activities and Aircraft Information

Controller materials (e.g. briefing material, flight progress strip)

Pilot materials (e.g. flight plan, charts)

Controller activities (e.g. transfer, co-ordination)

Variable aircraft information and pilot activities (e.g. route, speed)

Other Airspace and Other Keywords

Time and location (e.g. sector, destination)

Airport (e.g. runway, ground vehicles)

Other
Verbal Protocol Analysis

Work Stress Quantification and Evaluation
Using ErgoMOST


Frederic Charles Bartlett


Donald Eric Broadbent (1926–1993)


Otto Gustav Edholm (1909-1985)


Paul Morris Fitts


Ross A. McFarland


Bernardino Ramazzini


RAMAZZINI, B., 1700, De Morbis Artificum Diatriba (Modena, Italy: Typis Antonii Capponi).


Karl U. Smith


Bibliography

W. Karwowski
Center for Industrial Ergonomics, Department of Industrial Engineering, University of Louisville, USA

Bibliography


BIBLIOGRAPHY

HACKSTEIN, R., 1977, Arbeitswissenschaft im Umri&Greek;Gebhey, Bd. 1: Gegenstand und Rechtsvertr&uuml;Nnisse, Bd. 2 (Essen: Grundlagen & Anwendung).
HENDRICK, H.W., 1997, Good Ergonomics is Good Economics (Santa Monica: Human Factors and Ergonomics Society).
HENDRICK, H.W. and BROWN, O. Jr (eds), 1984, Human Factors in Organizational Design and Management (Amsterdam: North Holland).

KARWOWSKI, W., 1992, The human world of fuzziness, human
KARWOWSKI, W., 1991, Complexity, fuzziness and ergonomic incom-
KARWOWSKI, W. and AYOUB, M.M., 1984, Fuzzy modeling of
KIM, J.Y., STUART-BUTTLE, C. and MARRAS, W.S., 1994, The effects of
KIRKPATRICK, D., 1979, Techniques for evaluating training programs.
KIRWIN, A., 1999, Expansion of community modeling: a case study in
KLEINER, B.M., 1996, Macroergonomics: lessons learned from large
KLEINER, B.M., 1997, An integrative framework for measuring and
evaluating information management performance. International
KLING, J.W. and RIGGS, L.A. (eds), 1971, Woodworth and
KNAVE, B.G., WIBOM, R.I., VOSS, M., HEDSTROM, L.D. and
KNIRK, F.G. and GUSTAFSON, K.L., 1986,
KNIGHT, G., 1963, Hypnosis: a behavior therapy (New York: Grune &
KNIGHT, G., 1965, The treatment of psychoneurotic illness with
KNIGHT, G., 1966, Hypnosis and the treatment of illness (New
KNIGHT, G., 1971, Reciprocal inhibition (New York: Grune &
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Biomedical Engineering:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Computers in Medicine:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Ergonomics in Design:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Human Factors in Design:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Industrial Engineering and
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Medical Engineering:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Engineering:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Medicine:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology:
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
KIRK, J.W. and RIGGS, L.A. (eds), 1971, Rehabilitation Psychology,
Bibliography


MICHEL, D.P., 1994, Two types of chairs on stature change and comfort for individuals with healthy and herniated discs. Ergonomics, 37, 1231–44.


MORAY, N., 1979, Mental Workload (New York: Plenum).

MÜNSTERBERG, H., 1914, Grundzüge einer Psychotechnik (Leipzig).


Bibliography


