The Human-Computer Interaction Handbook

Fundamentals, Evolving Technologies and Emerging Applications



Edited by

Julie A. Jacko
Andrew Sears

Human Factors and Ergonomics

MICROSOFT CORP.
EXHIBIT 1016

THE HUMAN–COMPUTER INTERACTION HANDBOOK

Fundamentals, Evolving Technologies and Emerging Applications

Human Factors and Ergonomics
Gavriel Salvendy, Series Editor

Hendrick, H., and Kleiner, B. (Eds.): *Macroergonomics: Theory, Methods, and Applications*.

Jacko, J. A., and Sears, A. (Eds.): *The Human–Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*.

Meister, D., and Enderwick, T. (Eds.): *Human Factors in System Design, Development, and Testing*.

Stanney, Kay M. (Ed.): *Handbook of Virtual Environments Technology: Design, Implementation, and Applications*.

Stephanidis, C. (Ed.): *User Interfaces for All: Concepts, Methods, and Tools*.

Also in this Series

HCI 1999 Proceedings 2-Volume Set

- **Bullinger, H.-J., and Ziegler, J.** (Eds.): *Human–Computer Interaction: Ergonomics and User Interfaces*.
- **Bullinger, H.-J., and Ziegler, J.** (Eds.): *Human–Computer Interaction: Communication, Cooperation, and Application Design*.

HCI 2001 Proceedings 3-Volume Set

- **Smith, M. J., Salvendy, G., Harris, D., and Koubek, R. J.** (Eds.): *Usability Evaluation and Interface Design: Cognitive Engineering, Intelligent Agents and Virtual Reality*
- **Smith, M. J., and Salvendy, G.** (Eds.): *Systems, Social, and Internationalization Design Aspects of Human–Computer Interactions*
- **Stephanidis, C.** (Ed.): *Universal Access in HCI: Towards an Information Society for All*

For more information on LEA titles, please contact Lawrence Erlbaum Associates, Publishers, at www.erlbaum.com.

THE HUMAN–COMPUTER INTERACTION HANDBOOK

Fundamentals, Evolving Technologies and Emerging Applications

JULIE A. JACKO, Editor
Georgia Institute of Technology

ANDREW SEARS, Editor
UMBC

LEA LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS
2003 Mahwah, New Jersey London

Senior Acquisitions Editor: Anne Duffy
Editorial Assistant: Kristin Duch
Cover Design: Kathryn Houghtaling Lacey
Textbook Production Manager: Paul Smolenski
Full-Service Compositor: TechBooks
Text and Cover Printer: Edwards Brothers, Inc.

This book was typeset in 9/11 pt. ITC Garamond Roman, Bold, and Italic.
The heads were typeset in Novarese, Novarese Medium, and Novarese Bold Italic.

Copyright © 2003 by Lawrence Erlbaum Associates, Inc.
All rights reserved. No part of this book may be reproduced in any form, by photostat, microfilm, retrieval system, or any other means, without prior written permission of the publisher.

Lawrence Erlbaum Associates, Inc., Publishers
10 Industrial Avenue
Mahwah, New Jersey 07430
www.erlbaum.com

Library of Congress Cataloging-in-Publication Data

The human-computer interaction handbook : fundamentals, evolving technologies, and emerging applications / Julie A. Jacko, Andrew Sears, editors.
p. cm.—(Human factors and ergonomics)
Includes bibliographical references and index.
ISBN 0-8058-3838-4 (case)—ISBN 0-8058-4468-6 (pbk.)
1. Human-computer interaction—Handbooks, manuals, etc. I. Jacko, Julie A. II. Sears, Andrew. III. Series.

QA76.9.H85 H8568 2002
004′.01′9—dc21 2002011381

Books published by Lawrence Erlbaum Associates are printed on acid-free paper, and their bindings are chosen for strength and durability.

Printed in the United States of America
10 9 8 7 6 5 4

For François, Beth, Nicole, and Kristen.

CONTENTS

Series Foreword xiii
Foreword xv
Preface xvii
Handbook Web Site xix
Advisory Board xxi
About the Editors xxiii
List of Contributors xxv

Introduction. Evolution of Human–Computer Interaction: From Memex to Bluetooth and Beyond
Richard W. Pew 1

Part I
HUMANS IN HUMAN–COMPUTER INTERACTION
Mary Czerwinski 19

1 Perceptual–Motor Interaction: Some Implications for Human–Computer Interaction
Romeo Chua, Daniel J. Weeks, and David Goodman 23

2 Human Information Processing: An Overview for Human–Computer Interaction
Robert W. Proctor and Kim-Phuong L. Vu 35

3 Mental Models
Gerrit C. van der Veer and Maria del Carmen Puerta Melguizo 52

4 Emotion in Human–Computer Interaction
Scott Brave and Clifford Nass 81

5 Cognitive Architecture
Michael D. Byrne.....97

6 Modeling Humans in Human–Computer Interaction
Hidekazu Yoshikawa.....118

Part II
COMPUTERS IN HUMAN–COMPUTER INTERACTION
Robert J. K. Jacob.....147

7 Input Technologies and Techniques
Ken Hinckley.....151

8 Conversational Interface Technologies
Clare-Marie Karat, John Vergo, and David Nahamoo.....169

9 Visual Displays
Holger Luczak, Matthias Roetting, and Olaf Oehme.....187

10 Haptic Interfaces
Hiroo Iwata.....206

11 Nonspeech Auditory Output
Stephen Brewster.....220

Part III
HUMAN–COMPUTER INTERACTION.....241

A. Interaction Fundamentals
Julie A. Jacko.....243

12 Multimedia User Interface Design
Alistair Sutcliffe.....245

13 Visual Design Principles for Usable Interfaces
Suzanne Watzman.....263

14 Multimodal Interfaces
Sharon Oviatt.....286

15 Adaptive Interfaces and Agents
Anthony Jameson.....305

16 Network-Based Interaction
Alan Dix.....331

17 Motivating, Influencing, and Persuading Users
B.J. Fogg.....358

18 Human Error Identification in Human–Computer Interaction
Neville A. Stanton.....371

19 Design of Computer Workstations
Michael J. Smith, Pascale Carayon, and William J. Cohen.....384

B. Interaction for Diverse Users
Gregg Vanderheiden.....397

20 Genderizing Human–Computer Interaction
Justine Cassell.....401

21 Designing Computer Systems for Older Adults
Sara J. Czaja and Chin Chin Lee.....413

22 Human–Computer Interaction for Kids
Amy Bruckman and Alisa Bandlow.....428

23 Global and Intercultural User-Interface Design
Aaron Marcus.....441

24 Information Technology for Cognitive Support
Alan F. Newell, Alex Carmichael, Peter Gregor, and Norman Alm.....464

25 Physical Disabilities and Computing Technologies: An Analysis of Impairments
Andrew Sears and Mark Young.....482

26 Perceptual Impairments and Computing Technologies
Julie A. Jacko, Holly S. Vitense, and Ingrid U. Scott.....504

C. Interaction Issues for Special Applications
Jenny Preece.....523

27 Documentation: Not Yet Implemented, But Coming Soon!
Brad Mehlenbacher.....527

28 Information Visualization
Stuart Card.....544

29 Groupware and Computer-Supported Cooperative Work
Gary M. Olson and Judith S. Olson.....583

30 Online Communities: Focusing on Sociability and Usability
Jenny Preece and Diane Maloney-Krichmar.....596

31 Virtual Environments
Kay M. Stanney.....621

32 User-Centered Interdisciplinary Design of Wearable Computers
Daniel P. Siewiorek and Asim Smailagic.....635

33 A Cognitive Systems Engineering Approach to the Design of Decision Support Systems
Philip J. Smith and Norman D. Geddes.....656

34 Computer-Based Tutoring Systems: A Behavioral Approach
Henry H. Emurian and Ashley G. Durham.....677

35 Conversational Speech Interfaces
Jennifer Lai and Nicole Yankelovich.....698

36 The World Wide Web
Jonathan Lazar.....714

37 Information Appliances
W. P. Sharpe and S. P. Stenton.....731

Part IV
APPLICATION DOMAINS
Arnold M. Lund.....753

38 E-Commerce Interface Design
John Vergo, Sunil Noronha, Joseph Kramer, Jon Lechner, and Thomas Cofino.....757

39 The Evolution of HCI During the Telecommunications Revolution
Edmond Israelski and Arnold M. Lund.....772

40 Government Roles in Human–Computer Interaction
Jean C. Scholtz.....790

41 Human–Computer Interaction in Health Care
François Sainfort, Julie A. Jacko, and Bridget C. Booske.....808

42 A Framework for Understanding the Development of Educational Software
Chris Quintana, Joseph Krajcik, Elliot Soloway, and Cathleen Norris.....823

43 Understanding Entertainment: Story and Gameplay Are One
Jesse Schell.....835

44 Motor Vehicle Driver Interfaces
Paul Green.....844

45 Human–Computer Interaction in Aerospace
Amy R. Pritchett.....861

46 User-Centered Design in Games
Randy J. Pagulayan, Kevin Keeker, Dennis Wixon, Ramon L. Romero, and Thomas Fuller.....883

Part V
THE DEVELOPMENT PROCESS.....907

A. Requirements Specification
Michael J. Muller.....909

47 Requirements SpecificationWithin the Usability Engineering Life Cycle
Deborah J. Mayhew.....913

48 Task Analysis
Janice Redish and Dennis Wixon.....922

49 Contextual Design
Karen Holtzblatt.....941

50 An Ethnographic Approach to Design
Jeanette Blomberg, Mark Burrell, and Greg Guest.....964

B. Design and Development
Tom Stewart.....987

51 Guidelines, Standards, and Style Guides
Tom Stewart and David Travis.....991

52 Prototyping Tools and Techniques
Michel Beaudouin-Lafon and Wendy Mackay....1006

53 Scenario-Based Design
Mary Beth Rosson and John M. Carroll.....1032

54 Participatory Design: The Third Space in Human–Computer Interaction
Michael J. Muller.....1051

55 Unified User Interface Development
Constantine Stephanidis and Anthony Savidis...1069

C. Testing and Evaluation
Andrew Sears.....1091

56 User-Based Evaluations
Joseph S. Dumas.....1093

57 Inspection-Based Evaluations
Gilbert Cockton, Darryn Lavery, and Alan Woolrych.....1118

58 Model-Based Evaluation
David Kieras.....1139

59 Beyond Task Completion: Evaluation of Affective Components of Use
John Karat.....1152

Part VI
MANAGING HUMAN–COMPUTER INTERACTION AND EMERGING ISSUES
Hans-Jörg Bullinger and Jürgen Ziegler.....1165

60 Technology Transfer
Kevin M. Schofield.....1169

61 Human Values, Ethics, and Design
Batya Friedman and Peter H. Kahn, Jr......1177

62 Cost Justification
Randolph G. Bias, Deborah J. Mayhew, and Dilip Upmanyu.....1202

63 The Evolving Role of Security, Privacy, and Trust in a Digitized World
Steve Diller, Lynn Lin, and Vania Tashjian.....1213

64 Achieving Compatibility in Human–Computer Interface Design and Evaluation
Waldemar Karwowski.....1226

Conclusion. Perspectives on Human–Computer Interaction
Gavriel Salvendy.....1239

Author Index.....1243
Subject Index.....1269


Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

SERIES FOREWORD

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

The Human–Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications, is published at a very opportune time, when the Information Society technologies are emerging as a dominant force both in the workplace and in everyday life. For these new technologies to be truly effective, they must provide communication modes and interaction modalities across different languages and culture. They should accommodate the requirements of a diverse user population, including the aging and the disabled.

The *Handbook* provides comprehensive coverage of human–computer interaction as it has been evolving in the international arena of research, development, and practice. The book's 64 chapters were authored by leading international human–computer interaction gurus including academicians, researchers, and industry practitioners. For further in-depth coverage of the discipline, over 3,000 references are cited; and more than 125 tables and 450 figures facilitate the communication of knowledge and enliven the reader's experience.

This work should be of special value to software developers for interactive systems and to human–computer interaction professionals. For graduate students, this book provides a wealth of theoretically based and practically oriented information on understanding the human–computer interactive design process. Further, it addresses itself to design-diversified user populations, design-diversified development processes, and design-diversified applications.

The reader will discover a systematic, structured approach to the design, experimentation, operation, and evaluation of user interfaces so that emerging information technologies can be easily and joyfully accessible to all individuals.

The editors, in cooperation with their distinguished Advisory Board, have produced a most comprehensive human–computer handbook that establishes the boundaries of the discipline and which will become an invaluable resource in the professional's library.

Gavriel Salvendy
Series Editor
April 2002


Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

FOREWORD

This Handbook celebrates the success of human–computer interaction (HCI). Readers from within the discipline can take satisfaction in their substantial accomplishments: Basic research on menus, pointing devices, and screen design as well as design innovations in hot HCI topics online communities, information visualization, mobile devices, and interactive games. Practitioners can take pride in their contributions to better products and services that have gained growing acceptance by decision makers.

Newcomers to HCI will find informative section introductions that highlight the key ideas and guide them to the details. This Handbook provides them with grounding in the underlying cognitive principles (Part II), an appreciation of the range of design possibilities (Parts III and IV-A), and recognition of the growing sophistication of modern development processes (Part VI).

Outsiders can dip into specific topics of timely value to them, and expand their reading as their needs and interests grow. They will likely begin with chapters on applications for which they must build or improve user interfaces (Section IVC and V). Visionary readers will search for forward-looking ideas, especially the reflections on human values, ethics, and trust (Section VII). Every reader will benefit from the numerous references that connect to the foundational research.

It is satisfying to recognize the breadth and depth of HCI, and to reflect on its future. I have wondered if this volume marks HCI's emergence from childhood, its youthful adolescence, or young adult status.

The case for "childhood" is that HCI is just beginning to be accepted in academic departments and corporate boardrooms. Only a few years have passed since the topic became a funding area within governmental research support agencies (e.g., U. S. National Science Foundation and other federal counterparts) and the first doctoral programs were announced. On the professional side, usability engineers fight for acceptance, authors propose competing design guidelines, and analysts squabble over appropriate metrics of success.

The argument for "adolescence" is that the uncertainty of childhood has passed. HCI has already made its mark, as these chapters confirm, but this energetic adolescent still has to choose from many possible futures. It could become a basic science like physics and psychology; it could remain an eclectic interdiscipline like biophysics and sociolinguistics; or it could mature into a professional discipline with scientific foundations like architecture and medicine.

The rationale for the "young adult" status is that HCI has already produced interesting theories and stimulated important innovations such as graphical user interfaces, the World Wide Web, email, online communities, instant messaging, and multimedia. It has successfully done its part in bringing information and communications technologies to a diverse set of users and in fashioning devices that are well on their way to universality, ubiquity, and invisibility.

Different readers may come to different conclusions and all be correct. Like any sufficiently large intellectual domain, there is room for many concurrent viewpoints. Those who think HCI is still in childhood can guide its development by engaging in new applications and innovative technologies. They can try to influence HCI's maturation by refining, extending, and applying predictive and explanatory theories, while proposing new theories and integrative frameworks.

Those who see HCI in the adolescent stage can engage in broadening the field by introducing new educational programs, expanding participation in professional societies, and enlarging existing journals. Energetic adolescents should take some risks and explore affiliations with other disciplines such as sociology, semiotics, or nanotechnology; they can expand their experiences by working in cultures other than their own.

Those who see HCI as a young adult can promote its integration into traditional social structures. They can help usability professionals rise through corporate and government ranks and be more influential in controlling product development plans, budgets, and schedules. They can publicize HCI by engaging journalists to report HCI stories and make HCI issues more visible in related disciplines such as software engineering, networking, or security. HCI advocates still have work to do to gain acceptance by top corporate executives, key government officials, and leading science policy makers.

As for the future, I have high expectations and great hopes for HCI as a mature discipline and profession. While preserving our "youthful" infatuation with new and cool technologies, however, we must also address "adult" responsibilities for *usable*, *universal*, and *useful* technologies (CHI'99 Research Agenda Workshop; see Chapter 40). These three concepts are essential as we look to the future of HCI.

1. **Usable.** Existing user interfaces and their underlying systems are just too frustrating for most users. A major effort for software developers should be to increase the reliability and usability of every system. The frequency of system reboots, application crashes, and incompatible file formats that stop users in the middle of their tasks must be reduced. Then the incomprehensible instructions, mysterious menus, and troubling dialog boxes need to be revised to enable users to complete their work promptly and confidently. In our study of the frustrations encountered by more than 100 users, we received frequent comments about long download times for web pages, dropped sessions for networked applications, and the disruption caused by unsolicited email ("spam") and destructive viruses. As the number of users has grown, all these problems have become more serious. Novice users want the benefits of email or web services, but they are poorly equipped and motivated to overcome the problems that high-tech early adopters proudly conquered. Improved training can help, but improved designs are an important component of making the next generation of interfaces more appealing and usability more successful.

2. **Universal.** After systems are made more reliable, we will be ready to address the challenge of making them universally usable. We must enable people with diverse backgrounds to become successful and satisfied users—old and young, men and women, novice and expert; users with varied disabilities; and users with low motivation, low self-confidence, and poor reading skills. We will have to make it possible for users with differing language skills, cultures, and nontraditional social norms to participate in online communities, e-commerce, and e-learning. We must also enable people with limited or outdated technologies—slow modems, small screens, or older processors—to benefit from information and communications services. Advanced technical solutions will be needed to convert web pages to fit small mobile devices and provide web services by cellphone. Finally, we must learn to bridge the gap between what people know and what they need to know. Improved online help, tutorials, email assistance, and customer service are essential. These contributions will often come first from software producers in developed nations, but they need to be pressured to include adequate concerns for the needs and opportunities of users in developing nations.

3. **Useful.** Usable and universal technologies will make it possible to deliver vital services: Life-critical medical systems, military and police protection, safe transportation, and effective job training. Then content providers can create truly useful e-business, e-learning, e-healthcare, e-government, and many other applications. HCI professionals and researchers can promote greater respect for the discipline by addressing urgent political and global issues such as economic growth, community development, counterterrorism, and conflict resolution. By taking responsibility for difficult questions such as the contemporary issues of free speech, intellectual property, voting technologies, pornography control, and privacy, we will win respect within and outside our field. Better theories regarding human needs are required to understand what is missing and where the greatest opportunities lie. The next major direction I foresee is the enhancement of creativity support tools to make more people more creative more of the time. This ambitious goal will produce a sustainable chain reaction of further creativity and even better tools to effectively harness each individual's capacity to contribute and participate in shaping the future.

A hallmark of adulthood will be the willingness of HCI researchers and professionals to take on issues that transcend technology. We will gain respect as we contribute to systems that empower individuals, enrich human relationships, encourage cooperation, build trust, and support empathy. Our acceptance of responsibility for the future will be more than a model for other disciplines; it can bring hope to many people for a better life.

Ben Shneiderman
University of Maryland

PREFACE

This Handbook marks a critical juncture in the field of human–computer interaction (HCI). Over the last two decades, HCI emerged as a major discipline in computing, and was quickly energized by substantial contributions from other fields, such as engineering, psychology, education, and graphic design. The effective utilization of the resulting interdisciplinary breakthroughs has contributed to a heightened global awareness of the importance of HCI not just as an academic discipline. HCI in practice helps us achieve increased productivity, enhances our quality of life, envigorates competitiveness, and improves the quality of services through the effective design and use of interactive computing systems. HCI now has a home in every application, environment, and device, and is routinely used as a tool for inclusion. Therefore, this Handbook should be of tremendous value to practitioners, researchers, students, and academicians regardless of enterprise, because HCI, like computing itself, is now ubiquitous.

Composed of eight sections which include 64 chapters, the 1242 pages of this work were authored by over 120 of the most eminent researchers and professionals in the discipline from around the world. Each contribution was carefully reviewed by experts in the field, as well as by ourselves. The Advisory Board was instrumental throughout the process as they helped shape and refine our vision for this volume. We thank the contributing authors and the Advisory Board. Their commitment to the success of this volume was unwavering, and we are honored to have worked with each one of them.

The Handbook opens with an evolutionary perspective on HCI, which provides a sense of perspective on the field, recognizes significant visionary developments, and directs the reader to seminal literature. The book then explores the topics of humans in HCI, computers in HCl, interaction fundamentals, interaction issues for diverse users, and interaction issues for special applications. The 37 chapters within these sections provide a comprehensive knowledge base that distinguishes this volume from others in its field. The following section, Application Domains, is another unique feature of this work. In this section, HCI principles are applied to 9 specialized domains. The final 13 chapters explore the state of the art in the development process and the management of HCI. The volume concludes with an exploration of the future of HCI.

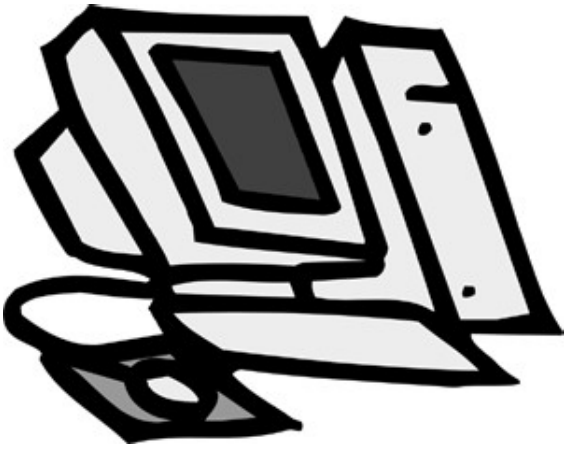
The editing of the Handbook was made possible with the very valuable assistance of Brynley Zorich, who so effectively coordinated the management of incoming contributions, reviews, and outgoing correspondence. It was truly a pleasure working with Gavriel Salvendy, Anne Duffy, and, more recently, Bill Webber, our brilliant editorial team whose insight and graceful facilitation was priceless to this effort.

Julie A. Jacko and Andrew Sears
May 2002



Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

HANDBOOK WEB SITE



Additional material related to this handbook can be found on the world wide web including:

- Electronic versions of all figures, including high-quality, color images where appropriate.
- An expanded index with additional keywords.

To view this, and other supplementary material, please visit:

www.isrc.umbc.edu/HCIHandbook


Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

ADVISORY BOARD

Hans-Jöerg Bullinger
Fraunhofer IAO
Germany

Stuart K. Card
User Interface Research Group
PARC
USA

John Carroll
Center for Human–Computer Interaction and Department of Computer Science
Virginia Tech
USA

Hidekazu Yoshikawa
Department of Socio-Environmental Energy Science, Graduate School of Energy Science
Kyoto University
Japan

John Karat
IBM T. J. Watson Research Center
USA

Waldemar Karwowski
Center for Industrial Ergonomics
University of Louisville
USA

Sara Kiesler
HCI Institute
Carnegie Mellon University
USA

Heidi Kroemker
Institute for Media Technology
Ilmenau Technical University
Germany

John Long
Department of Cognitive Engineering, Ergonomics and HCI Unit
University College London
UK

Arnold M. Lund
Sapient
USA

Aaron Marcus
Aaron Marcus and Associates, Inc.
USA

Thomas P. Moran
IBM Almaden Research Center
USA

Jakob Nielsen
Nielsen Norman Group
USA

Gary M. Olson
School of Information
The University of Michigan
USA

Judith S. Olson
School of Information
The University of Michigan
USA

Richard W. Pew
BBN Technologies
USA

Jenny Preece
Information Systems Department
UMBC
USA

George G. Robertson
Microsoft Research
USA

Michael J. Smith
Department of Industrial Engineering
University of Wisconsin—Madison
USA

Kay M. Stanney
Industrial Engineering & Management Systems
University of Central Florida
USA

Constantine Stephanidis
Department of Computer Science, University of Crete
Institute of Computer Science, Foundation for Research and Technology—Hellas
Greece

Tom Stewart
Systems Concepts
UK

Yvonne Waern
Department of Communication Studies
Linköping University
Sweden

ABOUT THE EDITORS

Julie A. Jacko is an Associate Professor of Industrial & Systems Engineering (ISyE) at the Georgia Institute of Technology and is the author or coauthor of over 70 research publications including journal articles, books, book chapters, and conference proceedings. Dr. Jacko's research activities focus on human–computer interaction, human aspects of computing, and universal access to electronic information technologies. Her research has been supported by the Intel Corporation, Microsoft Corporation, the National Science Foundation, and NASA. Dr. Jacko received a National Science Foundation CAREER Award for her research titled, "Universal Access to the Graphical User Interface: Design For The Partially Sighted." She is also a recipient of the National Science Foundation's Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honor bestowed on young scientists and engineers by the United States government. She is on the editorial board of the *International Journal of Human–Computer Interaction* and *Universal Access in the Information Society*. She served as Conference and Technical Program Cochair of the Association for Computing Machinery's Conference on Human Factors in Computing Systems (CHI 2001). She also served as Program Chair for the Fifth ACM SIGCAPH Conference on Assistive Technologies (ASSETS 2002). Dr. Jacko routinely consults for organizations and corporations on systems usability and human aspects of interactive systems design. She holds the B.S., M.S., and Ph.D. degrees in Industrial Engineering from Purdue University.

Andrew Sears is an Associate Professor and Chair of the Information Systems Department at UMBC. Dr. Sears' research explores issues related to human–computer interaction. His recent projects investigate issues associated with mobile computing, speech recognition, and the difficulties information technology users experience as a result of the environment in which they are working or the tasks in which they are engaged. His research projects have been supported by Aether Systems, Intel Corporation, Microsoft Corporation, Motorola, Platinum Technologies, NASA, and the National Science Foundation. Dr. Sears is the author or coauthor of over 70 research publications including journal articles, books, book chapters, and conference proceedings. He is on the editorial board of the *International Journal of Human–Computer Interaction* and *Universal Access in the Information Society*. He served as Conference and Technical Program Cochair of the Association for Computing Machinery's Conference on Human Factors in Computing Systems (CHI 2001), and has been on the program board for a variety of events including the Assets, ERCIM User Interfaces for All, HCII ad UAIS conferences and workshops. Dr. Sears routinely consults for organizations and corporations on issues related to interactive systems design and evaluation. He holds the B.S. degree in Computer Science from Rensselaer Polytechnic Institute and the Ph.D. degree in Computer Science with an emphasis on human–computer interaction from the University of Maryland–College Park.


Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

LIST OF CONTRIBUTORS

Norman Alm
Department of Applied Computing
University of Dundee
Scotland

Alisa Bandlow
College of Computing
Georgia Institute of Technology
USA

Michel Beaudouin-Lafon
Laboratoire de Recherche en Informatique
Université Paris–Sud/CNRS
France

Randolph G. Bias
Austin Usability
USA

Jeanette Blomberg
Department of Human Work Science
and Media Technology
Blekinge Institute of Technology
Sweden

Bridget C. Booske
University of Wisconsin—Madison
USA

Scott Brave
Department of Communication
Stanford University
USA

Stephen Brewster
Department of Computing Science
University of Glasgow
UK

Amy Bruckman
College of Computing
Georgia Institute of Technology
USA

Hans-Jörg Bullinger
Fraunhofer IAO
Germany

Mark Burrell
Sapient Corporation
USA

Michael D. Byrne
Department of Psychology
Rice University
USA

Pascale Carayon
Department of Industrial Engineering
University of Wisconsin—Madison
USA

Stuart K. Card
User Interface Research Group
PARC
USA

Alex Carmichael
Department of Psychology
Manchester University
UK

John M. Carroll
Center for Human–Computer Interaction
and Department of Computer Science
Virginia Tech
USA

Justine Cassell
MIT Media Lab
Massachusetts Institute of Technology
USA

Romeo Chua
School of Human Kinetics
University of British Columbia
Canada

Gilbert Cockton
School of Computing and Technology
University of Sunderland
UK

Thomas A. Cofino
IBM T. J. Watson Research Center
USA

William J. Cohen
Consultant
USA

Sara J. Czaja
Department of Psychiatry and Behavioral Sciences
University of Miami School of Medicine
USA

Mary Czerwinski
Microsoft Research
Microsoft Corporation
USA

Steve Diller
Cheskin
USA

Alan Dix
Computing Department
Lancaster University
UK

Joseph S. Dumas
Oracle Corporation
USA

Ashley G. Durham
Centers for Medicare and Medicaid Services
USA

Henry H. Emurian
Information Systems Department
UMBC
USA

B. J. Fogg
Stanford University
USA

Batya Friedman
The Information School
University of Washington
USA

Thomas Fuller
Microsoft Game Studios
Microsoft Corporation
USA

Norman D. Geddes
Applied Systems Intelligence, Inc.
USA

David Goodman
School of Kinesiology
Simon Fraser University
Canada

Paul Green
Transportation Research Institute, Human Factors Division
Industrial and Operations Engineering
and Mechanical Engineering
University of Michigan
USA

Peter Gregor
Department of Applied Computing
University of Dundee
Scotland

Greg Guest
Sapient Corporation
USA

Ken Hinckley
Microsoft Research
Microsoft Corporation
USA

Karen Holtzblatt
InContext Enterprises
USA

Hiroo Iwata
Institute of Engineering Mechanics and Systems
University of Tsukuba
Japan

Edmond Israelski
Abbott Laboratories
USA

Julie A. Jacko
School of Industrial and Systems Engineering
Georgia Institute of Technology
USA

Robert J. K. Jacob
Department of Electrical Engineering
and Computer Science
Tufts University
USA

Anthony Jameson
DFKI, German Research Center for Artificial Intelligence, and
International University in Germany
Germany

Peter H. Kahn, Jr.
Department of Psychology
University of Washington
USA

Clare-Marie Karat
IBM T. J. Watson Research Center
USA

John Karat
IBM T. J. Watson Research Center
USA

Waldemar Karwowski
Center for Industrial Ergonomics
University of Louisville
USA

Kevin Keeker
Microsoft Game Studios
Microsoft Corporation
USA

David Kieras
Electrical Engineering and Computer Science Department
University of Michigan
USA

Joseph Krajcik
Center for Highly Interactive Computing in Education
University of Michigan
USA

Joseph Kramer
IBM T. J. Watson Research Center
USA

Diane Maloney-Krichmar
UMBC
USA

Jennifer Lai
IBM T. J. Watson Research Center
USA

Darryn Lavery
Microsoft Corporation
USA

Jonathan Lazar
Department of Computer and Information Sciences
Towson University
USA

Chin Chin Lee
Department of Psychiatry
and Behavioral Sciences
University of Miami School of Medicine
USA

Jon Lenchner
IBM T. J. Watson Research Center
USA

Lynn Lin
Cheskin
USA

Holger Luczak
Institute of Industrial Engineering and Ergonomics
Aachen University of Technology
Germany

Arnold M. Lund
Sapient
USA

Wendy E. Mackay
Institut National de Recherche en Informatique
et en Automatique (INRIA)
France

Aaron Marcus
Aaron Marcus and Associates, Inc.
USA

Deborah J. Mayhew
Deborah J. Mayhew & Associates
USA

Brad Mehlenbacher
Department of English, and
Department of Psychology
North Carolina State University
USA

Maria del Carmen Puerta Melguizo
Department of Information Systems
and Software Engineering
Vrije Universiteit
The Netherlands

Michael J. Muller
IBM Research
USA

David Nahamoo
IBM T. J. Watson Research Center
USA

Clifford Nass
Department of Communications
Stanford University
USA

Alan F. Newell
Department of Applied Computing
University of Dundee
Scotland

Cathleen Norris
Department of Cognition and Technology
University of North Texas
USA

Sunil Noronha
IBM T. J. Watson Research
USA

Olaf Oehme
Institute of Industrial Engineering and Ergonomics
Aachen University of Technology
Germany

Gary M. Olson
School of Information
The University of Michigan
USA

Judith S. Olson
School of Information
The University of Michigan
USA

Sharon Oviatt
Department of Computer Science
Oregon Health and Science University
USA

Randy J. Pagulayan
Microsoft Game Studios
Microsoft Corporation
USA

Richard W. Pew
BBN Technologies
USA

Jenny Preece
Information Systems Department
UMBC
USA

Amy R. Pritchett
Schools of Industrial and Systems
Engineering and Aerospace Engineering
Georgia Institute of Technology
USA

Robert W. Proctor
Department of Psychological Sciences
Purdue University
USA

Chris Quintana
Center for Highly Interactive Computing in Education
University of Michigan
USA

Janice Redish
Redish & Associates, Inc.
USA

Matthias Roetting
Liberty Mutual Research Center
USA

Ramon L. Romero
Microsoft Game Studios
Microsoft Corporation
USA

Mary Beth Rosson
Center for Human–Computer Interaction
and Department of Computer Science
Virginia Tech
USA

François Sainfort
School of Industrial and Systems Engineering
Georgia Institute of Technology
USA

Gavriel Salvendy
School of Industrial Engineering,
Purdue University, USA, and
Department of Industrial Engineering,
Tsinghua University, China

Anthony Savidis
Institute of Computer Science,
Foundation for Research
and Technology—Hellas
Greece

Jesse Schell
VR Studio
Walt Disney Corporation
USA

Kevin M. Schofield
Microsoft Research
Microsoft Corporation
USA

Jean C. Scholtz
Visualization and Usability Group
National Institute of Standards and Technology
USA

Ingrid U. Scott
Bascom Palmer Eye Institute
University of Miami School of Medicine
USA

Andrew Sears
Interactive Systems Research Center
Information Systems Department
UMBC
USA

Bill Sharpe
The Appliance Studio
UK

Daniel P. Siewiorek
Human–Computer Interaction Institute
Carnegie Mellon University
USA

Asim Smailagic
Institute for Complex Engineered Systems,
College of Engineering
Carnegie Mellon University
USA

Michael J. Smith
Department of Industrial Engineering
University of Wisconsin—Madison
USA

Philip J. Smith
Institute for Ergonomics
Ohio State University
USA

Elliot Soloway
Center for Highly Interactive
Computing in Education
University of Michigan
USA

Neville A. Stanton
Department of Design
Brunel University
UK

Kay M. Stanney
Industrial Engineering & Management Systems
University of Central Florida
USA

Phil Stenton
Hewlett-Packard Laboratories
UK

Constantine Stephanidis
Department of Computer Science,
University of Crete
Institute of Computer Science, Foundation
for Research and Technology—Hellas
Greece

Tom Stewart
Systems Concepts
UK

Alistair Sutcliffe
Department of Computation
UMIST
UK

Vania Tashjian
Cheskin
USA

David Travis
Systems Concepts
UK

Dilip Upmanyu
IBM
USA

Gregg Vanderheiden
Trace Research & Development Center
Departments of Industrial Engineering
and BioMedical Engineering
University of Wisconsin—Madison
USA

Gerrit C. van der Veer
Department of Information Systems
and Software Engineering
Vrije Universiteit
The Netherlands

John Vergo
IBM T. J. Watson Research Center
USA

Holly S. Vitense
Department of Industrial Engineering
University of Wisconsin—Madison
USA

Kim-Phuong L. Vu
Department of Psychological Sciences
Purdue University
USA

Suzanne Watzman
Watzman Information Design
USA

Daniel J. Weeks
Department of Psychology
Simon Fraser University
Canada

Dennis Wixon
Microsoft Game Studios
Microsoft Corporation
USA

Alan Woolrych
School of Computing
and Technology
University of Sunderland
UK

Nicole Yankelovich
Sun Microsystems
USA

Hidekazu Yoshikawa
Department of Socio-Environmental Energy Science,
Graduate School of Energy Science
Kyoto University
Japan

Mark A. Young
The Maryland Rehabilitation Center &
Workforce Technology Center
State of Maryland and Department of Education
USA

Jürgen Ziegler
Fraunhofer IAO
Germany

THE HUMAN–COMPUTER INTERACTION HANDBOOK


Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Introduction

EVOLUTION OF HUMAN–COMPUTER INTERACTION: FROM MEMEX TO BLUETOOTH AND BEYOND

Richard W. *Pew*
BBN *Technologies*

If your cursor finds a menu item followed by a dash,
and the double-clicking icon puts your window in the trash,
and your data is corrupted cause the index doesn't hash,
then your situation's hopeless and your system's gonna crash!
—Author Unknown

Preamble **2**
1966 and Before **2**
State-of-the-Art 2
Vannevar Bush 3
J. C. R. Licklider 3
Douglas Englebart 4
Ted Nelson 5
Ivan Sutherland 5
1967–1977 ..... **5**
State-of-the-Art 5
Human–Computer Interaction and Screen Design 6
Interactive Programming 6
Human Factors Engineering 6
Alan Kay and the Palo Alto Research Center Nexus 7
Information Processing Theory, GOMS, and Verbal Protocols 7
Human Sciences and Advanced Technology Centre and the British Community 8
Design Guidelines and Style Guides 8
Final 1970s Developments 9
1978–1988 ..... **9**
State-of-the-Art 9
Iterative System Development 9
Interface Builders 10
Donald A. Norman 10
Human–Computer Interaction as a Professional Field 10
Usability Testing 11
Naturalistic Observation and Ethnography 11
1989–1999 ..... **11**
State-of-the-Art 11
Web Usability 12
Speech Technology 12
Cost-Justifying Usability 12
Continued Professional Development 12
Computer-Supported Cooperative Work 13
1999 and Beyond **13**
State-of-the-Art 13
Human–Computer Interaction Challenges and Ubiquitous Computing 14
New Methodologies 14
The Last Word 15
Acknowledgments **15**
References **15**

PREAMBLE

The editors decided to begin this handbook with a "history" chapter, not because we all like to read history, but because researchers and practitioners can benefit from a chance to step back from the bits and bites of the moment to reflect on the many different ways in which contributions have been and will continue to be made. Successful innovation is not so much the result of lucky guesses as it is understanding the need and the context of what is possible . . . so thoroughly that a solution seems obvious.

Some readers will have seen the anonymous e-mail that begins, "If an unnamed [automobile company] had developed technology like unnamed [software vendors], we would all be driving cars with the following characteristics":

1. Occasionally, your car would die on the freeway unexpectedly, and you would just accept this, restart and drive on.
2. The oil, water temperature, and alternator warning lights would be replaced by a single "general car default" warning light.
3. Occasionally, your car would lock you out and refuse to let you in until you simultaneously lifted the door handle, turned the key, and grabbed hold of the radio antenna.
4. Every time [automobile company] introduced a new model, car buyers would have to learn to drive all over again because none of the controls would operate in the same manner as the old car.
5. Etc.

We find these and many other similar net-icisms funny because on the one hand, they are absurd but on the other, they contain more than a grain of truth. It is the thesis of this chapter that, although we have made amazing progress—this handbook as a whole provides ample evidence of the progress we have made—in fact, our visions continue to outstrip our capacity to deliver, and our technology continues to evolve so rapidly that the symphony of well-orchestrated hardware and software in seamless support of the user's requirements seems to remain just out of reach. As Landauer (1995) so skillfully demonstrated, although computers are supposed to help us *solve* problems, in too many instances their interfaces still *are* the problem.

It is difficult to draw boundaries between the history of computers and the history of human–computer interaction (HCI). The history of computers and software has set the context in which the field of HCI has emerged. With this perspective in mind, this chapter will seek to provide a sense of context for the field as it exists today, in 2001; introduce a collection of remarkable and significant visionary developments; provide references to the seminal work in the field, with perhaps a little nostalgia thrown in; and, because the author does not consider himself a visionary, provide some modest hints at directions for the future. There is not space to do justice to all these topics. For those who would like more complete coverage of the history of HCI than is possible here, fortunately there are a number of other reviews of the historical developments to which the reader may refer, such as Association for Computing Machinery (1986), Baecker and Buxton (1987), Baecker, Grudin, Buxton, and Greenberg (1995), Carroll (1997), Gaines and Shaw (1986), Myers (1998), Myers, Hollan, and Cruz (1996), Nickerson and Landauer (1997), Rheingold (2000), and Shackel (1997, 2000).

No better way to organize this material than chronologically has emerged. The sections that follow will break the discourse into reasonably coherent epochs and for each epoch to consider:

- The visions that emerged
- The dominant hardware and software technology
- The important research and/or design methodologies
- The significant application innovations.

1966 AND BEFORE

State-of-the-Art

Throughout the history of HCI there has been a need to distinguish the interface requirements for programmers from those for users. In the period before 1963 or so, there were a great many constraints. Programmers entered programs by keyboard or prepared punched cards on special machines; to review and understand their programs, they read printouts produced on line printers. The human factors issues for programmers were how to format the printouts of their programs so they were easy to read and debug, because the only feedback from running a batch job was in the form of a rejected batch of cards and/or a printout of their program with one or more abstruse error messages. Initial submissions usually had formatting errors, because the formats were inexorably fixed and the program would not execute with even one such error. It often took several submissions to get to the point were the first substantive error was flagged, at which point the execution hung, and further correction and job resubmission were required to find the next bug.[1] Woe-be-unto the programmer who accidentally dropped a deck of cards and had to reorder them before the next submittal.

The human factors issues for the users were how to prepare program printouts in a form that they could be read and interpreted easily, especially given the constraint of line printers that could only present alphanumeric characters in a single, often difficult-to-read font with 80-character lines and limited formatting capabilities. The specification of how they were to appear was a problem for the programmers, of course. In the case of scientific computing, programmers and users were most often the same individuals; but, for accounting departments, communication between users and programmers was even rarer than it is today. In 1971, Gerald Weinberg published the first book documenting the problems of programmers and users, and describing the research under way to solve them. It took a strongly user-oriented perspective (Weinberg, 1971).

[1]Grace Murray Hopper (1906–1992) is credited with coining the term, "bug," when she discovered an error in the Harvard Mark II output was attributable to a moth that had infiltrated a set of relay contacts in the computer (Dickason, 2001).