Second Edition

HUMAN FACTORS ENGINEERING AND ERGONOMICS

A Systems Approach

Stephen J. Guastello

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Preface

This textbook is the outgrowth of teaching human factors engineering for 30 years to undergraduates. The course is an offering of the psychology department, just as it was decades ago when I was a student myself. The field of human factors psychology (or human factors engineering, or engineering psychology) has changed markedly during that time. Although it still stays true to its original concerns about the person–machine interface, it has expanded to include new developments in stress research, accident analysis and prevention, and nonlinear dynamic systems theory (how systems change over time), and some aspects of human group dynamics and environmental psychology. Computer technology has permeated every aspect of the human–machine system, and has only become more ubiquitous since the previous edition. The systems are becoming more complex, thus theories need to evolve to cope with the new sources of complexity.

It has been a challenge to find a textbook for the class under these conditions of technological change. At first, I found one that seemed just perfect with regard to the breadth and depth of coverage I was looking for. After a few years it only needed a supplementary reading or two to help out, but eventually it went out of print, never to return. The other textbook choices by that time had diverged greatly in how they characterized the scope of the field. One approach concentrated on tables and graphs for otherwise traditional topics. A second approach retrenched into the theories of cognitive psychology and focused less on the practical problems in human factors. Meanwhile, library shelves were filling up with books on human–computer interaction that were becoming progressively more dissociated from the core concepts of the human–machine interface. The fast pace of technological change did not help any textbook writer who had a mind to identify and extract the fundamental principles of the subject area.

In any case, I hereby present to you the new scope of the psychology of human–machine interaction. The typical roomful of students that I have in mind is usually composed of upper division students and a few graduate students. The class is typically composed of 60% engineering students of different sorts, 35% psychology students, and 5% sundry others. One implicit goal of the course is for the engineers to think more like psychologists, and the psychologists to think more like engineers. The sundry others usually show signs of thinking like both, and make the class situation more interesting for everyone.

I would like to take this opportunity to thank Joseph J. Jacobsen for helping to arrange some of the photographic opportunities that appear throughout this book.

New to This Edition

There are several new developments in this second edition, some of which span multiple chapters. Some of the more extensive areas of expansion include the following.

In earlier times, the allocation of functions between person and machine was a fairly straightforward separation of labor. Augmented cognition and automation are blurring this distinction, and the current thinking is that machines can adapt their functions when they detect that the operator is under stress. How does the machine make that determination? Is part of the stress related to the human not trusting the machine? The issues are first addressed in Chapter 2, but become more complex as the book unfolds.

The role of nonlinear dynamics in person–machine systems has grown as interest in how systems change over time has increased. The newest developments involve events that synchronize or emerge suddenly, apparently out of nowhere. The basic principles that are relevant to human factors have been expanded in Chapter 2, with specific applications to stress and human performance, occupational accidents and prevention, and complex systems in later chapters.

The design of visual displays has always been a staple topic in human factors. The latest innovations draw on evolving principles of iconography and synthetic vision systems. Although it was tempting to include them in the chapter on visual displays, they appear in the chapter on human–computer interaction where they build on some intervening material.

The chapter on cognition has changed substantially in light of developments that have consolidated in several theoretical areas. Look for resource competition theory, recognition-primed decision making, working memory, degrees of freedom in cognitive processes and psychomotor control, dynamic decisions, task switching and interruptions, subjective ratings of cognitive workload, and situation awareness. Navigation in real-world environments is also new to the chapter on environments.

New directions in psychomotor control are combining system control with the understanding of neural mechanisms that produce the behaviors. The practical objectives often surface in robotic components and designs for prostheses that can be controlled by human thought the way normal limbs are controlled.

There is a growing concern in society about cognitive workload and fatigue as more people find that they have too much to do, not enough time to do it in, and automation, which they do not necessarily trust, is making their work more mentally intensive. Long working hours can be hazardous. The effects of cognitive workload and fatigue have been historically difficult to separate because they both produce negative effects on performance over time, while other processes that transpire over time serve to improve performance. It is now possible to separate these effects with nonlinear models and experimental designs that capture all the ingredients of the models. Whereas systems have been traditionally designed to minimize the role of individual differences in cognition and personality, and with good reason, individual differences in cognitive responses to systems are now gaining importance.

New developments in accident analysis and prevention consist of a better understanding of the social context in which safety and risk occur. There has also been a recent shift in orientation from explaining *what happened* to a proactive orientation to anticipating *what could occur.* This is the principle of system resilience that takes on a few different forms and

is informed by nonlinear dynamics and complex systems theory. Another distinctive feature of the accident chapter is that the catalog of interventions for occupational safety has been updated. Once again, a comprehensive ergonomics approach to intervention offers some of the largest improvements in accident reduction.

Artificial intelligence was once the label given to computer programs that emulated human thought processes. The programs have now expanded to include knowledge discovery that is more independent of human control than ever before and to manage and manipulate huge databases that never used to exist. It is left to the reader to ponder whether we are reaching a turning point where the machines will control humans more so than the other way around.

Complex systems applications in human factors and ergonomics are becoming more common. The broadest new developments here include network theory, human collective intelligence, and how to control your very own fleet of robots or drone surveillance aircraft. The chapter also considers scenarios in which multiple integrated autonomous systems can go out of control.

Author

Stephen J. Guastello is a professor of psychology at Marquette University, Milwaukee, Wisconsin, where he specializes in human factors engineering and organizational behavior. He was a pioneer in the applications of nonlinear dynamic systems theory to psychology and in the development of statistical analyses for behavioral science data. He is currently researching nonlinear processes in cognitive workload and fatigue and sees human factors and ergonomics as ripe with new possibilities for complex systems analyses. Professor Guastello earned his PhD in industrial/organizational psychology from the Illinois Institute of Technology and BA degree in psychology from the Johns Hopkins University.

Some of his more extensive consultancies include human–computer interaction and expert systems for power plants and other applications, accident analysis and prevention, and the usability of prostheses. He has authored two previous books, *Chaos, Catastrophe, and Human Affairs* (1995, Erlbaum/Taylor & Francis) and *Managing Emergent Phenomena* (2002, Erlbaum/Taylor & Francis), and coedited *Chaos and Complexity in Psychology: The Theory of Nonlinear Dynamical Systems* (with M. Koopmans and D. Pincus, 2009, Cambridge University Press) and *Nonlinear Dynamical Systems Analysis for the Behavioral Sciences Using Real Data* (with R. Gregson, 2011, CRC Press). He is the founding editor-in-chief of the quarterly research journal, *Nonlinear Dynamics, Psychology, and Life Sciences*, published by the Society for Chaos Theory in Psychology & Life Sciences.

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