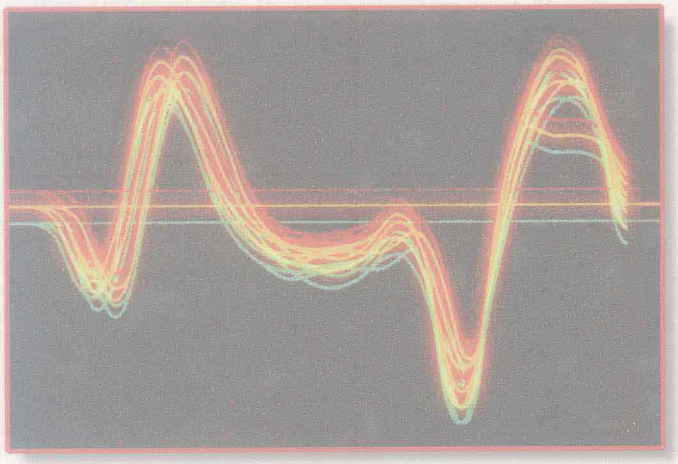
THIRD EDITION

MOTOR CONTROL AND LEARNING

A Behavioral Emphasis



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THIRD EDITION

MOTOR CONTROL AND LEARNING

A Behavioral Emphasis

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PREFACE

Most of us have marveled at one time or another about how highly skilled performers in industry, sport, music, or dance seem to make their actions appear so simple and easy, performed with incredible efficiency, smoothness, style, and grace. Like the first two editions (Schmidt 1982, 1988), this edition of *Motor Control and Learning: A Behavioral Emphasis* was written for those who would like to understand how it is that these performers can achieve such artistry while we, as beginners in a similar task, are clumsy, inept, and unskilled. This book was written particularly as a textbook for university or college undergraduate and graduate students taking courses in human performance or motor learning, primarily in fields such as kinesiology, psychology, or physical education. Students in other fields such as the neurosciences, physical and occupational therapy, biomedical or industrial engineering, and human factors (ergonomics) should also find the concepts contained here to be of interest, as movement behavior is a part of all of them. And for those who are (or are becoming) practitioners in these fields, the principles of motor behavior outlined here should provide a solid basis for tasks such as designing human-machine systems, developing training programs in sport or industry, or teaching progressions in dance or music.

The emphasis of the text is behavioral. That is, the primary focus is on movement behaviors that can be observed directly and on the many factors that affect the quality of these performances and the ease with which they can be learned. In this sense, the book has strong ties to the methods and thinking of experimental psychology. Yet, at the same time, the book focuses on the neurological and mechanical processes out of which these complex movement behaviors are crafted. Brain mechanisms that allow the detection of errors, spinal cord processes that are capable of generating patterns of skilled activities in locomotion, and various biomechanical constraints that act to determine the nature of our movement behaviors are all important if we are to understand high-skilled performance. This blending of behavioral, neurophysiological, and biomechanical analysis reflects the fact that the fields of motor behavior and motor learning, movement neurophysiology (or motor control), and biomechanics are rapidly moving together toward the shared understanding of complex movement behaviors.

This edition of the text retains the same goal of presenting an up-to-date review of the state of knowledge in movement control and learning, and it does so with a format that is similar to that of the previous editions. We have directed considerable effort toward including the most recent knowledge from a number of rapidly developing subfields, and each of the chapters has been revised extensively in light of these newer concepts. In addition to including more than 450 references to work published since the last edition, we have also strived to pay homage to some of the important early research developments in the various areas, and many of these are highlighted in sidebars throughout the book.

Some chapters from the previous edition have been reduced, combined with other chapters, or otherwise shortened in order to reduce complexities in the text without sacrificing its in-depth coverage or the richness of its concepts. And we have expanded certain chapters and sections to present new, exciting areas of research that have emerged since the previous edition. Perhaps this is evident most prominently with the addition of

a new chapter on coordination (chapter 8)—reflecting the growth of a topic area that was given only a few pages of discussion 10 years ago.

Many new practical examples from areas such as human factors, sport, therapy, and music illustrate these concepts and contain concrete suggestions for practical application. As before, the revised text reflects a logical progression, so that later chapters build upon concepts presented in earlier chapters, with the final result being a consistent, defensible framework of ideas about skills. Having such a framework, or point of view, is important for those who wish to use the information presented here, both so that contributions to new applications may be made and so that the design of continued skills research is aided.

The book is divided into three parts. Part I provides an introduction to research and fundamental concepts that are important to understanding motor behavior. The first chapter, a brief history of the field, is followed by a presentation of methods in movement research in chapter 2, focusing on various paradigms and statistical techniques used in the study of movement behavior. In chapter 3 the human is regarded as a processor of information, and we focus on the many ways that information is dealt with in motor behavior. The concept of attention is the focus of chapter 4, with particular emphasis on the role of attention in motor behavior.

Part II deals with motor control. Chapter 5 views motor control from a closed-loop perspective, in which the sensory contributions to movement control are examined, with particular emphasis on new research regarding the role of vision. In chapter 6, the focus shifts to contributions of the central nervous system to movement control, with emphasis on motor programs and the generalized motor program. Some principles of "simple" motor behavior are presented in chapter 7, together with a discussion of theoretical concepts that integrate the central and sensory contributions to movement control. Chapter 8 presents a discussion of the factors involved in movement control that make coordination both easy and difficult to achieve. The final chapter in this part includes a discussion of factors that determine skill differences among people, with emphasis on important themes about abilities and the prediction of skills.

Part III deals with the acquisition of skill, or motor learning. Chapter 10 concentrates on some special methodological problems for studying learning. The effects of practice, the structure of the practice session, and the many variables under the control of a teacher, coach, or therapist are discussed in chapter 11, while feedback contributions to learning are included in chapter 12. In both of these chapters, much new information is covered that demands important changes in our understanding of the processes involved in practice and the ways in which these impact on learning. Various theoretical treatments of motor learning are presented in chapter 13. And finally, chapter 14 deals with the factors associated with the retention and transfer of skills.

Throughout the long process of this revision there were a number of people who provided very highly valued input. Judy Wright, Marni Basic, and Rick Frey of Human Kinetics provided considerable feedback and encouragement for this major revision. Andrea Swanson helped with the references and the author index, and Erin Lanktree translated the sections that appear in the boxed text on page 217. And we called upon a number of colleagues to read and critique certain chapters. The many suggestions made by the following people were invaluable in making the necessary revisions: Jack Adams, Romeo Chua, Digby Elliott, Nikki Hodges, Jim Lyons, Matt Heath, Jason Murdoch, Jen Richardson, Stephan Swinnen, Seijiro Tsutsui, Chuck Walter, and Laurie Wishart. The final manuscript is much better as a result of all their efforts, and we are grateful.

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CONTENTS

PART 1

INTRODUCTION TO MOTOR BEHAVIOR

This first part introduces the field of motor control and learning. In chapter 1 the area is described, and the important distinctions separating motor control and learning from other, related fields of study are made. Then, a brief history of the field is given, showing how knowledge about movements from psychology and physical education, as well as from the neurosciences, has recently been combined. The second chapter deals with the various scientific methods used for studying motor skills. Here, we explain the tools of motor behavior research, focusing on the various ways in which motor behavior can be measured. Chapter 3 presents the information-processing approach, which is fundamental to understanding how humans think and act. The last chapter in this section describes how attention influences motor behavior.