CRC

QUANTITATIVE EXAMINATION *of* NEUROLOGIC FUNCTIONS

Volume II

Alfred R. Potvin
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CRC PRESS

Quantitative Examination of Neurologic Functions

Volume II: Methodology for Test and Patient Assessments and Design of a Computer-Automated System

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CRC Press, Inc.
Boca Raton, Florida

Library of Congress Cataloging in Publication Data

Potvin, Alfred R.
Quantitative examination of neurologic functions.

Bibliography: p.
Includes index.
Contents: v. 1. Scientific basis and design of instrumented tests — v. 2. Methodology for test and patient assessments and design of a computer-automated system.
1. Neurologic examination. 2. Neurologic examination—Data processing. I. Tourtellotte, Wallace W. II. Title. [DNLM: 1. Neurologic examination—Methods. 2. Computers. WL 141 B871q]
RC348.P68 1985 616.8'0475 84-3152

ISBN 0-8493-5926-0 (v. 1)
ISBN 0-8493-5927-9 (v. 2)

Direct all inquiries to CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida, 33431.

International Standard Book Number 0-8493-5926-0 (Volume 1)
International Standard Book Number 0-8493-5927-9 (Volume II)

Library of Congress Card Number 84-3152
Printed in United States

FOREWORD

The classic, or standard, neurologic examination gives essential information enabling the clinician to diagnose and localize a neurologic lesion, identify its pathologic nature, estimate its prognosis, and institute a therapeutic regime. It does not, however, measure objectively the degree of the patient's neurologic impairment. Doctors Potvin and Tourtellotte have long been interested in techniques to evaluate objectively and accurately such impairment and establish criteria that can be used to assess the course of spontaneous improvement or worsening and the clinical changes that follow or accompany responses to trials of therapeutic regimens. This book summarizes their many years of study of this problem in which they personally investigated quantitative techniques for evaluating neurologic functions in patients with a wide variety of neurologic diseases and impairments. It includes an encyclopedic survey of multiple methods of appraising neurologic functions, including instrumented evaluation of such functions, and concludes with a description of a computer-automated neurofunction laboratory.

Quantitative neurologic testing is a tedious and time-consuming technique, but is of utmost value under many circumstances, especially in evaluating the effectiveness of newly described therapeutic approaches. This book foretells advances in neurologic appraisal which may drastically alter future examination procedures.

Russell D. DeJong, M.D.
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PREFACE

In this book, the term quantitative examination of neurologic functions implies the use of instrumented devices or ordinal scale ratings to evaluate such functions as strength, reactions, steadiness, sensations, speed and coordination, stance, gait, range of motion, and activities of daily living. Tests of neurologic functions have been in development for over 100 years, with investigators from many scientific disciplines using several approaches. Some have purchased available tests or designed prototypes without considering the existing literature. Others have searched the multidisciplinary literature to identify the best available tests and have used or modified them or designed new tests suitable for a clinical setting. Still others have devoted extensive efforts to developing ultrasensitive multipurpose instrumented devices using the latest technology, and when successful, have modified the instrumentation for clinical use.

Although the field of quantification of functions includes numerous equivocal studies, a good number of sound investigations have also been done, and several dozen research laboratories have been used to evaluate the functions of patients routinely for a decade or more. These studies have provided convincing evidence that quantitative techniques can reliably document the functions of normal individuals and patients with a variety of sensory and motor disorders when proper tests, procedures, and measures are used.

Today, hardwired devices and mini- and microcomputer systems to evaluate neurologic functions exist in hundreds of clinical and research settings. Increasingly, pharmaceutical and medical device companies and government agencies are urging investigators to obtain sensitive, objective analysis of changes in functions with therapy or assistive devices. The number of clinical trials has increased dramatically, as has the published literature. Although the use of quantitative examinations is not yet a standard procedure, quantitative techniques are becoming an important and accepted method for evaluating clinical trials. With the present availability of low cost commercial mini- and microcomputers for evoked potentials, electroencephalography, and electroneuromyography, standardized comprehensive sensory and motor function assessments may also become a reality, simplifying current evaluation techniques and eliminating or minimizing less precise procedures. With continued progress, a clinician may soon be able to refer a patient to a Neurofunction Laboratory for evaluation much like he or she now refers a patient to the pulmonary function, cardiac stress, or evoked potential laboratory.

For over two decades, we have drawn upon the resources and experience of our colleagues in neurology, psychology, biomedical engineering, biostatistics, physical and occupational therapy, and surgery to develop approximately 100 tests of neurologic functions. The large number of available tests has allowed us to carry out both in-depth and wide-range studies by selecting tests and procedures to explore specific disorders and treatments. Our general approach has been to identify from a vast literature the available instruments, methods, and procedures; to replicate or modify existing tests, and to develop new tests; to evaluate the tests, as well as adult normal individuals and patients with disease or injury; to use the tests to assess clinical trials; and to make our findings available to others.

We undertook the writing of this first work on quantitative functional assessment because there is no comprehensive sourcebook for the design, development, evaluation, and clinical application of sensory and motor or perceptual-motor tests to which researchers can turn. In addition, there are few literature reviews on quantitative functional assessments that span the involved disciplines, leaving investigators in one discipline largely unaware of developments in other disciplines.

Our two volumes are intended to organize and synthesize many segments of the vast literature, to relate developments in the varied disciplines, to place in perspective the role of quantitative functional assessment, and to describe quantitative test batteries applicable for clinical use. We focus on the basic design, development, evaluation, and use of tests, providing sufficient detail for an engineer to replicate devices and for a medical technician to administer tests. We place less emphasis on neurophysiologic and other theories and mathematical and statistical methods, but direct investigators to appropriate references. Thus, the volumes may serve as introductory guides for neurologists, rehabilitationists, gerontologists, pharmacologists, toxicologists, psychologists, psychiatrists, psychotherapists, industrial and human factors engineers, and personnel managers, in addition to biomedical engineers who design devices, and biostatisticians who design and analyze studies to evaluate tests and clinical trials.

The two volumes each have two parts. Part I of the first volume provides an introduction to concepts associated with quantitative measurement of functions, the basis for test development, and a review of multidisciplinary efforts to develop and evaluate coded and instrumented tests of functions in normal individuals and patients. The second part of Volume I details our early development of individual sensory and motor tests. The instrumented tests are related to corresponding assessments in the classic neurologic examination and to coded derivatives of the neurologic examination (i.e., ordinal rating scale systems).

Part I of the second volume describes results of our studies to evaluate tests and administrative procedures in a manner that illustrates the importance of experimental evaluations for improving tests and that provides a guide for others. Data management and presentation techniques applicable for carrying out clinical trials are also described. Comparative data from many studies using an instrumented examination of neurologic functions in clinical trials are presented to illustrate the unique contributions of evaluation with instrumented tests. Part II of the second volume presents a review of our recent work in developing and evaluating a computer-automated system of neurologic function tests that greatly simplifies data management and analysis. In addition, we present the current status of quantitative examinations of neurologic functions, provide information for obtaining commercial devices, and give our perspective of future developments.

Some may say that evaluation of neurologic functions is not widely done in medical centers and clinics in the way that we describe it—that many of the techniques and ideas discussed and recommended are not widely used. Our justification, if one is needed, is that these books are written as a forward-looking effort. We describe tests and procedures that we believe should be more widely adopted.

We hope that our volumes will stimulate advancements in the field, not simply record past practice, and that with this sourcebook in hand, serious clinical investigators may start to design, implement, and evaluate quantitative functional test systems from a base of common knowledge. We are convinced that the field of quantification of neurologic functions is one where answers do make a difference and substantive data will quickly be put to use. We hope that our efforts will encourage others to join this work.

It would have been impossible to accomplish this work without the assistance and support of many of our colleagues and we wish to thank those named below and the many others with whom we have interacted over the years. We wish especially to express our gratitude to Glenn V. Edmonson, Russell N. DeJong, and Richard W. Pew, who created the environment at The University of Michigan that initially brought us together in this work: to Janet H. Potvin, George V. Kondraske, and Karl Syndulko, who persuaded us to write the book, offered perceptive suggestions and continued encouragement, and critically reviewed the multiple drafts; to James W. Albers, Christopher Balthrop, Robert W. Baumhefner, William G. Crosier, John A. Doerr, Edward Domino, Jon Estes, William G. Henderson,

Tho Huyhn, George V. Kondraske, Richard W. Pew, Jan Kuzma, John Lemburg, James Porter, Janet H. Potvin, Brian S. Repa, Joseph G. Salamy, Dorothy N. Snyder, Karl Syndulko, Gregory V. Stett, Richard F. Stribley, Jonathan E. Walker, George Wan, and Hiroshi Yoshida, our research colleagues who made numerous creative contributions to this work; to James W. Albers, Malcolm Stewart, and Richard Tindall, our manuscript reviewers, who provided valuable suggestions and critical commentary; to the publishers and copyright holders cited in the legends of selected tables and figures, who kindly permitted us to reproduce material; and finally, to all those who assisted with typing, preparation and proofreading of multiple drafts of the manuscript: Diane Guntrip, Diane Varnas, and the Neurology Service staff at VAMC Wadsworth, Brenda Perry and the staff and students in the Biomedical Engineering Program at The University of Texas at Arlington, and the staff of our National Institute of Handicapped Research Rehabilitation Engineering Center for Quantification of Sensory and Motor Function.

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July 4, 1983

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"When you cannot measure it,
When you cannot express it in numbers,
You have scarcely, in your thoughts,
Advanced to the stage of science,
Whatever the matter may be."

Lord Kelvin

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Part I

EVALUATION AND CLINICAL STUDIES

I. OVERVIEW

In the second part of Volume I (Chapters 5 through 9), we described in detail our large battery of tests to assess neurologic functions. Tests in the Neurofunction Laboratory include a comprehensive coded examination of neurologic functions (ordinal rating scales), an instrumented neuropsychologic examination, an instrumented examination of sensory and motor functions, and an instrumented activities-of-daily-living examination, along with electrophysiologic and clinical laboratory tests. In Part I of this volume, we present a review of our evaluation studies. Evaluations include test-retest reliability, variability of test measures, validity, repeated testing or learning, gender, lateral dominance, age, and motivation. We not only indicate the tests that successfully passed evaluation studies, but we also focus on tests that *a priori* appeared useful in a clinical environment but, after objective evaluation, were found to be unsatisfactory. When possible, we explain why the test was unsatisfactory, indicate improvements made, and report results of subsequent evaluations. In this way, we attempt to provide the investigator with a repository of ideas for designing and improving tests, procedures, and test evaluations.