Rethinking physical and rehabilitation medicine
Jean-Pierre Didier  
Emmanuel Bigand

Rethinking physical and rehabilitation medicine

New technologies induce new learning strategies

Springer
Members of the European Academy of Rehabilitation Medicine

Pr ALARANNTA Hannu
Helsinki (Finlande)
Pr ANDRE Jean-Marie
Nancy (France)
Pr BARAT Michel
Bordeaux (France)
Pr BARDOT André
Marseille (France)
Pr BARNES M. Ph.
Newcastle upon Tyne (Grande-Bretagne)
Pr BERTOLINI Carlo
Rome (Italie)
Pr CHAMBERLAIN M. Anne
Leeds (Grande-Bretagne)
Pr CHANTRAINE Alex
Genève (Suisse)
Pr CONRADI Eberhard
Berlin (Allemagne)
Pr DELARQUE Alain
Marseille (France)
Pr DELBRÜCK Hermann
Wuppertal (Allemagne)
Pr DIDIER Jean-Pierre
Dijon (France)
Pr EKHOLM Jan
Stockholm (Suède)
Dr EL MASRY Wagih
Oswestry Shropshire (Grande-Bretagne)
Pr EYSSETTE Michel
Saint Genis-Laval (France)
Pr FIALKA-MOSER Veronika
Vienne (Autriche)
Pr FRANCHIGNONI Franco
Veruno (Italie)
Pr Garcia-Alsina Joan
Barcelona (Espagne)
Pr GATCHEVA Jordanka
Sofia (Bulgarie)
Pr GOBELET Charles
Sion (Suisse)
Pr HEILPORN André
Bruxelles (Belgique)
Pr LANKHORST Gustaaf J.
Amsterdam (Pays-Bas)
Dr MAIGNE Robert
Paris (France)
Pr MARINCEK Curt
Ljubljana (Slovenia)
Pr McLELLAN Lindsay
Hampshire (Grande-Bretagne)
Dr McNAMARA Angela
Dublin (Irlande)
Pr MEGNA Gianfranco
Bari (Italie)
Pr MICHAEL Xanthi
Athènes (Grèce)
Dr OELZE Fritz
Hamburg (Allemagne)
Pr RODRIGUEZ Luis-Pablo
Madrid (Espagne)
Pr SJÖLUND Bengt H.
Umea (Suède)
Pr STAM Hendrik Jan
Rotterdam (Pays-Bas)
Pr STUCKI Gerold
Munic (Germany)
Pr TONAZZI Amadeo
Saint-Raphaël (France)
Pr VANDERSTRAETEN Guy
Gent (Belgique)
Dr WARD Anthony
Stoke on Trent (Grande-Bretagne)
Dr ZÄCH Guido A.
Nottwil (Suisse)
Christophe AVENA
Service d’anesthésie-réanimation
CHU de Dijon
Hôpital Général
3, rue du Faubourg-Raines
BP 1519
21033 Dijon Cedex
France

Michel BARAT
Équipe d’accueil 4136 – Handicap et système Nerveux
Université Victor Segalen Bordeaux II
Service de médecine physique et réadaptation
CHU de Bordeaux
Hôpital Pellegrin
Place Amélie-Raba-Léon
33076 Bordeaux Cedex
France

Emmanuel BIGAND
Institut universitaire de France
Université de Bourgogne
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Elodie BONNETAIN
LEAD UMR 5022 CNRS
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Jean-Michel BOUCHEIX
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Patrick DEHAIL
Équipe d’accueil 4136 – Handicap et système Nerveux
Université Victor Segalen Bordeaux II
Service de médecine physique et réadaptation
CHU de Bordeaux
Hôpital Pellegrin
Place Amélie Raba-Léon
33076 Bordeaux Cedex
France

Charles DELBÉ
Institut universitaire de France
Université de Bourgogne
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Jean-Pierre DIDIER
Professeur émérite de médecine physique et de réadaptation
Université de Bourgogne
Pôle de rééducation-réadaptation
23, rue Gaffarel
BP 77908
21034 Dijon Cedex
France

Marc FREYSZ
Service d’anesthésie-réanimation
CHU de Dijon
Hôpital Général
3, rue du Faubourg-Raines
BP 1519
21033 Dijon Cedex
France

Rémi GOASDOUÉ
Éducation et apprentissages, EA 4071
Université Paris-Descartes
45, rue des Saints-Pères
75006 Paris
France

Pierre-Alain JOSEPH
Équipe d’accueil 4136 – Handicap et système Nerveux
Université Victor Segalen Bordeaux II
Service de médecine physique et réadaptation
Rethinking physical and rehabilitation medicine
Agnès ROBY-BRAMI
Laboratoire Neurophysique et Physiologie
Université Paris-Descartes
CNRS UMR 8119
45, rue des Saints-Pères
75006 Paris
France

Service de médecine physique et réadaptation
Hôpital Raymond-Poincaré
104, boulevard Raymond-Poincaré
92380 Garches
France

Françoise ROCHEAU
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Virginie SAUÔT MD
Service de médecine physique et de réadaptation
C3RF
Rue des Capucins
BP 2449
49024 Angers Cedex 02
France

Faculté de médecine
Université d’Angers
1, rue Haute-de-Reculée
49045 Angers Cedex 01
France

Gerold STUCKI
Department of Health Sciences and Health Policy
University of Lucerne
Lucerne and SPF
Switzerland

Swiss Paraplegic Research (SPF)
Postfach
CH-6207 Nottwil
Switzerland
ICF Research Branch
WHO FIC CC Germany (DIMDI) at SPF
And at Institute for Health and Rehabilitation Sciences (IHRS)
Ludwig-Maximilian University
Marchioninistr. 17
81377 Munich
Germany

Patrice L. (Tamar) WEISS
Laboratory for Innovations in Rehabilitation Technology
University of Haifa
Mount Carmel
Haifa 31905
Israel

Annie WINTER
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France

Arnaud WITT
LEAD-CNRS UMR 5022
Pôle AAFE, Esplanade Erasme
Université de Bourgogne
BP 26513
21065 Dijon Cedex
France
CONTENTS

Executive summary ................................................................................................... XIII
Foreword.................................................................................................................... XXI

PART I
LEARNING AND EDUCATION
INTO REHABILITATION STRATEGY .................................................................1

Learning and teaching: two processes to bear in mind when rethinking
physical medicine and rehabilitation ................................................................. 3
J.-P. Didier

The International Classification of Functioning, Disability and Health (ICF),
a unifying model for physical and rehabilitation medicine (PRM) .................... 19
G. Stucki and A. Rauch

Rehabilitation and norms ..................................................................................... 53
J.-M. Mouillie, V. Saoût and I. Richard

PART II
IMPLICIT LEARNING:
A BASIC LEARNING PROCESS .........................................................................69

A historical perspective on learning: the legacy and actuality
of I. M. Pavlov and N. A. Bernstein .................................................................... 71
A. Roby-Brami and R. Goasdoué

Introducing implicit learning: from the laboratory to the real life .................... 95
E. Bigand and C. Delbé

Implicit learning, development, and education .................................................. 111
A. Vinter, S. Pacton, A. Witt and P. Perruchet
 Implicit learning and implicit memory in moderate to severe memory disorders .......................................................... 129
A. Moussard and E. Bigand

Learning processes and recovery of higher functions after brain damage ........ 149
M. Barat, J.-M. Mazaux, P.-A. Joseph and P. Dehail

PART III
LEARNING, MEDICAL TRAINING, AND REHABILITATION PRACTICE ............................................................................................................ 169

Benefits of learning technologies in medical training, from full-scale simulators to virtual reality and multimedia presentations ......................... 171
J.-M. Boucheix, E. Bonnetain, C. Avena and M. Freysz

Auditory training in deaf children .................................................................. 193
F. Rochette and E. Bigand

Virtual reality for learning and rehabilitation .................................................. 203
E. Klinger, P. L. (Tamar) Weiss and P-A. Joseph

Augmented feedback, virtual reality, and robotics for designing new rehabilitation methods ................................................................. 223
J.V. G. Robertson and A. Roby-Brami
EXECUTIVE SUMMARY

Part I – Learning and education into rehabilitation strategy

Chapter I – Learning and teaching: two processes to bear in mind when rethinking physical and rehabilitation medicine

The PRM (physical and rehabilitation medicine) specialist has to develop the functioning of the person in accordance with the life project, as it is defined into the CIF (International Classification of Functioning, Disability and Health). He or she appears as a “medical coach” in terms of health and functioning. The patient commonly has to learn by practice and/or by instruction how to do or how to perform a task, using implicit or explicit learning procedures, and the caregiver is the teacher who has to know and to understand the principles of teaching and learning. Is this indeed the case? We can discuss about when the caregiver’s instructions could be summarized as follows:

“Do it like that.”
“Do it like I do it.”
“Do it in a way that feels right for you.”

Thus learning and teaching are most often used in a context of empiricism with its relative ignorance of the paradigms and mechanisms involved. However, it is of great importance to take into account this relative ignorance when the array of resources used in rehabilitation, notably robotics and virtual reality, is providing new opportunities for learning and teaching.

Both learning and teaching are not only essential approaches in the rehabilitation process conducted by the PRM practitioner but also approaches that allow practitioners to reconsider PRM when new technologies present particularly attractive opportunities.

Chapter II – The International Classification of Functioning, Disability and Health (ICF), a unifying model for physical and rehabilitation medicine (PRM)

A unifying scientific model is of utmost importance for any professional, academic and scientific discipline. To be able to rely on a unifying model for functioning is essential for PRM, which can be understood as the “medicine of functioning.” The ICF is
thus a promising starting point for the development of rehabilitation practice and research.

In this chapter, the development of the ICF in the context of the United Nations system and its specialty agency the World Health Organization is explained. It is then reviewed how the ICF can be used both as reference standard and starting point for the classification and the measurement of functioning. Finally, it is shown how the ICF can serve as a unifying framework for the conceptualization of rehabilitation understood as a public health strategy and the medical specialty PRM and how it may serve as a basis for the organization and development of human functioning and rehabilitation research relevant for PRM.

Chapter III – Rehabilitation and norms

Medical practice aims at creating a norm; as such it is both normalizing and standardizing. It implies evaluations that draw a distinction between what is “normal” and what is pathological: this traditionally defines both its goals and its field of practice. Rehabilitation medicine is both on the margin and at the very heart of this founding distinction, and therefore also of the concepts or representations that underlie the definition of the norm and the actions triggered when a deviation from this norm is observed.

Associating “rehabilitation” and “physical medicine” leads to the use of a “global concept” involving all the various aspects of the patient’s situation that are affected by the handicap. In its various fields of practice, from functional rehabilitation to long-term follow-up care within the community, the practice of PRM is at the junction between medicine and society at large. Its field of analysis and intervention is therefore shifted from compensating for an impairment or restoring a function to adapting to a given set of social situations, with the risk that it will rely on, or even contribute to define, a set of “normal” social roles and situations.

Historical shifts in the uses of the word “rehabilitation,” occasionally in combination with “camp,” are a reminder – assuming one was needed – of the conceptual pitfalls involved, such as the fact that adaptation to the patient’s social environment is never in itself a “normal” sign of health, in the sense that it is “desirable.”

The process of learning new gestures and new ways of living therefore becomes central to the therapeutic process. Depending on whether goals and references will have been set by the patient within the framework of a process of normativity or defined externally, the patient will be able to call on his or her own motivational resources or depend on the feedback provided by the therapist.

Part II – Implicit learning: a basic learning process

Chapter IV – A historical perspective on learning: the legacy and actuality of I. M. Pavlov and N. A. Bernstein

Learning is defined as a relatively permanent modification of the organism’s activity resulting from its interactions with the external environment. There are two theoretical
streams: the main stream that we may call very schematically computo-representational neurosciences, which aims to improve understanding of the physiology of the nervous system, and various alternative approaches that share a more systemic or dynamical point of view, with strong references to psychology and a common aim to understand human activity. These streams differ on some important points, particularly on the question of the mechanisms of learning.

This debate would necessitate an extensive and detailed review of the experimental, theoretical and modeling evidences supporting or refuting both approaches, which are well beyond the scope of this chapter. We chose to tackle the question from a historical point of view, through the controversy that occurred between Pavlov and Bernstein during the 1930s.

The impressive legacy of Pavlov has fertilized very different fields in psychology, neuroscience, and formal neurons. It is commonly accepted in the community and very largely applied for learning, teaching, and therapy with unquestionable efficiency. It remains nowadays the mainstream paradigm for learning and adaptation and has received much evidence from basic and integrated neuroscience.

Although quite varied, the approaches in Bernstein’s tradition share common principles that differ markedly from the tradition of conditioning inherited from Pavlov. The drive for learning is action itself and not stimuli. The focus is put on dynamical processes and not on representation (called traces by Pavlov) and on the sensorimotor history of each individual. All the elements of interaction are considered, including the characteristics of the body structure and the multiple facets of the physical, social, and cultural environment. The theories of reference are more related to physical models of auto-organization and autopoiesis than to neuronal models developed by computational neuroscience.

However, rather than being alternative, these two streams of research should be presented as complementary approaches since they do not really share the same object of research.

Chapter V – Introducing implicit learning: from the laboratory to the real life

What and how do we learn implicitly?

Researches on implicit learning recently lead to revisit basic assumptions about human cognition. Human brains manage to internalize highly sophisticated structures of the environment through mere exposure to these structures in everyday life. One of the main issues of research remains to understand how these structures may be psychologically represented? According to some authors, the knowledge acquired implicitly may be represented in an abstract way. According to some others, the acquired knowledge rests on local organizations, statistically relevant in the environment. A supplementary issue of interest deals with the very implicate nature of this knowledge. For some authors, there is a continuum between implicit and explicit knowledge. Others argue that both types of knowledge do not confound, and some even suggest that knowledge is never entirely implicit. This chapter reviews these two main issues of research by considering the most influential studies in this domain.
Chapter VI – Implicit learning, development, and education

Implicit learning processes have been largely explored in adults, and some studies have been devoted to normally developing children as well as to disabled children. We will review the main developmental studies in this area of research in a first section of the chapter. Most of them have revealed that implicit learning processes operate efficiently from a very early age, and that they are also active in disabled children, while, in the latter, explicit learning processes are known to be impaired.

These results can legitimately elicit new hopes with respect to remediation activities with disabled children. The second section of the chapter addresses the benefits of using implicit learning processes as a way to remediate for behavioral impairments.

Chapter VII – Implicit learning and implicit memory in moderate to severe memory disorders

A lot of studies have shown that implicit learning is a very robust function that can be preserved, despite heavy explicit learning and memory disorders. Such capacities have been highlighted with amnesic patients and in Alzheimer’s disease through several lab situations, as artificial grammar learning for an example. In this task, participants see a number of pseudowords (such as MVTMX), composed by a combination of letters following a complex grammar that determines their association rules. After this learning period, participants see new pseudowords; half of them follow the same conception rules, while the others do not. Participants have to determine which of these new words are “correct,” according to this artificial grammar. Results show that patients have the same percentage of correct responses than normal control participants. However, when participants have to do an explicit task with this material, for example, to generate new pseudowords that follow the same grammar, patients have impaired performances, which confirm their memory disorders. These results show that new learning is possible despite cognitive disorders, and open new prospects for rehabilitation of heavy memory disorders. We will discuss how further studies could use these preserved capacities for helping amnesic or Alzheimer patients in their everyday life.

Chapter VIII – Learning process and recovery of higher functions after brain damage

Developmental psychology has long since shown the reality of changes in brain activity under the influence of intensive and systematic training and the influence of external stimuli on the structuring and function of the brain.

Learning processes work on the brain in different ways, operating through brain plasticity. In response to a new experience or new stimulation, neuroplasticity induces either changes in an already existing structure or the creation of new connections between neurones. The latter process leads to an increase in the density of synapses, while the former simply reinforces the most efficient or best adapted of the existing
pathways. In both cases, it is a matter of «remodeling» the brain in order to acquire these new data and, if required, to preserve them.

Practitioners confronted by patients suffering from cognitive deficiencies are faced with many methodological constraints: evaluation and especially the impact of deficiencies on the functioning of daily life and restriction of participation, and the choice of retraining method. The issue at stake here is nothing less than the credibility of reeducation in neuropsychology. Theoretical models have developed remarkably, thanks to our knowledge of cerebral function and to the concept of post-lesional plasticity. The fundamental problem is to reduce the effect of fragmentation of the functions assessed by analytical or cognitive neuropsychology and to clarify the transfer of abilities derived from reeducation to everyday life, beyond simply measuring learning of the items involved. The issue at stake in such training, whatever the theoretical modality, is to facilitate the functioning of preserved capacities and means of substitution put into action by patients themselves and their entourage.

Part III – Learning, medical training, and rehabilitation practice

Chapter IX – Benefits of learning technologies in medical training, from full-scale simulators to virtual reality and multimedia presentation

Emerging technology for medical training, including interactive animated images in anatomy, 3-D models, full-scale patient simulator, and virtual reality, is claimed to have great potential to enhance learning.

The literature presents many qualitative descriptions of technologies, but there is still little scientific research concerning the real benefits of these tools for professional training. In the first part of this chapter, we will present a review of the main recent studies on the ergonomics of technologies for learning and training.

In the second part of the chapter, we will report on a series of our experimental and empirical studies that concern the benefits of a full-scale patient simulator in emergency medical procedure training.

In previous research, full-scale simulators have been used in order to train operators working with complex systems presenting a great amount of risk such as power plants and aircraft piloting and to prevent serious errors or accidents. Training with a full-scale simulator in medical emergency is new.

The results of our studies revealed that full-scale patient simulators have been found to be very effective in emergency procedure training. Benefits were not limited to improved performance in the resuscitation tasks involved during the learning period. Benefits rather included the acquisition of relevant medical reasoning, deeper comprehension of dynamic events, better control, and awareness of the crucial features of the simulated scenario.
Chapter X – Auditory training in deaf children

The acquisition of the verbal language in childhood is commonly considered as a result of an implicit learning but supposes the efficiency of input system (auditory perception) and a repetitive and abundant exposure to language materials before the end of the sensitive period. In prelingually deaf children, as the rehabilitation of the input system (hearing aid or cochlear implant) depends on several factors, particularly the age of diagnosis, the first auditory stimulations are rare before 18 months (mean: 2 years). To develop verbal communication, the indispensable speech therapy focuses on salient multimodal perceptive oppositions in sounds and uses linguistic stimuli as soon as possible in discrimination and identification tasks.

When considering the underlying perceptive operations in language acquisition, a program including different kinds of nonlinguistic auditory stimuli (but sharing acoustic saliencies with language) in all perceptive tasks should improve language skills.

Chapter XI – Virtual reality for learning and rehabilitation

Given the high incidence of brain injury in the population and the need for additional rehabilitation tools, it is important to explore the possibilities brought by innovative technologies. Virtual reality (VR) has the potential to assist current rehabilitation techniques by offering new opportunities for learning. By providing a safe setting in which users may interact and develop goal-oriented activities within a virtual environment, VR allows the delivery of controlled multisensory stimuli and the creation of innovative learning approaches. VR assets in learning have already been used and proved, leading to their exploitation in rehabilitation. In this chapter, we will present some fundamental VR basic issues; we will give details about some VR-based learning approaches used in cognitive and motor rehabilitation and discuss assets and limits of VR for learning and rehabilitation.

Chapter XII – Augmented feedback, virtual reality, and robotics for designing new rehabilitation methods

Neuro-rehabilitation is currently undergoing a technological revolution! Groups of engineers and rehabilitation specialists are working on designing and testing a great variety of rehabilitation devices and systems. The reason for this is that, although it is generally accepted that rehabilitation improves outcome after stroke, patients are still left with impairments causing various levels of handicap and limiting their integration in community life. Comparison of traditional rehabilitation techniques has failed to show superiority of one over another, and concepts for rehabilitation have been changing over the last 20 years, with the biggest change being evaluation. There is a move to make rehabilitation techniques more evidence based. As such, numerous research teams have set about to create more effective rehabilitation techniques based on the principles of motor control and learning and incorporating new technology to fulfil the principal goals of rehabilitation: increased functional ability and increased participa-
tion in the community. The aim of this chapter is to discuss applications for augmented feedback (AF) in the rehabilitation of motor skills of patients with neurological disorders, in particular within VR environments associated or not with mechatronic devices (robotics). First, we will examine some motor learning principles relevant to rehabilitation and how AF fits into these concepts. We will then go on to review applications of AF used for the rehabilitation of specific movement parameters. We will also discuss the use of feedback distortion to manipulate action–perception coupling and systems based on movement observation.
FOREWORD

It is a great pleasure to write the preface to this book “Rethinking Physical and Rehabilitation Medicine.” Learning and teaching are introduced in this book as fundamental concepts in Rehabilitation Medicine.

In Rehabilitation Medicine we deal with patients who have permanent disabilities as a result of congenital disorders, injury, or disease. We generally use three types of interventions. The first type concerns medical interventions, for instance treatment of spasticity in order to create a better starting point for functional movements. The second type is teaching the patient new or modified functional movements. The third type is to compensate for lost functions, for instance supplying a wheelchair when walking is impossible.

Teaching functional movements requires teaching skills. However, medical specialists in Rehabilitation Medicine have no specific training in education and teaching. This book gives a very comprehensive overview of the principles of learning and teaching. It helps to understand the underlying neurophysiological mechanisms of learning, which is a special form of plasticity of the nervous system. It probably also helps to design better and more effective rehabilitation programs.

Nowadays, new technologies, for instance robotics and virtual reality, have been introduced in Rehabilitation Medicine. This book discusses principles of motor learning in relation to the opportunities offered by the use of robotics and virtual reality. “Implicit learning” is another important topic that is discussed in depth.

“Rehabilitation and norms” is an interesting chapter of this book. Assessing people with disabilities, as we regularly do as part of our rehabilitation practice, implies having a concept of “normality” and being able to draw a line between normal and abnormal. It is interesting to think about various definitions of normality, their application in
Rehabilitation Medicine, and how the concept of normality can be used for inclusion or exclusion of people with disabilities.

This book is highly recommended to any reader involved in Rehabilitation Medicine or care for people with disabilities.

Gustaf J Lankhorst
President
Académie Européenne de Médecine de Réadaptation
European Academy of Rehabilitation Medicine