BIOGRAPHICAL SKETCH

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NAME	POSITION TITLE
Jonathan R. Wolpaw	Director, National Center for Adaptive Neurotechnologies Chief, Laboratory of Neural Injury and Repair Wadsworth Center/NYS Dept Health
eRA COMMONS USER NAME (credential, e.g., agency login) WADS051	

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
Amherst College, Amherst, MA	BA	05/66	Biology
Case Western Reserve University, Cleveland, OH	MD	06/70	Medicine
Mt. Sinai Hospital, Cleveland, OH	Internship	06/71	Medicine
Med Ctr Hosp & Univ Vermont Sch Medicine, Burlington, VT	Residency	07/76	Neurology

A. Personal Statement

I am a board-certified neurologist who has spent the past 35 years exploring and modulating spinal cord plasticity and its functional correlates in animals and more recently in humans. My lab originated and validated the basic protocol for operant conditioning of spinal proprioceptive reflexes. Furthermore, we have conducted extensive physiological and anatomical studies in primates and rats that have revealed the complex plasticity in spinal cord and brain associated with reflex conditioning and with other interventions (e.g., cortical stimulation, peripheral nerve transection). In recent years, we have focused on the functional impact of spinal cord plasticity in health and disease, and have shown that appropriate reflex conditioning can improve walking in rats with partial spinal cord injuries (Chen et al. 2006, see C3 below). I am collaborating with Dr. Aiko Thompson's clinical research group to extend this new therapeutic approach to people.

In addition, over the past 25 years, I have been deeply involved in brain-computer interface (BCI) research and in its clinical applications. Our Wadsworth BCI group first demonstrated the usefulness of EEG sensorimotor rhythms for BCI-based communication and control, and has extended this to multi-dimensional movement control. We have also overseen the first large-scale clinical trial of BCI technology for use by people with severe disabilities. Furthermore, our group developed the general-purpose BCI software platform BCI*2000* and has provided it to more than 1200 research groups throughout the world. In addition, we organized and managed the first four international BCI conferences. Members of our group contributed substantially to the first comprehensive BCI textbook (Wolpaw & Wolpaw 2012) (see C5 below).

Over the past 30 years, the Wadsworth spinal cord plasticity and BCI groups have been consistently supported by grants from the NIH, other Federal agencies, and private foundations. These have included several complex multi-site projects that I have led as PI; I am now the Director of the National Center for Adaptive Neurotechnologies. Our work has been described in many papers in first-quality journals and has been recognized by a number of national and international awards. I have also described the work in many invited presentations and lectureships, and in numerous review articles and chapters. In addition, I have welcomed and supervised the participation of numerous graduate and undergraduate students as well as postdoctoral fellows in this work. Many of them have made significant contributions to the work and have received appropriate recognition in terms of authorships and meeting presentations. At the same time, I have contributed to the local, national, and international scientific communities by serving on many advisory committees and grant review panels and in numerous other ways.

B. Positions and Honors

<u>**Positions and Employment**</u>

1964-1969 Research Fellow, Department of Radiation Biology (Dr. Oddvar F. Nygaard), Case Western Reserve University, Cleveland, OH

1972-1974 Staff Associate, Applied Neurology Research Branch (Dr. J. Kiffin Penry), National Institute of Neurological and Communicative Disorders and Stroke, NIH, Bethesda, MD

1975-1976 Instructor in Neurology, University of Vermont School of Medicine, Burlington, VT

1976-1978 Staff Fellow, Laboratory of Neurophysiology (Dr. Edward V. Evarts), NIMH, Bethesda, MD

1978-1980 Research Neurologist, Neurobiol Dept, AFRRI; and Assoc Prof (Adjunct), Depts Neurol & Physiol, Uniformed Services Univ of the Health Sciences, Bethesda, MD

1980-Present Chief, Lab Neural Injury & Repair (formerly Nervous System Disorders) (1998-), Head, CNS Studies Section (1980-), Wadsworth Center, New York State Dept Health, Albany, NY; Professor (1988-), Biomedical Sci, SUNY; Research Prof Neurol (1986-), Adjunct Prof Pharmacol & Neurosci (1995-), Albany Med Coll; Adjunct Prof Physiol Cell Biol (2004-), Ohio State Univ; Research Investigator, Stratton VA Medical Center Albany, NY (2008-); Medical Staff Member, Helen Hayes Rehabilitation Hospital, W. Haverstraw, NY (2009-); Adjunct Prof Neurology, The Neurological Inst, Columbia Univ (2012-)

Board Certification

American Board of Psychiatry and Neurology (Neurology), 1978.

Service

Wadsworth IACUC 1981-1999; Epilepsy Assoc Cap Dist Profes Advis Board 1982-2004; NYS Dept Health IRB 1990-2000; Neurology A Study Sect, NIH 1991-1995; Helen Hayes Hospital IRB 1996-2000; NYS Spinal Cord Injury Research Board 1999-Present; Assoc Editor, IEEE Trans Neural Syst Rehab Eng 2002-Present; Mathematical Bioscis. Institute Advisory Comm. 2007-2008; Assoc. Ed., Neurosci., The Scientific World Journal 2008-; Editorial Board, Neural Plasticity 2008-; Lifeboat Foundation Scientific Advisory Board, Neuroscience 2008-; Scientific Advisory Board, Center for Sensorimotor Neural Engineering 2009-; National Advisory Board on Medical Rehabilitation Research (NIH, NICHHD) 2010-; Editorial Board, Journal of Neural Engineering 2011-; Chairman, Stratton VA IRB 2015-.

Honors and Awards

Keynote Speaker, Univ Miami Neural Engineering Research Day, 2016; SPIE Pioneer Award, 2016; First President, Brain-Computer Interface Society, 2015; Lawrence S. Sturman Excellence in Research Award 2015; Keynote Speaker, UWM College of Health Sciences Spring Research Symposium, 2015; Keynote Speaker, UNYTE Translational Research Network, Univ of Rochester, NY, May 2014; Keynote Speaker, BrainGain Project, Nijmegen, The Netherlands, 2013; Keynote Speaker, ACM SIGHIT International Health Informatics Symposium, Miami, 2012; Keynote Speaker, Fifth International Graz BCI Conference, Graz, Austria, 2011; Keynote Speaker, Myoelectric Controls Symposium, University of New Brunswick, 2011; Pioneer in Medicine Award, IBMISPS, 2010; Mary Notter Lecture, Department of Neurobiology and Anatomy, University of Rochester, 2010; G. Heiner Sell Memorial Lecture, American Spinal Injury Association, 2009; Grass Traveling Scientist, University of Manitoba, 2008; Finalist, Saatchi and Saatchi Award for World Changing Ideas, 2008; Engineering in Medicine and Biology Society Outstanding Paper Award, IEEE Transactions in Biomedical Engineering, 2008; Excellence in Research Award, University at Albany, State University of NY, 2007; BEST Lecture, Clarkson University, 2007; Beach Memorial Lecture, University of Miami, 2007; American Paraplegia Society Jayanthi Charitable Foundation Award, 2006; World Technology Network Fellow, 2006; Commissioner's Recognition Award, New York State Department of Health, 2006 (leader of winning group); Altran Foundation Innovation Award, 2005 (leader of winning group); Pirelli INTERNETional Award, 2005 (leader of winning group); Servier Lecture, University of Montreal, 2004; James S. McDonnell Foundation, 21st Century Research Award, 2003; Pangborn Award, Wadsworth Center, 1999; Computerworld Smithsonian Laureate, 1998; Election to American Neurological Association, 1987; Hans Berger Award, American Clinical Neurophysiological Society, 1977.

C. Contributions to Science

1. Cortical Components of the Human Auditory Evoked Potential

My first substantial scientific endeavor explored the later components of the human auditory evoked potential (AEP). This work showed for the first time that the late AEP is composed of several concurrent components, one of which arises in auditory cortex. Subsequent studies with several different collaborators further developed this discovery and, in addition, showed that the newly described AEP components provided the basis for a sensitive measure of drug effects on cortical function. The initial 1975 paper on this work was well received at the time and, 40 years later, is still frequently cited.

a. Wolpaw JR, Penry JK. A temporal component of the auditory evoked response. Electroencephalography and Clinical Neurophysiology 39:609-620, 1975.
b. Wolpaw JR, Penry JK. Acute and chronic antiepileptic drug effect on the T complex interhemispheric latency difference. Epilepsia 19:99-107, 1978.
c. Wood CC, Wolpaw JR. Scalp topography of human auditory evoked potentials: II. Evidence for overlapping sources and involvement of auditory cortex. Electroencephalography and Clinical Neurophysiology 54:25-38, 1982.

d. Cacace AT, Satya-Murti S, Wolpaw JR. Human middle latency auditory evoked potentials: vertex and temporal components. Electroencephalography and Clinical Neurophysiology 77:6-18, 1990.

2. Activity-Dependent Plasticity in the Mammalian Spinal Cord

My primary research effort over the past 35 years has been the study of activity-dependent plasticity in the spinal cord as a model for exploring the mechanisms of learning and memory in the mammalian CNS. This work demonstrated that the simplest spinal cord reflexes could be changed by operant conditioning, and thereby overturned the centuries-old assumption that these reflexes were hard-wired. I have led a lengthy series of studies with several different major collaborators (reported in over 80 primary articles) that have described the physiological and anatomical changes in the spinal cord that underlie this simple learning. These have begun to reveal how concurrent plasticity in the brain induces and maintains the spinal cord plasticity that is directly responsible for the modified reflex. This work shows that the substrate of this simple motor learning is a hierarchy of brain and spinal cord plasticity; it thereby disproves the traditional assumption that motor learning is the product of plasticity limited to cortex and immediately subcortical structures. Evidence that this hierarchy and the hierarchies underlying other motor skills change continually throughout life has led me to develop a new concept of spinal cord function (the *negotiated equilibrium* hypothesis) that is beginning to replace the concept of the spinal cord as a hard-wired reflex center that has prevailed for 200 years.

a. Wolpaw JR, Braitman DJ, Seegal RF. Adaptive plasticity in primate spinal stretch reflex: initial development. Journal of Neurophysiology 50:1296-1311, 1983.
b. Wolpaw JR, Tennissen AM. Activity-dependent spinal cord plasticity in health and disease. Annual Review of Neuroscience 24:807-843, 2001.
c. Wolpaw J R, Chen XY. The cerebellum in maintenance of a motor skill: A hierarchy of brain and spinal cord plasticity underlies H-reflex conditioning. Learning & Memory 13:208-215, 2006.
d. Wolpaw JR. What can the spinal cord teach us about learning and memory? Neuroscientist 16:532-549, 2010.

3. Therapeutic Applications of Spinal Reflex Conditioning

Ten years ago, I initiated with my colleague Dr. XY Chen studies exploring the potential therapeutic uses of operant conditioning protocols that change spinal cord reflexes. This work was based on the hypothesis that, because abnormalities in spinal reflexes contribute to the disabilities associated with spinal cord injury and other disorders, a protocol that produces beneficial change in these pathways can help to restore useful function. Our initial animal studies with Dr. Y Chen showed that appropriate reflex conditioning could improve locomotion in spinal cord-injured rats, and subsequent studies with Dr. Aiko Thompson showed that reflex conditioning could also improve locomotion in people with incomplete spinal cord injuries. Furthermore, in accord with the predictions of the *negotiated equilibrium* hypothesis (see C2 above), the production of this beneficial plasticity initiates widespread plasticity that produces a global improvement in performance. This work is now being confirmed and extended to other CNS pathways and other disorders by a number of laboratories. Operant conditioning protocols that target beneficial plasticity to specific CNS pathways could provide an important new therapeutic method that can complement other rehabilitation therapies and enhance restoration of useful function to people with spinal cord injuries, strokes, and other disorders.

a. Chen Y, Chen XY, Jakeman LB, Schalk G, Stokes BT, Wolpaw JR. The interaction of a new motor skill and an old one: H-reflex conditioning and locomotion in rats. Journal of Neuroscience 25:6898-6906. 2005.
b. Chen Y, Chen XY, Jakeman LB, Chen L, Stokes BT, Wolpaw JR. Operant conditioning of H-reflex can correct a locomotor abnormality after spinal cord injury in rats. Journal of Neuroscience 26:12537-12543, 2006.
c. Thompson AK, Pomerantz F, Wolpaw JR. Operant conditioning of a spinal reflex can improve locomotion after spinal cord injury in humans. Journal of Neuroscience 33:2365-2375 PMCID: PMC3579496, 2013.
d. Thompson AK, Wolpaw JR. Operant conditioning of spinal reflexes: from basic science to clinical therapy. Frontiers in Integrative Neuroscience 8:25, 2014.

4. Multidimensional Control with an EEG-based Brain-Computer Interface (BCI)

Early (pre-1980) studies of human ability to control specific features of the scalp-recorded EEG had therapeutic goals and sought unidirectional control of a single feature. My colleague Dr. McFarland and I showed that people could acquire bidirectional control (i.e., could learn to increase or decrease) an EEG sensorimotor rhythm; we went on to show for the first time that they could acquire simultaneous independent control of two or even three different sensorimotor rhythm features and could use that control to produce rapid and accurate multidimensional movements of a computer cursor or other output device. These demonstrations disproved the common belief that such complex control can only be provided by signals recorded from electrodes implanted in the brain. This demonstration introduced a new approach to restoring communication and control to people with severe neuromuscular disabilities, and in a wider sense provided important new insight into the key issues involved in using brain signals as new CNS output channels.

a. Wolpaw JR, McFarland DJ, Neat GW, Forneris CA. An EEG-based brain-computer interface for cursor control. Electroencephalography and Clinical Neurophysiology 78:252-259, 1991.
b. Wolpaw JR, McFarland DJ. Control of a two-dimensional movement signal by a noninvasive brain-computer interface in humans. Proceedings of the National Academy of Sciences USA 101:17849-17854. PMCID: PMC535103, 2004.
c. McFarland DJ, Krusienski DJ, Sarnacki WA, Wolpaw JR. Emulation of computer mouse control with a noninvasive brain-computer interface. Journal of Neural Engineering 5:101-110. PMCID: PMC2757111, 2008.
d. McFarland DJ, Sarnacki WA, Wolpaw JR. Electroencephalographic (EEG) control of three-dimensional movement. Journal of Neural Engineering, 7:036007. PMCID: PMC2907523, 2010.

5. Concepts and Principles of Brain-Computer Interface (BCI) Research and Development

BCI research and development is a new field that has arisen and grown very rapidly over the past 20 years. I have led the effort to enunciate key concepts and principles for this new field. I was first author on the 2002 review paper (see below) that summarized the field's rationale and goals; it is still by far the most frequently cited BCI paper (>3000 citations). My Wadsworth colleagues and I initiated and led the first four International BCI Meetings. The organization and management of this series is now a principal function of the newly formed BCI Society, an international organization of BCI scientists, engineers, and clinicians which I helped to found. I initiated the development, by my colleagues Drs. Schalk and McFarland and others, of the general-purpose BCI software platform BCI2000; we have provided it to more than 1200 research groups throughout the world. Together with Dr. EW Wolpaw, I edited the first comprehensive BCI textbook (see below). I also helped to define the principles underlying current efforts to apply BCI technology in neurological rehabilitation (see below). I just finished serving as first president of the new BCI Society.

a. Wolpaw JR, Birbaumer N, McFarland DJ, Pfurtscheller G, Vaughan TM. Brain-computer interfaces for communication and control. Clinical Neurophysiology 113:767-791, 2002.
b. Wolpaw JR (Guest Editor), Birbaumer N, Heetderks WJ, McFarland DJ, Peckham PH, Schalk G, Donchin E, Quatrano LA, Robinson CJ, Vaughan TM. Brain-computer interface technology: a review of the first international meeting. IEEE Transactions on Rehabilitation Engineering 8:164-173, 2000.
c. Daly JJ, Wolpaw JR. Brain-computer interfaces in neurological rehabilitation. Lancet Neurology 7:1032-1043, 2008.
d. Wolpaw, JR, Wolpaw EW (Eds.) (2012). Brain-Computer Interfaces: Principles and Practice. Oxford University Press.

URL to a Full List of Published Work

http://www.researchgate.net/profile/Jonathan_Wolpaw/publications

D. Research Support

<u>Current Research Support</u>

NIBIB (P41)	Wolpaw (PI)	7/15/14-7/14/19

NIH/NICHD
Center for Adaptive Neurotechnologies
The goal of this NIBIB Biomedical Technology Resource Center is to build a unique technological infrastructure and to use it to guide beneficial plasticity in the nervous system, to replace lost neuromuscular functions, and to characterize and localize brain processes both spatially and temporally.

1 I01 BX002550-01	Wolpaw (PI)	8/01/14-7/31/18

US Department of Veterans Affairs
Operant Conditioning of Spinal Reflexes to Improve Function after Nerve Injury
The goal of this project is to determine whether appropriate reflex operant conditioning protocols can improve locomotion after peripheral nerve injury and regeneration in rats.

PO1 HD32571 (English)	Wolpaw and Chen (Project IV PIs)	6/01/12-5/31/18

NIH/NICHD
Spinal Circuits and the Musculoskeletal System: Project IV (Regulation of Spinal-Musculoskeletal Interactions)

The major goal of this Program Project Grant is to evaluate the effects of therapeutic interventions on the relationship between spinal circuits generating movements and the musculoskeletal system after this relationship has been reconstituted following peripheral nerve injury.

R25 HD088157 Schalk and Wolpaw (Joint PIs) 3/1/16-2/28/19
NIH/NICHD
Short Course in Adaptive Neurotechnologies
The goal of this Short Course is to provide the knowledge and expertise needed to design, develop, and disseminate novel adaptive neurotechnologies that can greatly improve the treatment of neurological disorders.

P2C HD086844-01 Kautz (PI) 9/1/15-8/31/20
NIH/NICHD)
National Center of Neuromodulation for Rehabilitation (NC NM4R)
This project creates a national educational resource for researchers to promote use of the exciting tools of NM4R to develop the next generation of rehabilitation interventions and to understand and study neuroplastic nervous system changes during rehabilitation.
Role: Consultant

Past Research Support

DOH01-ISSCI5-2015-00001 Kaminsky (PI) 2/01/16-8/31/16
NYS Spinal Cord Injury Research Board (SCRIB)
Operant Conditioning of Spinal Cord Reflexes
The goal was to develop tests for defining the impact of spinal reflex conditioning on locomotion in people with spinal cord injuries.
Role: Project-1 Leader

R01 NS069551 Thompson (PI) 9/01/10-5/31/16
NIH/NINDS
Changing a Reflex to Improve Locomotion
The goal was to investigate the impact of changing a spinal reflex on impaired locomotion in people with chronic incomplete spinal cord injury.
Role: Co-Investigator

R01 EB00856 Wolpaw, Schalk (Joint PIs) 9/01/02-6/30/15
NIH/NIBIB
General Purpose Brain-Computer Interface System
The goal of this Bioengineering Research Partnership (BRP) was to develop and test clinically practical BCI systems.

R01 HD36020 Chen (PI) 5/01/97-7/31/15
NIH/NICHD
Supraspinal Control of Spinal Cord Plasticity
The goal of this research was to define the complementary roles of cortex and cerebellum in reflex conditioning and to show that conditioning can be targeted to modify specific aspects of motor function.
Role: Co-Investigator

R01 NS22189 Wolpaw (PI) 4/01/85-10/30/14
NIH/NINDS
Adaptive Plasticity in the Spinal Stretch Reflex
The goal was to delineate the complex pattern of brain and spinal cord plasticity that underlies spinal reflex conditioning.

R01-NS061823 Wolpaw, Chen (Joint-PIs) 2/01/08-7/31/14
NIH/NINDS
Spinal Reflex Conditioning and Locomotion
The goal of this project was to evaluate the complex motor effects of reflex conditioning protocols.

VA258PO417 Ruff, Wolpaw, Bedlack (Joint PIs) 9/27/10-11/26/13
US Dept of Veterans Affairs
ALS/BCI Cooperative Research Study
The goal was to determine whether people severely disabled by ALS can and will use a brain-computer interface (BCI) in their daily lives and whether the VA can support them in this usage.