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DEVELOPMENTAL PSYCHOPHYSIOLOGY

Until now, individuals interested in measuring biological signals non-invasively from typically developing children had few places to turn to find an overview of theory, methods, measures, and applications related to psychophysiology recordings in children. This volume briefly surveys the primary methods of psychophysiology that have been applied to developmental psychology research with children, what they have accomplished, and where the future lies. It outlines the practical problems that active developmental psychophysiology laboratories encounter and some solutions to deal with them. Developmental psychophysiology holds the key to forming the interface between structure and function central to psychological growth.

Louis A. Schmidt is Associate Professor of Psychology, Neuroscience and Behavior at McMaster University in Ontario, Canada. He is a Core Member of the Offord Centre for Child Studies, Division of Child Psychiatry at McMaster Children's Hospital. He received his Ph.D. from the University of Maryland, College Park. His research interests are developmental psychophysiology, human social and affective neuroscience, and the use of EEG/ERP measures to understand individual differences in temperament and affective responses in normal and special populations.

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Developmental Psychophysiology

Theory, Systems, and Methods

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Foreword

Developmental psychophysiology is an emergent discipline that applies the technologies of psychophysiology to study developmental processes. The history of developmental psychophysiology reflects the unscripted dance of investigators moving in and out of disciplines, research questions, populations, clinical problems, physiological measures, and technologies. Developmental psychophysiology represents the products of scientific curiosity and ingenuity as investigators boldly attempt to apply new technologies to study classic problems and unanswered questions regarding the developmental trajectory of psychological processes. Unlike the psychologist, who studies both observable behaviors and subjective reports, the psychophysiologist investigates responses that do not require verbal responses or overt behaviors. Thus, the tools of psychophysiology provide developmental scientists with opportunities to expand the investigative envelope of inquiry to include the preverbal infant.

Before we can place developmental psychophysiology in perspective, we need to examine briefly the history of psychophysiology. Psychophysiology is at the crossroads of several disciplines, each with preferred models, paradigms, and measures. Unlike physiology with its focus on mechanism and structure or cardiology with its focus on clinical status, psychophysiology was driven by paradigms derived from psychology, often treating physiological parameters as if they were observable behaviors. The early psychophysiologists, defined by their use of the polygraph, applied the polygraph to "transform" unobservable psychological or mental processes into measurable physiological variables (e.g., Razran, 1961).

Early papers by Fere (1888) and Tarchanoff (1890) provide visionary statements of the paradigms that would define psychophysiology. Their papers focused on using electrodermal activity as indicators of psychological responses to a variety of stimuli. Reports of measured electrical activity

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generated by physiological systems piqued the interest of many psychologists during the late 1800s and early 1900s to use these signals as indices of psychological processes. The Fere and Tarchanoff papers provide examples. Others used these techniques to investigate atypical mental processes. For example, Peterson and Jung (1907) recorded electrodermal activity in normal and insane individuals seeking an objective measure of mental illness. Berger (1929) birthed human EEG research by placing electrodes on the scalp of his son and recording electrical activity via a string galvanometer and a smoked kymograph (devices long expunged from the memories of psychophysiologists). The reliability of these electrical signals and their sensitivity to psychological phenomena intrigued many scientists and provoked interest in applying these techniques to monitor mental processes.

Given the strong interest in mental processes, these early investigators had only a minor interest in the neural mechanisms mediating these responses. Ironically, the origin of modern psychophysiology is often linked to the classical conditioning of autonomic activity, which, as Pavlov (1927) demonstrated, requires the involvement of higher brain structures in the modulation of visceral responses (for a more detailed discussion of this paradox, see Porges, 2007a, b). The history of psychophysiological research with heart rate measures has a different trajectory. Heart rate entered psychophysiology from medicine and physiology. Non-invasive measurement of the electrical signal from the heart provided physicians with an opportunity to evaluate myocardial conductivity. The measurement of beat-to-beat heart rate provided physiologists with indices of neural influences. Blockade and surgical manipulations provided scientists with the ability to identify and estimate the vagal and sympathetic influences on the heart.

Developmental psychophysiology emerged with a convergence of questions from both developmental psychology and medicine. Developmental scientists found the research on classical conditioning intriguing as a possible "window" into the psychological world of young children. Most classical conditioning research (e.g., Pavlov, 1927) focused on the effect of stimulus contingencies on autonomic processes. By the 1960s, psychologists had the tools to measure the autonomic nervous system (e.g., electrodermal, heart rate) and were importing the paradigms that Soviet psychologists developed, based on the pioneering work of Pavlov, to study infants (e.g., Brackbill, Lintz, & Fitzgerald, 1968). Occurring simultaneously with these events, heart rate and heart rate variability started to be used as an index of the status of the nervous system in neonates and fetuses (e.g., Yeh, Forsythe, & Hon, 1973). Early developmental psychophysiologists (e.g., Bartoshuk, 1962; Graham, Clifton, & Hatton, 1968) studied the heart rate responses to various stimuli

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to index processes of orienting, attention, conditioning, and habituation. As the technologies and interests in heart rate variability emerged from both psychophysiological research with adults (e.g., Porges & Raskin, 1969) and obstetrics and neonatology (e.g., Hon & Lee, 1963), heart rate variability as a measure of individual differences and mental effort was infused into developmental paradigms (e.g., Porges, Arnold, & Forbes, 1973).

Progress in developmental psychophysiology was related to the unique opportunities of collaboration and communication that the new emergent discipline provided. Developmental psychophysiology challenged scientists with new research questions that attracted researchers with diverse skills and backgrounds. Since proximity facilitates collaboration and the integration of various scientific perspectives, a few nodes can be identified as having provided environments that nurtured developmental psychophysiology. It is possible that developmental psychophysiology owes its current success to the Fels Longitudinal Study. In the 1920s, Arthur Morgan, President of Antioch College, approached Samuel Fels, a philanthropist, to study the research question: "What makes people different?" Lester W. Sontag, the physician at Antioch College, was appointed as the first Director of the Fels Longitudinal Study in 1929. During his tenure, Sontag assembled an impressive team of scientists with interests in development, psychology, and physiology. In the 1960s, the Fels Research Institute was home to pioneering psychophysiologists John and Beatrice Lacey and discipline-defining developmental psychologists Jerome Kagan and Michael Lewis. In 1957, Frances Graham left Washington University Medical School, where she worked with very young infants suffering from hypoxia, and moved to the University of Wisconsin. At the University of Wisconsin, her developmental perspective and interest in the newborn expanded to include psychophysiological methods after her interactions with psychophysiologists such as Peter Lang, David Graham, and Rachel Keen Clifton.

Another strong influence on the roots of developmental psychophysiology came from Brown University. The Brown developmental psychologists provided an important and new emphasis on the study of young infants as an experimental science. This new subdiscipline of experimental child psychology required objective measures, even when the children were not verbal. Lewis Lipsitt and his colleagues directed their research to study early operant learning in the very young infant using the polygraph to monitor sucking and heart rate changes. A final and more personal node on this historical journey is the psychology department at the University of Illinois at Urbana-Champaign during the 1970s. This fertile node provided a unique mix in which my developmental perspective interfaced with the individual

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difference strategies of Michael Coles and the cognitive perspective of Emanuel Donchin. During our period together, we moved our psychophysiology laboratories to online computers, extended quantification procedures to time series models, and conducted research on the basic physiology of psychophysiological variables (e.g., Coles, Donchin, & Porges, 1986; Porges & Coles, 1976).

As we evaluate the progress of developmental psychophysiology, a discipline that is less than 50 years of age, we need to appreciate the pioneers who asked bold questions, built and designed their own equipment, carried the equipment into hospitals and clinics, and hand scored each heart beat and electrodermal response. The current volume is timely as methods have improved, paradigms have been refined, and clinical questions have been expanded. In addition, psychophysiology has moved from treating physiology as behavior to a more integrative understanding of the nervous system and the role that neurophysiological systems have in mediating behavior and psychological processes.

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Preface

The field of cognitive and affective neuroscience has burgeoned during the last 20 years, prompting the publication of several handbooks. The allied field of psychophysiology included two such comprehensive collections over the last 7 years but, surprisingly, only one chapter in each was dedicated to issues pertaining mainly to children (Fox, Schmidt, & Henderson, 2000; Fox, Schmidt, Henderson, & Marshall, 2007) as was the case some 20 years earlier (Porges & Fox, 1986).

Today, there has been considerable research attention directed toward understanding brain-behavior relations in a developmental context. Interdisciplinary approaches to the study of behavior in which development and brain are interfaced have blossomed. We now routinely observe researchers in developmental psychology interacting with people in the fields of behavioral and cognitive neuroscience, and vice versa. This book reflects the spirit of the multidisciplinary nature of science and the dialogue of our two disparate worlds: one as a social developmental psychologist (LAS) and the other as a cognitive neuroscientist (SJS).

The seeds for this book were sown five years ago as a result of our frequent discussions of science, life, and the human condition. In addition to the friendship that quickly developed from our many talks over the years, there soon emerged the realization that, although more and more developmental child psychologists were beginning to study brain-behavior relations in a developmental context, a lack of resources in the area from which they could draw was apparent.

One purpose in compiling this book was to bring together a number of scientists into one intellectual forum that would cover most of the psychophysiological methods in our field, as well as the uses to which we put them. The book is nominally organized into four major sections. We start with a discussion of how the use of psychophysiological techniques might

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help us understand the complex interactions that exist in the study of human development before moving into the other chapters contained within the four major sections. Section I contains chapters that cover issues related to electrocortical measures including event-related potentials (ERPs) and continuous EEG measures across auditory, visual, cognitive, and socio-emotional processes in children. Section II presents chapters related to autonomic and peripheral psychophysiological measures including heart rate, heart rate variability, and electrodermal and electromyographic responses in children. Section III includes chapters discussing the theory and methods of non-invasive hormonal measures used to study human development. Section IV offers chapters outlining the collection of reliable psychophysiological data in basic research settings with pediatric populations.

Developmental psychophysiology is the study of psychological processes during development using physiological measures. Developmental psychophysiology essentially covers the conceptual issues and practical techniques for doing much of the exciting burgeoning research in the field of cognitive developmental neuroscience. Although development spans the period from conception to senescence, the focus of this edited volume is primarily on children and the recording of non-invasive electrical signals and non-invasive hormonal measures from birth to the adolescent years in typically developing humans. Moreover, the book was not intended to provide exhaustive coverage of all psychophysiological theory, methods, and measures. Clearly, there are other methods and measures that psychophysiologists use in their work that we have not covered here but are reviewed extensively elsewhere in other handbook volumes (see Cacioppo, Tassinary, & Berntson, 2000, 2007; Coles, Donchin, & Porges, 1986, for extensive reviews). We also did not include a discussion on the use of functional brain imaging measures (e.g., fMRI, PET). Although developmental psychophysiologists use these methods, an adequate discussion of these methods and measures was beyond the scope of this volume.

Until now, individuals interested in measuring biological signals non-invasively from typically developing children had few places to turn to find an overview of theory, methods, measures, and applications related to psychophysiology recordings in children. In this volume, we survey briefly the primary methods of psychophysiology that have been applied to developmental psychology research, what they have accomplished, and where their promise lies in the future. We also outline some of the practical problems encountered and solutions developed by active developmental psychophysiology laboratories to deal with them. Developmental psychophysiology is a rapidly growing field that holds the key, we feel, to forming the interface

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between structure and function necessary for the growth of developmental psychology.

With this book, we have endeavored to provide the research community with the resources to enable them to collect reliable psychophysiological signals and data from children, including the knowledge of how to avoid some of the pitfalls that many established researchers in the field have taken years to learn. Our hope is that this book will serve as a resource for researchers and students working in the areas of development psychology, developmental cognitive and affective neuroscience, clinical child psychology and psychiatry, and pediatric medicine.

Louis A. Schmidt — Sidney J. Segalowitz
Hamilton, Ontario — St. Catharines, Ontario
July 2007

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potentials and oscillations, methods for EEG/ERP analysis, cognitive functions, and EEG.

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